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YEAR 2010
VOL.22 NO.3

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TWAS newsletter

NEWSLETTER OF THE ACADEMY OF SCIENCES FOR THE DEVELOPING WORLD

Published with the support of the Kuwait Foundation for the Advancement of Sciences

THE 57 COUNTRIES BELONGING TO THE ORGANIZATION OF THE ISLAMIC CONFERENCE (OIC) ARE HOME TO 1.5 BILLION PEOPLE. THAT'S ONE QUARTER OF THE WORLD'S POPULATION. OIC COUNTRIES, MOREOVER, ARE YOUTHFUL COUNTRIES. AN ESTIMATED 40% OF THE POPULATION IS LESS THAN 15 YEARS OLD. BUT OIC COUNTRIES HAVE YET TO TAKE ADVANTAGE OF THEIR RICH ENDOWMENT OF HUMAN RESOURCES. INDEED 29 OF THE 57 OIC COUNTRIES ARE LOW-INCOME COUNTRIES. WHY IS THIS SO? AN ABSENCE OF SCIENCE ACCOUNTS FOR PART OF THE PROBLEM, SAYS MOHAMED H.A. HASSAN, TWAS'S EXCECUTIVE DIRECTOR.

Pathways to progress in the Muslim world

OIC countries spend on average just 0.4% of their gross domestic product (GDP) on science and technology. Each country, moreover, has on average just 525 researchers per one million population. In contrast, southeast Asian countries have, on average, 700 researchers per one million population and, in many of these countries, this figure is rapidly rising. What is undeniable is that where there is growing scientific capacity, there is growing economic prosperity.

Compare the situation in OIC countries with that in South Korea. South Korea spends 2.6% of its GDP on R&D and has more than 3,100 researchers per one million population. South Korea was a developing country in the 1970s, but is now a high-income country with the world's 15th largest economy.

In the past, the world focused on dramatic differences in the levels of scientific capacity and economic wealth between the developed and developing worlds. That gap persists. But, increasingly, there is also a growing divide among countries within the developing world itself.

On one side of the ledger is a group of large developing countries with emerging economies, most notably Brazil, China and India, but also Chile, Indonesia, Malaysia, Mexico, South Africa and others that have made significant progress over the past two decades in building their scientific capacities and growing their economies.

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Published quarterly with the support of the Kuwait Foundation for the Advancement of Sciences (KFAS) by TWAS, the academy of sciences for the developing world
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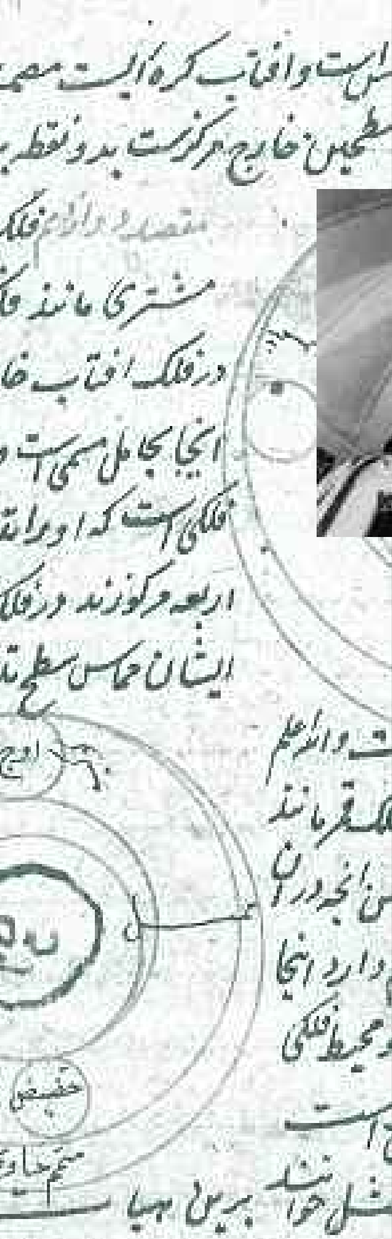
PRINTING
Stella Arti Grafiche, Trieste

Cover image:
Flickr/Martin Sharman



On the other side of the ledger are developing countries that have stalled or even slid backwards in their scientific capacity and that have failed to keep pace in efforts to develop their economies. Many of these countries are OIC members.

Here are some statistics illustrating this gap. The developed world, with about 20% of the world's population, currently produces almost three quarters of scientific articles published in peer-reviewed journals. The developing world accounts for about one quarter of the world's peer-reviewed scientific articles. Even more worrisome, OIC countries with nearly 40% of the developing world's population (and about 25% of the world's population) produce just over 3% of the world's peer-reviewed scientific publications.

