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DANIEL SCHAFFER, THE TWAS PUBLIC INFORMATION OFFICER, WILL STEP DOWN FROM HIS POST IN JANUARY. IN HIS CONCLUDING ARTICLE FOR THE *TWAS NEWSLETTER*, HE SPEAKS ABOUT HAVING BEEN WITNESS TO THE HISTORIC CHANGES IN SCIENTIFIC CAPACITY TAKING PLACE IN THE DEVELOPING WORLD OVER THE PAST DECADE AND A HALF.

A Fond Farewell

This will mark my final issue as the editor of the *TWAS Newsletter*. Early next year, I will be retiring as the public information officer of TWAS and returning home to the United States to begin the next chapter of my life.

It has been an honour and a privilege to observe and chronicle the enormous shifts in science that have occurred since the late 1990s when I began my tenure at TWAS. Expecting to be here only a year, I have stayed much longer. It has been a fascinating journey.

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At the time of my arrival, significant currents of change in science in the developing world were surfacing at a serene and largely uneventful pace. No one could have predicted that science in the South – and indeed the entire world – was about to embark on an era of profound transformation.

I remember my first TWAS general conference held in Brazil in 1997, just a few weeks after I had arrived. The presentations were first rate. Yet much of the discussion focused on aspirations, not accomplishments.

Now fast forward to the TWAS general conference in Brazil in 2006. The presentations were again exceptional. But, this time, so too was the level of confidence. Aspirations were matched by a broad range of accomplishments, proudly stated, as well as a prevailing sense that the future would be even brighter. Here is what I wrote at the conclusion of the TWAS conference in Brazil in 2006:

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ICTP Campus, Strada Costiera 11
34151 Trieste, Italy
tel: +39 040 2240327
fax: +39 040 224559
e-mail: info@twas.org
website: www.twas.org

EDITOR
Daniel Schaffer

MANAGING EDITOR
Gisela Isten

ASSISTANT EDITORS
Tasia Asakawa
Cristina Serra

CONTRIBUTING WRITER
Linda Nordling

DESIGN & ART DIRECTION
Sandra Zorzetti, Rado Jagodic
www.studio-link.it

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"Science and technology have clearly experienced much progress since TWAS last met in Brazil. The nation may be on the verge of joining a select but growing group of nations where science-based sustainable development is the norm and where the strength of scientific institutions does not depend on individual benefactors but is woven into the fabric of government and society."

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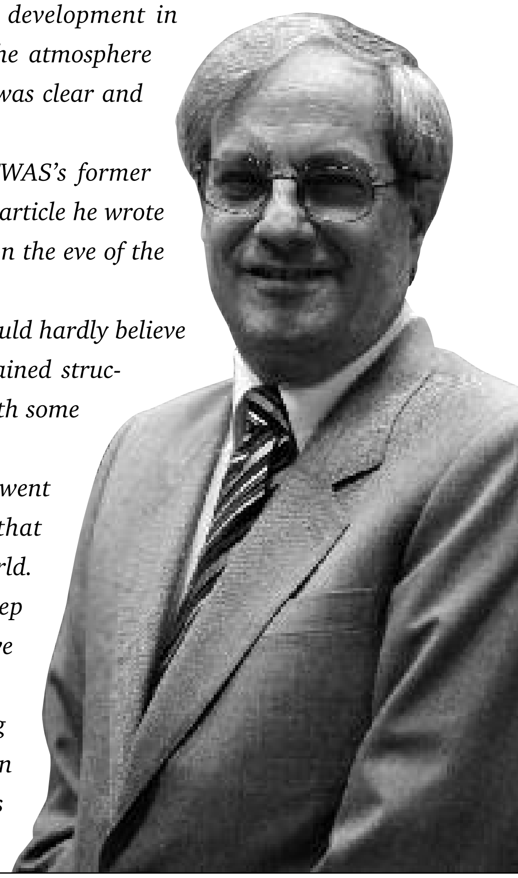
The same sense of rapid progress and buoyant optimism was echoed in 2003 in China, where TWAS held the general conference marking the Academy's 20th anniversary.

Before a packed audience in the Great Hall of the People, which included a large contingent of school-age children, President Hu Jintao opened the meeting with an announcement that China's first astronaut had returned safely to the Earth.

It was all part of a larger effort to showcase the historic advances that were taking place in science-based development in China and, more generally, in the developing world. The atmosphere was festive, the rhetoric was purposeful, and the vision was clear and compelling.



Compare this to the memorable description that TWAS's former executive director Mohamed H.A. Hassan provided in an article he wrote for Nature *magazine recalling his initial view of China on the eve of the Academy's general conference in 1987:*

"When I landed at Beijing's international airport, I could hardly believe my eyes. The airport, consisting of a few poorly maintained structures, was no larger than the airport in Trieste, a city with some 220,000 people that was home to the TWAS secretariat.

"TWAS's founding president Abdus Salam", Hassan went on to say, "had told me on more than one occasion that TWAS could make a real difference in the developing world. With his elegant English accent and penetrating deep brown eyes, he had an uncanny ability to make you believe what he believed.

"Yet Beijing's international airport, marked by peeling paint and dim lighting, a lack of signs and service, and an endless and anxious wait for luggage and the few taxis

that were available suggested that it was going to take a lot of work to realize Salam's dream – even (and perhaps especially) in the world's most populous nation. I could not help but think that the Academy might be just a tad too small to do the job."

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Now let's move several years ahead to the first decade of the 21st century.

When TWAS held a general conference in Delhi in 2002, there was no denying that science-based development was charging ahead in India at an unprecedented pace and that a new dawn in science was rising.

Yet there was also a sense that these positive forces, however welcomed, had gained a strong foothold in only a few select scientific fields – most notably, information and communication technologies and, to a lesser extent, pharmaceuticals.

While there was much to praise, there was also a prevailing sense that the advances were fragile and could stall or even be reversed at a moment's notice – and that if such a reversal occurred, it would be difficult to get back on the right track.

Yet here's the more positive sentiment that I noticed upon the return of TWAS to India in 2010: "The country's shimmering future was on full display, most notably in the ceaseless construction and buoyant optimism that is evident everywhere you look. India's science- and technology-based growth is not confined to a few isolated areas but is now a nationwide phenomenon."

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What has been true of Brazil, China and India has become increasingly true in a growing number of countries across the developing world. Today global science is indeed a global phenomenon that is no longer confined to the developed world.

Yet the rapid changes in science in the developing world pose challenges as well as opportunities.

First, there is the issue of the countries left behind.

As several surveys conducted by TWAS have shown, some 80 developing countries, mostly located in sub-Saharan Africa and countries with predominantly Muslim populations, continue to lag far behind in scientific capacity.

These countries are home to 1.6 billion people, nearly 20% of the world's population. Their scientists, however, produce less than 1% of the publications published in peer-review

international scientific journals. Not surprisingly, these scientifically lagging countries are also among the world's poorest countries.

Second, there are existential issues posed by the pressures that have been placed on the Earth's resources and ecology. According to the United Nations, global population reached 7 billion people on 31 October 2011. That is one billion people more than in 2000.

The population of the world passed 1 billion in 1800. So, thresholds that took hundreds of thousands of years to cross, now take little more than a decade. If current trends continue, global population could reach 10 billion by 2050.

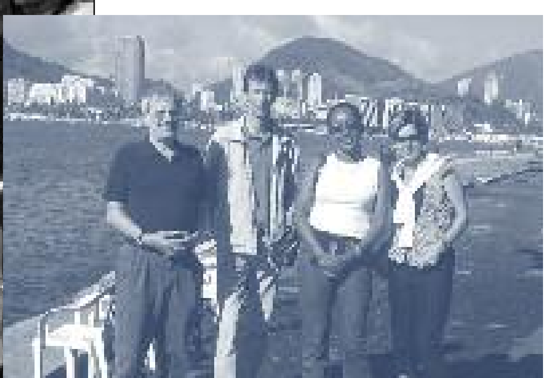
The world's endlessly growing population, combined with the increasing wealth and dramatic life-style changes occurring in a growing number of developing countries, have placed unprecedented pressure on the world's resources. According to some studies, on an annual basis the world now consumes 30% to 50% more resources than it can replenish. This trend is unsustainable.

And, third, there is the issue of scientific collaboration in a world separated by nation states that are engaged in intense competition for wealth and power.

How will developed countries react to their declining status in global finance and science? These countries are unlikely to fall far (if at all), but they will have to share the stage with others.

Will developed countries graciously welcome the emerging economic and scientific powers, or will they be suspicious and resentful of the newcomers? How will the attitude of the established powers in science affect the future of global science, which will inevitably be characterized by a shift in strength and focus from the North to the South?

Conversely, how will emerging economies deal with their rapidly rising influence?



Will scientists in developing countries choose to draw on their growing scientific capabilities to ally largely with colleagues in developed countries in ways that deepen conventional pathways to cutting-edge science. Or, will they ally largely with scientists in developing countries to create new pathways of global scientific exchange marked by South-South cooperation?

Better yet, are there ways to simultaneously pursue South-North and South-South cooperation to strengthen both frontier science and science for *development? If so, what might a successful paradigm for global science in the 21^{st} century look like, and what should be the responsibilities of scientifically advanced and scientifically lagging countries in the new 'ecumenical' union of global science?*

None of these issues were readily discussed when I began my tenure at TWAS. But today they are at the forefront of the dialogue on science in rich and poor countries alike.

On the one hand, these discussions show how successful efforts to promote scientific capacity building have been in a growing number of emerging economies and developing countries. On the other hand, they show just how far we still have to go to ensure that all countries have the ability to embrace science to propel their economies forward.

The good news is that the ledger sheets on science are rapidly changing as an increasing number of developing countries move from the column marked 'in need of assistance' to the column marked 'able to give assistance'. Undoubtedly this change is here to stay, creating both new opportunities and new challenges that I will leave to my successor to observe and record on behalf of TWAS.

For me, it has indeed been a privilege to witness and explore such historic changes. I owe a deep measure of gratitude to many individuals who have made my tenure at TWAS so interesting and rewarding. Most notably, I would like to extend a warm thank you to Mohamed H.A. Hassan, who led the Academy during most of my time here, and to Romain Murenzi, who assumed the reins of the Academy last April. I also owe a great deal of thanks to the TWAS public information office staff. Gisela Isten has been with the Academy since nearly its inception, and her 'institutional memory' continues to play a key role in the public information office. Thanks also to Peter McGrath and Brian Smith, who have moved on to other positions (Peter is now the Academy's programme officer and Brian is with UNESCO in Paris), as well as to Tasia Asakawa and Cristina Serra, who arrived later in my tenure and who are part of the editorial team for my final TWAS Newsletter *issue. And then there are people outside of TWAS to whom I owe a great deal, most notably Rado Jagodic and Sandra Zorzetti, who have been responsible for the newsletter's design and graphics, and Linda Nordling, who has been a contributing writer. And, finally, I would like to extend a warm thanks to the TWAS members, eminent scientists largely from developing countries whose research, dedication and enthusiasm have inspired my – our – efforts from the very beginning.*

I sincerely thank you all. I wish you a fond farewell and I hope that our paths cross again sometime soon.

Daniel Schaffer
TWAS Public Information Officer
Trieste, Italy

SCIENTIFIC EXCELLENCE IN PAKISTAN

THE INTERNATIONAL CENTER FOR CHEMICAL AND BIOLOGICAL SCIENCES IN PAKISTAN CONTINUES TO PURSUE SCIENTIFIC EXCELLENCE DESPITE GROWING BUDGET CONSTRAINTS AND POLITICAL UNCERTAINTIES.

Located in Pakistan's financial centre and largest city, Karachi University's International Center for Chemical and Biological Sciences (ICCBS) is one of the developing world's finest research and training centres in its field.

The large complex, which covers more than 40 hectares, is comprised of 10 research buildings that contain some of the region's most sophisticated laboratory equipment. The complex also includes a residential area with 50 houses, five apartment buildings and an international guesthouse.

ICCBS carries out research, training, product development and service delivery in the chemical, biological and biomedical sciences. The centre also provides diagnostic, analytical and clinical testing for a broad range of clients in both the public and private sectors.

Over the past 40 years, more than 600 students have earned doctorate and master's degrees at the centre. These degree-granting programmes have served as the focal points of ICCBS efforts to provide world-class training to young scientists coming primarily from developing countries, including those belonging to the Organization of Islamic Cooperation (OIC), an international network comprised of 57 Muslim countries.

ICCBS also conducts cutting-edge research for the discovery of clinically important enzymes and antioxidants, explores innovative methodologies for the synthesis of novel proteins, devises effective pharmacological evaluations of bioactive compounds, and seeks to identify new varieties of horticulture plants through applications of biotechnology.

The centre employs 400 people, including more than 80 researchers with advanced degrees. In addition to their in-house teaching and research responsibilities, many researchers offer fee-based consultancy services to manufacturers and farmers in Pakistan.

ICCBS also oversees an ongoing series of short-term, non-degree 'certificate' programmes in subject areas ranging from how to build energy-efficient greenhouses to the testing and analyses of indigenous and novel pharmaceuticals. In addition, ICCBS organizes international conferences, symposia and workshops for participants from Pakistan and abroad on topics ranging from natural products, molecular medicine, spectroscopy, nanotechnology and computational medicinal chemistry.

