large) classes," an "over-concentration of students' learning" in their three-year major courses of study, and "an archaic calendar" which frustrates study abroad and enrollment in courses in other Harvard faculties. In response, he seeks to "create closer communities of learning between students and faculty," reaffirming for professors "the central importance of undergraduate teaching. Only if we succeed in this effort can we hope to change students' perception that the better part of a Harvard College education is to be found outside the classroom."

One can discern in Kirby's detailed remarks the forthcoming demise of the Core curriculum, and its replacement with distribution-based general education; lessened concentration requirements (and later choice of field of study); perhaps a new calendar and January "J term"; universal international experiences for students; and more.

In the meantime, Kirby describes an ambitious program (unexpectedly so, given financial constraints) of construction to better student services: gutting the Hasty Pudding building, beginning this spring, to create a new 272-seat College theater; renovating Loker Commons to include a big-screen TV and a student pub; renovating Hemenway Gymnasium with the Law School; and, to accommodate growing interest and faculty hiring in film studies, building screening rooms, an animation studio, and video viewing and editing stations in Sever Hall.

Three highlights emerge from Kirby's discussion of faculty expansion. First, he sets a new goal for the faculty population of 750 assistant, associate, and full professors by 2010, compared to 672 as of this January 1. (His predecessor, Jeremy R. Knowles, had in 2000 set a course to increase the faculty ranks from about 600 then to 660 by the end of this decade.) Reversing recent experience, much of that expansion is to be in the junior ranks, Kirby says, putting a premium on nontenured searches and on encouraging promotion to tenured positions from within—so much so that assistant professorships may now, for the first time, be described as "tenure track."

Second, he spells out areas of apparent intellectual opportunity. Those for humanities and social sciences conform to earlier reports (see "Arts and Sciences Aspirations," January-February, page 69). In life sciences, Kirby suggests new FAS focus on fields such as bioinformatics, bioengineering, neuroscience, evolutionary processes, and systems biology. In physical sciences, highlighted fields include particle astrophysics, mathematical physics, and climate science. Some of those targets obviously overlap with the new aims of the faculty's Division of Engineering and Applied Sciences, which is also venturing into computational biology, complex-systems research, quantum technology, and an array of subjects involving electrical engineering and research computing.

Finally, Kirby announces the beginning of a new series of "divisional" appointments. The divisional academic deans have been empowered to pursue scholars whose work spans departments, and to move forward on attracting new professors to Harvard in concert with, but not solely at the behest of, existing departments. This break with disciplinary tradition may symbolize most clearly Kirby's pursuit of what he calls "heroic efforts at connection and coordination."

In an extended discussion of the thorny issue of faculty diversity (see "Women and Tenure," page 62), Kirby adds this evocative note on the academic lives FAS members may face: "[I]n a largely tenured faculty where the social divide between senior and junior colleagues can still seem enormous, and with nontenured colleagues scattered across more than 30 departments, being a female or minority colleague can be an isolating experience"—an issue to be addressed, he urges, as the professorial census rises.

FAS's physical planning embraces completion of large projects such as the Center for Government and International Studies (CGIS) straddling Cambridge Street, and the heavy work or initial stages of others, such as the 137,000-square foot Laboratory for Interface Science and Engineering and the 460,000-square-foot Northwest Building north of the University Museum complex. This structure, scheduled for completion in 2007, will be "entirely interdisciplinary research space," Kirby writes, not the province of any one department; initial tenants will be the Center for Brain Science plus clusters of researchers in bioengineering, physics, and particle physics. In the future, of course, lies expansion into Allston.

"[We] raised less in external funds than we had anticipated for building projects," Kirby reports, listing the Widener Library renovation, CGIS, and the science structures. More real-estate-related debt financing is surely in the offing. Beyond, "one can easily imagine that our ambitions for the College, the faculty, and our physical campus will require fundraising of a significant order"—the forthcoming capital campaign.

The case for that effort, he concludes, emerges from a new spirit of faculty members "speaking to each other across disciplines, developing plans *as*, and *across*, academic divisions, in tandem with a view of a new undergraduate curriculum," and housed in physical facilities designed to encourage scholarly interchange.

Seeing Biological Systems Whole

Marc Kirschner, one of the world's leading cell biologists, has a new office. He apologizes for a mess that hardly exists—a microscope and some other paraphernalia are stacked against the far wall of the room—before slumping into a chair to talk about the 15-month-old department of systems biology at Harvard Medical School (HMS), which he has directed since its founding in October 2003. But Kirschner, who is Walter professor of systems biology, likes finding connections between fields. He hasn't been talking about the new department for long before he launches into a brief history of molecular biology.