So the fundamental challenge is this: How can scientific and technological capacity be built in OIC countries to help reduce poverty, sustain economic growth and address critical environmental problems.

To achieve these goals, OIC countries must develop sound and sustainable policies that nurture and subsequently tap the storehouse of knowledge possessed by their best scientists, and that integrate science, technology and innovation into national economic development strategies.

Scientific capacity building programmes in OIC countries must not only address critical challenges and shortcomings. The programmes must also be designed to take advantage of opportunities.

For example, it is estimated that 70% of the world's energy and 40% of its minerals are located in OIC countries. That, of course, represents a source of great wealth. But perhaps even more importantly, OIC countries have a vast potential for the production of renewable energy, especially solar energy.

Some energy experts, for example, believe that the solar energy potentially available in North Africa could not only meet all of the region's energy needs by 2050 but also generate an excess supply that could satisfy at least 15% of Europe's energy needs as well. The Moroccan government declared in January 2010 that it will seek to finance a USD9 billion solar thermal energy initiative designed to meet nearly 40% of the country's electricity needs by 2020. Such announcements strongly suggest that the era of solar energy may be closer than we think.

But renewable energy is not the only cutting-edge science and technology where opportunities lie for OIC countries. Advances in nanotechnology could improve access to safe drinking water; investments in space technology and information and communication technologies could enhance environmental monitoring; and breakthroughs in biotechnology, if fully embraced by the public and agriculturalists, could help to dramatically improve crop yields.

All of this, of course, requires strengthening scientific capacity. There are four critical points of action that could provide a roadmap for success. First, each OIC country must promote the development of research universities and institutes of high quality. Each OIC country should establish at least one world-class research university. To date, just a single university

in an OIC country – Istanbul University – is among the world's top 500 universities, according to the well-respected global survey of universities conducted by Shanghai Jiao Tong University.

Second, each OIC country should establish at least one world-class science centre or museum comparable in quality to the scientific centres in Kuwait and Egypt. There are some 2,400 science museums across the globe. Only 20 are in OIC countries.

Third, OIC countries should forge stronger ties between the policy and scientific communities. In part, this means strengthening ministries of science and technology and raising the profile of science in such critical ministries as finance. And, in part, this means taking advantage of the "strength in numbers" that lies in working closely with the members of such international organizations as the IAP, the Global Network of Science Academies, and the Commission on Science and Technology for Sustainable Development in the South (COMSATS).

Fourth, it is important for OIC countries to strengthen national merit-based science academies – knowledge-based organizations whose members are among a country's most outstanding scientists. One of the major objectives of academies is to provide objective, evidence-based advice to their governments on critical issues related to science-based development – something that governments need now more than ever.

The future economic well-being and prosperity of OIC countries depends, in large measure, on policies and programmes that strengthen scientific capacity and build strong foundations for sustained economic growth. The blueprint for achieving these goals should be comprised of broad-based strategies that provide a realistic plan for adequate funding of research and training, the development of scientific institutions of excellence, sustained efforts to promote public appreciation and understanding of the importance of science, and the opening of effective channels for regional and international scientific cooperation.

There are promising signs that OIC countries now get it when it comes to valuing science as a primary tool for development. Indeed the issue before them is not "it" (that is, science which they acknowledge to be important), but "getting on with it" (that is, putting in place policies that can help increase capacities in science and that, over time, translate into sustainable economic growth). ■

Mohamed H.A. Hassan
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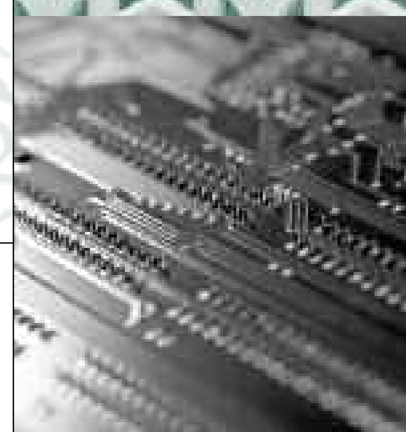

A similar version of this article will be published in the Muslim World Almanac *published by the Research and Documentation Society in Karachi, Pakistan (see* www.muslimworldalmanac.com*).*

BIODIVERSITY FOR LIFE AND LIVING

MORE THAN 150 PEOPLE ATTENDED THE TWAS SESSION, "THE CHALLENGE OF BIODIVERSITY", HELD AT THE 2010 EUROSCIENCE OPEN FORUM (ESOF). THE SESSION TOOK PLACE IN TURIN, ITALY, IN JULY 2010.