The ICCBS annual core budget totals USD5.5 million. A portion of the centre's overhead funds is derived from the Husein Ebrahim Jamal (HEJ) Foundation and the Dr. Panjwani Trust. ICCBS also receives USD2 million a year in development funds from the government of Pakistan. These funds are allocated through the country's federal Higher Education Commission (HEC).

MATCHING FUNDS

Over the past five years, grant funds for research conducted by individual scientists have matched the core budget. In addition, the centre has attracted an additional USD1.5 million a year from abroad for research projects carried out in collaboration with other scientific institutions.

Atta-ur-Rahman – Pakistan's former minister of science and technology and chair of HEC – currently serves as ICCBS 'chief patron' providing strategic guidance for the centre's broad-ranging goals. Between 1990 and 2002, as ICCBS director he managed the centre through a period of unprecedented growth.

The current director is Muhammad Iqbal Choudhary, who was Atta-ur-Rahman's student nearly 30 years ago. Pirzada Qasim Raza Siddiqui, vice-chancellor of Karachi University, heads the ICCBS executive board.

Choudhary oversees the centre's day-to-day activities. He has established a framework of 'shared management' in which each faculty member is assigned responsibility for a specific set of administration tasks in addition to his or her teaching and research responsibilities.

ICCBS has twice won the Islamic Development Banks (IDB) Prize for Science and Technology, which includes a check for USD100,000. In 2004, IDB honoured ICCBS for its contributions to science-based devel-

opment, especially in Pakistan. In 2010, IDB honoured HEJ Research Institute of Chemistry (HEJRIC), a constituent component of ICCBS, for its contributions to the field of chemical sciences.

"Both were days of enormous pride for the centre", says Choudhary. "Receiving the most prestigious prize that IDB gives to scientific institutions is a distinct honour. Receiving it twice in six years is unprecedented and truly rewarding."

PERSPECTIVE

Pakistan gained its independence in 1947 following nearly a century of British rule. For more than 50 years following independence, science remained a low priority on the government's agenda as the newly created country struggled to meet the basic needs of its citizens and deal with continual political and religious strife.

However, beginning in 2000, with the support of the military ruler Pervez Musharraf, and spurred by initiatives conceived by Atta-ur-Rahman, Pakistan embarked on an unprecedented effort to improve education and scientific and technological capacity. That effort continued through 2008 when Musharraf stepped down.

Progress during this decade of reform was impressive. For example, the number of scientific publications written by Pakistani scientists in international peer-reviewed journals increased 600% and the number of citations of articles written or co-written by Pakistani scientists footnoted in international peer-reviewed journals rose 1,000%. Thomson Reuters (formerly ISI) Web of Knowledge, identified three Pakistani universities – the University of Karachi, Quaid-i-Azam University and the National University of Science and Technology (NUST) – among the top 500 universities in its global ranking of institutions of higher education.

Critics of the government's reform efforts, however, contended that greater emphasis was placed on higher education than on primary and secondary education, and that the reforms may have been introduced too quickly for the measures to be fully integrated into the existing system of higher education – let alone within the larger society.

In 2008, as stated earlier, a new government assumed power in Pakistan. Soon after, the world's most severe financial crisis in more than a half century battered the

economies of developed and developing countries alike.

Responding to the steep economic downturn and subsequent turmoil, the Pakistani parliament enacted substantial cuts to the government's overall budget and delayed or terminated a large number of initiatives that had been launched during the previous decade. Universities and research institutes were not exempt from the government's fiscal retrenchment.

Then, in 2010, historic floods swept across the country, upending the lives of some 20 million people and causing an estimated USD43 billion in damages. The disaster added to Pakistan's woes and placed additional constraints on the country's finances, including its investments in science and technology and higher education.

DECLINING FORTUNES

ICCBS has not escaped these problems. The centre, in fact, has been forced to confront an unprecedented budget crunch, requiring it to sharply curtail a number of its research and training activities.

Nevertheless, ICCBS has weathered the economic storm better than most other scientific institutions in Pakistan, largely as a result of its ability to obtain external funding and to generate revenues through the commercialization of its services and products.

Atta-ur-Rahman believes that the quality of ICCBS research and training does not simply lie in its superb infrastructure but also in the superior work that the faculty and researchers do. To fulfill this goal, he maintains ICCBS needs a skilled faculty that receives adequate compensation and rewards for its efforts.

"Core funding for the faculty", he says, "can only be provided by the government." The 2010 budget imposed a 50% reduction in the budget of the Ministry of Science and Technology compared to the previous year, leaving it with annual funding of USD19.2 million. The parliament also reduced the 2010 budget of the federal Higher Education Commission (HEJ) by 40%.

HEC's budget now stands at USD17.5 million. Core funding for ICCBS, which comes largely from both the HEC and the Ministry of Science and Technology, was pared from USD6 million to USD5.5 million.

The cutbacks not only forced ICCBS to cancel new projects but also to dramatically curtail the scope of its existing activities. "If substantial funds are not restored," Atta-ur-Rahman says, "the situation is likely to become even worse, placing the centre's hard-earned international reputation at risk."

Choudhary echoes Atta-ur-Rahman's concerns, noting that the centre's research and training efforts have stalled in the face of the government's deep budget cuts. He ominously adds that "decisions made over the next year or two are likely to determine whether ICCBS can maintain the level of excellence that it has achieved after decade of efforts."

"Financial stability and infrastructure development", Atta-ur-Rahman notes, "are critical elements in the success of any research institution. Such success requires a continual flow of funding at adequate levels commensurate with the scope of activities that are taking place now and in the near future."

Atta-ur-Rahman and Choudhary cite other challenges as well. For example, terrorist threats deter foreign researchers from visiting Pakistan and have required the centre to send its researchers and students to other countries for specialized training. At the same time, trade regulations marked by high tariffs have not only increased the cost of imported chemicals but have also caused lengthy delays in the delivery of products that are essential for conducting experiments. A 30% depreciation in the value of Pakistan's currency, which has taken place over the past three years, has raised the cost of purchases and placed additional strains on the centre's depleted budget.

"For all of these reasons," Choudhary says, "we have issued urgent appeals for the government to reconsider its budget cutbacks."

Meanwhile, social unrest and growing incidences of violence, combined with a sharp economic downturn and limited career opportunities, have led an increasing number of bright young Pakistani scientists to pursue their careers in other countries, where they enjoy higher compensation, better job prospects and greater security.

KEEPING ON

"To keep our most highly educated and best trained youth at home, we must be able to offer them benefits and opportunities that are comparable to what they can receive in other countries. We do not currently have the resources to do that", Choudhary says.

"If the government fails to adequately support its scientists and scientific institutions, the progress that has been achieved during the past decade could be undone", Choudhary warns.

"ICCBS", he adds, "has been able to recruit a talented and an experienced faculty. It has attracted excellent students that compare favourably to the best students enrolled in institutions in both developing and developed countries. It has built adequate research facilities. It is widely viewed as an institution of accomplishment and acclaim. And it has shown that it has the capacity to help boost the national economy and raise the scientific profile both within Pakistan and abroad."

However, Choudhary laments that none of these worthy contributions to the country's well-being will continue to be realized unless the "government continues to acknowledge the centre's value and supports its efforts."

WHY FROGS MATTER

EUGENIA MARIA DEL PINO (TWAS FELLOW 1989) HAS DEVOTED HER CAREER TO THE STUDY OF THE EMBRYOLOGICAL DEVELOPMENT OF TROPICAL FROGS. SHE IS CURRENTLY ONE OF THE WORLD'S LEADING RESEARCHERS IN THE FIELD.

Frog experts (or herpetologists *in* lingua scientifica*) love nothing better than to wade through rivers in search of strange animals to study. Boots on the ground – or better yet in the mud – is often the best pathway to a successful career.*

But such exploits are not for TWAS Fellow Eugenia del Pino, a developmental biologist based in Ecuador. The frog species that helped her make a name for herself in the field did not come from tangled, remote patches of rainforest. Instead, they were extracted from the manicured gardens of her university, the Pontifical Catholic University of Ecuador (PUCE), located in the country's bustling capital Quito. Today, she is renowned the world over as one of the leading experts on the embryological development of tropical frogs.

Her journey has not been without challenges. She had to work hard for a chance to earn a scholarship to acquire an advanced research degree in the United States. Upon returning to Ecuador she had to keep on fighting to make time for her research amid competing administrative and teaching duties – a balancing act that many developing world scientists would recognize from their own working lives. And, once her career took hold, she has had to overcome the isolation that often accompanies life as a biologist studying basic science in Ecuador, a country best known for research on biodiversity and conservation.

The hard work has paid off. She is not only a leading researcher in her field but is now helping a new generation of Ecuadorian biologists reach for the international A-league of research as well.

THE WINDING ROAD

Eugenia del Pino was born in 1945 in Quito. She earned an undergraduate degree in science education at PUCE in 1967. Soon after receiving her degree, she left the country to pursue a graduate degree – the only real opportunity for Ecuadorian students to do so at the time.

A grant from the Latin American Scholarship Program of American Universities (LASPAU) enabled her to enrol at Vassar College in Poughkeepsie, New York, USA. But when del Pino arrived at the college in autumn 1967, she had an unpleasant surprise. The university did not recognize her Ecuadorian degree as being equivalent to its US counterpart. As a consequence, it assigned her a second-year undergraduate (sophomore) status. After challenging the ruling and spending six months on probation, del Pino proved that she was indeed graduate student material.

She says that this problem persists for students from developing countries seeking to study in developed country institutions.

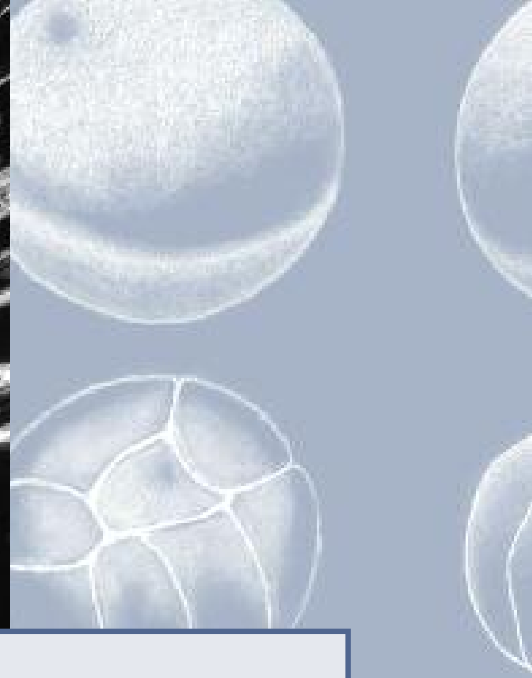
"Europe", she explains, "has a standardized system. If you study at the University of Salamanca in Spain and then move to Heidelberg University in Germany, there is no problem. But if you go from South America to the US or to Europe, then your student status often depends on how well the academic advisors know the institution that you come from in addition to how well you do."

del Pino's next hurdle came after she completed her Master's degree in 1969. The conditions of her fellowship stated that she should return to Ecuador after completing her studies. But del Pino had her eyes set on a PhD. If she returned to Ecuador with a Master's degree, she could walk into a teaching job and carry out the basic sort of research that 'expert' observers at the time thought sufficed for a developing country. But del Pino wanted to learn advanced research techniques and return to her country as a young scientist of international quality.

Ecuador is home to a large number of frogs with unique developmental attributes.

Again, her persistence prevailed. After some wrangling with administrators about her grant, she was allowed to enrol at Emory University in Atlanta, Georgia, USA, for a PhD. She spent three years there studying under Alan Humphries Jr., a developmental biologist who worked on *Xenopus laevis*, the frog equivalent of such model species as the fruit fly *Drosophila melanogaster* and the common mouse. Scientists rely on such organisms to study biological phenomena ranging from genetics to animal behaviour (see box, p. 14).

At Emory, surrounded by top scientists, del Pino felt she was in her environment. "There was a lot of scientific intellectual exchange with my professor. Each day we would go to the cafeteria to have a cup of coffee and discuss the latest aspects of science. People would

MODEL SPECIES

Biologists focus their studies on selected species, so-called model organisms, reasoning that studies of one particular species of frog will provide insights into other frogs as well.

One of the best-known model species is the fruit fly Drosophila melanogaster. *Fruit flies, as owners of fruit bowls the world over will attest, breed fast and are easier to keep alive than kill off. Genetic mutations in this unassuming fly are easy to study. As a result, the fruit fly has been used extensively in genetic research. In fact, it remains one of the most important model species in science to this day.*

Another iconic model species is the laboratory mouse Mus musculus. *Strains of mice have been bred with immune system deficiencies, enhanced risk of developing cancer or proneness to obesity. The goal is to study conditions that are common in humans. Since mice DNA is quite similar to human DNA, testing on lab mice is a common step in evaluating new treatments and drugs.*

Other common models animals include the nearly transparent zebra fish embryos and its avian namesake the zebra fish, as well as controversial higher mammal models such as cats, dogs and rhesus monkeys.

But the frog Xenopus laevis *– originally from South Africa and introduced in laboratories for pregnancy testing in humans before the advent of modern detection techniques – has a unique place in the study of development, largely due to the fact that transplantation of embryonic structures is easily done in the embryos of this frog. Much of our understanding of early development is derived from research done on* Xenopus.

As science progresses, more organisms are coming under biologists' microscopes. An important area of study nowadays is how lesser studied species differ from the most common model species.

offer their opinions with passion and without reservation. It was an interesting way of learning", she says. Nevertheless, she decided to return to her home country after obtaining her PhD in 1972.

