New York City, for instance, the public was bombarded with the message that elderly people, especially, should protect themselves from mosquito bites, says assistant commissioner Marcelle Layton of the city's department of health.

Another riddle of the 2000 outbreak is why an early warning system for viral activity was such a fiasco. In several states, researchers bled so-called sentinel chickens weekly and tested them for West Nile antibodies. For other insect-borne viral diseases, such as St. Louis encephalitis, chickens become infected before people do and are a time-proven indicator. But very few chickens became seropositive for West Nile virus this summer, and not one did so before the first human cases.

Dead birds, on the other hand, are too sensitive an indicator; they have been found in many states where there has not been a single human case, and spraying insecticides would have been premature. CDC researchers are now focusing their efforts on developing surveillance indicators that are a better predictor of human cases, says CDC's Petersen, so that public health authorities can take precautions once the risk becomes substantial. For instance, researchers are now combing through the data gathered this year in Staten Island, the New York borough where there was a cluster of cases. The hope, says Petersen, is that these will reveal a pattern that could have foreboded the epidemic. Researchers found high numbers of infected *Culex salinarius* mosquitoes in the area; they may prove to be significant. "But in all likelihood, it may be a couple of years before we can adequately predict the risk," he says.

For that reason alone, Petersen won't speculate where the disease will next crop up—but he knows it will. And, because no drugs or a vaccine exists (see sidebar on p. 1483), West Nile is bound to claim new human victims. "We know it's going to be more than just a couple, and we know it's not going to be hundreds of thousands," says Peterson. "But we can't say much more with any certainty." **–MARTIN ENSERINK**

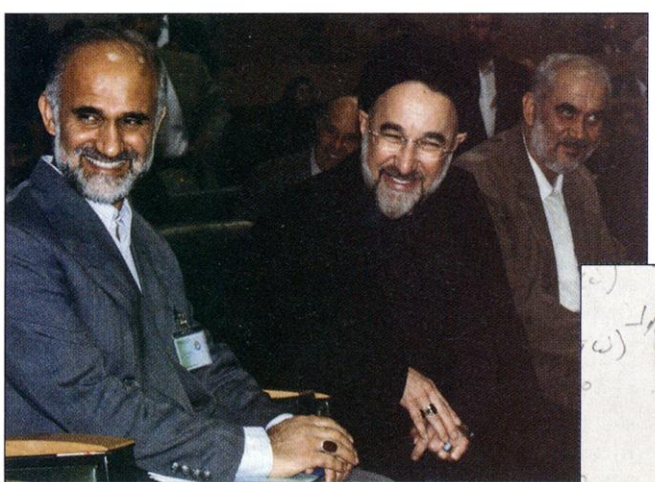
IRANIAN SCIENCE

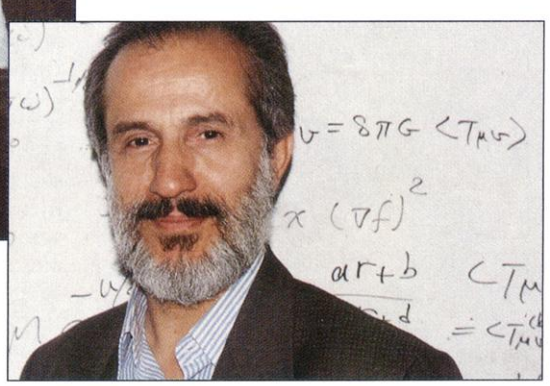
Iran's Scientists Cautiously Reach Out to the World

Two decades after Iran's Islamic revolution, a reformist president wants researchers to expand collaborations with colleagues abroad

TEHRAN—When Reza Mansouri left a cushy university post in Vienna to return to his native Iran in 1980, the young theoretical physicist found himself caught up in a whirlwind. In the wake of the revolution that overthrew the Shah the year before, the new "Supreme Leader"—the Ayatollah Ruhollah Khomeini—was reinventing Iran as an Islamic republic, and talented researchers were fleeing in droves to safer and more lucrative posts abroad. Mansouri was going against the flow—an opponent of the Shah, he says he wanted "to do something for my country. Everything was in turmoil then, and science was low on the list of priorities." Along with his colleagues, Mansouri endured Iraqi rocket attacks against Sharif University of Technology, where he is a physics professor, during Iran's bloody 8-year war with Iraq in the 1980s. "Back then, people talked about 'Islamic physics' and 'Islamic science.' It took a long time for them to understand that physics is physics and science is science. But I think we're on the right track now."

