New wave. Demonstrators in Cairo's Tahrir Square sparked a societal revolution now spreading to scientific research and development.

A New Day for Egyptian Science?

In the aftermath of Egypt's popular uprising, the country is embracing a grand vision to make scientific research the engine of a powerhouse economy. Can Egyptian scientists make it happen?

CAIRO—The wide hallways of the chemistry building at Cairo University are impressively lined with gray marble speckled with white. But a passing glimpse into a laboratory at Egypt's most prestigious seat of public higher education reveals a ramshackle collection of aging equipment well below the standards of a typical American high school. Mahmoud Saleh shakes his head. "A former university president owned a marble factory," the chemist explains. "Meanwhile, our labs don't have the basics; we have to pay out of our own pockets for research material." Given that the full professor of chemistry receives a salary of $400 a month, that's a tall order.

But now scientists like Saleh are carrying Egypt's 25 January revolution, which led to the downfall of longtime president Hosni Mubarak and his dictatorial regime, to the country's universities and research institutes. They are demanding academic freedom, a living wage, an end to corruption, and a clear strategy to help Egypt tackle the coming challenges. The interim government, overseen by the army, is listening. "Countries do not move forward except with scientific research," Prime Minister Essam Sharaf said on 1 June, when announcing plans for a massive new science city outside Cairo (see sidebar, p. 280).

Egypt's current leaders are not waiting for a new elected government, expected to take over sometime in 2012, to make changes. They say that the revolution's ultimate success depends on jump-starting the flagging economy and that one crucial way to do that is to transform the country's troubled research establishment. Last month, science and technology spending won a huge funding increase, from $400 million in 2010–11 to $500 million in the fiscal year that began 1 July, and professors at public universities can soon expect a 50% pay boost.

In the aftermath of the revolution, science enjoys widespread public support and respect here. Ahmed Zewail, an Egyptian-born Nobel laureate in chemistry, won a raucous standing ovation in a packed auditorium near Tahrir Square on 2 June shortly after Sharaf approved his vision of a science city. "Little children follow Zewail in the streets," marvels Lisa Anderson, president of the private American University in Cairo (AUC). "They all want to be chemists."

The surge in public support for bolstering Egypt's R&D efforts is one of the surprising repercussions of the political upheaval. After decades in the economic and political doldrums, many here see R&D as a vital tool for revitalizing their country. Young scientists are suddenly optimistic. "The revolution has given me hope that science will become a strategic goal for Egypt," says Nor Abdallah, a geology graduate student at Cairo University. Adds chemistry graduate student Mohamed Shehata: "We don't imagine we can compete with Europe, Japan, or the U.S., but we can with China and India. A few decades ago, we led the Arab world, and in a few years we can do so again."

Transforming that hope into reality won't be easy, however. Despite the announced increases, Egypt still lags far behind many other developing countries in R&D spending and research output (see graphic, p. 279). "The biggest obstacle now is funding," says Amr Salama, who heads the recently created ministry of scientific research and technology. Yet the needs go well beyond money. Scientists and administrators are at odds over how to revamp a politicized university system, and new laws and regulations are needed to encourage university researchers to file patents and create businesses. And few scientists trained solely in Egypt have experience pursuing cutting-edge research or competing for grants. Meanwhile, new universities springing up along the Persian Gulf and in Saudi Arabia threaten to accelerate the brain drain that has long afflicted Egyptian research (*Science*, 16 October 2009, p. 354). "This will take time," says Lahcen Achy, an economist at the Carnegie Middle East Center in Beirut. "You can't immediately reshape institutions."

CREDIT: AMR NABIL/ASSOCIATED PRESS

Published by AAAS

War and stagnation

When the Arab Republic of Egypt was created in 1953, the ancient nation's prospects seemed bright compared with those of its neighbors in Africa and Asia. Many African nations lacked infrastructure and had endured long and bitter conflicts to free themselves from colonialism. China was isolated, India mired in poverty, and South Korea devastated by war and occupation. By contrast, Egypt had a relatively peaceful transition to independence, and the new government expanded the universities and research institutes set up under British rule, emphasizing applied sciences.