Upon her return, del Pino taught biology first at the University of Guayaquil on the coast and then at PUCE in Quito, her *alma mater*.

EMBRYONIC RESEARCH

Soon after beginning to teach at PUCE, del Pino was offered a position to head the biology department at PUCE, which she accepted. At the time, she was the only member of the department with a PhD. Teaching twelve hours a week, she had little time or money to kick-start her research career. Yet, she felt that she needed to do research to retain the skills she had learned at Emory and to foster a research culture in her department.

But what to study? del Pino's department couldn't afford to buy *X. laevis*, the frog she had worked on at Emory. Luckily, Ecuador is home to a large number of frogs with unique developmental attributes.

The frog that she found in the university garden at PUCE was a type of marsupial frog. Rather than dispatching their eggs in water to hatch into tadpoles, these frogs carry the eggs in a 'backpack' on their backs until they hatch.

As members of one of the more than 60 species of marsupial frogs described in the South American rainforest, these 'garden-variety' frogs were not new to science. But little was known about how their embryological development differed from frogs that lay their eggs in water.

Ecuador is home to a large number of frogs with unique developmental attributes.

One big question was how the eggs could survive in the female's pouch. del Pino discovered that unlike normal frog eggs, which hatch in fresh water, marsupial frog embryos need a salty environment – akin to that found in living bodies – to thrive. If placed in fresh water, the embryos die.

Other questions related to the speed of development of embryos. Frog embryos deposited in water develop quickly. In less than two days they are tadpoles. But marsupial frog embryos can develop more slowly since they are protected in their pouches.

After a while, the international research community began noticing what del Pino was doing in her laboratory. In 1989, del Pino was asked by *Scientific American* to write a feature article on marsupial frogs, which was printed in the 10 different language editions of this prominent journal.

In 1995, her interest spread – or should we say jumped – to other frogs. She has studied Ecuador's famous poison arrow frogs whose toxin indigenous people used to tip their hunting arrows. She has also examined the development of foam-nesting frogs, which get their name from the fact that they build a nest out of material with the squishy texture of a marshmallow. "The nest floats on water and prevents predators from eating the eggs", she says. She has also worked on the molecular characterization of development in the frogs she studies.

However, research has at times been lonely work. Unlike Emory, there were no colleagues close at hand at PUCE to discuss her findings or toss around ideas.

"I came back to Ecuador where I found myself quite isolated. It was as if I spoke a different language, intellectually. There was no one who really understood what I was doing", she says. "The advent of the internet and fast and reliable communications have helped. But isolation is still the order of the day for many scientists in Ecuador."

This isolation is a problem for many developing country scientists the world over, del Pino adds, espe-

cially in small developing countries that lack a critical mass of scientists.

"Science does not develop in isolation. In the developing world, we often still lack the criticism of colleagues that is such a valuable tool for sharpening the scope of research. On the other hand, research analysis often requires quiet thought done in quiet places by yourself. It is nice, however, to have a balance of isolation and communication with scientific peers", she says.

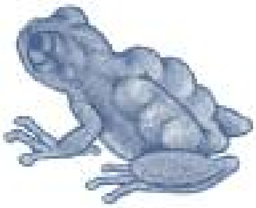
Isolation is a problem in small developing countries that lack a critical mass of scientists.

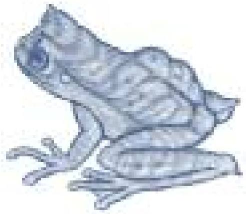
AIMING HIGH

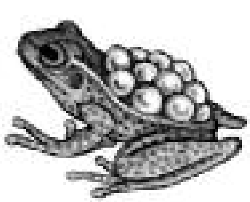
del Pino is passionate about passing on her research skills to her students and encouraging them to put Ecuador on the global research map. The idea that a research finding can be 'good enough' for a developing country does not float her boat.

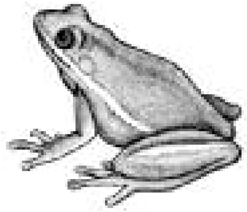
"Many scientists from here will do research and then not publish their findings at all or only publish them in local journals. I publish in local journals too, because I think it's important to communicate what I do locally. But I've always wanted to let the global scientific community know what I'm discovering, and I tell my undergraduate students to aim for that too." Of the 250 students in her department, about a quarter travel abroad to do advanced studies. During that time they produce international articles. "Those who return to Ecuador keep publishing in international journals", she says.

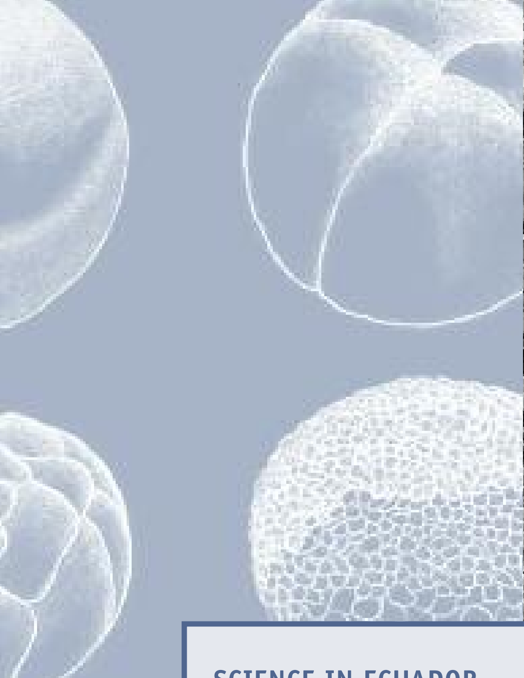
del Pino has collected many international accolades over the years. In 1996, she became an honorary foreign member of the American Society of Ichthyologists and Herpetologists. In 2000, she was awarded the L'Oréal-UNESCO award for women in science. In 2003, she was given the Sheth Distinguished International Emory Alumni Award. In 2005, she delivered the TWAS Medal Lecture; and earlier this decade she served on the TWAS Council. In 2006, she became an honorary foreign member of the American Academy of Arts and Sciences, and the same year she was elected











SCIENCE IN ECUADOR

Political instability has been the main threat to science and technology in Ecuador since the advent of democracy in 1978. Over the past three decades, the country has had no less than 12 presidents, exercising power on average for less than three years each.

Formal science in Ecuador has its roots in the 1950s. Yet it was not until 1984 that the promotion of science and technology was fully incorporated into the country's political framework. A separate ministry of science and technology did not exist until the mid-1990s.

International comparisons show that Ecuador's investment in science is low. According to UNESCO's 2010 Science Report, *Ecuador spent 0.15% of its gross domestic product (GDP) on research and development (R&D) in 2007. This is dwarfed by the expenditures Latin America's scientific giants Brazil, Chile and Argentina, which spent 1.07%, 0.67% and 0.51% of their respective GDPs on R&D in 2007 (Chile's figure is from 2004). Ecuador's government has recently announced that it plans to substantially increase public investment in science in the coming years.*

Ecuadorian science does have firm support from industry. The business sector is a major research funder, accounting for nearly half (45.5%) of the country's research expenditures in 2007.

Due to its extraordinary biodiversity, Ecuador is famous for conservation science. The Galapagos archipelago off the coast of Ecuador houses the Charles Darwin Research Station, operated by a non-profit organisation. However, agriculture, resource extraction and engineering are big areas of investment for the public sector and receive substantial industrial research funding as well.

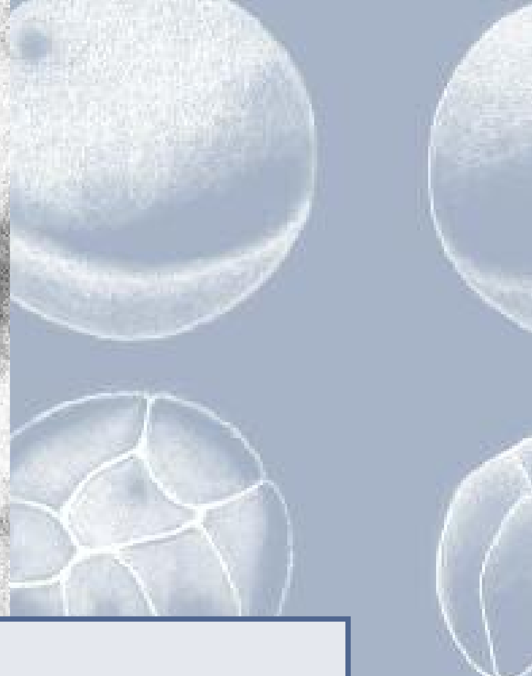
a foreign associate of the US National Academy of Sciences in the US – the only Ecuadorian scientists to date to receive that honour.

She has also received praise at home. In 2006, she obtained the Eugenio Espejo Medal on the Sciences – a major recognition for research given by the mayor and the city of Quito. She has been honoured for the conservation work that she has carried out in the Galapagos Islands. She is a member of the Latin American Academy of Sciences and a founding member of the *Sociedad Ecuatoriana de Biologia*.

GALAPAGOS ISLANDS

del Pino has also played a part in the protection of the fragile biodiversity of the Galapagos Islands. The islands, which lie off the coast of Ecuador and belong to the country, are famous for inspiring Charles Darwin to develop his theory of evolution. Today, they are a prime tourist destination and a significant source of revenue for the country. However, in recent years, fishermen have been clashing with conservationists in the archipelago over fishing quotas.

In 2005, the government of Ecuador banned 'long-



JEWELS OF THE RAINFOREST

Ecuador is home to an astounding array of amphibians. Its known indigenous frog species number more than 400, and new ones are being discovered all the time. In January 2010, scientists on an expedition through Ecuador's rainforest were reported to have found 30 new frog species.

These often beautifully coloured 'jewels' of Ecuador's rainforests, highlands and coastlands include the notorious poison dart frogs; frogs that lay their eggs in the vegetation; and frogs that carry their eggs in a pouch. Some have developed unique symbioses with other jungle dwellers. For instance, leaf cutter ants feed on the Lithodytes lineatus *frog's tadpoles. The frogs lay their eggs in flooded parts of ant nests that are used as refuse heaps.*

However, frogs are coming under threat all over the world from pollution, climate change and human encroachment on their habitats. According to the UN 'red list' of threatened species, 7% of all known amphibian species are critically endangered – the highest percentage among any group, including mammals or birds.

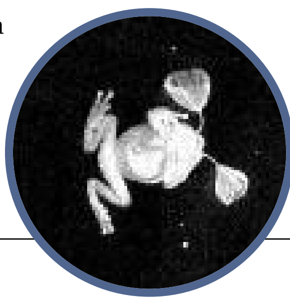
The destruction of the habitat and changes due to climate change can be seen all over Ecuador. For example, the attractive harlequin frog – once a common sight in the highlands around Cotopaxi, a snow-capped volcano near Quito – are no longer sighted.

This species is one of del Pino's favourite frogs because it moves very slowly and doesn't jump. However, due to disease and climate change, it vanished from the area in the 1980s and may now be extinct.

lining' in the 700,000 hectare Galapagos National Park Marine Reserve. This method of fishing which uses long lines of baited hooks and is infamous for producing disastrous by-catches that include dolphins, rays, sharks and even seabirds among the collateral victims. However, with the demand for seafood booming in markets in Asia in particular, illegal fishing remains a threat in the national park, and the islands' small fishing community is an important constituency for the Ecuadorian government.

del Pino's relationship with the islands began with dispatching her students to participate in research projects in the archipelago. From 1986 to 1996, she was a member of the council of the Charles Darwin Foundation, which has a research institute on the islands. In the early 1990s, she served as the foundation's vice president. But the political troubles that brewed on the islands – at one point researchers were taken hostage by angry fishermen – made her feel she was out of her depth. She left the board and returned to her frogs.

She loves to come back to the islands now and then, but her favourite times there are not spent gawking at manta rays or admiring giant tortoises. She loves to sit in the dining hall of the Charles Darwin Foundation's permanent



research station in Puerto Ayora listening to the visiting scientists from all over the world sharing their day's findings. This reminds her of research discussions when she was a student in the United States. "I have seen all the animals, and I admire the beauty and the landscape. But it's the intellectual ambiance of the Charles Darwin Research Station that I love most of all", she says.

SUCCESS AND CIRCUMSTANCE

During nearly four decades of carrying out research in Ecuador, del Pino has seen the country's research capacity grow. However, some things remain the same and perennial challenges persist. Funding is one. The government of Ecuador invests in science, but basic developmental biology is often overshadowed by the study of biodiversity and ecology. She understands the government's dominant concerns. "In terms of research to boost Ecuador, is it a priority to investigate how frogs develop, or should it be spent on curing malaria or improving crops?", she asks.

> ***"I tell my undergraduate students to aim for publishing in international journals."***

Facilities and resources present another long-term problem. It seems that no matter how much things improve in Ecuador's universities, laboratories in developed countries remain several steps ahead, she says. "Things are definitely better now than in the 1970s at my university. But the gap between us and the developed world is probably as great as it was when I started out, or even greater because science now progresses so quickly."

Yet, she believes that great science comes down to more than having the most modern equipment and facilities. Ultimately, she says, success in science depends on brains. And brains can even flourish in resource-poor laboratories.

"One colleague once said to me that no one has all of the facilities that one wishes, and one should work with what is available. The key to success is to use the facilities that one has in an optimal way", she says.

