R&D, mostly at Ames, on alternatives to rare-earth magnets, says Patrick Davis, a program manager. Researchers are exploring the potential for induction motors and switch-reluctance motors. But lower efficiencies and greater bulk will likely keep them at a disadvantage to permanent-magnet motors for hybrid cars. They could be more attractive in all-electric cars, where more space will be available under the hood, notes Boyd.

Finding new permanent-magnet materials is the goal of one of the first 37 research projects that were selected for funding by DOE's Advanced Research Projects Agency–Energy. The ARPA–E program is reserved for high-risk research that could produce breakthroughs if successful. George Hadjipanayis, a University of Delaware physicist and principal investigator of the $4.5 million, three-year effort, says three approaches will be taken in a bid to find materials that can double the field strength of $Nd_2Fe_{14}B$. Both rare-earth-free magnets and magnets requiring smaller amounts of rare earths will be investigated. A team at the University of Nebraska will search for ways to improve the magnetic properties of iron–cobalt alloys. Hadjipanayis says some theoretical studies have hinted that the addition of tungsten could alter the molecular lattice of the iron–cobalt alloy, improving its anisotropy. A second approach, to be carried out at Ames, will evaluate a wide range of elements, including lithium, zinc, manganese, and selenium, for combination with rare earths and a transition metal. If successful, the newly discovered magnetic materials could require significantly less of the rare earths.

Hadjipanayis will lead a third, bottom-up approach to discover nanocomposites that offer a higher density of magnetic energy than $Nd_2Fe_{14}B$. Models have predicted that a combination of materials such as rare-earth compounds and materials like iron–cobalt should perform dramatically better if they can be manipulated at a scale of 20 to 30 nanometers, he says. "The first challenge is to make the magnetic nanoparticles with a high coercivity. Challenge two is to make the iron–cobalt nanoparticles with high magnetization. And then we will try to assemble them in some two-dimensional and three-dimensional arrays and try to make a magnet out of them." **David Kramer**

Europe reflects on a decade of higher education reforms

A maze of top-down and bottom-up initiatives has rattled Europe's universities and set them on their bumpy way toward transparency, compatibility, and mobility.

"Who would have thought, 10 years ago, that the countries of Europe could start a process of changing their higher education systems? And that they would do it without any laws, without any overt leverage? To have achieved anything would have been significant," says Tim Birtwistle, an emeritus law professor at the UK's Leeds Metropolitan University. Not only have the political goals of the so-called Bologna Process been achieved, but a plethora of national reforms and a grass-roots response by the academic community are under way. Noting that most participating countries now use the bachelor's, master's, PhD sequence or a similar degree system, and that "learning has become more important than teaching," Birtwistle, one of the UK's designated "Bologna experts," says that "a lot has been achieved, even while much remains to be done."

At the 10th-anniversary celebration of the Bologna Process, held this past March in Budapest and Vienna, education ministers tipped their hats by launching the European Higher Education Area. The Bologna Process's overarching goals, for which the EHEA is both an umbrella and a symbol, are transparency and recognition of degrees from one institution by another; comparability and compatibility of courses and degrees among universities; and increased mobility—facilitating students spending time at other institutions during a degree and switching institutions and fields for successive degrees. The Bologna Process, named for the Italian city where it was officially proposed in 1999, originally included 29 countries (see PHYSICS TODAY, May 2001, page 21); Kazakhstan joined this year, bringing the current total to 47.

The Bologna Process is epochal for the whole of Europe, says Luigi F. Donà dalle Rose, a physicist at the University of Padua and one of Italy's Bologna experts—people paid by the European Commission to stay abreast of implementation and to consult and disseminate information about the process. In Italy, for example, university curricular planning had been based on principles from the first half of the 20th century. In the meantime, with higher education no longer reserved for the elite classes, the number of students has ballooned to 1.5 million. The old university system was not cut out to serve the masses, says Donà dalle Rose.

Convergence and contradictions

Probably the most obvious result of the Bologna Process is the convergence of degree structures. All disciplines in participating countries are moving to a three-degree system. Italy and many other countries have switched from offering a long first degree to offering something akin to a bachelor's plus a master's. In Spain, starting with the coming academic year all universities will adhere to a new four-year bachelor's degree system. In many countries, master's programs are mushrooming. In Germany today, there are a third more master's than bachelor's programs, according to Barbara Kehm of the International Center for Higher Education Research in Kassel.