The concept of biodiversity remains difficult to grasp. Yet, in its broadest sense, the definition hasn't changed much over the past several decades. As the US Office of Technology Assessment (OTA) described it in the 1980s, biological diversity "is the variety and variability among living organisms and the ecological complexes in which they occur."

To address the challenges posed by biodiversity, the United Nations proclaimed 2010 the International Year of Biodiversity (IYB). With the encouragement of the UN, a broad range of international organizations, government agencies, research centres, universities and citizen groups have been working both together and on their own to raise public and political awareness of the importance of preserving biodiversity for current and future generations.

Surveys and studies suggest that the Earth may be home to 10 million species. Some estimates place the figure as high as 100 million. To date, however, we have succeeded in classifying just two million species.

Yet, as its definition suggests, biodiversity isn't simply a matter of describing, observing and recording the external features, or phenotypes, of species – in short, identifying species. In fact, biodiversity can be defined at many different levels – in terms of genes, species, habitats and ecosystems.

Each level of biodiversity, moreover, is related to the other levels; yet, each is also distinct and complex in its own right. Together, the

TWAS Newsletter, Vol. 22 No. 3, 2010

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varying definitions help us appreciate why biodiversity is one of the keystones of sustainable development.

Biodiversity supplies an endless array of ecosystem services that are essential to human well-being. For this reason, as we compromise biodiversity, we also compromise, in unhealthy ways, the air we breath, the food we eat and the water we drink. Biodiversity is also a primary source of our medicines. It helps moderate our climate. It protects us from natural hazards.

Unfortunately, modern human activities are posing a threat to biodiversity. Experts estimate that species are becoming extinct at a pace that is 100 to 1,000 times faster than in the past. Studies indicate that over the course of the previous century, forest biomes have been converted to other ecosystems – largely monoculture agricultural ecosystems and grazing lands – at an annual rate of 100,000 to 200,00 square kilometres a year.

Alarmed at the prospect of rapid and relentless biodiversity loss, delegates at the World Summit on Sustainable Development (WSSD), held in Johannesburg, South Africa, in 2002, called for "a significant reduction by 2010" in the "current rate of biodiversity loss at the global, regional and national levels, as a contribution to poverty alleviation and to the benefit of all life on Earth".

This goal has not been met. Indeed, by most measures, the rate of biodiversity loss has accelerated over the past decade in the face of rapid global economic growth, increasing levels of pollution, the adverse impacts of climate change, rampant land-use development and poor planning practices. Some experts claim that if present trends continue 10% to 20% of all species on Earth may disappear over the next five decades.

The events and studies set in motion by the International Year of Biodiversity, which will culminate in a high-level meeting of member states at the UN headquarters in New York City in September and a biodiversity summit in Nagoya, Japan, in October, are providing a unique opportunity to focus global attention on the issue of biodiversity and explore the full range of its importance and impact.

SEA AND LAND

How many species are there on Earth seems like a simple question. But the answer has proven

EUROSCIENCE OPEN FORUM

The EuroScience Open Forum (ESOF), a biennial event launched in 2004, has become Europe's pre-eminent meeting for discussions of scientific research and innovation. The first four meetings of ESOF were held in Stockholm, Munich, Barcelona and Turin. The next meeting is scheduled to take place in Dublin, in 2012.

As a general science event designed to engage both the participation of the scientific community and public, ESOF provides broad-ranging discussions on cutting-edge scientific and technological developments and workshops on teacher training, career development and ties between business and science. ESOF organizers also hold a series of public events designed to bridge the gap between science and society and to build support for scientific research.

The meeting in Turin drew more than 4,500 participants from 63 countries, including 900 young scientists. More than 500 journalists were also in attendance.

For additional information, see www.euroscience.org.

extremely difficult to provide. While satellite voyages into our universe have shown that Mars, like Earth, was once a watery planet, we still do not know how many species there are on our own planet, despite the fact that we have been counting species for several centuries.

"I doubt we will ever come up with a precise number," noted Ferdinando Boero, professor of zoology at the University of Salento, Italy, in a presentation at the session on biodiversity organized by TWAS at the Euroscience Open Forum (ESOF) in Turin, Italy, last July.

Boero went on to observe that biodiversity and the ecosystem services it provides are critical for keeping the Earth healthy and vital. Yet the number of species that are known to exist on Earth is in constant flux as scientists identify new species and try to find out whether those species that are endangered have become extinct.

Boero, who is a renowned marine biologist specializing in the study of jellyfish, added that it is misleading "to think of biodiversity solely in terms of terrestrial species". Since humans are land organisms, he observes that we tend to focus on terrestrial organisms. "But, in doing so, we often neglect the enormous variety of species and ecosystems found in marine basins."