These sentiments parallel del Pino's own pathways to success. She has shown that, given the right training and an entrepreneurial mind, researchers in developing countries can beat a path for themselves beside the greatest in their fields. In her field of research, they may be able to do so without even having to don boots to wade through the rainforest. The sedate gardens right outside the office windows, in fact, have proved to be just as promising. Unfortunately, frogs all around the world are vanishing due to disease and climate changes. Such trends concern both her and her colleagues – and should concern us as well.

CARS GO GREEN IN BRAZIL

WITH MILLIONS OF FLEX-FUEL CARS AND A SIGNIFICANT RELIANCE ON BIOFUELS, BRAZIL'S NATIONWIDE AUTO FLEET IS UNIQUE. NOTHING LIKE IT CAN BE FOUND IN ANY OTHER COUNTRY. IN THE FOLLOWING ARTICLE, JOSÉ GOLDEMBERG (TWAS FELLOW 1990) AND PATRICIA GUARDABASSI FROM THE INSTITUTE OF ELECTROTECHNICS AND ENERGY AT THE UNIVERSITY OF SÃO PAULO EXPLAIN HOW BRAZIL HAS MADE SUGARCANE-BASED ETHANOL A SIGNIFICANT SHARE OF ITS TRANSPORTATION FUEL.

Technically speaking, there is nothing new under the sun when it comes to burning biofuels in internal combustion engines. In the late 1880s, Henry Ford used ethanol produced from corn to power some of the first automobiles in the United States. In 1900, at the World Exposition in Paris, Rudolf Diesel used biofuels produced from peanut oil to propel an innovative engine that came to bear his name.

In the early years of the 20th century, however, biofuels proved too costly to compete with fossil fuels, which at the time were not only cheaper to produce but also seemed inexhaustible.

Brazil has produced sugarcane in large quantities for hundreds of years, dating back to the colonial period. As early as the 1920s, Brazilian researchers conducted technical studies on ethanol-powered vehicles, even focusing on whether ethanol could be effectively used to power championship racing cars.

In 1931, the government passed a law requiring all gasoline consumed in Brazil to include 5% ethanol from sugarcane. To advance this goal, it provided generous subsidies to both sugarcane farmers and ethanol producers. In addition, it regulated prices at the pump to ensure that customers could afford to purchase ethanol. The subsidies were designed to keep the price of ethanol comparable to that of gasoline. In a trend that signaled the success of the effort, over the years the ethanol content was gradually raised to 7.5%.

In the early 1970s, Brazil, like the rest of the world, was rocked by the oil crisis. At the time, the country

imported nearly 80% of its crude oil. As domestic supplies dwindled and prices rose, the cost of imported oil quadrupled from USD600 million in 1973 to USD2.5 billion in 1974. In those years, oil accounted for nearly one-third of Brazil's imports and consumed nearly half of the country's hard currency.

A HELPING HAND

In the midst of this crisis, Brazil's sugar producers called on the government to help reduce the country's dependence on imported oil by mandating an increase in the amount of ethanol in gasoline. Utilizing the idle capacity of the country's sugar refineries, they contended, could advance such an initiative without requiring significant investments in new industrial infrastructure.

In response to this proposal, in November 1975, the federal government established the National Alcohol Programme (Pró-Álcool). The law set a national production goal of 3 billion litres of ethanol by 1980. The figure was projected to rise to nearly 11 billion liters by 1985.

The government's strategy for increasing ethanol production relied on two different processes. The first called for using ethanol as an octane enhancer in gasoline. The attractiveness of this strategy was that it required no major changes in engine designs. Anhydrous ethanol would be mixed with gasoline in portions ranging from 20% to 25%, creating a mixture commonly called 'gasohol'.

> ***Technically, there is nothing new under the sun when it comes to burning biofuels in internal combustion engines.***

The second strategy was labeled 'neat' or 'pure' ethanol. Its attractive feature was obvious: No fossil fuels would be used. But there was a drawback. Conventional engines could not efficiently burn pure ethanol because of the fuel's lower energy content.

As a result, engines would have to be redesigned with higher compression ratios. This would require a drastic change in auto manufacturing – something that automakers were reluctant to do unless the government was willing to provide assurances that consumers would purchase ethanol-powered automobiles and that a sufficient number of ethanol gas pumps would

be available to make it convenient for customers to buy this kind of fuel.

In short, the decision to produce substantial quantities of ethanol in Brazil was not simply driven by the marketplace. It was based, in large measure, on the government's desire to address what it considered to be both a national security issue and a balance of payments issue. Success would also depend on the government's willingness to engage in a long-term strategy that would require its direct involvement to prime the market and propel it forward.

Meanwhile, sugar producers welcomed the government's ethanol programme. After all, it would allow them to divert sugarcane to ethanol production and thus make their industry more resilient to volatile fluctuations in sugar prices on the international market. Yet they too expected the government to lend a helping hand in the form of subsidies.

BIOFUELS NATION

Consumers, of course, also had to be persuaded to come on board. As a measure of economic independence, the ethanol programme spurred Brazilian nationalism, even though Brazilian automobile manufacturers could no longer export their cars, and Brazilian drivers sometimes found that they could not fill their tanks in neighbouring countries because service stations did not sell ethanol. Indeed service stations with ethanol-blended gasoline were even in short supply in some Brazilian states. The government sought to tap the country's national pride to make up for these inconveniences. Yet, ultimately, the success of the initiative would depend on the price and availability of the fuel.

With an integrated strategy for acceptance in place, the production of ethanol-powered cars began in earnest in the late 1970s. Between 1979 and 1985, these automobiles accounted for 85% of all new car sales. At the same time, the share of ethanol in gasoline reached 20%.

As described in the initial decree passed by the government in the mid 1970s, a decade later two fleets of automobiles were operating in the country. Some cars used a blend of up to 20% anhydrous ethanol and 80% gasoline. Other cars operated entirely on neat ethanol.

In 1985, ethanol production hit a bump in the road as oil prices fell and sugar prices rose on international markets.

As a result, sugar farmers returned to marketing a greater portion of their sugarcane as a food, not fuel, crop. The government, in turn, reduced its subsidies for ethanol production, causing supplies to dwindle even as demand held steady – at least at first. By 1990, however, sales of cars running on pure ethanol fell to just over 10% of the total number of cars purchased.

Ever-changing market conditions, marked by fluctuations in the price of sugar, showed that the sales of ethanol-powered cars would likely stall as the price of sugar rose.

The decision to produce substantial quantities of ethanol was not simply driven by the marketplace.

FLEX-FUEL

Beginning in 2003, ethanol use began to increase again with the introduction of flexible-fuel engines. While powered with high-compression engines capable of efficiently burning pure ethanol, these cars were also equipped with sensors that could detect ethanol-gasoline blend ratios and adjust the ignition electronically. They could run on gasoline blends containing from zero to 100% ethanol.

Flex-fuel cars were an immediate success. Today, they comprise more than 95% of all new cars sold in Brazil. Drivers, in effect, can choose the cheapest blend of fuel on any given day.

Brazilians currently drive nearly 25.5 million automobiles. The majority of cars running only on neat ethanol, which numbered 2.8 million in 2000, have been retired. Today, more than 12.5 million flex-fuel cars ply the roads. Their numbers are rapidly increasing.

The ethanol that fuels these cars is produced in 440 distilleries – more than two-thirds of which produce both sugar and ethanol. In 2009, ethanol production reached 27 billion liters, using sugarcane grown on four million hectares as their fuel stock. By 2015, ethanol production is projected to reach 47 billion liters. The land required to meet this production level will likely exceed six million hectares.

The cost of producing ethanol in Brazil has declined significantly over the years. In 1980, ethanol cost three times more than gasoline on the international market. As a result of technological advances and economies of scale, by 2004 the prices of ethanol and gasoline were comparable. In Brazil, it has remained this way ever since.

Nevertheless, over the past 25 years, government subsidies totaling USD50 billion were needed to sustain the programme. To generate these revenues, the government increased gasoline prices.

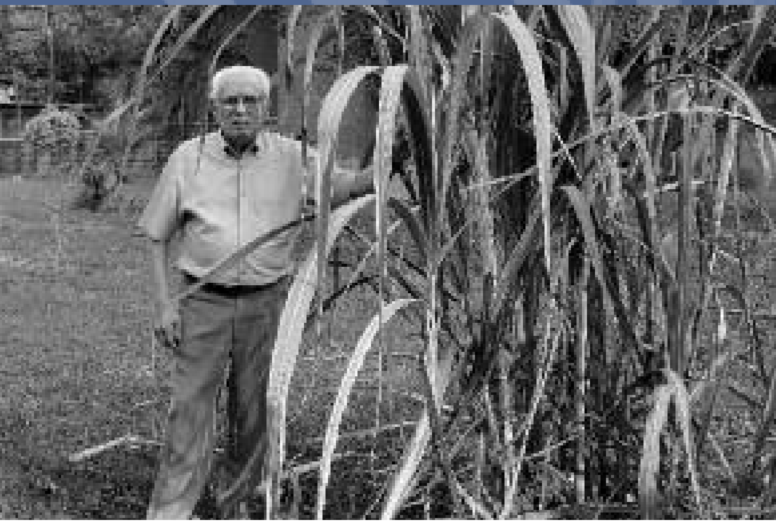
While the public did not necessarily welcome these price increases, the money generated – and subsequently invested in the country's nascent ethanol industry – ultimately reduced capital outlays for oil imports and thus played an important role in helping to balance Brazil's payment sheets.

Brazil's experience with ethanol thus serves as an important example of how government policies designed to help industries get off the ground can achieve lasting benefits for society.

The primary driver behind the decline in the cost of production of ethanol lies in the economies of scale and the corresponding increase in productivity, which has climbed nearly 4% a year over the past three decades. The number of litres of ethanol produced per hectare of sugarcane harvested more than doubled from 2,000 litres per hectare in 1976 to more than 5,000 liters per hectare in 2008.

ACCOUNTING FOR SUCCESS

Economic and strategic factors have been crucial elements in reducing the country's dependence on



crude oil. However, environmental issues have also been a key.

Unlike gasoline, ethanol does not spew such pollutants as sulfur oxides and particulates into the atmosphere. These pollutants are largely responsible for poor air quality in large cities like Beijing, Mexico City, São Paulo and Los Angeles. In São Paulo, for example, air quality has improved remarkably after ethanol was introduced on a large scale.

Over its life cycle, ethanol from sugarcane produces considerably lower amounts of carbon dioxide compared to gasoline. That's because sugarcane bagasse, the fibrous waste that remains after the plant is crushed, often serves as the primary source of heat and electricity in ethanol production plants.

Land use changes, including massive clearing of forests for the expansion of sugarcane plantations, could potentially increase greenhouse gas emissions. However, the expansion of sugarcane production in the state of São Paulo, where two-thirds of Brazil's ethanol production originates, is taking place mainly in pastures through the intensification of cattle production. São Paulo state's cattle population has increased in density from 1.28 heads per hectare in 2004 to 1.43 heads per hectare in 2009. This has allowed 0.88 million hectares of pasturelands to be released for the cultivation of other crops, especially sugar cane.

Traditionally, sugar-producing units were family-owned enterprises such as Cosan, São Martinho, and Santa Elisa. More recently, large Brazilian companies, including Votorantim, Vale, and Odebrecht, have become important players. Foreign companies have also entered the sugarcane business, including Tereos and Louis Dreyfus from France, Abengoa from Spain, BP from Britain, and Mitsui and Marubeni from Japan. The financial sector – for example, Merrill Lynch, Soros and Goldman Sachs – has also increased its presence. Petrobras, Brazil's state-owned oil company, has begun to invest in this area as well.

In August 2010, Shell and Cosan signed an agreement to create a global ethanol business, seeking to benefit from growing demand for biofuels. The European Commission (EC) approved the joint venture, which is projected to generate more than US$20 billion in annual sales.

More than 95% of all new cars sold in Brazil are flex-fuel.

The presence of such a vast array of foreign investors has given the ethanol industry a new vibrancy and infused it with new methods of innovative management. Over the next decade, investments by foreigners are expected to more than double from 12% to at least 30% of the total.

ENERGY IN BALANCE

There is a significant difference between the production of ethanol from sugarcane, which takes place in Brazil, and the production of ethanol from corn, which takes place in the US, and from wheat and sugar beets, which takes place in Europe.

In the US and Europe, ethanol is processed largely by burning fossil fuels, which is the main source of energy for electricity production. In contrast, in Brazil, the sun and photosynthesis are largely responsible for the process.

Scientists use the concept of ‘energy balance’ to evaluate the use of fossil fuels in producing ethanol. Energy balance entails comparing the amount of energy contained in the ethanol to the amount of fossil-fuel energy used to produce it. For sugarcane, this ratio is 8:1. For corn in the US, it is 1.34:1.

These figures are based on many difficult assumptions involving, for example, energy-inputs related to the use of fertilizers and pesticides. Yet research indicates that sugar-based ethanol emits 80% less carbon dioxide than gasoline while ethanol from corn emits just 30% less.

What accounts for this difference? Transforming corn into ethanol is much more energy-intensive than transforming sugarcane into ethanol.

FOOD VS. FUEL

Critics of ethanol production, residing largely in the US and Europe, claim that growing demand for fuel crops, such as corn, rapeseed, sugar beets and wheat, is reducing the amount of land available for forests and agriculture.