Today, after what one Iranian chemist describes as "20 years of frustrating trial and error," science in this politically isolated but oil-rich nation may be on the verge of resurgence. The nation's reform-minded president, Mohammad Khatami, and his allies are promising more money for R&D and are reorganizing universities to beef up graduate education and research. They are also cracking open the door to closer cooperation with scientists abroad—including those in the United States, the country Khomeini branded "the Great Satan" in 1979 when revolutionaries occupied the U.S. Embassy here, holding 52 diplomats hostage for more than a year.





Restoring an Islamic tradition? Science Minister Moin and President Khatami intend to pour more resources into research. Reza Mansouri (*inset*), who returned to his homeland 20 years ago, thinks that Iran's science is finally back on track.

Such reforms may seem basic, but Iran's government is walking a tightrope. It's pressured by hard-liners on the right who oppose reforms and by liberal university students—many of whom now glimpse the outside world via the Internet and satellite TV receivers—eager for change. Indeed, even as the hard-liners celebrated the anniversary of the embassy takeover on 3 November with their annual anti-American, flag-burning festival in the streets of Tehran, moderates were quietly working to bridge a gulf of mistrust and heal old wounds. In the first high-level visit in more than 2 decades, a U.S. delegation led by National Academy of Sciences (NAS) president, Bruce Alberts, visited Iran in September, issuing a joint statement with Iran's academy afterward, pledging to initiate six joint workshops over the next 2 years. Although that NAS visit was carefully kept out of the Iranian news media and was not sponsored by either government, Sharif University Professor Abolhassan Vafai—one of the Iranian organizers—told *Science* that it represented "a breakthrough."

But serious obstacles must be overcome if this budding relationship is to blossom. These range from logistical hurdles—such as the lack of diplomatic relations between

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Iranian Women Hear the Call of Science

SHIRAZ—In the cavernous main hall of Shiraz University's otherwise modern library, arrows pointing WOMEN and MEN in opposite directions aren't for the toilets. They direct students to the main reading rooms—which are separate, but equal.

Some witty female scholars joke that the WOMEN sign should be pointing upward, not sideways. For women are a growing presence at Iran's universities: From Shiraz in the south to Tehran in the north, they now make up nearly 60% of incoming classes, almost double their share in 1978. But as in many other countries, some female academics in Iran point to a glass ceiling that keeps their representation among university professors low.

Separate, but closing the gap. Women are making gains in the academic community, says Faranak Seifolddini, despite institutions such as reading rooms for each sex.

Still, the rise in the number of female students in recent years belies the outsider's impression that Iranian women—who are required to wear chadors in public and are barred from becoming Islamic clerics—are bit players in a male-dominated society. "It was a real culture shock when I returned here 6 years ago," admits Faranak Seifolddini, who got her Ph.D. in city planning from the University of Wisconsin and is now an assistant professor at Sharif University of Technology in Tehran. "But things are changing, and opportunities are opening up."

The situation is a far cry from that in neighboring Afghanistan, where the ruling Talaban, Islamic fundamentalists, has barred women from working or attending universities. In contrast, Iranian women—who played minor roles in science for decades—are now coming into their own. "Nearly two-thirds of the new students in my department are young women," says chemist Fakhry Seyedeyn-Azad, an assistant professor at the University of Isfahan. Some observers say Iranian women are making gains because they tend to be more dedicated than young men are. "Young women have fewer options than men, so they are devoting more time to their studies," says psychologist Shahireh Bahri, deputy director of Iran's Office of International Scientific Cooperation.

