pedigree of theory that would enable one to analyze this formally."

Working up estimates of the costs and benefits of mutation in bacteria under various conditions is one important step in that direction. Previous studies have suggested the frequencies at which beneficial and deleterious mutations arise. Now Sniegowski is planning to factor in the cost of DNA synthesis fidelity to see how much this could contribute to the selection and maintenance of baseline mutation rates. This approach might also help researchers studying adaptive mutation. Enhanced variability is not the only potential benefit of increased mutation rates; another benefit might be a reduced cost of maintaining high fidelity. So systems that crank up their mutation rates may persist because of their cost-reducing benefits rather than their variability-generating abilities.

"One way to think of the cost of fidelity is that its impact depends on the current economics of a population," says Sniegowski. If maintaining high-fidelity DNA synthesis is pricey, then cells under stress might be unable to afford it.

Drawing on the combined wisdom of theory and experiment, such approaches might help sort out some of these unresolved questions. And the increasing interest in evolvability may spark additional approaches. Evolutionary biologist Christopher Wills of the University of California, San Diego, for one, is enthusiastic about the possibilities: "I'm very glad that the evolution of evolvability is finally starting to catch people's attention." **–MARINA CHICUREL**

Marina Chicurel is a writer in Santa Cruz, California.

GERMANY

A Former Capital Stakes Its Future on Science

Most of the politicians have left for bustling Berlin, but scientists are hoping to keep Bonn from becoming a post–Cold War backwater

BONN—When reunified Germany moved its capital back to Berlin a few years ago, this placid city seemed poised to fade into obscurity. Instead, Bonn is seeking to redefine itself as one of the country's foremost science cities. Last week, the cornerstone was laid for a $100 million edifice, the Center of Advanced European Studies and Research (CAESAR), which is now rising on the banks of the Rhine. Bonn's 183-year-old university, once known primarily for its law and liberal arts faculties, has been pouring resources into its medical and natural sciences departments. The federal government's science and education ministry and the main research granting agency, the Deutsche Forschungsgemeinschaft (DFG), have remained in Bonn rather than joining the exodus to Berlin, and the city is now home to several international science secretariats. Bonn is also busy refurbishing a collection of unique science museums. All this is intended to breathe more scientific life into a place that, even in the depths of the Cold War, novelist John le Carré dismissed as "a small town in Germany." But Bonn's ascension is by no means assured: It faces stiff competition from established science bastions like Heidelberg and Munich, as well as upstarts in the east such as Dresden and Leipzig.

Bonn's venerable university is spearheading the basic research end of this attempt to take on the rest of Germany. The university now houses Europe's most advanced center for epilepsy research, and it is considering a proposal to build a $35 million "Life and Brain Center" that would promote collaborative neurobiology projects between academia and industry. "The idea is to build on a U.S.-style model that would bring together basic researchers, the neurological medical sciences, and the biotech industry," says Bonn University neuropathologist Oliver Brüstle, who has become one of Germany's most controversial and outspoken scientists since his research team submitted the first application in Germany to import embryonic stem cells for nerve-cell regeneration research (see p. 1811).

Renovating and innovating. Bonn University's main building and artist's conception of CAESAR *(below)*.

CREDITS: (LEFT TO RIGHT) UNIVERSITY OF BONN; CAESAR RESEARCH CENTER

Brüstle, who spent 4 years at the U.S. National Institutes of Health, says he sees great potential for Bonn as a research center—as long as Germany's political and scientific establishments permit the sort of research that needs to be done. The political turmoil over Brüstle's stem cell research—which the DFG has approved in principle, but the German government is now debating—is in some ways emblematic of the problems that Bonn and other German research centers face. University research is often impeded by excessive bureaucracy, and the research and education ministry has been stymied in some of its efforts to make research more flexible.

CAESAR is trying to buck these hidebound research traditions. "We want to become Germany's leading example of high flexibility in research," says CAESAR's scientific director, applied mathematician Karl-Heinz Hoffmann. Even though the center is government-funded, it does not operate under rules that bog down research and clog turnover at most German institutes. Scientists are hired on 5-year contracts, for example, and are required to finish their research projects within that time.

For now, CAESAR's 70 scientists are housed on the upper floors of an office building in Bonn's old town, not far from the birthplace of composer Ludwig van Beethoven. Over the next 2 years, after the center's new headquarters and labs are finished, CAESAR will expand to about 300 researchers in fields ranging from biology to computer science.

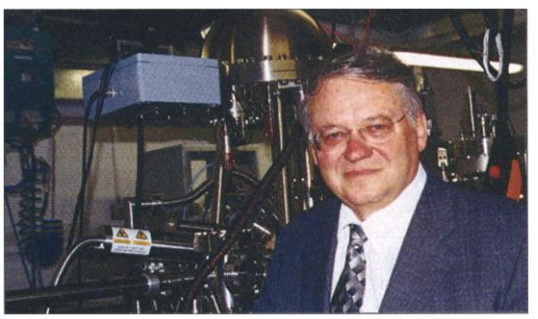
CAESAR, whose acronym recalls the Roman general who invaded the Rhineland 2000 years ago, is aiming to conquer a far different territory: emerging markets in fields such as nanotechnology, "smart materials," and biosensors. For example, CAESAR has

teamed Michael Moske's solid state physics group with Beate Schmid's molecular biology group to develop "microbalances"—resonant quartz sensors that use nucleic acids to help detect minute changes caused by modulations of mass. Other groups are developing materials that aim to improve the links between human and machine, such as connecting electronic devices with nerve cells or other human tissues.