For these critics, the arithmetic is straightforward. They argue that there is a finite amount of land worldwide that can be used for forests and farming. Thus as more land is devoted to fuel crops, less land is available for other vital needs.

For biofuels critics, the most visible outcome of this trend has been the spike in food prices that took place 2007 and 2008, leading to food riots in a number of poor countries. Price spikes struck again in early 2011, which some observers claimed helped to fuel the protests in Tunisia, Egypt and other Arab countries.

But the issue is much more nuanced and complicated. First, while significant fluctuations in prices have taken place, food prices have generally declined across the globe since 1975. Second, studies show that fluctuations in food prices have followed similar tracks both in regions where fuel crops are grown and in regions where they are not. Third, higher prices for food crops may actually enhance the meager incomes of impoverished farmers and farm labourers who depend on these crops not just for their nourishment but also for the money it generates. And, fourth and most importantly, only a small percentage of the world’s arable land is devoted to fuel crops.

Currently, 1.5 billion hectares of land worldwide is being used for agriculture. Another 440 million hectares is potentially available, including 250 million hectares in Latin America and 180 million in Africa.

Land used for biofuels totals some 24 million hectares. That’s just 0.55% of the world’s total agricul-

Flickr/Rufino Uribe

tural landmass. Thus even if crops grown for fuel were to increase by an order of magnitude, such cultivation would still represent just a fraction of the world's arable land.

The bottom line is this: It is not the increase in the cultivation of fuel crops that has caused the recent spike in food prices. Rather, as a recent World Bank study has shown, price rises have been due to a myriad of factors, including high energy and fertilizer prices, the depreciation of the US dollar, drought in bountiful agricultural regions, growing global demand for grains (particularly in China), speculative activity on future commodities trading, and regional issues driven, for instance, by subsidies for biofuels production in the US and Europe.

In the US, for example, between 2006 and 2007, land planted in corn increased nearly 20% – from 30 to 37 million hectares. Most of this expansion came at the expense of acreage grown in soybeans, which declined by more than 15% – from 31 to 26 million hectares. Some observers claimed that this shift in land use in the US created a 'domino effect' that led Brazilian farmers to increase soybean production, largely by clearing forests in the Amazon.

Research, however, indicates this was not the case. The amount of land used for soybeans in Brazil has not increased since 2004. The forces driving deforestation in the Amazon, as stated earlier, reside in the expansion of cattle ranches and not soybean cultivation.

The world doesn't have to choose between food and fuel crops. We can have both.

IN DEVELOPING COUNTRIES

Approximately 110 countries worldwide produce sugarcane. According to the UN's Food and Agricultural Organization (FAO), the 15 largest producers are responsible for nearly 90% of the total sugarcane crop.

Some ethanol-producing countries may come as surprise. For example, Malawi has been producing ethanol since 1982. Half of Malawi's annual output of 18 million litres of ethanol is used domestically and half is exported to other African countries. In South

America, in addition to Brazil, Colombia produces some 320 million litres of ethanol each year, largely for its domestic market.

The prospect for additional biofuels production in developing countries is high, especially given the fact that many developed countries have adopted laws requiring gasoline to include a certain percentage of ethanol. The US, for instance, has called for 7% of the country's demand for transportation fuels to be met by renewable energy by 2020. The EU has stated that 10% of all energy consumption should come from 'non-mineral' sources by the same year. To fulfill this mandate, the EU will likely need to import biofuels from developing countries.

The technology for the production of biofuels is more than a century old. The fuel has proven to be trustworthy, tried and thoroughly tested. Over the past three decades, moreover, the production process has become more efficient and the scale of production has increased substantially, driving costs down. In addition, developing countries would welcome the revenues that biofuels exports would generate.

The key question is this: Why haven't other sugarcane-producing countries in the developing world replicated Brazil's successful biofuels experience and reserved a portion of their sugarcane crop for ethanol production?

The primary answers lies not only in the developing world, where governments have yet to take full advantage of the economic return that ethanol production offers, but also in the developed world, where the US and EU have subsidized their own sugar growers and ethanol producers while imposing import duties on ethanol imports. As a result, imported ethanol costs more than it would if free trade measures were adopted.

DRIVING INTO THE FUTURE

By 2030, experts anticipate that approximately one-third of the world's automobiles will be hybrids, electrical cars or biofuel-driven cars. That means two-thirds of the cars on the road will continue to be powered by engines burning fossil fuels.

Thus despite efforts to commercialize hybrids and electrical cars, fossil fuels will continue to play an important – indeed a preeminent – role in world transportation systems over the next two decades, if not longer. Most internal combustion engines, however, will likely be flex-fuel engines and thus be able to use ethanol as well as gasoline.

Ethanol produced from sugarcane has proved to be the best option to meet the environmental and economic challenges posed by the continued use of internal combustion engines. Equally important, research shows that more than enough land is available worldwide to ramp up ethanol production to meet projected increases in demand.

The world, in short, doesn't have to choose between food and fuel crops. We can have both. And since most of the remaining land suitable for sugar-based ethanol crops is located in developing countries – and particularly Africa – there is the added benefit that increased ethanol production would help some of the world's poorest countries generate the revenues they need to expand their economies and improve the living standards of their citizens.

Ethanol, simply stated, is an energy option we cannot afford to ignore.

José Goldemberg
Patricia Guardabassi
Institute of Electrotechnics and Energy
University of São Paulo
São Paulo, Brazil
goldemb@iee.usp.br
guardabassi@iee.usp.br

WOMEN IN SCIENCE IN KUWAIT

FAIZA AL-KHARAFI, THE FIRST FEMALE VICE-CHANCELLOR OF A MIDDLE EASTERN UNIVERSITY AND THE REGION'S WINNER OF THE 2011 L'ORÉAL-UNESCO SCIENCE PRIZE FOR HER WORK ON CORROSION, EXPLAINS WHY HER COUNTRY, KUWAIT, IS SEEING AN INCREASE IN THE NUMBER OF WOMEN SCIENTISTS.

Many scientists struggle to explain the economic or social value of their research. Faiza Al-Kharafi is not one of them.

The Kuwaiti chemist's field of interest – corrosion – costs Kuwait up to 5% of its gross domestic product (GDP) each year due to damages to oil and gas pipelines and refineries.

This is no small sum. Oil and gas account for nearly half of Kuwait's gross domestic product (GDP) and nearly 95% of its export revenues. With 70 billion barrels of proven reserves, Kuwait, home to just 2.7 million people, has the world's fifth largest oil reserves.

More than money is at stake. Corrosion also eats away at water pipes, posing a continual challenge for the delivery of safe drinking water. It can also pose serious direct risks to worker safety. In June 2000, for example, a leak caused by a corroded pipe led to an explosion in the Mina Al-Ahmadi refinery, located 45 miles from the capital, Kuwait City. The disaster killed six workers and caused billions of US dollars worth of damages to the installation.

The economic and social importance of fighting corrosion was a deciding factor in Al-Kharafi choosing to study it. "I went into this specialization to try to help




EATING AWAY AT CORROSION

Corrosion is the deterioration of material, usually metal, due to its interaction with its environment. Water is a key culprit; oxygen another. The curse of rust is well-known to anyone owning a car in a rainy climate.

Corrosion is a particular problem in oil pipelines and refineries, where the failure to detect and treat corrosion can be catastrophic. At the conclusion of an oil well's life, more and more water is pumped into the well to push out the oil. As the water flows through the pipes, it causes corrosion that can be difficult to detect. Meanwhile, external corrosion can be caused by rainwater or, for buried pipelines, by electrical currents in the soil.

Corrosion can be prevented in a variety of ways. Methods such as cathodic protection have proven effective for more than 50 years. In what can be described as an electronic slight of hand, the surface that is to be protected is electronically connected to another, more easily corroded metal that acts as an anode.

In effect, electrolytes are redirected from one material to the other. This breaks the 'corrosive circuit', helping the protected material to become more rust-resilient.

Cathodic protection is less effective in moist environments, which, of course, are among the most likely places for corrosion to take place. It is for this reason that 'galvanizing' surface treatments have become the strategy of choice for combating corrosion. New coatings, such as epoxy coatings, polyurethane coatings, environment friendly titanium dioxide (TiO2) coatings and nanocoatings have proven increasingly resistant to the corrosive effects of water and pollution.

The cutting edge of corrosion research, which lies in material science, seeks to predict where corrosion is most likely to take place both among and within materials. Computers are used to monitor corrosion. Researchers, however, continually seek to improve their models because even microscopic corrosive action in otherwise unaffected pipes can cause huge economic and physical damage over time. Nanotechnology researchers are working on self-healing materials that would automatically correct damage caused by corrosion.

address some of my country's most compelling challenges related to oil and water", she explains.

Al-Kharafi was one of the recipients of the L'Oréal-UNESCO prize in 2010: five USD100,000 awards that are given annually to exceptional women in science across the world. Her contributions to the field include working with corrosion inhibitors that can be painted onto pipes or blended into the alloy.

She has also published a number of major studies examining the impact of corrosion on refineries and cooling systems as well as drinking water and desalination plants. In addition, she has engaged in broad-ranging analyses of the impact of pollution on corrosion. For instance, she contributed to research showing how pollution levels can be directly monitored by analysing the atmospheric corrosion of certain alloys (see box above, 'Eating Away at Corrosion').

ROLE MODEL FOR OTHERS

Al-Kharafi's professional reach extends beyond corrosion research. A mother and grandmother, she is also a role model for Kuwait's rapidly growing number of female scientists.

In 1993, she became the first woman to lead a Middle Eastern university, spending a decade overseeing Kuwait University's (KU) USD200 million budget and 1,500-strong staff. In 2005, *Forbes* magazine named her one of 100 Middle Eastern women 'to watch'.




SCIENCE IN KUWAIT

Kuwait is small in size. But its scientific profile in the Arab region looms large. The country produces more scientific articles per million of its population (222 per million in 2008) than any other country in the Arab region. It also produces many patents – only Saudi Arabia produced more in 2008.

Moreover, Kuwait University, created in 1966 shortly after the country's independence from British colonial rule, is the fourth best in the region, after the American University in Lebanon, the United Arab Emirates University and the Suez Canal University in Egypt.

Kuwait is a wealthy country, and its quality of living is high. Its human development index is the highest in the Arab region and its gross domestic product (GDP) per capita is the third highest.

However, like most countries in the Middle East, the proportion of money dedicated to research and development (R&D) in Kuwait is lower than in developed countries. Kuwait spent 0.09% of its GDP on research and development (R&D) in 2007, third in the region after Qatar (0.33%) and Oman (0.17%) but much less than the EU average of 1.9%.

Low R&D spending in the Middle East is partly due to the region's oil riches, which push up GDP. But there have been calls to increase the amount of funding spent on R&D across the region. In 2006, Qatar announced it aimed to lift its gross R&D expenditure to 2.8% of GDP over a five-year period. The Organisation of the Islamic Cooperation (OIC), a network of Muslim countries, is working towards more and better research investments in the region.

In 2008, Kuwait followed suit with the ambition that it would increase its R&D budget to 1% of GDP by 2014. The target was part of national plans to tackle problems identified by a review of science in the country, including the absence of science governance at the state level, lack of cooperation between scientists and the public sector and a poor capacity to innovate in line with society's needs.

The government is, by far, the largest R&D funder in the country. It accounted for 97.6% of the country's R&D budget in 2007. Given the country's dependence on oil, engineering is an obvious focus of research. But the country is also strong in medicine and water science. Agriculture is a growing priority, since Kuwait is currently leasing land in fertile areas of the world to secure its food supply.

Women were a rare sight when Al-Kharafi began her university studies in the 1960s – first at Ain Shams University in Egypt where she earned an undergraduate degree in 1967 and then in her home country at Kuwait University, where she obtained master's and doctorate degrees in 1972 and 1975.

"Few women studied science then", she says. "We were 15% or less of the entire student population", she recalls.

But things have changed dramatically over the past few decades. Today, 40% of KU's science faculty research staff and 70% of the university's students are women.

Asked to explain why there is such an upswing in female graduates, she simply says: "Society has changed."

Kuwaiti women are among the most emancipated in the Gulf region. They can travel, drive and work without their husbands' or fathers' consent. Unlike their sisters in neighbouring Saudi Arabia, they are




V. Durruty / P. Guedj for L'Oréal Corporate Foundation

Wikipedia/Rust Bolt

allowed to vote – a right they obtained in 2005. In 2009, four women won parliamentary seats in the country's general elections.

Today it is common for Kuwaiti women to pursue higher degrees, says Al-Kharafi. "Women seek to be well-educated. They want to be engineers. They want to be doctors. You find women working in all sorts of jobs now", she says.

Today, 40% of Kuwait University's science faculty research staff and 70% of the university's students are women.

EDUCATION BEGINS AT HOME

Yet enthusiasm for learning and success does not fully explain why women outnumber men at KU two to one. Kuwaiti men, too, hanker for education. But they are much more likely than women to study abroad, Al-Kharafi says.

"Most women prefer staying with their family while males study in universities outside the country. That may be one of the reasons why Kuwaiti universities have more females."

The flexibility of an academic career also appeals to women, she adds. "Working in a university is more convenient for women than working in industry. It offers more flexible hours, which is good for mothers."