That view is echoed by the government. "If women are given equal opportunities, they tend to do better than men, because they are more diligent," says Research Minister Mostafa Moin. And they have good role models too: The daughter of Iran's president, Mohammad Khatami, is a math major at Sharif University.

But there are indications that women are having trouble rising to the academic world's higher echelons. According to the research ministry, only about 6% of full professors, 8% of associate professors, and 14% of assistant professors were women in the 1998–99 academic year. However, women accounted for 56% of all students in the natural sciences last year, including one in five Ph.D. students. At Shiraz University, only about 30 members of the 500-strong faculty are women, officials say. Although promotion is based on a point system, one assistant professor contends that "it is more difficult for women to get those promotions." Adds Seifolddini: "When it comes to advancement at the higher levels, it's still better to be a man. But that may be changing."

Others scoff at the notion of a glass ceiling. "In my department, half of the 12 Ph.D. students are women," says analytical chemist Nahid Pourreza, who became chair of the chemistry department at Shahid Chamran University in southwestern Iran 9 years ago. Seyedeyn-Azad, too, says she hasn't encountered such problems: "I don't think there are barriers to my career because I am a woman." **–R.K.**

CREDITS: R. KOENIG

the two countries, making it difficult for researchers in either nation to obtain visas—to lingering disputes, including U.S. State Department allegations that Iran is developing weapons of mass destruction. The latter led to a U.S. ban on the sale of many types of scientific equipment to Iran. And looming in the background—like the five-story-high murals of Khomeini all over Tehran—is the ever-present threat of another crackdown by Iran's powerful Islamic conservatives.

Despite those barriers, interviews in Tehran, Shiraz, and Isfahan with three dozen Iranian scientists and university officials—many of whom earned their Ph.D.s in the United States—revealed that researchers here are eager to join the world's scientific community, even if they risk retaliation by hard-liners. "Our scientists can't work in a vacuum," says Habib Firouzabadi, president of Iran's Chemical Society and a professor at Shiraz University. Although much of Iran remains a scientific backwater today, Mansouri, who heads Iran's Physical Society, predicts that with better funding and international connections Iranian science will rise to world-class levels in fields such as math and physics within a half-century.

Deep roots

Ten centuries ago, scientists in Persia, the ancient lands that later became Iran, were light-years ahead of the rest of the world. During that Golden Age of Islam, Persian mathematicians helped complete the system of decimal fractions and made advances in algebra and trigonometry, while chemists pioneered uses of alcohol and sulfuric acid.

Although Persian mathematicians were renowned for centuries, scientists in Western Europe eventually eclipsed their Islamic counterparts. And it wasn't until the second half of the 1900s that Iran's secular government built top-notch technical universities and institutes, including Tehran's Aryamehr (now called Sharif) University of Technology—modeled in part on the Massachusetts Institute of Technology—and Shiraz University, which cultivated close ties with the University of Pennsylvania. Iranian colleges sent their brightest graduate students abroad for study.

After the 1979 revolution, Sharif, Shiraz, and other universities severed ties with the West, and many top professors fled the country. One informal study found that there are now nearly twice as many Ph.D.-level Iranian-born physicists in the United States as in Iran. Although Islamic revolutionary leaders backed higher education, their emphasis was on mass education rather than "elitist" research. Science suffered most during the strife-torn 1980s, when Iran's leaders were preoccupied with restructuring the country and the war with Iraq sapped resources.

During the 1990s, Iran devoted more at-

tention to higher education; a newly discovered oil field and the hike in world oil prices are now pumping up resources for universities and research. Today, Iran has nearly 100 government-run higher education institutions—more than four times the number of state colleges in 1978, with nearly an eightfold increase in students. Doctoral programs in natural sciences—rare before 1979—have taken root in many parts of the country. At Shiraz University, for example, Chancellor Mahmood Mostafavi says there are now about 300 Ph.D. students, versus just one in 1983.

Despite the burgeoning numbers, many Iranian scientists complain that the quality of education and research suffers because few professors have adequate time or funding. "Universities have grown like mushrooms, but they haven't redefined their goals," which should include "a major increase in resources for research," says Firouzabadi.