In fact, few of the Earth's animal and plant phyla (the broad taxonomic grouping just below the classification that divides organisms into the animal and plant kingdoms) are solely terrestrial species. Yet many phyla found in marine environments are found only there. If we're looking for unique species, then we must set our sites seaward, Boero says.

Many marine organisms, Boero acknowledges, are an important source of nutrition for humans. This is especially true in poor coastal countries where fish have traditionally been a major part of the diet.

Historically, fish harvests were largely in balance with the reproductive rates of fish. In fact, Boero maintains that developed countries have a great deal to learn from developing countries when it comes to devising strategies for the sustainable harvesting of fish species.

However, he notes that today more than 75% of the world's marine fisheries are overfished and that such popular marine species as cod, halibut and haddock have experienced steep declines in population and could face extinction in the decades ahead – or, more likely, become so few in number that commercial fishing becomes unviable.

Such trends could have adverse consequences not only for humans but also for ocean ecosystems. As we "fish out" adult species, Boero explains, we create demographic imbalances within marine ecosystems. In such situations, predators like jellyfish, preying on fewer and fewer larvae and eggs, further reduce the populations.

As a result, Boero notes that the number of jellyfish in ocean waters has been rapidly increasing. He warns that "we could be facing a metamorphosis comparable to what existed in the Precambrian era when jellyfish dominated ocean ecosystems."

BIO TECH

Could biotechnology help meet the challenges posed to biodiversity? Yes, said Decio Ripandelli, head of the biosafety unit at the


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International Centre for Genetic Engineering and Biotechnology (ICGEB), based in Trieste, Italy. Ripandelli also spoke at the biodiversity session organized by TWAS at ESOF.

The notion of putting biotechnology to work to help protect and preserve biodiversity has its critics who view biodiversity primarily as a policy and management problem for which technology may be able to assist on occasion but cannot be relied on to solve the problem on its own.

Biological diversity, the critics note, speaks of untamed places where Nature has its way. In contrast, biotechnology ominously points towards a growing dependence on complex tools that could prove difficult to manage and that could ultimately carry unintended consequences that may prove difficult to control. Critics also contend that whatever benefits biotechnology may have, they will likely come at a cost that many developing countries cannot afford.

Not so, said Ripandelli. Genetically modified organisms (GMOs) keep pests at bay, improve plant resistance to water scarcity and, in general, help sustain yields in the face of changing weather and climate conditions.

In addition, GMOs serve as an ecological alternative to the excessive use of chemical inputs – pesticides and fertilizers – that were an important component of the first "green revolution" but that pose increasing risks to the health of our water and soil.

So what role can biotechnology play with respect to biodiversity?

"Biotechnology," Ripandelli observed, "is a valuable tool for reducing habitat loss and devising strategies for more sustainable land use practices. Since 1996, the amount of agricultural land worldwide in which GM crops are cultivated has grown at more than 10% a year.

In 2005, experts estimated that GM crops were cultivated on more than 90 million hectares of agricultural land and that land in developing countries accounted for nearly 40% of that total. In 2009, the amount of agricultural land cultivated with GM crops had risen to 134 million hectares and the amount of land in developing countries with GM crops had increased to more than half of the world total.

Safety, Ripandelli acknowledged, remains the utmost concern for biotechnology and critics alike. Indeed the future of biotechnology, he said, depends on genetically engineered crops proving to be safe for both people and the environment. And, he added, it's not enough for experts to confirm that biotechnology is safe. It's also important for the pubic to perceive that the technology is safe.

"We know all-too-well the perceived risks that biotechnology poses," he said. "They range from adverse impacts on non-target species and ecosystems, to the unwanted invasion of alien species, to the possibility that a modified gene loses its effectiveness over time.

"Scientists continue to work diligently on all of these fronts. And thus far, the research shows that biotechnology can safely be incorporated into existing agricultural practices", he asserted.

"Broad dissemination of scientific findings, South-South and South-North cooperation and the promotion of innovative research in both developed and developing countries are essential if biotech-

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nology is to play a critical role in improving our lives and our environment. The conservation and sustainable use of biodiversity will be but one of the benefits that can be derived from this potentially transformative technology," Ripandelli told the audience.

PUBLIC UNDERSTANDING

If you ask your neighbours to define biodiversity, most will look dumbfounded. In fact, a recent survey conducted by the European Union (EU) showed that one out of three Europeans had never even heard of the word.

That was the message Marco Cattaneo, science writer and director of *Le Scienze* – the Italian edition of *Scientific American* – conveyed to those attending the ESOF session. Clearly, when it comes to public awareness, those involved in the International Year of Biodiversity have their work cut out for them.