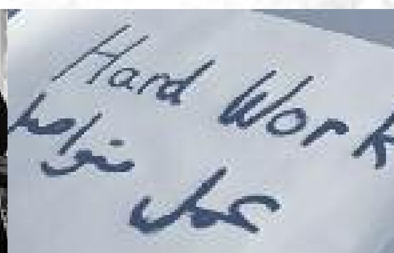
Her own passion for chemistry needed time to mature. She was interested in science from a young age. But it was only when she began to do research that she fell in love with chemistry.

"When studying a wide range of subjects in secondary school or even at university, I found some areas of chemistry difficult. But when I started pursuing research on my own, I really fell in love with the subject."

A contributing factor to her initial reluctance to pursue a career in chemistry may have been that no one in her family shared her passion for science. She is a member of one of Kuwait's prominent business dynasties and most of her relatives work in fields related to economics or politics. Her late father was a well-known Kuwaiti businessman and chairman of the country's national bank. Her brothers work in finance and politics. One of them, Nasser, looks after the family's large fortune.

Science has remained scarce in her own immediate family. Her husband is chairman of Kuwait's chamber of commerce. None of her children have pursued careers in science, although two studied engineering.

"One of the engineers is a politician and a member of parliament", she says. "The other is in business with



V. Durruty et P. Guedj for L'Oreal Corporate Foundation

WOMEN IN SCIENCE IN KUWAIT

Key statistics on women in science, technology and engineering in Kuwait

- *Female adult literacy rate (2007) 93.7%*
- *Female primary school enrolment (2006) 87%*
- *Female secondary school enrolment (2006)............................. 80%*
- *Female tertiary education enrolment (2006)........................... 64%*
- *Women among science students (1995/1996)......................... 73%*
- *Women among medical students (1995/1996) 73%*
- *Women among engineering students (1995/1996) 49%*
- *Women who chose to study science (1995/1996).................... 8.9%*
- *Men who chose to study science (1995/1996)........................ 3.5%*
- *Kuwaiti R&D personnel who are women (2007) 33.4%*
- *Female labour force participation rate (2006) 49%*

Source: AAAS, UNESCO Institute of Statistics http://www.aaas.org/programs/international/wist/countries/kuwait.shtml

his father. My other children, all university educated, have their own business pursuits. I am the only scientist in the family."

After leaving Kuwait University in 2002, she moved into an advisory role befitting her excellent political and economic connections. She was appointed to a position on Kuwait's Supreme Council of Planning and Development, which advises the country's president on policy issues.

As a member of the council she has contributed to reforming Kuwait's educational policy, among other things, seeking to make it more inquiry-based and interactive. In 2004, she was elected a TWAS Fellow, where she now serves as vice-president from the Arab region. Between 2003-2008, she was vice-president of the Arab Science and Technology Foundation.

Politics comes easy to her, Al-Kharafi says. "When I was the president of Kuwait University, I could not separate science from politics. I worked closely with ministers and members of parliament when I was at the university, largely to promote policies that would benefit education."

However, she will not turn her back on her passion – research. Throughout her long and distinguished career, she has remained active in academic research despite her other responsibilities. When she became president of Kuwait University, her students would do the legwork, but she would be involved in data analysis and interpretation. "That confirmed once again the invaluable role that teamwork plays in scientific research", she says.

Al-Kharafi has great hopes for the future of Kuwait, and she is passionate about encouraging young people – men and women – to study science and contribute to the development of their country. She knows it is not for everybody. "Studying takes years of hard work. But the benefits are worth the effort", she says. "Our society needs scientists. I advise young science students to work very hard, to be dedicated and to love what they do, which, at the end of the day, is the most important thing." ■

DIGGING FOR SUCCESS

ALEXANDER KELLNER, ONE OF BRAZIL'S FOREMOST PALAEONTOLOGISTS AND WINNER OF THE 2010 TWAS PRIZE IN EARTH SCIENCES, EXPLAINS WHY THE FUTURE IS BRIGHT FOR ASPIRING DINOSAUR AND FOSSIL HUNTERS IN DEVELOPING COUNTRIES.

Many children grow up loving dinosaurs. But few can turn their passion into a career. The prospect is especially challenging for youngsters in the developing world, where funding and jobs are scarce.

But if the challenges are overcome, the rewards can be great, says Alexander Kellner, one of Brazil's foremost vertebrate palaeontologists.

"Africa, for example, is virgin territory when it comes to digging for fossils", he says. "South America is a bit better off, but there are still extensive areas that, when prospected, will yield exciting and important new discoveries."

Kellner knows what he is talking about. As an undergraduate geology student at the Federal University of Rio de Janeiro (UFRJ) in the 1980s, the odds were stacked against him for studying Brazil's fossils.

Location was not the problem. The country's main collection, including many fossils recovered by the 'father' of Brazilian vertebrate palaeontology, Llewllyn Ivor Price, were housed at the National Department of Mineral Production (DNPM).

However, there were no formal internships for undergraduates at DNPM at the time. It took perseverance bordering on harassment for Kellner to get his foot in the door.

"It's a funny story", he says. He first approached the DNPM's chief researcher working on fossils, Diogenes de Almeida Campos. "I told him I wanted to learn about vertebrate palaeontology. He looked at me and said 'I'm very busy right now. Why don't you come back in one year?'" But Kellner didn't give up. "I said, 'Do you have some books? A desk? A chair? That is all I need to get started.'"

When Kellner returned the following day, the senior scientist handed him a book on the osteology of reptiles. It was a thick volume of almost 600 pages written in English, which was not very commonly spoken or read in Brazil at the time.

The tome was clearly intended to scare Kellner off.

But again, Kellner persisted. Day after day he turned up at the DNPM and sat with his nose in the book.

Eventually, de Almeida Campos also reappeared. Kellner remembers fondly what happened next. "He said, 'You are not going anywhere, are you?' I said, 'No.' He said, 'In that case we should talk.'"

It marked the starting point of a long and fruitful collaboration. The two have described more than a dozen new species together. One of them, *Thalassodromeus sethi* (named in 2002), has a formidable 1.44 metre long skull, three-quarters of which is comprised of a giant head crest. The discovery allowed the two scientists to establish a new hypothesis that pterosaurs used their crests to regulate body temperature.

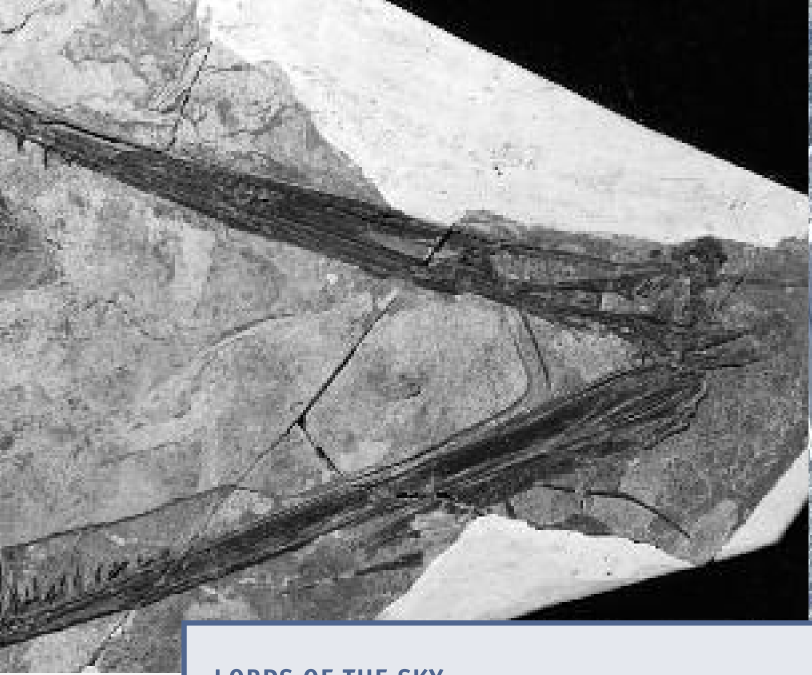
Going on an expedition is almost like having a blind date.

Kellner has also conducted significant research on his own. Much of his work has focused on describing pterosaur fossils recovered from a location in north-eastern Brazil known as the Araripe Basin where there are outcroppings of the Santana Formation that represents some of the most important fossil deposits in the world.

"There is a layer in the formation where we find exceptionally well-preserved flying reptiles, the best in the world at this point", Kellner says. Using the fossils, and comparing them with others, he has established for the first time a comprehensive theory of the evolutionary history of the pterosaurs.

At first, his research was desk-bound. There was no money to pay for expeditions, and DNPM's cellars – where he started his career – were stuffed with material to work on. He earned his MSc degree at UFRJ in 1991, a decade after enrolling for his undergraduate degree. Despite having started doing research as an undergraduate, it was not until he was pursuing his PhD at Columbia University, in New York City, that he began to feel established in his career.

Going to the United States was an eye-opener, he says, although at first he did not much fancy taking his career stateside. "At some point before beginning my PhD I was invited to go to the US. At the time, my interest in going there approached the same level of interest I would have had to go to the far side of the



LORDS OF THE SKY

Pterosaurs were the lords of the skies from the late Triassic until the end of the Cretaceous period (215 to 65 million years ago). Their wings – which, depending on the particular species, spanned from 25 centimetres to 10 metres – were formed by membranes of skin, muscle and other tissues stretching from their legs to their forelimbs.

The Italian naturalist Cosimo Collini described the first pterosaur fossil in 1784. However, Collini erroneously believed the fossil's wings to be paddles and deduced that he had found an aquatic species.

The French naturalist and zoologist Georges Cuvier introduced the idea of pterosaurs flying in 1801. Pterosaur fossils have since been discovered on almost all continents.

Contrary to popular belief, pterosaurs were not flying dinosaurs. It would be more accurate to say that they were the cousins of dinosaurs. The two shared a common ancestor before parting ways in evolutionary terms.

Another common misconception is that pterosaurs are the forefathers of current-day birds. In fact, most palaeontologists believe that birds are the only offshoots of the order Dinosauria that survived the great extinction 65 million years ago. Sadly, all traces of the order Pterosauria vanished with the dinosaurs.

moon. In Brazil, we had a bit of a critical view of the US", he says.

However, Kellner's first experience in the US would dramatically change his mind. He was invited to the 69th annual meeting of the Society of Vertebrate Palaontology's in 1989 in Austin, Texas.

"It was in a five-star hotel. I couldn't believe it – palaeontologists meeting in such an elegant place. I was used to filthy places. And I was amazed by the presentations. The first one I listened to was by an Australian guy who spoke about palaeopathology, using the fossil record to study disease. I had never heard about his fascinating, innovative work."

For Kellner, the meeting was a wake-up call. "I realized that if I wanted to be part of the international science community, I had to do my PhD outside Brazil."

He enrolled for his doctorate at Columbia University, which has an excellent graduate programme organized in collaboration with the American Museum of Natural History. The programme is supervised by John Maisey, a curator who has worked extensively in Brazil. Kellner obtained his PhD in 1996 after five years of study.

The following year he returned to the National Museum of the Federal University of Rio de Janeiro, which had just opened a position as professor and curator of the geological and palaeontological department. Kellner has worked there ever since.

The year Kellner earned his PhD was also the year he published his first article in the prestigious science journal *Nature*. The meat-eating *Santanaraptor*, which had been unearthed at the Santana Formation, stood only a little over a metre tall. But the fossil included petrified soft tissues such as blood vessels and muscle

PALAEONTOLOGY IN THE SOUTH

During the 19th century, palaeontology findings were concentrated in Europe, in particular in the United Kingdom, and later in the United States.

During the 20th century, however, the scope has widened. Fossil 'hotspots' were discovered in South America, Mongolia and China. And major discoveries have taken place in India, Madagascar and Antarctica.

Dinosaur fossils were found in China as early as 300 CE. In old texts, they are described as dragon bones, although most scientists presently believe that they were actually bones of large mammals.

Today, China has a large collection of fossils. One of the anecdotal reasons for this is that Mao Zedong loved fossils and supported their discovery. To this day, China's resources in the field of palaeontology are the envy of colleagues around the world.

Findings in South America, mainly in Bolivia, Argentina and Brazil, include one of the largest dinosaurs ever described. The 100-tonne Argentinosaurus *was a quadruped vegetarian (sauropod) dinosaur and would have measured 30-35 metres in length.*

The fossil was discovered in the Huincul Formation in southern Argentina. Kellner and his colleagues have also described Futalognkosaurus dukei*, which constitute the most complete of the giant dinosaurs discovered thus far in Argentina.*

Developing countries – including many in Africa – are virgin territory for fossil hunters. The most important finds of this century could well come from one of these unexplored areas.

As Kellner built his international reputation, he had more opportunity to go out into the field. His favourite expedition is a recent one to Antarctica, where he spent almost 40 days camping on the James Ross Island on the northeastern extremity of the continent. This was the site of the first dinosaur discovery in Antarctica in 1986. Kellner visited with a large group of scientists, looking mainly for dinosaurs and flying reptiles – his special area of interest.

The team collected three tonnes of materials, mostly plants and invertebrates. The main fossil vertebrate find was the oldest Antarctica marine reptile discovered to date.

fibres – possibly the best such find in a dinosaur. The discovery inspired Kellner and other scientists across the world to go back over fossils to look for clues of preserved soft tissue.

Kellner wasn't too disappointed that he didn't find any pterosaurs. "I'm not going to study those invertebrate and plant fossils, but somebody will."