Another serious problem is the brain drain, which has spurred the government to find ways to keep top scholars at home. One lure is the Institute for Advanced Studies in Basic Sciences, founded in 1993 in the northern city of Zanjan by one of Iran's top scientists—astrophysicist Youssef Sobouti, known for star-cluster research. Thanks largely to his center and the 12-year-old Institute for Physics and Mathematics in Tehran, Sobouti contends that "physics research, judged by publications in international journals, has improved markedly in Iran over the last 10 years." He encourages his students to make use of the Internet, foreign journals, and overseas contacts. But not every Iranian researcher has good opportunities to travel abroad or access to scientific literature. The most recent issue of *Science* available at Shiraz's regional science library is 6 years old.

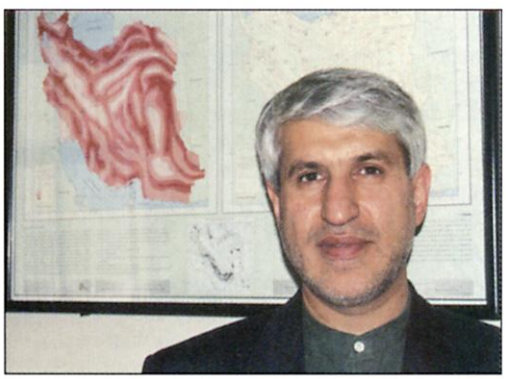
Outside scientists tend to agree that theoretical physics and mathematics—neither of which requires much instrumentation—are Iran's healthiest disciplines. And although biology lags behind other fields, Iran gets good marks in traditional branches of chemistry. "The quality of the science I saw was quite high, and their lab equipment was better than I had expected," says Alberts. Echoing that view is Nobel laureate F. Sherwood Rowland,

Fanning the flames. Stoked by hard-liners, anti-American protesters stage their annual flag-burning festival.

Earthquake Researchers Prepare for the Next Big One

TEHRAN—When a devastating earthquake rocked the Manjil region in Iran on 20 June 1990, the tremors also shook seismology research in that country. That night, Mohsen Ghafory-Ashtiany rolled out of his bed in Tehran and headed to the danger zone in northwestern Iran, where 13,000 persons perished and 60,000 were injured. He and his then-tiny staff surveyed the damage and mapped out a plan for bolstering earthquake research and preparedness. "The Manjil quake marked a turning point," he says.

Ghafory-Ashtiany was then fewer than 6 months into the process of building a new seismology institute from scratch; the Manjil quake shook loose far more funding. Now Ghafory-Ashtiany directs a 190-person staff—including 59 scientists—at the new, quake-proof headquarters of the International Institute of Earthquake Engineering and Seismology (IIEES), which boasts advanced soil analysis and structural engineering labs, as well as a computer center that displays real-time data transmitted via satellite from seismographs scattered across Iran. IIEES is also at the epicenter of an expanding "earthquake-awareness" campaign that includes nationwide TV programs and annual quake drills at every school.



Antiearthquake epicenter. Mohsen Ghafory-Ashtiany with map of Iran's seismic hazards behind him.

There are good reasons for the focus on seismology research and education: The Iranian plateau is one of the world's most seismically active regions, and many cities—including Tehran—lie in high-risk earthquake zones. Last century, 20 major earthquakes claimed more than 100,000 lives in Iran and severely damaged hundreds of towns. Before the Manjil quake, however, there were only two Iranian labs devoted to earthquake-related research and fewer than 40 university faculty members in seismology and earthquake engineering. Today there are seven such labs and 260 scientists and engineers. During the 1990s, the number of seismic recording stations in Iran nearly tripled to 43, and the number of "strong motion" stations, designed to measure how quakes affect ground movement, rose from 270 to about 1000.