"At first, molecular biology was a kind of controversial term," he muses. "Biochemists did not like it because, they said, 'Well, you know, we're already doing molecular biology.' Ultimately, it became something clearly very different, and it was defined not so much by the subject matter, but by the *approach* to the subject matter, by the experimental tools that were being used," he says. "Today, this field is disappearing, because it's being incorporated into every other field. As an approach, it was so successful that it became part of everything"—immunology, microbiology, cell biology.

For Kirschner, this is both a scientific parable and a mission statement for his growing department, recently relocated to a new array of laboratory offices on the fifth floor of HMS's Alpert Building. Since its inception (see"Biomedical Momentum," November-December 2003, page 54), the department has hired four new faculty members—bringing the total to nine on its way to a planned complement of 25—and drawn up ambitious plans for a cross-river education program. Its aspirations, though, reach far beyond the University itself. Kirschner thinks that he and his colleagues may change fundamentally the way that researchers think about biological problems.

Pamela Silver and Marc Kirschner

"Maybe people say, 'Why give this field such attention? We're already doing systems biology,'" he says. "But what I hope will emerge is an approach—a highly integrative approach, a highly mathematical approach, a highly computer-based approach, using more quantitative measurement than anyone has ever done, more modeling. In the end we'll look back and say, 'This is new. This is *not* what people were already doing.'"

Systems biology is an interdisciplinary method based on the idea that the sum of a biological system really *is* greater than its parts—that pieces of an organism can be understood completely only in the way they work together within a particular environment. Traditional biological research breaks a system down into its parts and tests each one separately. According to systems-biology proponents, that's like trying to understand how a movie projector works by pulling gears out of the machine and staring at them under a flashlight. Not only are things a lot more complicated than that, the individual gears will tell you nothing about how parts work together to get a moving picture onto the screen. Systems biology tries to understand components—such as the biological molecules that hasten or impede the spread of information or disease through the body—by examining how they function in their native habitat, not just in a laboratory tray. Kirschner's own research, for instance, applies a systems-biology approach to the dynamics of cell division. Whether a particular cell divides at a certain moment depends on several environmental factors, he explains. He's taking these influences into account to figure out what combination of conditions impels a cell to duplicate.

"Physics, in retrospect, looks like such a simple problem, where one proton looks like every other proton," Kirschner says. "Biology, by contrast, is made up of individual organisms that are themselves different from all other organisms, at least in natural populations, and they experience different environments, different histories. You can say, 'Well, that's just an experimental nuisance'—and that's been the justifiable attitude of all biologists up until now." But systems biology approaches research on a scale that traditional methods cannot because it appropriates the tools of several disciplines—from theoretical mathematics to evolutionary biology—and uses them in tandem. Its practitioners gather massive amounts of data from various sources and analyze them with advanced modeling and computational techniques. They begin to get a sense of the forest beyond the leaves.

According to Kirschner, technological innovation has not yet caught up with the field's potential—many researchers don't yet have as many tools as they would like for making routine measurements—but this hasn't dissuaded anyone from making a strong start. As quickly as the field has sprouted in academic medicine, it's also taken root with some pharmaceutical companies convinced that it heralds the next step in honing drug treatments. Kirschner is critical of suggestions that systems biology is a short-term pharmaceutical panacea, but he does think the field's embrace of variance makes it a powerful tool for better dealing with individual patients. "In, say, medicine, for example, where you really want to know if somebody is going to get a disease or not get a disease, or how they're going to react to a certain treatment," he explains, "all these little dirty facts about their genetic variation or their environmental or experience differences are crucial."

Getting at those facts requires eclectic talents. Assistant professor of systems biology Vamsi Mootha, who accepted a spot in the department last summer just before winning a MacArthur Fellowship, is a mathematics and computer-science major who went to medical school. His research centers on a classic subject, the mitochondrion (an organelle in the cytoplasm of cells that contains genetic material and enzymes important for cell metabolism), but his technique straddles a large number of fields. "I try to take a systematic approach," says Mootha. "We're hoping to understand how [this] organelle is assembled from its individual components into a functional machine inside of the cell, and how its assembly changes in development and in disease."

Beyond his heavily computational and model-based approach, Mootha uses biochemistry and physiology and has managed to keep one foot in the medical clinic. His research has so far generated insights

Photograph by Tracy Powell

into metabolic diseases like type-2 diabetes and the French-Canadian version of Leigh syndrome (a progressive illness, usually found in children, that affects the brain), and his eclectic background makes it possible for him to carry these results further than many researchers could. "I'm keen on translating some of my results back into the clinic as well," he says.

Bringing fields together is what systems biology is all about. Harvard's department is trying to strengthen itself by reaching for resources outside HMS as often as possible—even if that means going all the way to Cambridge. "Even though we have this department of systems biology, the full realization of systems biology anywhere, but here in particular, has to involve the contributions of people in several different departments," Kirschner explains. He's recently been working with administrators in the Faculty of Arts and Sciences (FAS) and the Division of Engineering and Applied Science, both across the river, to help involve faculty members from other schools and departments with the program.

