disaster looming. The "success" of the new efforts has been due mainly to the enthusiasm of the reformers, he says—and once the novelty wears off, what's left will be bad mathematics poorly taught. He and other critics are particularly worried by what they see as an overdependence on computers and calculators. The prospect of students who need a calculator to divide by 10 is real, Andrews says: "There is a sizable percentage of [students] who cling to these machines like drowning men to rafts and are unable to perform even the simplest arithmetic computations [without them]."

In a critique reminiscent of the wider debate about academic standards, Andrews charges that reformers have failed to confront what he sees as the real problem: students who don't study. In fact, because the new classes aim to make calculus more appealing, he says they risk teaching to the lowest common denominator. He and others say that the first wave of reformed textbooks have "dumbed down" the subject, downplaying technical mastery of integrals and derivatives, and abandoning proofs altogether. He thinks math departments would do better with a consistent policy for assigning homework than by overhauling the traditional calculus course.

Indeed, John Polking of Rice University—who considers himself "neutral" in this debate—notes that the textbook-adoption committee at Rice has so far rejected all new-style texts as inadequate. The chief target for much of the criticism is a text produced by the Harvard Calculus Consortium, which critics say sacrifices rigor for a warm and fuzzy approach. Ultimately, say mathematicians such as Hung-Hsi Wu of the University of California, Berkeley, such texts will leave students confused and uncertain about the logical connections among ideas in the course.

Reformers, of course, see things differently. While cautioning that "it's too soon" to judge whether calculus reform is truly working, Morton Brown of the University of Michigan says that his school's experience shows definite improvements in students' learning. In fact, he says, this brand of new math is actually increasing students' work time, not decreasing it. As for dependence on calculators, "We spend a lot of time making sure that the students do not simply plug in black-box solutions," Brown says. "If they do that on the test, they get zero credit."

The dumbing-down tag especially rankles reformers. "I deeply resent, and categorically deny, this implication that the calculus reform represents any dilution of homework or dumbing down of the course," says William McCallum of the University of Arizona, who is associated with the Harvard project. "One of the things that interested me most about calculus reform was the challenge of coming up with real homework problems that asked the students to think. I think this is one of the great achievements of the movement."

As the charges and countercharges fly, it's clear that a definitive evaluation is badly needed, says Polking. But that's easier said than done. For one thing, there's no agreement on what it means for reform to succeed. Criteria range from student attitudes toward calculus, to the grades they get in later courses, to the number that go on to major in mathematics. Even the obvious criterion—that students emerge with a better understanding of calculus—is elusive, notes Andrew Gleason, one of the Harvard project leaders. "What does it mean to understand calculus?" he asks. "We had session after session debating this question."

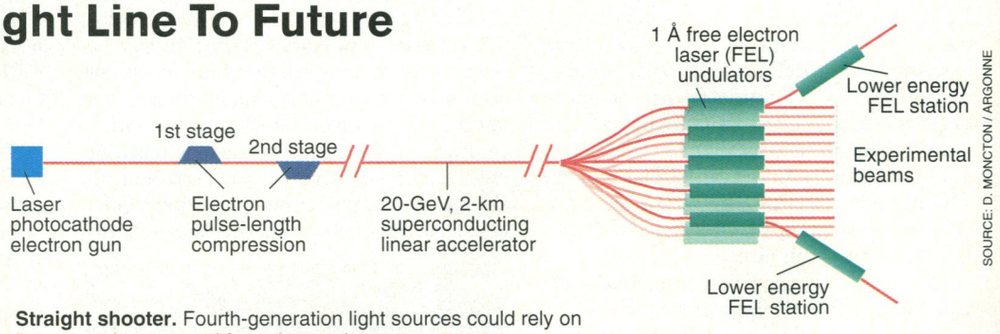
No matter which side prevails, all parties agree that the debate itself shows a healthy degree of concern for teaching. A decade ago major mathematical meetings all but ignored issues of pedagogy, while in Orlando there were more than 50 sessions on education. The reform movement, backlash and all, has "given the teaching of calculus a much greater emphasis in all of our institutions," notes Polking. "That's definitely progress."