The IIEES, established with seed money from the United Nations Educational, Scientific and Cultural Organization (UNESCO), but now fully financed by Iran's science ministry, has a track record in international cooperation, having embarked on research efforts with geophysicists in France, Japan, Russia, Italy, and Switzerland. Most ambitious is the Iranian-French connection, which encompasses projects involving 15 scientists at several French geophysics laboratories. The main focus is to study how Iran's Zagros fold thrust belt deforms, increasing the earthquake risk. To that end, researchers have installed 25 Global Positioning System receivers in and around Iran to measure the movements of mountain ranges, and they plan to build 75 seismological stations along a 750-kilometer-long stretch of the Zagros Mountains.

A number of U.S. geophysicists, anxious to tap into Iran's seismology data, have approached the IIEES about possible cooperative projects. Ghafory-Ashtiany says no agreements have been reached so far, but the U.S. and Iranian science and engineering academies are considering a joint workshop on "lessons learned from recent earthquakes." One sticking point to better relations has been U.S. technology-transfer bans, which have prevented the IIEES from buying U.S. seismology and structural-engineering equipment. Instead, they order the devices from Japanese and European manufacturers. "It's a shame," says Fariberz Nateghi, a Columbia University Ph.D. who heads IIEES's earthquake engineering research center. "We spent $6 million on lab equipment in the last couple of years, and we would have preferred to buy U.S.-made instruments because they are better." But in spite of the lack of U.S. technology, "we've made great progress over the last 10 years," says Ghafory-Ashtiany, "and we think Iran is much better prepared for the next major earthquake." **–R.K.**

CREDITS: (TOP TO BOTTOM) HASAN SARBAKHSHIAN/AP; R. KOENIG

who visited Iran with the NAS group. "A few top universities and medical research units have first-class personnel, with equipment that's a little behind the curve but still competitive," he says. But Alberts and Rowland concede that they may have been shown only the best of what Iran has to offer.

Eroding the barriers

Iranian officials say they're committed to nurturing the best scientific centers and shoring up weak disciplines. "We want to enhance the quality of science here, increase access to the Internet, and bolster the links between universities and research centers," Iran Science Minister Mostafa Moin told *Science*. He says he expects to get approval for "new roles and missions" for his ministry by March, including directing a reorganization of the national research labs and the university system to promote graduate studies. Moin also notes that the government has pledged to boost R&D spending from 0.44% of the gross domestic product—about $350 million in 2000, including $25 million for basic research—to a more robust 1% over the next 5 years, with industry expected to contribute another 0.5% of GDP to research.

But the government has fallen short on similar promises in the past, skeptics say. "The pattern is that the government and parliament approve more funds for science, but the administration doesn't get that money to researchers," says Mansouri, who heads the National Research Council's basic science committee.

Meanwhile, Moin and President Khatami are encouraging Iranian scientists to strengthen ties with foreign researchers. In a speech at a meeting of the Third World Academy of Sciences here in October, Khatami said that science transcends politics and that scientific dialog could help bridge the gap between Iran and "those countries with which our relations are not totally amicable." Besides hosting the Third World Academy conference, Iran has reached out to two international efforts: It has agreed to take part in the Large Hadron Collider at CERN, the European particle physics laboratory near Geneva, and plans to contribute to SESAME, a synchrotron that will be moved from Germany to Jordan as soon as funds are raised.

A grander challenge is to build research capacity within Iran. Scientists here complain that U.S. rules barring the export of technology to Iran make it extremely difficult to buy U.S.-made instruments or supplies. "Even the simplest scientific equipment for education seems to be considered 'sensitive,' " says astrophysicist Ahmad Kiasatpour of Isfahan University.

That ban continues, but the State Department has eased some restrictions on travel to Iran by U.S. researchers, and the two nations appear to be using scientists to test the waters of rapprochement. A breakthrough came in December 1998, when a U.S. delegation got permission to attend a conference in Tehran on nonrenewable energy sources. Then, after 8 months of negotiations between the Iranian and U.S. science academies—mediated by Jeremy Stone, then president of the Federation of American Scientists, and Iranian-born chemical engineer G. Ali Mansoori of the University of Illinois, Chicago—Iran in September 1999 sent a delegation to visit the NAS and scientific societies in Washington, D.C. This year's visit by the U.S. delegation was the latest in this tentative *pas de deux*.