Then came a series of devastating conflicts with Israel, which sapped money and morale. "The 1967 war destroyed everything," recalls Karimat Mahmoud El Sayed, a crystallographer who studied in the United Kingdom and took a job in 1966 as a young professor at Ain Shams University here. "There was no money except for the military through the 1970s and 1980s," she says. "We had to pay out of our own pockets to design experiments for students." During that period, leaders of nations such as South Korea, Taiwan, and then China began to invest in science. "They grew because of sustained commitment to S&T," says Maged Al-Sherbiny, president of Egypt's Academy of Scientific Research and Technology and assistant minister for scientific research. "We went to war again and again." Today, compared with a country like South Korea, "we're in a disastrous situation because we've invested so little."

PHOTO CREDIT: MAHAN KALPA KHALSA; (GRAPHIC SOURCE) SCIENCE RESEARCH/THOMSON REUTERS

"I hope we can generate a culture of R&D as a basis of reorganizing Egypt's industry."

—AMR SALAMA, SCIENCE MINISTER

President Anwar Sadat made peace with Israel in 1978, but his assassination 3 years later and the rise of Mubarak marked the start of "a long period of oppression," Al-Sherbiny says. "No one had a clear freedom of speech. There was a sense that nothing would change and everything was stagnant." Mubarak and his National Democratic Party were famously indifferent to R&D. "Imagine a president saying that it was better to import technology than to produce it!" Saleh says. "This was the view at the top of the government."

That neglect is reflected in Egypt's research output. Between 2000 and 2010, scientists in Egypt published fewer than 35,000 research papers, according to data from Thomson Reuters. That is nearly twice the number published in Saudi Arabia but far less than Turkey's 148,000 papers and a fraction of South Korea's 269,000 during the same period. Egyptian research papers received, on average, about five citations—more than Saudi Arabia's 4.2 and about the same as Turkey's, but well below South Korea's rate of seven.

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A Tale of Three Countries

EGYPT

POPULATION: **83 Million**

LAND AREA: **1,000,000 sq km**

GROSS DOMESTIC PRODUCT: **$188 Billion**

TURKEY

POPULATION: **76 Million**

LAND AREA: **780,600 sq km**

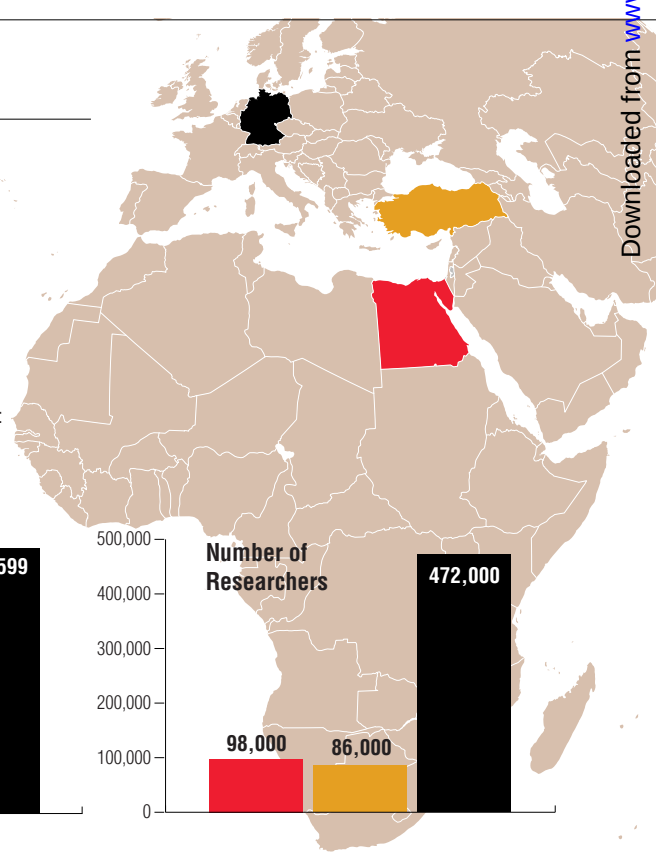
GROSS DOMESTIC PRODUCT: **$615 Billion**