–Barry Cipra

X-RAY SOURCES

Linacs Offer Straight Line To Future

GRENOBLE, FRANCE—The current family of electron storage rings in Japan, Europe, and the United States is giving researchers new insight into the structure of matter, but they are essentially old tools. Although these third-generation machines are bigger and more costly than their predecessors, they produce their intense x-rays by the same basic method: They accelerate electrons and force them into a circular path with powerful magnets.



Straight shooter. Fourth-generation light sources could rely on linear accelerators and free-electron lasers.

But last month, an international community of x-ray scientists meeting here* decided to stop going around in circles. They agreed that the fourth-generation machines to be built sometime in the next 20 years should generate x-rays by a different strategy. The new facilities would use linear accelerators (linacs) to accelerate the electrons, then feed them into free-electron lasers (FELs) to produce shorter, more intense pulses than anything now available or in the works.

Reaching consensus on this novel approach surprised those attending the workshop. "Nobody really expected this outcome," admits Guy Luijckx of NIKHEF, the Dutch National Institute for Nuclear and High-Energy Physics. "It was remarkable." The idea of using linacs and FELs builds upon theoretical work at the Stanford Linear Accelerator Center and at DESY, Germany's particle physics laboratory near Hamburg—work that Herman Winick of SLAC says was seen by some researchers as "a solution looking for a problem. … But when we asked users if they would be interested in this degree of coherence, higher brightness and peak power, and shorter pulses," he says, "their answer was a resounding yes!"

The current generation of x-ray sources accelerate electrons to energies ranging from 6 billion to 8 billion electron volts as they speed around circular racetracks. The circulating beams pass through devices called wigglers and undulators, where they swerve back and forth through gauntlets of magnets. In doing so, the electrons generate intense, pencil-thin beams of x-rays. The shorter, narrower, and more intense the x-ray pulse, the sharper the resulting image. And the pulse size, in turn, depends on the size of the electron bunches in the accelerator. "We want to decrease the bunch size in all three dimensions," says Jörg Rossbach at DESY. "The linac is the natural solution."

One advantage of linear accelerators is their ability to create bunches of electrons with pulses as short as 100 femtoseconds and much less than 1 millimeter in length, compared to the 10 picoseconds' duration and

* Workshop on Fourth Generation Light Sources, organized by the Beam Dynamics Panel of the International Committee for Future Accelerators, Grenoble, 22 to 25 January.

several millimeters' length available from circular accelerators. Linacs can also produce narrower beams because the electrons are not following a curved path, where the emission of photons causes the beam to widen. "The beam size decreases linearly with energy in a linac," says Rossbach, "while it increases quadratically with the energy in a storage ring."

Dedicated linacs for the x-ray community will become available in some 15 years, predicts David Moncton, director of the Advanced Photon Source at Argonne (Illinois) National Laboratory, which started test runs last year (*Science*, 31 March 1995, p. 1904). Moncton foresees superconducting linacs that will "fan out the beam through a switchyard" to as many as 50 free-electron lasers running in parallel (see drawing).

The FELs, which would convert the electrons' energy into x-rays, also play an important role. Like present-day wigglers and undulators, FELs send an electron beam through a series of hundreds of magnets with alternating polarities. But their brilliance is expected to be several orders of magnitude higher because of the amplifying effect of stimulated emission, in which each x-ray photon triggers the emission of the next, resulting in a burst of coherent radiation.

FELs, however, are also the big holdup in this effort to straighten out storage rings. Current designs have mirrors at both ends to increase the radiation intensity in the device so that stimulated emission becomes possible. But x-ray scientists would like to dispense with the mirrors. "At these wavelengths, mirrors reflect badly and cannot deal with the intensity of the radiation," explains Luijckx.

To solve that problem, researchers hope to obtain stimulated emission during one pass by bunching the electrons sufficiently through a principle known as SASE (Self-Amplified Spontaneous Emission). "[SASE] would solve a lot of problems," says Luijckx. But the SASE has not yet been demonstrated experimentally at short wavelengths, although two test linacs are now under construction at DESY to test the principle. "In general the theorists agree that it will work," says DESY's Gerhard Materlik. "Now we have to test it."