It can nevertheless be frustrating, because going out

PUBLICATIONS AND ACHIEVEMENTS

Kellner has published more than 160 primary studies and four popular science books including: Pterossauros – os senhores do céu do Brasil *('Pterosaurs – lords of the Brazilian sky') and the novels* Na terra dos titãs *('In the land of the titans') and* Mistério sob o gelo *('Mystery below the ice'). He has also taken part in documentaries on fossils (e.g.,* Antarctica – a summer of 70 million years*, and* Dinosaur Hunters*).*

Kellner was appointed a member of the Brazilian Academy of Sciences in 1996. He is also honourable member of the New York Palaeontological Society and the Sociedad Paleontológica de Chile*. He is a research associate of the American Museum of Natural History and of the Chinese Institute of Vertebrate Palaeontology and Palaeoanthropology (IVPP).*

An avid science communicator, Kellner writes monthly in the column Caçadores de Fósseis *('Fossil Hunters') for* Ciência Hoje *On Line, a project of the Brazilian Society for Scientific Progress.*

on an expedition you never know what you will find, he says. "It's almost like a blind date", he explains.

Kellner's 'blind dates' have taken him to Chile, Iran and China, among other places. But his most successful expeditions in terms of fossils found have been in his home country. "There is still a lot of potential to find new fossils in Brazil", he says.

However, the continent that beckons Kellner at the moment is Africa.

"Africa is a big question mark for fossils. I would love to work in Africa because everything you find there is likely to be important."

The problem with Africa is security, he says. Travel is expensive, and geological maps, which are important to know where to start digging, are patchy at best. However, Kellner says that he has had an invitation from a colleague, a geologist working for a Brazilian petrochemical company in Angola, to come look at some things they found while prospecting.

Today, there are more opportunities for aspiring palaeontologists in Brazil than when Kellner was an undergraduate.

This is partly due to Kellner's own hard work in popularizing his research. The National Museum had

TWAS PRIZE WINNER

In 2010, Kellner was a recipient of the TWAS Prize in Earth Sciences, which he shared with Anil K. Gupta, Department of Geology and Geophysics at the Indian Institute of Technology in Kharagpur, India. Gupta was honoured for his fundamental contribution to the understanding of the past variability in the Indian summer monsoon on multidecadal to centennial time scales (for additional information, see 'TWAS Announces 2010 Prize Winners', www.twas.org*).*

an exhibition in 1999, which he organized, called *No Tempo dos Dinossauros* (In the time of the dinosaurs) that introduced the wider Brazilian public to Brazilian dinosaurs.

"That was when we were discovered by the media, and more and more people got interested. Today we have ten times more interest than we did before." In 2006, he also organized the display of the first large-scale dinosaur skeleton in Brazil. "The Brazilian Congress has recognized us for our efforts", he proudly states.

These days his students have access to information from around the world through the internet – something Kellner wasn't able to do during his studies. Still, he urges his students to travel abroad for at least some time while studying for their doctorate – six months or so – to be exposed to the global community of palaeontologists. When possible, he tries to take his students to the annual meeting of the Society of Vertebrate Paleontology, which made such an impression on him.

The thick osteology book that first sparked his interest is still in the DNPM's library. But undergraduates today are no longer scared off by it. Kellner tells his students to follow their dreams. With hard work, there is a splendid future for enterprising young palaeontologists across the developing world, he says.

A splendid future awaits enterprising young palaeontologists across the developing world.

However, they must also be prepared to leave a little something to fate. "There is always a bit of luck in the fossil hunt", he acknowledges. "You need to be able to fight hard and walk the extra mile. Luck, however, belongs to those who are prepared and work hard. That's true of all professions, including palaenotology.

"Uncovering a fossil", he says, "does indeed involve a bit of luck. But if you are not prepared and well trained, you will never be lucky."

CULTIVATING SCIENCE IN UGANDA

THE NATIONAL AGRICULTURAL RESEARCH LABORATORIES (NARL) IN UGANDA IS AT THE CENTRE OF THE COUNTRY'S EFFORTS TO SECURE MORE SUSTAINABLE FOOD SUPPLIES WITHOUT PLACING THE ENVIRONMENT AT RISK.

Agricultural research in Uganda can be traced to the establishment of the Entebbe Botanical Gardens in 1898.

At the time, Entebbe, which is located on the shores of Lake Victoria some 40 kilometres from the capital city of Kampala, was the seat of the British protectorate government.

The British were keen to maximize their return from the fertile fields of Uganda, so they founded the gardens that today stretch 1.5 kilometres along the Lake Victoria shoreline. The garden included an inventory of indigenous plants and became a test-bed for introduced species.

The oldest studies on Ugandan soil types and colonial cash crops such as cotton and coffee originated in the gardens. Other plants are preserved here as well. Visitors can still admire its small patch of rainforest – the only rainforest that has been preserved so close to Uganda's capital. Scenes from the first Tarzan movies were shot here in the 1930s.

In 1937, the colonial government's agricultural research activities moved to a rubber farm on a hill 13 kilometres northwest of Kampala. The government had acquired the farm from its Danish owners in 1934. The new headquarters were named Kawanda Agricultural Research Station.

In the 1950s, researchers at Kawanda undertook a detailed mapping of Ugandan soils. By the time Uganda gained independence in 1962, the research institute's focus shifted from commercial agriculture to a more development-oriented agenda. The late 1960s also witnessed the beginning of serious training efforts for indigenous scientists. At first, the scientific staff was entirely white. Indigenous Ugandans worked only as technicians or data collectors.

The founding father of ethnically Ugandan science was Zerubabel Nyiira who was trained as a technician at Kawanda and eventually received his PhD in bioecology and biostatistics. He would later become the first chief executive officer of the Uganda National Council for Science and Technology, serving from 1990-2005.

The 1970s and early 1980s were a turbulent time in Uganda, and the institute did not escape unscathed.

While it continued to function throughout the reign of Idi Amin, it was overrun in the mid-1980s when the national resistance army marched on Kampala from the west to challenge Yusuf Lule, who had become president after Amin.

The army camped out at the institute, which provided an important strategic advantage because of its hilltop location. The institute was looted and many of its research records were destroyed.

After the war, the new government, headed by president Yoweri Museveni, rebuilt the institute. In 1992, it became a part of the newly created National Agricultural Research Organisation (NARO). At the time, it was called the Kawanda Agricultural Research Institute (KARI). In 2005, its name was changed to the National Agricultural Research Laboratories (NARL).

NARL has Uganda's most advanced agricultural laboratories.

RESEARCH

NARL has evolved from the cotton- and coffee-based research centre of the colonial era to a broad-based institute for agricultural development and farmer training.

Today NARL's efforts extend far beyond Kawanda hill. The laboratory has many collaborative activities with other NARO institutes – most notably, NaCCRI in Namulonge, which administers Uganda's research activities on such commodities as banana, millet, maize and cotton.

However, NARL has the country's most advanced agricultural laboratories, and is at the forefront of a significant foray into modern biotechnology.

NARL research is carried out in eight units.

- The Plant Genetic Resources Centre and Entebbe Botanic Gardens is the only unit not based in Kawanda. Its duties include characterizing Uganda's plant genetic resources and encouraging their sustainable use by farmers.
- The Natural Agricultural Biotechnology Centre not only houses Kawanda's state-of-the-art genetic engineering laboratory, but also pursues research that uses more traditional breeding technology, including tissue culture.
- The Crop Post-Harvest Research Unit explores strategies for reducing post-harvest losses of crops, including improvements in storage techniques, pest management and marketing systems.
- The Soil Fertility Management and Agrometeorology Unit concentrates its research efforts on soil management.
- The Biocontrol Unit develops and promotes the use of biological control of pests, plant diseases and weeds.
- The Agricultural Engineering and Appropriate Technology Research Centre adapts agricultural engineer-

UGANDA'S NATIONAL DEVELOPMENT PLAN

Uganda's National Development Plan for 2010/11–2014/15, which was approved by government in April 2010, identifies eight priority growth sectors: agriculture, forestry, tourism, mining, oil and gas, manufacturing, information and communication technologies and housing development.

Science is one of the complementary growth sectors identified in the plan. The goals include to:

- *Reduce the ratio of science to arts graduates from 1:5 to 1:3 by 2015.*
- *Boost the number of researchers to 10 researchers per 1,000 labourers.*
- *Increase public spending on R&D.*
- *Create a Ugandan ministry of science and technology.*
- *Establish four science park and technology incubation centres to provide innovation support for young scientists.*
- *Encourage the private sector to invest in research and development.*

ing technologies to meet farmer and market demands.

- The Food Biosciences Research Centre conducts research in food quality, safety, nutrition, preservation, processing, storage and marketing.
- The Agricultural Research Information Centre coordinates agricultural information for NARO and promotes linkages between the different parts of Uganda's agricultural research system.

Kawanda also houses other research scientists, including many from the banana research programme, the administrative responsibility for which was moved to Namulonge in 2005. The International Institute for Tropical Agriculture also has permanent staff in Kawanda.

TRAINING

NARL plays a key role in training the next generation of Ugandan agricultural scientists. A few decades ago, most scientists at Kawanda received their degrees from foreign institutions. Today, the goal is to train as many scientists as possible in the country, although the lion's share of PhD students at Kawanda still obtain their degrees from abroad.

Funding for training comes through dedicated programmes, such as the agricultural training programme funded by the World Bank, or as part of grants allocated for research.

Finding staff to supervise students is a challenge. There is a lack of mid-career researchers at NARL. When NARO was created in 1992, a hiring freeze had been in place for several years. As a result, many researchers are now reaching retirement and there are few candidates ready to fill their shoes.

Brain drain is another problem. There is intense competition within Uganda for agricultural scientists and many staff receive offers for better paying jobs in neighbouring Rwanda.

Realising that Uganda needs its scientists to stay home, the government raised public sector scientists' salaries by 15% in June 2010.



INNOVATIVE EXPERIENCES IN SCIENCE AND TECHNOLOGY SERIES

For the past decade, TWAS – in collaboration with several other organizations and funding agencies, including the United Nations Development Programme's Special Unit for South-South Cooperation (UNDP-SSC), the Global Environmental Facility (GEF) and the Packard Foundation – has published a series of profiles of scientific institutions of excellence in the developing world. The case study on the National Agricultural Research Laboratories (NARL)*, which is summarized here, has been conducted with our newest partner, the Science Initiative Group (SIG), which heads the Regional Initiative in Science and Education (RISE) of the Carnegie Corporation of New York. Previous case studies can be browsed online at* www.twas.org*. For print copies of the profiles, contact* info@twas.org*. To learn more about SIG and RISE, see* sites.ias.edu/sig.

FUNDING

Agricultural research receives more funding from the Ugandan government than any other area. In 2008-2009, it accounted for more than half of the government's UGX76 billion (USD 31 million) science and technology budget.

However, NARO also obtains funding from international donors and foreign research funders. NARL's annual budget reached USD5 million in 2010. Only USD1 million came from the government of Uganda.

NARL scientists must apply for grants to supplement the institute's core funding. "Our scientists are proactive in writing project proposals", says Ambrose Agona, director of NARL.

Additional income is derived from services to Ugandan commercial farmers. The institute is working on a business model to enable poor farmers to access these services as well.

The funding situation has improved in recent years. The country has received an injection of cash from the Millennium Science Initiative (MSI), a five-year, low-interest loan provided by the World Bank to build capacity in science and technology. Several research projects at Kawanda, including the fruit fly project, receive MSI funding.

Yoweri Museveni, president of Uganda, has also promised that at least some of the wealth from the country's newfound oil fields will be used to strengthen the science base.

Nevertheless, funding remains a constraining factor, says Andrew Kiggundu, who heads NARL's biotechnology laboratory. Yet, at least the money is becoming more consistent and predictable, he adds. "The feeling is good now. I think our budget will grow."

FIELDWORK

Since independence in 1962, Ugandan agriculture research has focused increasingly on the needs of poor farmers. Today, extension services are a cornerstone of NARO's operations – and also one of its biggest challenges.

The political and social turbulence that marked the 20th century has left scars on Uganda's farming community. When the country was a protectorate of the UK, the colonial government told farming communities what to grow. If farmers refused, they were pun-

ished. Coffee has a local name, *chiwoko*, which literally translates as 'canes' since the colonial government would cane people for refusing to grow it.

Towards the end of the colonial period, farmers began to organize into co-operatives. This allowed subsistence farmers to sell some of their crops and use the revenues to invest in education and equipment. The British and Ugandans jointly ran courses at a co-operative college in Kampala. They settled disputes, established a bank and developed marketing strategies for a population with largely no experience in accounting and sales.

Each co-operative had 100 to 150 farmer members who elected their own committees. However, as time passed, the co-operatives became increasingly ineffective and corrupt. Today, only Uganda's tea growers organize themselves into co-operatives. Their produce is sold at auction and co-operatives serve the purpose of inhibiting farmers from undercutting each other's prices.

The current government liberalized Uganda's economy in the early 1990s. Within a few decades, Ugandan farmers went from being told what to do to being given the freedom to plant anything they like. Today, farmers receive advice from many different players, including development agencies, the 'green' lobby and scientists.

Farmers receive advice from many different players, including development agencies, the 'green' lobby and scientists.

The government's extension services have been carried out by the National Agricultural Advisory Services (NAADS) since its introduction in 2001. Its mandate is to develop a demand-driven, farmer-led agricultural service delivery system that targets poor subsistence farmers. NAADS emphasizes the needs of women, youth and people with disabilities.