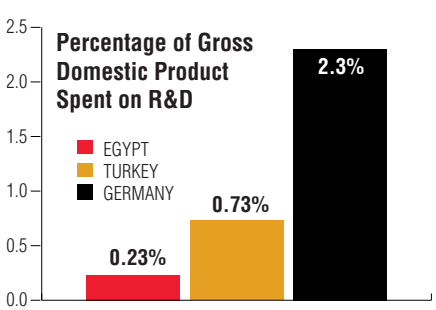
GERMANY

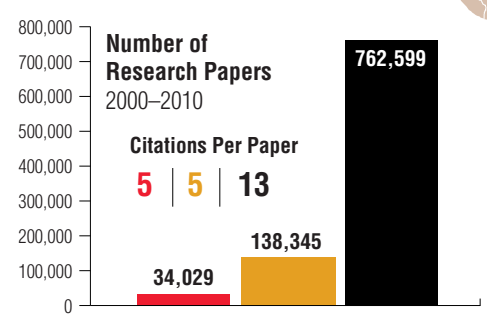
POPULATION: **82 Million**

LAND AREA: **356,900 sq km**

GROSS DOMESTIC PRODUCT: **$3.3 Trillion**







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Changes began slowly to take hold in the past half-dozen years, however. In some fields, such as archaeology, funds and training from other countries helped spawn world-class projects (see sidebar, p. 282). More Egyptian scientists trained abroad returned home to agitate for academic reforms. A competitive grant-giving agency—similar to the National Science Foundation in the United States—called the Science and Technology Development Fund (STDF) was set up in 2007 to provide researchers with desperately needed funds for materials and equipment. About 40% of the modest $17 million budget goes to research projects, with most of the rest for equipment and materials. And 2 years ago, the old system that allowed university committees to promote faculty members without applying clear metrics—an invitation for corruption and favoritism—began to be scrapped. "Now it takes 10 years after you get your Ph.D. to become a full professor," says Mohamed El-Deab, a physical chemist at Cairo University.

Applying research

Despite those innovations, under the Mubarak regime public universities were run largely by party favorites, and there was little incentive for ill-paid academics to do more than teach, Egyptian scientists and administrators say. The ministry of scientific research lacked a seat in the Cabinet and the ability to implement new programs. Scientific conferences required approval from security forces.

Then came the 25 January revolution, which erupted on Facebook and Twitter as well as the street. "S&T played a major role before, during, and after the revolution," Al-Sherbiny says. "Communication technologies provided the platforms of expression, and an intellectual ferment created change."

When the interim government took over in February, Salama argued successfully for a new science ministry, which has greater power and influence. (He is also minister of higher education.) That higher profile seems to be paying off. Last month, Salama pushed through a 34% increase in science and technology spending for the 2011–12 fiscal year that began 1 July. "Egypt spends about 0.2% of its GDP [gross domestic product] on scientific research," Salama said in a recent interview in his ministerial office near Tahrir Square, a vast open plaza that remains the scene of large demonstrations as recently as last Friday. Developed countries, he notes, spend 3% to 4%, including private sector contributions. By next year, he hopes to boost spending to 0.8% of GDP

Tackling Egypt's New Plague

Half a million Egyptians are infected with hepatitis C each year, the highest rate in the world. Between one in 10 and one in five—mostly in poorer rural areas—are afflicted with the virus, which can lead to severe liver damage and death. At least some of the growing crisis stems from unsterilized needles used in the past to inject villagers with treatments for the chronic illness of schistosomiasis, a parasitic infection.

The standard treatment for hepatitis C is interferon, a genetically engineered drug that can cost more than $12,000 per patient, a staggering figure for a developing country (*Science*, 8 April, p. 159). Egyptian pharmaceuticals are often of poor quality, and many people resort to traditional remedies. "It is 2011 and we can't even produce enough interferon," says Hassan Azzazy, a chemist at the American University in Cairo. "It's unbelievable." Just testing for hepatitis C is time-consuming and expensive.

When it comes to testing, Azzazy is taking matters into his own hands. With the help of an $850,000 grant from the National Qatar Research Foundation, he and Qatari colleagues have come up with a nanotechnology method that they say detects viral RNA more quickly and cheaply than current methods. When exposed to a hepatitis C–specific primer in a solution of nanometer-sized gold particles, the virus will bond with the primer and the gold. That clumping turns the solution blue, thanks to gold's optical properties; a virus-free solution remains red. Instead of days or weeks, researchers can pinpoint the virus in less than an hour, more accurately, and at a fraction of the cost, Azzazy says. Detection is only the first step to dealing with the hepatitis C epidemic, but a better, cheaper method would save money and ensure that only people with the virus are treated.

"A simple and inexpensive means of screening persons for hepatitis C would be very valuable," says Jay Hoofnagle, director of liver disease research at the U.S. National Institutes of Health in Bethesda, Maryland. He's not familiar with the nanogold technology and warns that any method will need extensive testing to ensure accuracy. But he adds that "in Egypt, the problem of hepatitis C is so much greater that a less expensive test, even if not as rigorously accurate as our currently licensed assays in the U.S., would be a great help."