Because of these barriers, Moncton believes circular machines "will be the x-ray servers for the next 20 years. We have to do 5 years of R&D on linacs and FELs to see how happy we are with their performance before we make any decisions." But users are already preparing for the day when they can go straight. "We are running workshops to find out what really will happen at these huge peak brilliances and femtosecond pulses," says Materlik. "This is opening up a completely new horizon."

–Alexander Hellemans

Alexander Hellemans is a writer in Amsterdam.

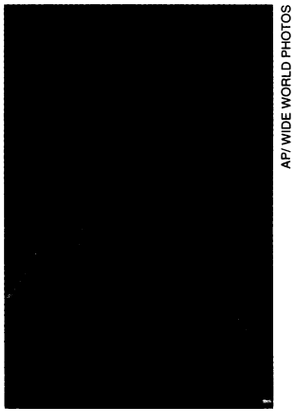
MEETING BRIEFS

Heavy Hitters Anchor the AAAS Lineup at Annual Meeting

BALTIMORE—Within a few short blocks of this city's baseball stadium, U.S. Vice President Al Gore came out swinging in his speech at the Annual Meeting and Science Innovation Exposition of the American Association for the Advancement of Science (AAAS, the publisher of *Science*). At the gathering, held from 8 to 13 February, Gore had choice words about political opponents and their support of science; we cover that and other notable presentations here. An additional story, on biological clock research presented at the meeting, starts on page 905. Coverage of later sessions will appear next week.

Gore Courts and Exhorts

While Republican presidential hopefuls made last-minute pitches to Iowa voters as that state kicked off the 1996 U.S. primary season, U.S. Vice President Al Gore was busy wooing the scientific community. In a 12 February speech at the AAAS meeting—the first of three talks this week on science and technology—Gore derided the Republican Congress for opposing research and pleaded to see more "white lab coats of American scientists" on Capitol Hill.



AP/ WIDE WORLD PHOTOS

Rallying cry. U.S. Vice President Al Gore called for scientists to get more involved in politics.

Gore also challenged researchers to build better bridges among disciplines and with society (see accompanying story). But he saved his strongest language for House Republicans who oppose Administration policies on environmental research and applied technology programs. With the exception of boosting funding for the National Institutes of Health, Gore said House members "were approaching science with the wisdom of a potted plant" and supporting "a science policy straight out of science fiction."

The audience seemed pleased with the message, laughing at Gore's references to Republican statements criticizing atmospheric research, and gave him a standing ovation. "A lot of people here are worried about what's going on" in Washington, says Al Teich, who directs policy at the AAAS. "This adds to the chorus of people" calling for the community to take a more activist approach in defending research budgets. Republicans, however, told *Science* after the speech that Gore was merely trying to score political points. Representative Robert Walker (R–PA), who chairs the House Science Committee, dismissed the talk, saying that "scientists are smart enough to recognize when they are being used in a game of politics."

Gore maintains that scientists can play a larger role in educating politicians. "Walk through the halls and you will see the Gucci loafers of corporate lobbyists," but few people clothed in scientific garb, Gore said. "Page through a directory of members of Congress and you will find over 150 lawyers, but only six scientists, two engineers, and one science teacher among the 535 people in the House and Senate."

That is not wholly a partisan view. Thomas Weimer, Republican staff director of the House Science Committee's basic research panel, told a weekend session on the current Congress that "we must be aware that there is a real education problem with" newer House members, few of whom have a scientific or technical background. But Weimer notes that the House moderated its stance on R&D cuts over the past year, and he rejects the Administration's contention that Republicans intend to gut government R&D. The biggest difference in the long-term budget plans of the two parties, he says, is the pace of the reductions: The Republican plan would do it gradually over 7 years, while the Administration has delayed most of its cuts until early in the next century.

Gore, however, insists there are major differences between the White House and Congress on science and technology issues, and he used his speech to drive home the point. He cited a host of legislative accomplishments that demonstrate the Administration's commitment to science, from stronger patent protection for inventors to higher funding for some research agencies. And he exhorted scientists to "enlist in the army of persuasion whose battle cry says knowledge is important for knowledge's own sake." But