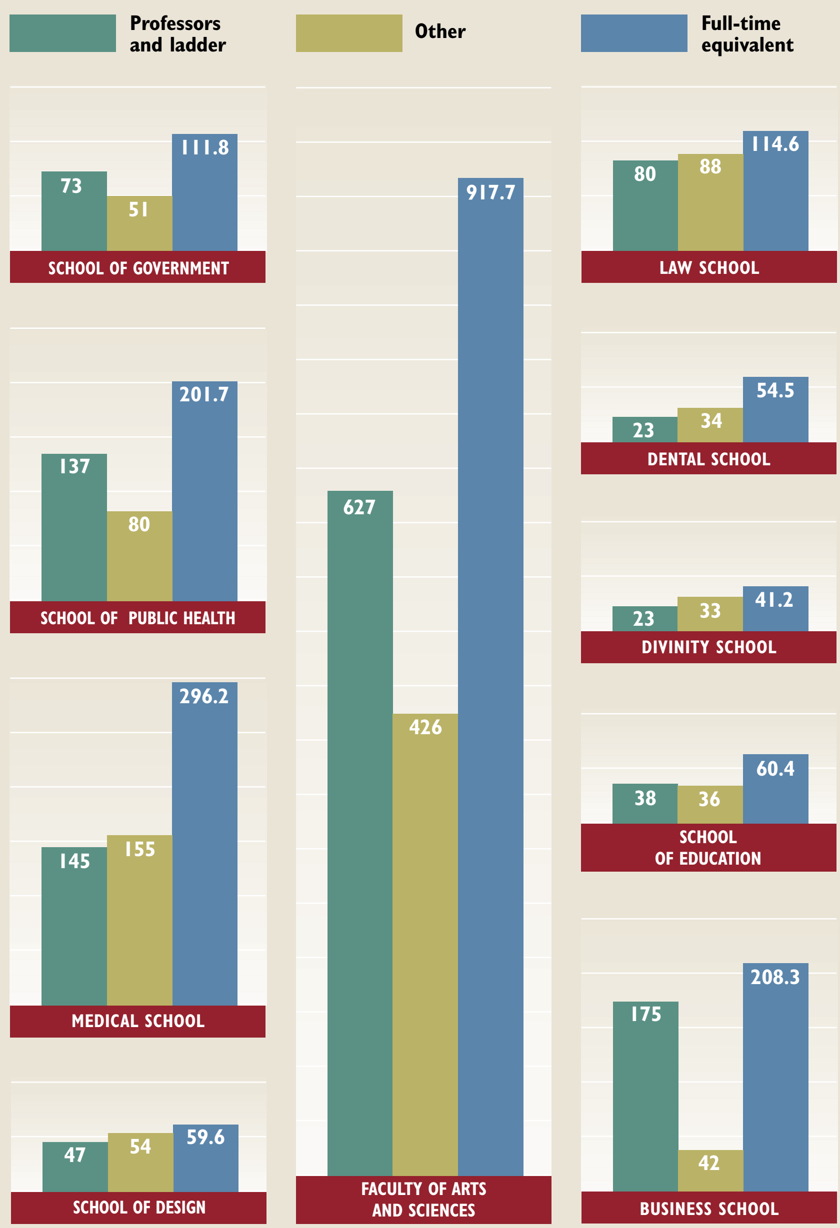
He says he'd rather do that than hire a full complement of mathematicians, chemists, engineers, biologists, and computer scientists to make his own department self-sufficient. Not only would this bloat the size of its faculty; it would deracinate researchers from their intellectual communities. "Engineers who participate in biology still want to have their roots in an engineering faculty," Kirschner says. "We have a situation here where we have all the elements at Harvard as a University, but not all the elements in Cambridge, and not all the elements in Boston."

Kirschner thinks this collaboration with other faculties will offer a foundation for what he considers the department's most exciting priority: education. Describing students as "the common focus for everyone's interests," he explains that he and his colleagues have promoted a teaching commitment in their recent faculty recruitment. This strategy is counterintuitive in a job market that usually puts a premium on nonteaching research positions, but Kirschner says the sort of people who are interested in teaching are the sort of people he'd want to have as col-

HARVARD BY THE NUMBERS

Harvard's faculty consists of both tenured professors and "ladder faculty" (associate and assistant professors), and other teaching faculty (professors of practice, lecturers, adjuncts, and visitors). Adjusted to full-time equivalents, the heft of the Faculty of Arts and Sciences becomes apparent. So does the mix—of regular faculty appointees versus others, often practitioners (compare business and law, for example). These data for the fall of 2003 exclude hospital-based medical-faculty members (who equal those shown, from the "Quad" departments), and 9,000-plus unpaid medical and dental clinical appointees.