Although Egypt lacks a tradition of tech transfer from science to business (see main text), Azzazy hopes to turn the virus-detection method into Egypt's first innovative biotech company. "Private industry here is really undeveloped," he says. "There are virtually no spinoffs, minimal R&D, and a large number of students and scientists who are not productive. We have to change the culture to teach our students to be entrepreneurs." He's doing just that: When not in the lab, Azzazy teaches a class in bioentrepreneurship. **–A.L.**

Building biotech. Hassan Azzazy (*center*) hopes to start Egypt's first biotech company.

CREDIT: HASSAN AZZAZY

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"S&T played a major role before, during, and after the revolution. … An intellectual ferment created change."

—MAGED AL-SHERBINY, ASSISTANT SCIENCE MINISTER

and to reach 2% by 2014–15. He's confident that as the country moves toward democracy and transparency, domestic as well as international funding will supplement government spending. "I hope we can generate a culture of R&D as a basis of reorganizing Egypt's industry," he says.

Carnegie's Achy warns that more money alone won't solve Egypt's R&D troubles: "You may allocate more to universities, but it's a question of whether it goes to research." Although the new funds will mostly be spread among the ministry's dozen research institutes and the public universities, exact allocations remain unclear.

Many Egyptian administrators are emphasizing applied rather than basic science, focusing on topics such as renewable energy and water desalination and health threats such as schistosomiasis and hepatitis C (see sidebar, p. 281). They also say Egypt has solid research teams in biotech, nanotechnology, and microelectromechanical systems, which need injections of funding to morph into actual industries.

Salama installed a new manager at STDF, a civil engineer, to reorient its portfolio to include more applied and social science research. "I want the fund to direct its activities toward servicing the Egyptian economy, not just basic science," Salama says.

Many researchers accept that focusing on applied research is essential. "Egypt doesn't have the luxury to do basic research. We have needs to be met now," says biochemist Hassan Azzazy of AUC. Others, including foreign scientists, aren't so sure. *Science* Editor-in-Chief Bruce Alberts, a former president of the National Academies of Sciences, who recently visited here to meet with senior officials, warns that "without good basic science to support the applied science efforts, the long run is unlikely to work out well."

Freeing universities

Despite agreement on applied research, scientists and administrators don't see eye to eye on all issues. Scientists are unhappy that STDF's funding will not be increased for the foreseeable future despite the overall 34% increase for science. "We need equipment, and there's no budget," El-Deab says. He considered himself lucky to get a $1000 grant 2 years ago to buy chemicals. But Salama says the fund got significant boosts in previous years.

Salama's thorniest problem is how to revamp a vast S&T organization that includes 18 universities, 85,000 researchers, and hundreds of thousands of students. There is widespread agreement that faculty salaries, which are less than the $450 monthly income of an average Egyptian household, urgently need raising. "We pay our custodians more than the Cairo University professors," says AUC's Anderson. A

CREDITS (TOP TO BOTTOM): MAHAN KALPA KHALSA

Modernizing Mummy Maintenance

GIZA, EGYPT—The Giza pyramids were built 4500 years ago to guarantee eternal life for Old Kingdom pharaohs. A short distance away, more than 140 technicians, scientists, and conservators are busy ensuring that the countless beautiful objects produced by 3 millennia of crafters will also survive the ages. Physically, Egypt's newest monument has a lower profile—it's nestled 10 meters underground. But the massive new conservation center of the Grand Egyptian Museum stands out as one of the largest and most modern conservation facilities in the world, foreign archaeologists say. That's in stark contrast to Egyptian facilities in some other disciplines, in which researchers struggle with antiquated equipment (see main text).

The center's 18,000 square meters—nearly half the footprint of the Great Pyramid—include seven spacious and well-equipped laboratories to

Modern mummy care. Technicians at Giza rehab the remains of an ancient Egyptian.

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new graduate in computer science can earn more in the private sector than a full professor does at a public university. Professors must find other jobs to make ends meet, and both teaching and research suffer as a result. "If you have to pay for housing, education, and food, you only have enough to cover one of those; for the remainder you have to find other work," Saleh says.

Salama won approval from the Ministry of Finance to boost those salaries by 50%, which won't come out of the 34% science increase. "I know professors are in a bad situation; they are my colleagues," he says. "They should be able to live credible lives with dignity and be able to fulfill family obligations so they can teach and research well."