Most EU citizens, Cattaneo pointed out, are concerned about the environment. But when it comes to biodiversity, they perceive the problem as abstract and distant and, at best, a problem that affects others who live far away.

"Just one-third of those surveyed said they would be willing to take personal action to address the challenges posed by biodiversity loss," Cattaneo noted. Moreover, 40% of those surveyed said that economic development was more important than biodiversity. This is the prevailing sentiment on a continent that is one of the world's richest and that has a strong framework for environmental protection which enjoys widespread public support.

That's why both Cattaneo and several members of the audience in the discussion that followed the presentations maintained that biodiversity conservation efforts cannot stand solely on their own and that it is critically important to link such efforts to strategies for sustainable economic growth.

Such initiatives, it was noted, must take place on two fronts. First, biodiversity proponents must illustrate how natural resources are a primary source of economic and social well-being whether the issue is food production, water quality, the spread of disease or the availability of basic materials for infrastructure development.

Second, proponents must advocate the adoption of new global accounting schemes capable of measuring the value of ecosystem services and assessing the adverse impacts that biodiversity loss and damages to ecosystems have on a country's economy.

And that, in the final analysis, may be the most important message that can be conveyed during the International Year of Biodiversity: that biodiversity is not just an issue that absorbs the attention of scientists and intellectuals but, in fact, is a pocketbook issue that affects us all. ■

For more on biodiversity, see 'Diversity Lost and Found' an interview with Julia Marton-Lefèvre, p. 29.

INDIA RISING

BY ALMOST ANY MEASURE, INDIA IS ON A ROLL. SINCE THE GOVERNMENT BEGAN TO LIBERALIZE THE NATION'S ECONOMY IN THE EARLY 1990s, INDIA'S GROSS DOMESTIC PRODUCT (GDP) HAS GROWN AT AN AVERAGE ANNUAL RATE OF 6%. THE PACE HAS ACCELERATED TO 8% AND, AT TIMES, EVEN 9% OVER THE PAST FEW YEARS.

What's true for the economy is also true for science. Government spending on research and development (R&D) has grown by 15% or more each year over the past several years.

> ***... the 21st century will be an Indian century.***
>
> Manmohan Singh
> Prime Minister of India

India has well-established world-class research institutions and dynamic government R&D agencies. It has built and currently operates a significant number of world-class scientific facilities, including a synchrotron radiation facility. It has the world's largest constellation of remote sensing satellites used for Earth observations. It has assembled and operates an impressive array of supercomputers, and it is emerging as a major global player in computer software design. It boasts a prominent pharmaceutical industry noted for the production of generic drugs and low-cost vaccines. It participates in such mega-science projects as the International Rice Genome Project, Large Hadron Collider and ITER.

India's growing capabilities in science and technology, not surprisingly, have attracted the attention of international corporations. Indeed some 700 multinational corporations have established R&D field offices in India. Intel's latest computer chip is being developed at its R&D centre in India. So too is the prototype for General Electric's latest airplane engine.

PEOPLE AND SCIENCE

This impressive list of institutions and projects is just a small sampling of India's scientific and technological prowess. Such prowess would not have been possible without a critical mass of well-educated professionals and a vast pool of scientists and technologists. Recent statistics, in fact, show that India has more than 50 million citizens who hold university diplomas, graduate and post-graduate degrees.

About 25% of India's population is considered middle class. That equals some 300 million people. But it is also true that nearly half of the population remains largely on the periphery of the economy, often relegated to observing the progress from afar. For many of these people, meeting basic social and economic needs remains a constant struggle. Indeed, over 400 million Indians – roughly 40% of the population – live on less than USD2 per day.

Consequently, in this vast country of breath-taking progress and heart-breaking poverty, one of the most critical challenges is this: How can India continue to drive cutting-edge science and technology forward


Jayanth Chennamangalam


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while simultaneously addressing the pressing social and economic needs of the vast majority of its people?

SCIENCE IN PERSPECTIVE

The quest for knowledge is deeply rooted in India's identity as a nation. In fact, the country began to build a strong foundation in modern science during the first days of its independence.

In the 1950s, Jawaharlal Nehru, India's first prime minister, substantially expanded support for the nation's institutes of science and technology, which are the glittering jewels of the country's scientific enterprise. During the next decade, India led the "green revolution," which served as the basis of its historic efforts to feed its citizens and which set the stage for the economic growth that was to follow.

The quest for knowledge is deeply rooted in India's identity as a nation.

In the 1970s and 1980s, the Indian government began to loosen restrictions on the economy and promote greater competition. These measures, however, commonly proved to be modest and halting, and were often given secondary consideration to the larger goal of protecting the country's domestic enterprises.