In Germany, scholars are resisting the switch to a system of three-year bachelor's and two-year master's degrees, Kehm says, "especially in engineering and the natural sciences. They think it's impossible to train an engineer or a physicist in three years. University professors cannot imagine what kind of jobs these animals will get." Maybe three years will end up as a good upgrade for jobs that previously did not require a college education, she says.

"Governments across Europe wanted more students to leave after the new shorter first degree," says Gareth Jones, a physicist at Imperial College London who has been active in the Bologna reforms, "but that is not happening. There is not much interest from employers for physicists or engineers with only a bachelor's degree." In the UK, he notes, "the Bologna reforms have had much less impact than in the rest of Europe because most of them were already in place here." Still, he says, in physics and engineering, most of the UK's shorter master's degrees are not accepted as up to snuff by academics in other countries.

Implementations of the Bologna Process that are widely considered as successes include the introduction of the European credit transfer system and the formation of accreditation agencies that check the transparency of programs. In many countries, says Predrag Lažetić, a researcher at the Center for Education Policy in Bel-

ESZTER GORDON

Education ministers met this past March to mark 10 years since the Bologna Process began.

grade, Serbia, "The Bologna Process was the motivation to introduce national quality assurance."

No one can object to the Bologna Process goals in the abstract, says Lažetić. But because they are vague and there are so many players, "a lot of countries have introduced a lot of reforms that are politically in the same direction, but in reality we still have 40 different degree structures, and what a bachelor's and master's mean differs in different countries. We want comparability but not convergence. Mutual recognition but not standardization." In practice, he says, the goals become contradictory.

Physics is not plagued by such splintering, insists Hendrik Ferdinande, a physicist and Bologna reformer at Ghent University in Belgium. He points to *A European Specification for Physics Bachelors Programmes,* a document that this past March got the stamp of approval from the European Physical Society. The document, he says, will inspire all physics departments as they reform their bachelor's degrees in the coming years.

In some countries, notably Germany, Austria, Italy, Spain, and Greece, students have protested against the Bologna Process. They complain that, among other things, more content is being squeezed into less time and encouraging mobility despite the troubled economy is unrealistic. They object that requiring quizzes, homework, and attendance rather than evaluating students solely on big final exams is micromanaging and makes university too much like secondary school. They say universities are selling themselves to the private sector. And they complain that civil-service employment opportunities are not available at the bachelor's level.

Unfortunately, says Guy Haug, a Bologna Process founding father, "some countries have packaged unpopular reforms as Bologna, including things that have nothing to do with the Bologna Process." As examples, he lists charging tuition for the master's degree, replacing student grants with loans, and having overfull auditoriums. In general, says Lažetić, "Students are supportive of the Bologna Process. But they say it should be implemented in a holistic way, not á la carte, and they say more thought needs to go into student welfare."

"A pedagogical revolution"

Student welfare is at the heart of Tuning Europe, a project that has made deep inroads since it began in 2000 in response to the political launch of the Bologna Process. The project seeks to make degrees at each level within a given discipline "compatible, but keep the variety of Europe," says Tuning Europe cofounder Julia Gonzalez, an anthropologist and vice rector at the University of Deusto in Bilbao, Spain. Adds Donà dalle Rose, who coordinated the project for physics, "Tuning is a kind of answer on the university side to the challenges put forward by the Bologna Process." Physics was one of the original handful of disciplines to undertake tuning—that number has now surpassed two dozen.

Through surveys of faculty, students, employers, and alumni, learning outcomes were outlined for each degree level. "The main finding is that we should describe topics in terms of

Tuning physics in the US

Taking a page from the education reforms in Europe, groups around the world have been exploring tuning as a tool for making university programs more relevant and transparent. In the US, physics was one of two fields Utah began tuning last year.

Utah's nine publicly funded colleges and universities took part in a tuning pilot project that included schools in Minnesota and Indiana. With $150 000 apiece from the Lumina Foundation for Education, each participating state picked two or three fields to tune; the exercise is part of the nonprofit, Indiana-based foundation's goal of upping the percentage of people in the US who earn a college degree from around 40% now to 60% by 2025.