But professors want more. They also want academic freedom and a less corrupt system. Under Mubarak, presidents and deans were political appointees, and department chairs were selected solely by seniority. "Right now, it all depends on the person in charge, and this leads to corruption," El Sayed of Ain Shams complains. "The head of a department can funnel money to his own lab. There is no transparency. We know nothing about the university budget."

Frustrated faculty members and students in recent months have pressed for direct elections of university presidents and deans to ensure accountability. "Elections will help us feel free," El Deab says. That doesn't sit well with administrators. "No other country in the world elects a university president or dean," Salama says. "I hope we reach a compromise acceptable to the university society which comes near to what developed countries do." In that system, a board of trustees, which includes some faculty representatives, chooses university leaders.

As of last month, negotiations were still ongoing. The contentious debate itself marks a radical shift in a country where power has traditionally been hierarchical and dissent was either discouraged or downright dangerous. "Now people are expressing themselves very freely. This has never happened before," says Salama, whose ministry has regularly been besieged with demonstrators in recent months. "It's a major change in Egypt."

But Salama and ministry officials warn that changing university and institute culture will require a new flexibility on the part of researchers. Faculty jobs are still seen as secure lifetime positions. "Here, when you get a position in a university, you are a pharaoh—and we have to change this," Al-Sherbiny says. He and Salama will push for greater competition based on performance. "I intend to have a system in which no one stays for life in the same place," Al-Sherbiny

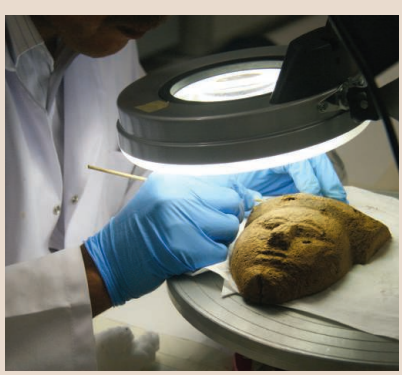
"The revolution has given me hope that science will become a strategic goal for Egypt."

—GRADUATE STUDENT NOR ABDALLAH, CAIRO UNIVERSITY

CREDITS (TOP TO BOTTOM): MAHAN KALPA KHALSA

handle stone, wood, and organic material, from heavy carved artifacts to fragile bits of papyrus. "I was astonished at the size and facilities," says Nigel Strudwick, a British Museum curator who toured the site. "I don't think I've seen better ones anywhere," including at the British Museum.

The labs are a radical departure from the past. Cairo's century-old Egyptian Museum, which has been the main repository for ancient artifacts, has been notorious for its dank and chaotic storerooms, and there has long been a dearth of well-trained Egyptian specialists to take care of the diverse objects, foreign archaeologists say.



Face off. A technician cleans a carved funeral mask.

The new center was developed in conjunction with Japan's ministry of culture, which loaned money covering more than half of the building's costs and equipment. But archaeologists say that what made this project so successful was the Japanese commitment to providing professional training, ensuring that a well-educated cadre of Egyptian technicians and researchers can carry out their work. The plan was developed and backed by Egypt's Ministry of Culture and the Supreme Council of Antiquities, which provided the remainder of the funding. The belowground conservation center is part of an ambitious $550 million effort that will eventually cover 117 hectares, include the world's largest museum, and accommodate 5 million visitors annually.

The complex is 4 years behind schedule and millions of dollars over budget; it likely won't be completed until 2015. Still, work continues despite the revolution, and the recently opened conservation center already houses 10,000 artifacts, says its technical director, Hussein Kamal. During a recent visit, young workers, many of them women, were busy conserving artifacts using an impressive array of ultrasonic cleaners, laser tools, scanning electron microscopes, x-ray diffraction, and infrared devices. "There is a new breed of Egyptian conservator now, which I find very reassuring," Strudwick says.

Kamal says the facility will eventually be a boon to foreign Egyptologists, long hampered by strict rules forbidding export of ancient materials but stymied by the lack of modern labs within the country. "If you work on an archaeology mission, with ministry approval, it will be easy to do your analysis here," he says.