As CAESAR probes the human-machine interface, other institutions in Bonn are serving as Germany's interface between science and policy-making. Last year, the DFG added a $20 million wing to its Bonn headquarters, signaling a long-term commitment to the city, and the research ministry has also kept its main building here. In addition, the two most important centers for expanding German academic and scientific influence abroad—the Alexander von Humboldt Foundation and the German Academic Exchange Service—are housed in Bonn. They recently benefited from an extra $82 million in federal grants to bolster their programs to attract top scientists to Germany (*Science*, 9 March, p. 1876). Also striking an international note, the United Nations has established five secretariats in Bonn, including those overseeing conventions on climate change, desertification, and the preservation of migrating species.

Across town, the Max Planck Institute for Radio Astronomy held an open house last month that drew nearly 6000 visitors to mark the 30th anniversary of its 100-meter radio telescope in nearby Effelsberg. Billed as the world's largest moveable radio telescope, it has helped the institute's scientists learn about the early development of the universe by analyzing pulsars, quasars, and distant galaxies. And Bonn is bringing science to the public as well. The science-oriented Deutsches Museum Bonn, for example, is putting on a major exhibit this year, in coordination with the Smithsonian Institution in Washington, D.C., on the history of the Nobel Prizes. Farther down Bonn's "museum mile" is the Museum Alexander Koenig, a century-old zoological institute that is expanding (see sidebar).

From his vantage point in the hothouse of Bonn's 200-year-old Botanical Garden, botanist Wilhelm Barthlott views Bonn as an ideal place for scientists to pursue research and to find ways to apply it. He should know: Industry beat a path to Barthlott's door after he and a colleague explained the "lotus effect"—how the leaves of the lotus and related species, which have a rough and complex surface structure studded with wax crystals, are so good at keeping themselves clean. A host of "lotus effect" products—such as self-cleaning paint and Teflon-like pan coatings—are now on the market. Today, Bonn itself is aiming to become a hothouse for German science—although it may be a few years before that ambition takes firm root. **–ROBERT KOENIG**



Hailing CAESAR. Scientific director Karl-Heinz Hoffmann sees strength and flexibility.

Zoology Institute Shakes Off the Dust

BONN—The Museum Alexander Koenig has long been a taxonomist's dream but a bench researcher's nightmare: scientists jammed into cramped basement labs, having to elbow their way past stuffed giraffes and antique wooden cases packed with desiccated birds or formaldehyde-soaked snakes. But the century-old museum, which began as the vision of the Bonn University ornithology professor for whom it is named—a researcher who amassed Europe's largest collection of species of stuffed birds—is now being transformed into a modern research center. These days, DNA sequencers are more important than formaldehyde, and global biodiversity research is pushing aside old-fashioned expeditions to bag trophies.

Now undergoing a $14 million renovation and expansion, the present building of the Museum Koenig was finished just before World War I broke out; it was converted to a field hospital during the war and afterward a barracks and prison. It reopened as a zoological museum in 1934; then Nazi minister Hermann Göring tried to turn it into a hunting museum. Its basement was again converted to a hospital during World War II, and afterward the museum was co-opted by the West German government, briefly housing the offices of the first postwar chancellor, Konrad Adenauer. It wasn't until the 1950s that the museum was able to reassemble its collection and return in earnest to research.

Officially a zoological research institute, the museum was also designated an Institute for Terrestrial Biodiversity in 1997—connecting it to a worldwide biodiversity research network—and it was the first German museum to establish its own molecular biology lab for speciation research. Its 15 full-time researchers keep the Global Register of Migratory Species, and they coordinate the Biodiversity Monitoring Transect Analysis (BIOTA) project for East Africa, focused mainly on Kenya. "We are setting up biodiversity observatories and measuring the impact of humans on that diversity," says Jörn Köhler, a biologist with the museum's BIOTA program.

Young at heart. Like other Bonn institutions, the Museum Alexander Koenig is pouring money into modernization.

Nearby, in a workroom packed with lizard cages, renowned herpetologist Wolfgang Böhme lords over an extensive collection of reptile and amphibian species. He recently succeeded in tracking down a population of dwarf crocodiles—believed for years to be extinct—that lives in the deserts of southeastern Mauritania. In addition, he and a colleague verified an extinct giant lizard species, *Celestus occiduus*, by examining the stomach contents of a preserved lizard collected in Jamaica in 1851.

In another jammed lab on the museum's lower floor, evolutionary biologist Bernhard Misof's research group is conducting phylogenetic studies to better understand the startling burst of speciation of killifish in ponds and creeks in the Central African rainforests. His group also is studying speciation processes of other animals, including skinks, amphibians, dragonflies, and butterflies. "We were the first museum in Germany to establish its own molecular biology lab," boasts Misof, whose equipment includes DNA sequencers and protein electrophoresis instruments. With the museum expansion project and the blossoming of Bonn as a science city, he says, "there is great potential here." **–R.K.**

CREDITS: R. KOENIG