Says Lumina program director Kevin Corcoran, "The Achilles heel of higher education is that people cannot describe what degrees mean without using credit hours." Tuning is a faculty-driven process that aims to spell out—for prospective students, their parents, faculty, potential employers, and policymakers—the competences of a graduate: What skills does a bachelor of physics have? A master?

"Even with a relatively consistent physics curriculum, there are significant variations in how well the major learning outcomes are achieved," says retired physicist William Evenson, the Utah System of Higher Education consultant who led the state's physics tuning panel. The panel's student representative, Jeff Hodges, who is in his first year of PhD work at the University of Utah, says, "It shocks me to be in graduate school with people who do not have any [upper-division] E&M under their belt." In the tuning process, he says, "we focused on defining degree programs. How do you tell a teacher what a student needs to know, without telling them how to teach? We came up with skill sets."

Guided by input from students, alumni, faculty, and private-sector employers, the academic panel developed a list of dozens of skills. For starters, the list says a physics bachelor should have an understanding of the role of evidence, of cause and effect, of experiment, of scientific ethics, of science as a community effort. A bachelor should have estimation skills, understand simple models, practice laboratory safety, be able to carry out error analysis, and be able to present an informal talk on a lab experiment or class project.

"It is realistic to expect students to accomplish a certain level by a certain degree," says Evenson. "We are not saying what the curriculum should be or how you get those competences. We recognize that every institution has a different set of students, a different mission. So every institution will have their own take on how to achieve these outcomes." In addition to transparency, he says, "tuning focuses a lot on accountability."

But Brad Carroll, a panel member from Weber State University in Ogden, says, "Ultimately, it is about curriculum. If you find that businesses say they want people who work well in teams, we might restructure lab courses. If we find out that they need more electronics, we might change what we teach." Each faculty panel member, he says, will take results from the tuning process back to their own department, "and we may make curricular changes."

The Utah tuning panel members are now advising the Texas Higher Education Coordinating Board, which, as part of a $1.8 million grant over four years from Lumina, is launching tuning in four engineering fields. One aim in Texas is for students to be able to more easily transfer among institutions, says Mary E. Smith, the board's assistant deputy commissioner for academic planning and policy. "We have lots of swirling students that take classes all over the place." The hope behind Texas's tuning effort, she says, "is to get more students to successfully graduate from engineering programs in our state. Our data show that Texas is not meeting its targets for graduating STEM [science, technology, engineering, and math] students. Tuning is part of [our plan for] closing the gap by 2015."

Toni Feder

competences, rather than content," says Donà dalle Rose. For physics, some three dozen generic and subject-specific competences emerged. For bachelor's and master's graduates, the generic competences include varying levels of "capacity for analysis," "capacity for synthesis," "learning to gather relevant information," "teamwork," "ethical commitment," and "good working knowledge of the English language." Specifically in physics, graduates at those levels should display "deep knowledge and understanding," "experimental skills," and abilities in estimation, mathematics, searching the literature, and problem solving, among other things.

The tuning process "changed my way of thinking," says Donà dalle Rose. "I try to convince my students that what is important is what remains in their minds. Looking at outcomes rather than content means rethinking how to shape the lecture, how to make it more interactive." Tuning, he adds, represents a "pedagogical revolution. The European convergence of higher education and the national reforms together made fertile soil for the tuning process."

"No university will accept a group of people telling them what to do, so the way implementation is done is up to each university," says Fernando Cornet, a physicist at Spain's University of Granada and a member of the physics tuning team. "But tuning is somehow a landmark. It has been accepted by everybody. Each country has modified it a bit and adapted it to their mentality and culture." Implementation is also helped, Donà dalle Rose says, by "many concepts being impressed by national law."

"Tuning has become core to so much of the Bologna Process," says Birtwistle. "It incorporates learning, students, employability." Taking into account the private sector, he adds, "is anathema to some wings of liberal education. But everyone needs a job."

The concept has spread quickly. The first knock-off project, for which Gonzalez and others in Europe have served as consultants, was for 18 countries in Latin America. Pilot tuning projects have been undertaken in the US (see accompanying story), and projects are on the books in Africa, Russia, Lithuania, Georgia, Australia, and India.