The government-directed economy of the first four decades of India's independence provided modest growth (3% to 5% a year) but failed to unleash the entrepreneurial spirit of its people. The tariff walls that were built, while designed to nurture economic security and growth, shielded India's economy from international competition and often limited the country's access to the latest and best technologies.

At the same time, the rules and regulations that were put in place – and rigorously enforced – gave government a front-and-centre role in the economy. Indeed the intricate bureaucratic framework upon which the economy operated often slowed economic growth and stymied innovation. Neither the scientific community nor the hundreds of millions of impoverished citizens were consistently well-served by these policies.

LIBERATING SCIENCE

The liberalization of the economy, begun in 1991, placed India on a fast track for economic growth. It also unleashed the scientific capabilities found in India's institutes of science and technology and, to a lesser extent, in its universities. Most importantly, it set India on a path to becoming an enterprising, innovative country – a process that is still unfolding nearly 20 years later.

What has followed over the past two decades has been truly astounding. In the 1990s, the country's scientific enterprise was largely restricted to a few areas of strength related to what the government perceived as the country's most compelling and immediate needs.

There were large investments in national defence designed to build modern weapons systems to help defend the nation. There were large investments in a


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BARC

national space programme intended to help India develop state-of-the-art capabilities in both satellite communications and the monitoring of natural resources. And there were large investments in nuclear R&D as an expression of national purpose and pride, and as a response to the nation's inability to obtain nuclear technology from other countries because of its unwillingness to sign the Nuclear Non-Proliferation Treaty. India felt the treaty favoured the existing nuclear powers and was discriminatory against countries that did not have nuclear technology.

Over the past 60 years, defence, space and nuclear R&D have accounted for about three-quarters of the government's total investment in R&D, which itself has been responsible for more than 70% of India's overall R&D expenditures. That has left limited funding for everything else, including agricultural research, biotechnology, energy and the environment.

Conducting clinical trials in India costs one-half of what it costs in the United States.

The critical difference over the past several years is that dramatic increases in government spending for R&D have allowed sufficient sums of money to be devoted to other areas as well. In addition, growing investments in the private sector have expanded the reach of India's R&D activities. Indeed, as both financial resources and national confidence have increased, there is a growing sense among India's policy and scientific communities, as well as business leaders and entrepreneurs, that the country "is too big to absent itself from any field of science and technology," as expressed in the *Report of the Steering Committee for the 11th Five-Year Plan (2007-2012)*.


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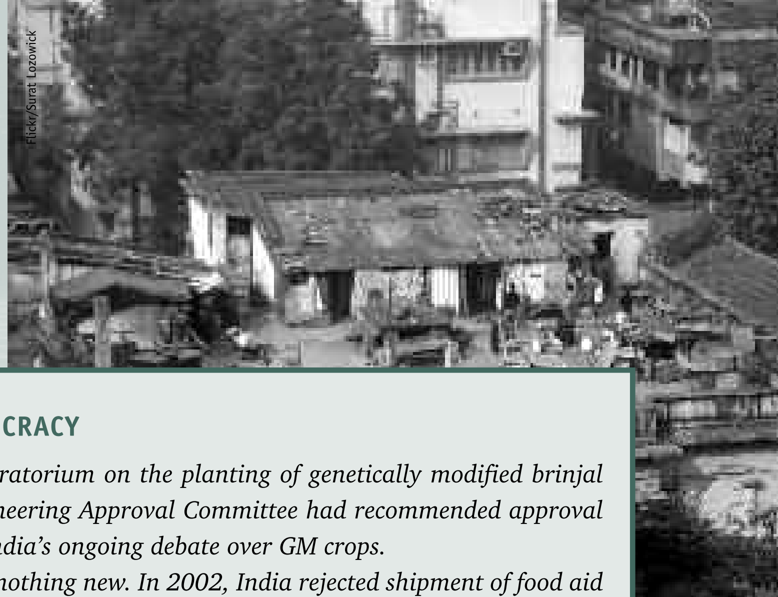
BUILDING ON STRENGTHS

So where do India's strengths in science and technology lie?

- India has world-renowned IT companies. Such companies first emerged at the low-end of the value chain during the 1990s, with the development, for example, of telephone call centres and help-line services. Today, however, ITs in India are increasingly involved in higher-end endeavours – for example, software design and e-health delivery services. Some

Only 60% of India's municipal waste is collected. An estimated 80% of India's cities have one or more air pollutant that exceeds national standards.