University Faculty



SOURCE: *HARVARD UNIVERSITY FACT BOOK*

Chart by Stephen Anderson

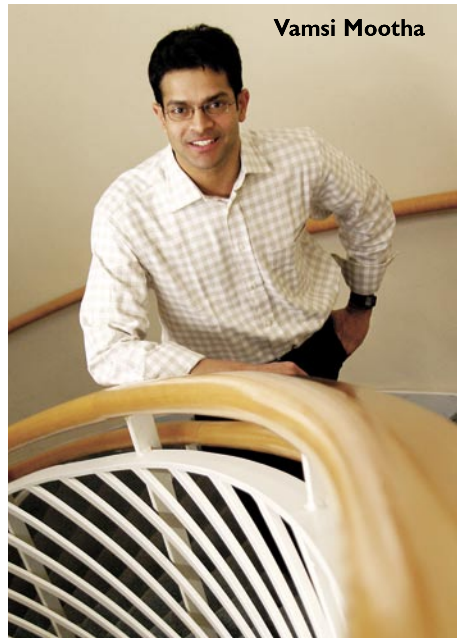
leagues: "It's sort of a litmus test of a person's collegiality."

The department has already begun to put an innovative education program into place: last October, FAS unanimously approved plans for a Ph.D. program (slated to begin this fall) that will enable students to pursue their education and research in systems biology, but won't be run by Kirschner's department alone. Students will be able to work under the tutelage of faculty members from both sides of the river. "We want it to be extremely interdisciplinary," says professor of systems biology Pamela Silver, who is largely responsible for planning the program's details. "We hope that this will act as a catalyst between the Medical School and Cambridge." The program, she says, will center on close interaction between students and faculty members, and students will regularly have an informal group meeting with faculty members, alternating between Cambridge and the HMS campus to help bridge the physical barrier between the two locations.

The department is working to bring systems biology to the College community, too, by offering a course this spring ("Genomics and the Biology of Complex Systems") that will be open to high-level undergraduates. "The graduate program will be a good forum for us actually to think about undergraduate education," Kirschner says. "It's a tremendous opportunity to bring these integrated concepts to people who are still in the formative stages of their lives." (It also helps to generate interest in the graduate program.)

"I'd like students to feel a bit more empowered about how they choose what to do their research on," Silver says. "We'd try to encourage them to branch out." (As she has done: she both examines the regulation of genes in the context of the nucleus and works in synthetic biology, designing organisms to perform specific actions.) But in a nascent field that brings the resources of two campuses into a single classroom, the opportunities to branch out are sometimes greater than undergraduates' backgrounds will allow. Many budding biologists don't have the mathematical expertise that systems biology demands, while many students interested in applying their mathematics skills have a scant sense of biological processes.

Silver and her colleagues are trying to overcome this hurdle by introducing the procedures in more accessible form through the undergraduate sections that accompany lectures. Much of the heavy math will be replaced by computerized tools and simulations that are comparatively easy to learn. And Kirschner says the department plans to free its undergraduate course from the jargon of research biology. "There's a real tendency in biology courses to throw out more terms than are typically thrown out in a language course, so that it becomes a vocabulary exercise," he says. "But not every book that I read by a foreign author did I read in the original language, and I still got something out of it. We're going to have to provide some of that translation. And there are going to be some people who get interested enough in the field that they no longer want it in translation."



Vamsi Mootha

TRACY POWELL

The new course amplifies Kirschner and Silver's shared belief that what systems biology offers is more than a research method: it's a new way of looking at the world, and one they think should be shared as widely as possible. "Even if undergraduates go on to investment banking or something, it's important for them to understand biology in terms of its complexity, and in terms of what we understand about complex systems—how they behave physiologically and how they change in response to the environment. That is a truer view of the biological system," Kirschner says. "And if they take that away with them, they will be in a better position to understand the kind of problems that face them in *their* real-world situations."

~NATHAN HELLER

Leaner Libraries

The pilot project with Google announced by the Harvard University Library in December is a small step toward a future of possibilities in which almost any book in any Harvard library can be opened on-line (facing page). Meantime, the present.

Sidney Verba

KRIS SNIBBE/HARVARD NEWS OFFICE

At the Harvard College Library (HCL)—a core group including Widener, Houghton, Lamont, Cabot (science), Loeb (music), and (for the moment) six other libraries—budgetary constraints have required library administrators to make staff and service cuts. Faculty members said ouch, on the HCL's and their own behalf, at a faculty meeting on January 11.

In fiscal year 2004, ended last June, the library had income of $73 million. Just over 57 percent was subvention income, the bulk of it from the Faculty of Arts and Sciences (FAS) and the central administration and some from the Harvard-Yenching Institute. Until recently, subventions from FAS and the president had risen annually by an inflation index (determined by the University), plus 1.5 percent. This was "well above the rate of