Several kilometers away in Cairo, a $200 million National Museum of Egyptian Civilization is under construction, which will also contain new labs and storage facilities. The first of these, focused on mummies, will open this summer with at least 30 scientists and 60 conservators, according to Ismail Badawy, a conservation consultant on the project. Egyptologists are keeping their fingers crossed that the new government will continue these archaeological success stories. "I very much hope that the generous funding which is there at present can continue," Strudwick says. **–A.L.**

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adds. "You will have to compete with someone from outside [your institution]. Without competition, I don't think Egyptian universities are going to improve, much less compete with international universities."

The business of science

As they work to transform the university system, Egyptian scientists are also looking to strengthen their connections to industry. Michael Harms, who directs the German Academic Exchange Service here, says the country "has to bridge the gap between the university and industry. Every year you have 750,000 graduates flooding the labor market." But there are few industrial jobs available. That makes teaching at a university one of the few options for many science and technology graduates, despite the low pay.

Biotech and other high-tech industries are nascent or nonexistent, researchers say. "There is not a single biotech company in Egypt," AUC's Azzazy says. "This is unacceptable." Egypt's economy consists primarily of a service sector made up mostly of small businesses and large state-owned enterprises that are often inefficient, Achy says. There is little precedent for small, innovative high-tech companies.

AUC boasts some of the country's best labs at its sprawling new campus in the desert outside Cairo. The modern highway leading to the university is lined with rows of new palace-style mansions and glass office buildings, many still under construction, a sign of Egypt's prospering elite. "There is plenty of money sloshing around, and a lot of people looking for investments," Anderson says.

But little of that investment goes into venture capital funding for R&D. "Industry has the money but is reluctant to contribute," El Sayed says. "We've tried—giving lectures, consulting—but until now they import whole factories from abroad." Says Azzazy, laughing, "Tech transfer in Egypt today is buying a new European machine."

And there are few links between industry and university researchers. El Sayed is one of a handful who does consulting work with companies; she says the bulk of the money goes to the university administration, leaving her with a paltry 20%. "Right now, the private sector doesn't believe in the importance of R&D," says Abdallah, the geology student at Cairo University. "When they see the potential in university labs, they will invest." Achy says that industry will remain skittish until it is clear its money won't be wasted.

That may hinge on creation of new laws governing spinoffs, investments, and taxes. "There is no Bayh-Dole here," Anderson says, referring to the U.S. legislation that lays out intellectual-property regulations for federally financed research and allows universities to profit from inventions created in their labs. In contrast to U.S. institutions, AUC must be cautious in pushing ahead with commercializing faculty inventions, lest it endanger its tax status. Such uncertainty is anathema to investors. Anderson adds that clarifying the rules of the game "is something the Egyptian government could do which would cost virtually nothing. And if Egypt navigates the next few years well, it can be the next fashion among investors."

Demanding democracy. At Cairo University, shown here, and at other Egyptian universities, staff members want to choose their own leaders.

CREDIT: KHALED EL-FIQI/EPA/CORBIS

Achy warns, however, that real change will be gradual. He notes that Tunisia moved more than a decade ago to increase R&D funding, provide incentives for researchers, and improve links with industry—and those efforts are only now starting to pay off, as Tunisia enjoys new businesses, skill sets, and foreign investment.

Even as they try to improve conditions at home, Egyptian scientists are looking outward to collaboration with others. Last month, for example, Egypt agreed to continue supporting the troubled Synchrotron-light for Experimental Science and Applications in the Middle East now under construction in Jordan. The ambitious project, well behind schedule, brings together unlikely bedfellows, including Iran, Israel, and the Palestinian Authority, and supporters had feared that a post-revolution withdrawal by Egypt could threaten the entire effort. "We will honor our obligations," Salama says. Like other nations, Egypt will contribute an additional $5 million over 5 years to cover a shortfall in SESAME's budget. Egypt is also pressing ahead to become an associate member, rather than simply an observer, at CERN. "We have five scientists working there, and I would like to increase that number," Salama said after a recent visit to the Geneva accelerators.

The revolution's success in pushing for dramatic change in the R&D sector will depend largely on the new government Egyptians choose during elections slated for later this year. That government will face a 34% illiteracy rate, a population projected to double by 2060, a poverty rate hovering at 20%, and high expectations for turning around the stalled economy. Nevertheless, many Egyptians in the R&D establishment say they are hopeful they can overcome the inertia of the Mubarak years and play a critical role in creating what Zewail calls "an Egyptian renaissance." At his 2 June appearance, he told the cheering audience that "we can only solve our problems by restructuring the science and technology system." That's a revolutionary faith that he and his colleagues hope will spread far beyond their labs.

–ANDREW LAWLER

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