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BIOTECHNOLOGY IN INDIA: SCIENCE AND DEMOCRACY

In March 2010, the Indian government imposed a moratorium on the planting of genetically modified brinjal (eggplant) even though the government's Genetic Engineering Approval Committee had recommended approval of the variety. This marked another dramatic turn in India's ongoing debate over GM crops.

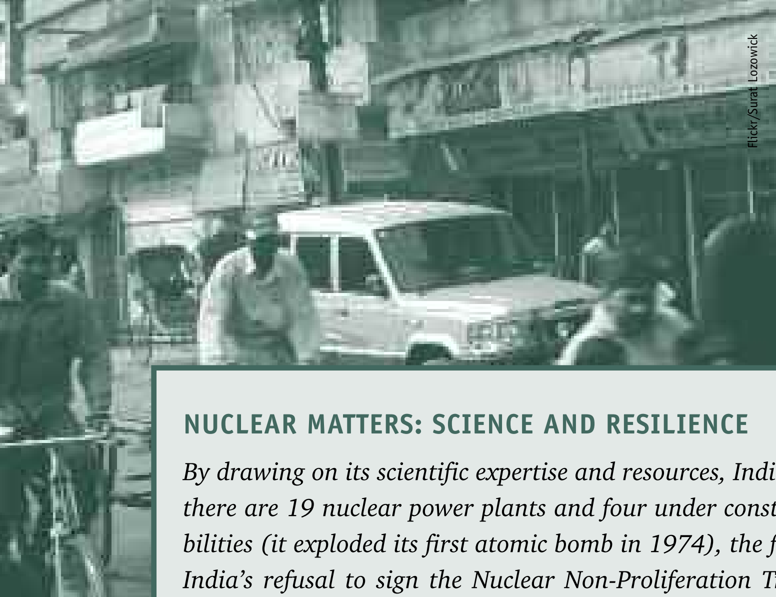
When it comes to GM crops, mixed signals in India are nothing new. In 2002, India rejected shipment of food aid from the US because of fears that the shipment may have contained GM commodities. The same year, India's government approved the cultivation of GM cotton. India is currently testing 56 GM crops, including 41 food crops (for example, mustard, rice and tomatoes as well as eggplant). But only non-food crops have so far been cultivated for market.

Advocates of GM crops contend that they could help India address its food challenges in the years ahead by serving as a key component of the country's efforts to launch a "second green revolution" to increase harvests without increasing water and chemical inputs. Critics contend that GM crops have been largely promoted by such large international corporations as Monsanto, and that these companies have focused on cash crops that are prominent in the developed world – crops that do not meet the needs of India and other developing countries. Even more importantly, critics argue that insufficient testing has taken place to determine whether GM seeds pose a threat to the irreplaceable genetic pool found in wild seeds and whether pests will ultimately be able to become resistant to the genetic modifications. In any case, farmers' organizations were largely reluctant to adopt GM food crops, which the Indian government took into consideration when it announced the moratorium on GM brinjal.

The debate over biotechnology, which will likely continue in the years ahead, reflects the lively democratic environment in which discussions over science and development take place in India.

of the world's foremost IT firms – including, Infosys, Tata Consultancy Services and Wipro – are located in India and owned by Indians. Overall, IT revenues have grown from just over USD10 billion in 2001-02 to more than USD46 billion in 2008-09, representing an annual increase of more than 25%.

- India also has a world-class pharmaceutical industry. It is the fourth largest producer of pharmaceuticals, accounting for 5% of the world's exports in this sector of the global economy. That is a higher percentage than Canada and Japan. Two-thirds of India's exports go to developing countries. It is for this reason, India has been dubbed "the pharmacy of the developing world". In the late 1990s, Shantha Biotechnics helped revolutionize the world of vaccines by introducing an r-DNA vaccine to combat Hepatitis-B. Shantha's efforts cut the per dose cost of the vaccine from USD15 to USD1 (today the vaccine can be administered for USD0.30). The Serum Institute of India currently supplies a majority of the vaccines that international organizations such as UNICEF distribute to combat measles and DTP (diphtheria, tetanus and pertussis). India, in fact, boasts a growing number of research institutions and pharmaceutical companies that are seeking to develop vaccines to immunize people against a wide range of infectious diseases.
- India has global strengths in the manufacture of automobile components. In fact, until recently, it was one of the few areas in manufacturing where the nation had reached international status. Half of the automobile components manufactured in India are exported to Europe and the United States. India, moreover, recently took another step forward with the creation



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In 1991, the number of telephone subscribers in India was 5 million. In 2009, the number stood at 562 million.