Diplomatic restrictions, however, sharply limit informal research cooperation. Some U.S. scientists complain that Iran is reluctant to grant them visas; for that reason, the vast majority of scientific visits are made by Iranian-born Americans who use their Iranian passports to gain entry. Meanwhile, Iranians complain bitterly about being fingerprinted, photographed, and questioned each time they enter the United States to attend conferences. "They treat you as if you were a criminal, not a scientist," says physicist Mehdi Golshani.

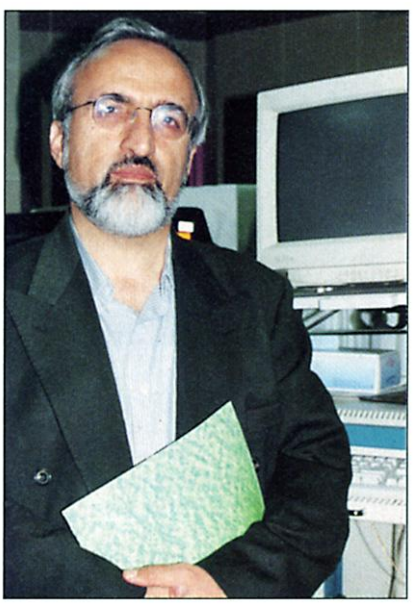
Behind those restrictions lie U.S. suspicions that Iran is channeling resources into weapons programs. "Iran's pursuit of weapons of mass destruction and ballistic missile delivery systems continues unabated and has even accelerated in the last few years," contends Robert J. Einhorn, assistant U.S. secretary of state for nonproliferation. In testimony last month before a Senate panel, Einhorn aired concerns over a Russian firm's construction of a 1000-megawatt nuclear reactor in Bushehr, which will be Iran's first nuclear power station. The project, he stated, could "be used by Iran as a cover for maintaining wide-ranging contacts with Russian nuclear entities," which might prove useful for developing nuclear weapons.

Iranian officials say the Bushehr reactor is merely a power plant and deny that the country maintains efforts to build chemical, biological, or nuclear weapons—pointing out that Iran has signed treaties against proliferation. And although the Shahab missile program is an open secret, Iranians claim it is a defensive effort necessitated mainly by the threat from neighboring Iraq, which rained SCUDs on Iranian cities during the bloody 8-year war.

A long road ahead

Although science is a higher priority in today's Iran, not everyone is convinced that reforms will take root quickly—especially if the nation's hard-liners, led by Ayatollah Ali Khamenei, continue to wield ultimate power. Although the Khatami administration and parliament have become more liberal, hard-liners still control the Guardian Council, which vets proposed laws. The government has suppressed student dissent and shut down liberal newspapers. Meanwhile, a fundamentalist terrorist group—the Mujahedeen Khalq—has unleashed scattered attacks, prompting the government to assign revolutionary guards toting submachine guns to escort Third World Academy scientists on visits last month to universities and archaeological sites.

In spite of these internal tensions, Iranian scientists see growing opportunities to break out of years of isolation. Take the effort to explain northern Iran's "esophageal cancer belt," where such cancer is 10 times more common than elsewhere. Last year, Reza Malekzadeh, who heads Tehran University's new Digestive Disease Research Center, visited scientists at the U.S. National Cancer Institute (NCI) to revive interest in cooperative research, and the NCI reciprocated recently by sending a staffer on an exploratory visit to Iran.



CREDIT: R. KOENIG

Better late than never. Reza Malekzadeh is forging ties with the West to understand Iran's esophageal cancer problem.

Early next year, one of Malekzadeh's young researchers will be a visiting fellow at NCI, learning techniques for tracking genetic links to cancer. Meanwhile, Malekzadeh and other members of Iran's medical academy have invited one of the top experts on Iran's cancer belt—University of Montreal researcher Parviz Ghadirian—to visit his homeland for the first time in 19 years to discuss collaborating.

"By working together, we might get to the bottom of this," says Malekzadeh. But, he concedes, precious years have been lost: "We should have done this long ago."

–ROBERT KOENIG