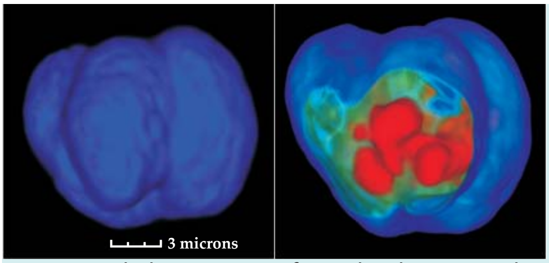
An ongoing process

Going into the second decade of the Bologna Process, "the first priority should be not to add any more new goals," says Haug. Education ministers have repeatedly widened the list of goals involving credit systems, lifelong learning, funding, the link between education and research, and other things. One official goal, adopted in 2009, is for the percentage of students who study abroad to grow to 20% by 2020. The additions have "blurred the initial short list of structural changes," Haug says, and, combined with the expanding circle of participating countries, "complicated enormously the implementation of the Bologna Process. We need to make sure that what remains to be done is done. And where initial reforms have not been done properly, I am quite certain some countries will reconsider." For example, he expects that some of the new bachelor's programs will be switched from three-year to four-year degrees.

"I think time will do the job," says Bologna expert Regine Bolter, a computer science professor at the University of Applied Sciences in Dornbirn, Austria. "The more students with new degrees that go into the workforce, the more accepted these new degrees will get."

Haug also predicts that the "core" countries, by which he means European Union members and candidates plus Norway, Switzerland, and Iceland, "will move faster and won't try to drag along everyone." So far, he says, the Bologna Process has been like "an aircraft without a pilot" and "there have been a huge number of very positive reforms and an equally impressive number of misconceived ones. I hope the second decade of the process will be better controlled." **Toni Feder**

Physicists invited to apply their insights to cancer



Robust methods for early cancer detection may be developed from tomographic imaging of single cells. These images show the nuclear surface (left) and a slice from the reconstructed isotropic three-dimensional image (right); DNA density increases from green to red. The images are formed with computed tomography, but whereas clinical CTs use an x-ray source and detector, here the source was white light and the detector a microscope equipped with a CCD camera. (Courtesy of Vivek Nandakumar, Laimonas Kelbauskas, Roger Johnson, Deirdre Meldrum, Center for Ecogenomics, Biodesign Institute, Tempe, AZ.)

Can physicists help get cancer research out of a rut? That's what the National Cancer Institute is betting on with the roughly $150 million it's spending over five years on a network of 12 centers, each a multi-institutional, multidisciplinary collaboration led by a physical scientist. "We're taking cancer, turning it on its side, giving it to a new group of people, and seeing what happens when we combine what we already know with what they come up with," says Larry Nagahara, NCI program director for the Physical Sciences–Oncology Centers (PS–OCs). The centers got started last fall.

Cancer research hasn't seen a major paradigm shift in 30 or 40 years, according to William Grady, who studies signal deregulation and epigenetic modifications in gastrointestinal cancer at the Fred Hutchison Cancer Research Center in Seattle. "Most advances involve revisions and refinements. We do not have medical treatments that can cure [most cancers] despite decades of effort."

The idea behind the PS–OCs is to bring cancer research fresh perspectives, such as relating disease to the physical properties of cells. "What's new is thinking not only in terms of the chemical concentrations of signaling proteins, but also in terms of their spatial organization within the cell," says physicist Jan Liphardt, principal investigator of the PS–OC led by the University of California, Berkeley. Another example, he says, is that tumors are firmer than surrounding tissue. "What has not been known is whether this stiffening is a bystander, or if mechanical changes are intimately involved in cancer progression." To find out, researchers in Liphardt's PS–OC injected mouse breasts with cells engineered to crosslink collagen and then added cancer cells. They found that cancer grew faster in breasts that had been preconditioned to be stiff.

One project at the MIT-based PS–OC involves "measuring the instantaneous growth rate of single cells at known points in the cell cycle," says Scott Manalis, whose team developed a resonator that can weigh single cells to femtogram resolution. "We can measure mass, density, and charge. There are many interesting clinical questions we can ask with this," he says, "such as, Can these physical properties of cells tell you how patients will respond to therapeutics?"

"The thing about cancer," says physicist Paul Davies, who heads up the PS–OC based at Arizona State University, "is that you are never going to solve the problem by details. You cannot micromanage. It always outmaneuvers you." The cell, Davies says, is so "stupendously complex we will never figure out on the level of individual interactions what to do. But we may not need to. If physical features turn out to trigger cancer, we don't need to know all the gory details."