The effort, however, has fallen short of its goals. A National Service Delivery survey of 2008 concluded that just 14% of the households had received visitors from an extension worker in the past year. Female-headed household fared even worse – less than 7% had met extension officers.

A World Bank survey published in 2011, *Science, Technology and Innovation in Uganda: Recommendations for Policy and Action*, found that even those farmers who had been visited by NAADS officers often did not change their behaviour.

"The people who have done well are people who have listened carefully to the information that was provided and used it in ways that made them more entrepreneurial. They have learned this is an investment that pays off if they apply what they have learned", says Kiggundu.

The biggest challenge is getting to poor, remote farming communities.

One problem facing extension services is that Ugandan science is dispersed. "A lot of research has been funded by donor projects that do not have a centralized data deposition policy", says Kiggundu. A new act of parliament requires every Ugandan to deposit copies of publications in national repositories. However, many Ugandan scientists are unaware of this obligation, Kiggundu says.

The Agricultural Research Information Centre, which is part of NARL, coordinates agricultural information for NARO and promotes linkages between the different parts of Uganda's agricultural research system. It serves as an information resource for Ugandan farmers and farming students, as well as for other researchers.

NARO also conducts its own outreach. "We use the media, most notably radio and agricultural forums, to present our findings to the public", says Robert Anguzu, NARO's public relations officer. The biggest challenge is getting to poor, remote farming communities, he says. Radio has proven to be the best medium for reaching poor people, since programmes go out in local languages.

The organization also arranges competitions to promote technology take-up in farming communities. "We might have a contest for the 'best village' or for the most 'complete farmer'", says Anguzu. Prizes range from fertilizer to watering cans and wheelbarrows. "It's a teaching opportunity and fun too", Anguzu says.

Research in NARO is still settling into the new institutional structure imposed in 2005. In the years to come, each of the agricultural institutes will grow into their new roles. For NARL, this includes being a high-technology resource partner for other institutes.

SCALING UP

With its 100-year old history, agricultural research receives more funding from the Ugandan government

than any other research sector. However, this situation may change as the government turns it attention to national efforts to exploit its newfound oil resources. Health research is also likely to get a boost, as are information and communication technologies.

That's not to say that agricultural research funding will shrink. If the government keeps its promise to increase its commitments to research, all sectors will be winners. Yet, the onus will be on all agricultural research centres to demonstrate their impact on social well-being. This will require an even stronger focus on outcomes, particularly in terms of getting research results to farmers.

As mentioned earlier, NARL already sells information to large-scale farmers. But the market has to include small-scale farmers. "We are trying to market ourselves to the small-scale farmers", says Drake Mubiru, head of NARL's soil science division. But this has proven difficult given how widely dispersed they are and how committed they are to their current practices.

"Government efforts over the past several years have begun to level the playing field and facilitate our ability to reach small-scale farmers", says Kiggundu. "Policies are finally lining up and it feels as if most people are moving in the same direction."

TAKING ROOT

With political support for science growing and renewed effort going into extending agricultural technologies to poor farmers, the next few years could see a significant improvement in the financial status and public impact of NARL.

The challenges facing Ugandan science remain daunting. Climate change will create increasing risks for farmers, especially poor farmers with no savings to dip into if crop yields are disappointing. Water management will become increasingly important to compensate for variations in rainfall. A growing population will place added demands on food crops and medicinal plants. Land management will have to become more sophisticated to stem biodiversity loss and conserve agricultural land. New pests could arise requiring urgent action.

Uganda, thanks in some measure to the NARL, now has the capacity to conduct the research needed to meet these challenges head-on. What is needed is sustained commitment and increasingly sophisticated ways of communicating the knowledge to farmers. But the basics are already in place.

Some 50 years after Uganda's independence, the country's agricultural researchers are leading the way to a better future for all Ugandans. With adequate support from the government and increasing ingenuity, Uganda's farmers stand a good chance to fulfil the high hopes that have been placed on them to ensure adequate foods supplies in the years ahead. ■

ATTA-UR-RAHMAN PRIZE

• TWAS announced the launch of the Atta-ur-Rahman Prize in Chemistry at its 22nd General Meeting in Trieste, Italy on 22 November. The annual award will be given to a young chemist in a scientifically lagging country. The first recipient of the award will be announced at the 23rd General Meeting of TWAS scheduled to take place in Tianjin, China, from 17-21 September 2012.

Atta-ur-Rahman

Atta-ur-Rahman (TWAS Fellow 1985 and coordinator general of COMSTECH) says, "The intention of the prize is to encourage young researchers in scientifically lagging countries to pursue careers in cutting-edge fields of chemistry." The research currently taking place in many developing countries, he notes, focuses largely on traditional fields of chemistry, while cutting-edge chemistry now encompasses a much wider range of subject areas, including the emerging fields of cell signalling, neuroscience, bioinformatics and structural biology. For additional information about the Atta-ur-Rahman Prize in Chemistry, please contact prizes@twas.org.

FRENCH HONOUR

• **Sospeter Muhongo** (TWAS Fellow 2004) has been honoured with the Order of Academic Palms by the

Sospeter Muhongo

French government. Muhongo is full professor of geology at the University of Dar Es Salaam, Tanzania; honorary professor of the University of Pretoria in South Africa; editor-in-chief of the *Journal of African Earth Sciences*; and vice president of the Commission of the Geological Map of the World. He was previously founder and regional director of the ICSU Regional Office for Africa in Pretoria, South Africa. Muhongo is a fellow of the Chinese Academy of Geological Sciences, the Geological Society of Africa, and the African Academy of Sciences. He is also a member of numerous editorial boards of scientific journals, the executive board of the African Inter-Parliamentary Forum on Science, Technology and Innovation, and the OECD's International Experts Group (Global Science Forum). For his scientific contributions in the field of geology, he has received several previous honours, including the first Robert Shackleton Award for Outstanding Research in Precambrian Geology of Africa, and Tanzania's National Award for Outstanding Research in Science and Technology.

MOST INFLUENTIAL ALUMNUS

• **Farouk El-Baz** (TWAS Fellow 1985) has been honoured as "Most Influential Alumnus" by the Missouri University of Science and Technology (MUST) in Rolla, Missouri, USA. El-Baz obtained his MS in 1961 and PhD in 1964 from the university. At the time, it was named the Missouri School of Mines and Metallurgy. The university also honoured him with the "Alumni Achievement Award for Extraordinary Scientific Accomplishments" in 1972, an honorary professional degree in 2002 and doctor of engineering in 2004. During the ceremonial events, El-Baz met with faculty and students of the Department of Geological Sciences and Engineering to speak about his professional journey in applying space photography to geological investigations. El-Baz is a veteran of NASA's Apollo programme and director of Boston University's Center for Remote Sensing. He is renowned for research on desert landforms and the location of groundwater in arid

Farouk El-Baz

lands and for his pioneering work on applying space images in the fields of geology, geography and archeaology.

SME CLASS OF FELLOWS

• **Pradeep Rohatgi** (TWAS Fellow 1989) was elected to the Society of Manufacturing Engineers (SME) Class of Fellows for his "world leadership in research, education, institution building and development of manufacturing technology of cast metal matrix composites that are

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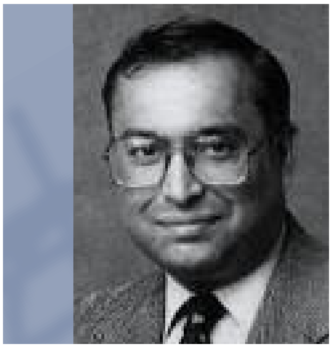
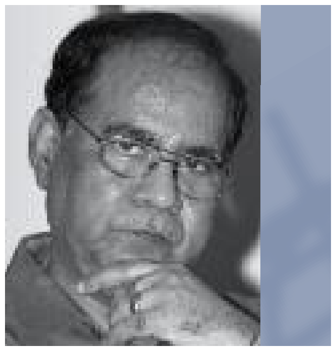


Pradeep Rohatgi

widely manufactured and used by industry." He received the honour with nine other fellows at a ceremony in Chicago, USA, in November. Rohatgi is distinguished professor of materials engineering at the University of Wisconsin-Milwaukee (UWM) and founding director of the UWM Center for Composites and the Center for Advanced Materials Manufacture. He obtained his DSc from MIT in 1964 and previously served as professor at the Indian Institute of Science (IIS) in Bangalore and founding director of the Indian Council of Scientific and Industrial Research (CSIR) Regional Research Laboratory in Trivandrum and Bhopal.

MULTIPLE HONOURS

• **Baldev Raj** (TWAS Fellow 2006) received several honours in 2011, including: The 10th Indian Nuclear Society Homi Bhabha Lifetime Achievement Award; H.J. Bhabha Gold Medal and Memorial Award by the Indian Science Congress; J.C. Bose Fellowship Award of the Department of Science and Technology, India; honorary professor of Sichuan University in Chengdu, China; honorary fellow of the Australian Institute of High Energetic Materials; erudite visiting professor of Mahatma Gandhi University in Kerala, India; distinguished visiting professor at the Indian Institutes of Technology in Mumbai and Kharagpur; and Distinguished Nayudamma Memorial Lecturer by the Council of Scientific and Industrial Research, India. Raj is distinguished scientist and director of the Indira Gandhi Center for Atomic Research, where he has led several successful R&D programmes involving the development of materials, fabrication tech-



Baldev Raj

nologies, non-destructive testing techniques, corrosion science and technology and the characterization of microstructural evolution. These programmes have played a pivotal role in advancing the science and technology for fast breeder reactors and nuclear fuel reprocessing.

CATALYST PROJECT LAUNCHED

• The FP7 EU Capacity Development for Hazard Risk Reduction and Adaptation (CATALYST) project was launched in October at an official kick-off meeting on the premises of the United Nations University's Institute for Environment and Human Security (UNU-EHS) in Bonn, Germany. TWAS is one of seven partners in four countries involved in this project, which is designed to identify and share knowledge in best practices related to natural hazard and disaster risk reduction. The project addresses EU policy activities in disaster risk reduction, within and outside Europe, and seeks to improve communication and information exchange among policymakers, researchers, representatives of non-governmental organizations and other stakeholders. Activities include four regional workshops in Asia, Africa, the Caribbean region and Europe, virtual workshops focusing on critical issues related to risk management, a policy notebook and the creation of a website that will serve as an information hub for material related to natural hazards and risk management, mitigation and adaptation. In addition to improving risk management strategies, the project will also seek to bring risk management knowledge to bear on economic development issues and the global sustainability agenda. For more information, see *www.catalyst-project.eu*.

GEOENGINEERING INITIATIVE

• Nations, NGOs and individuals should engage in a dialogue to explore the potential risks and benefits of solar geoengineering and to help establish effective governance for research. That is the conclusion of a new report, *Solar Radiation Management: The Governance of Research,* prepared as part of the Solar Radiation Management Governance Initiative (SRMGI). The initiative was convened by the UK's Royal Society, the Environmental Defense Fund (EDF) and TWAS. SRMGI, which was established in Marchc 2010, seeks to explore how to govern the developing research area of solar radiation management, a type of geoengineering that would cause a small percentage of inbound sunlight to be reflected into space to reduce global warming. For addition information, see: *www.srmgi.org*.

WHAT'S TWAS?

TWAS, the academy of sciences for the developing world, is an autonomous international organization that promotes scientific capacity and excellence in the South. Founded as the Third World Academy of Sciences by a group of eminent scientists under the leadership of the late Nobel Laureate Abdus Salam of Pakistan in 1983, TWAS was officially launched in Trieste, Italy, in 1985, by the Secretary General of the United Nations.

TWAS has more than 1,000 members from 90 countries, 73 of which are developing countries. A 13-member council is responsible for supervising all Academy affairs. It is assisted in the administration and coordination of programmes by a secretariat, headed by an executive director and located on the premises of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. The United Nations Educational, Scientific and Cultural Organization (UNESCO) is responsible for the administration of TWAS funds and staff. A major portion of TWAS funding is provided by the Italian government.

The main objectives of TWAS are to:

- Recognize, support and promote excellence in scientific research in the South.
- Provide promising scientists in the South with research facilities necessary for the advancement of their work.
- Facilitate contacts between individual scientists and institutions in the South.
- Encourage South-North cooperation between individuals and centres of science and scholarship.

TWAS played a key role in the establishment, in 1993, of the Organization for Women in Science for the Developing World (OWSDW, formerly the Third World Organization for Women in Science, TWOWS). Some 3,200 women scientists from more than 90 countries in the South are members of OWSDW, making it the largest organization of women scientists in the world. Its main objectives are to promote the leadership of women in science and technology in the South and to strengthen the participation of women in science-based development and decision-making. The secretariat of OWSDW is hosted and assisted by TWAS.

www.owsd.org

Since 2000 TWAS has provided the secretariat for IAP, the global network of science academies. IAP, which was established in 1993 as the 'InterAcademy Panel on international issues', unites more than 100 science academies worldwide; provides high-quality independent information and advice on science and development to policymakers and the public; supports programmes on scientific capacity building, education and communication; and leads efforts to expand international science cooperation.

www.interacademies.net/iap

Since 2004 TWAS has also hosted the secretariat of the InterAcademy Medical Panel (IAMP), an association of the world's medical academies and medical divisions of science academies. IAMP is committed to improving human health worldwide through the coordinated action of its 69 members. **www.iamp-online.org**