NUCLEAR MATTERS: SCIENCE AND RESILIENCE

By drawing on its scientific expertise and resources, India has developed into a prominent nuclear nation. Today, there are 19 nuclear power plants and four under construction. India also has extensive nuclear weapons capabilities (it exploded its first atomic bomb in 1974), the full dimensions of which have been kept secret because of India's refusal to sign the Nuclear Non-Proliferation Treaty, contending that the treaty discriminated against non-nuclear countries. A deal recently signed with the United States, which would allow India to receive civilian nuclear technology from the United States and other nuclear countries, could help to dramatically accelerate the construction of nuclear power plants in India and thus help address potential energy shortfalls. It also reflects the shift in international perceptions of India in light of its recent economic growth. Once a nuclear pariah, India is now a potential customer and research partner.

of the Nano, an automobile manufactured by Tata Motors that is priced at USD2,500. It also has a long-standing global presence in the production of textiles and silks. India is unique among rapidly growing developing countries in that its initial centres of growth resided in services, not manufacturing. However, the manufacturing sector has recently displayed increasing strength as evidenced by a 15% growth rate in the past year. Policy makers and business leaders are now exploring ways to improve the efficiency of manufacturing through applications of science and technology. In the years ahead, manufacturing could become another key area of economic growth within the country.

- On the basic science side, India has had traditional strengths in mathematics and physics, and it has conducted world-class research in chemistry and material science. It also has a well-deserved reputation for excellence in the biological sciences and pursues internationally recognized research in oceanography, seismology and space science. India is forging stronger links between science and development and taking significant steps to promote technology transfer by building sturdy legal and regulatory frameworks to protect, for example, intellectual property rights and forge closer ties between government-sponsored research centres and the private sector.

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In sum, India has one of the most extensive and complex S&T enterprises in the developing world – one that enjoys world-class status in a growing array of fields.

NURTURING HUMAN RESOURCES

India is hoping that it will be able to strengthen its S&T capabilities at even a faster pace in the years ahead.

In 2007, for example, it launched the Innovation in Science Pursuit for Inspired Research (INSPIRE) programme to encourage students to enrol in science courses and pursue careers in science. The key elements

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of INSPIRE include awards of 5,000 rupees (USD110) to 1 million students between the ages of 10 and 15 as an enticement to study science; 10,000 scholarships worth 100,000 rupees (USD2,100) a year, also over a five-year period, to both university undergraduate and masters' degree students, who major in science; and 1,000 full fellowships for PhD and postdoctoral students, ages 22 to 27, in science, engineering and medicine. Upon successful completion of the fellowships, recipients are also guaranteed five years of employment in their field of study.

In addition, in 2008, the government announced plans to build 30 new central universities, eight new institutes of technology, five new institutes of science education and research, 20 new institutes of information and communication technologies, 1,600 polytechnic and vocational schools and 50,000 skills development centres.

India's success in S&T capacity building has been widely recognized across the globe.

Fulfilling these promises represents a daunting financial and administrative challenge, especially in light of a potential shortage of qualified faculty. Nevertheless it is also a reflection of India's grand ambitions in science and technology.

India has also recently announced the creation of a National Science and Engineering Research Board, modelled after the National Science Foundation in the United States. Former TWAS president C.N.R. Rao, who now serves as chairperson of the Prime Minister's Science Advisory Council, spearheaded the drive to create the board, which will provide competitive grants to Indian scientists and engineers. The board was officially launched in March 2010 with an initial annual budget of more than 10 billion rupees (USD210 million).

India's success in scientific and technological capacity building – and future plans to build upon this success – have been widely recognized and hailed across the globe, particularly in developing countries. Indeed some developing countries are now looking to India as a possible model to follow.

PROBLEMS PERSIST...

India's public officials and scientists would be the first to admit that, despite the progress that has been made, daunting problems persist.

Disappointing numbers. While India has recently approached the 1% threshold of expenditures in R&D as proportion of GDP, it still lags far behind other countries. China, for example, now spends 1.5% of its GDP on R&D (its GDP, moreover, is more than four times that of India), South Korea spends 3.5% and Taiwan 2.6%.

The trends are similar when it comes to publications and patents.

In China, for example, scientists increased their share of publications in internationally peer-reviewed


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journals from 1.5% to 6.2% between 1999-2008. In contrast, in India the percentage inched forward from 2.5% to 2.6%. Today, India ranks 10th in the world in internationally peer-reviewed scientific publications. That's up from 12th in 2003. While India's publication output has accelerated over the past several years, it still falls short of its ranking in the 1970s, when it was eighth. Equally worrisome from India's point of view is that scientists in just 40 Indian institutions account for half of the peer reviewed publications.

The disparity in patents between China and India is even more glaring. In 2006, China received 2,452 patents while India received just 648. The good news is that the number of patents has increased with the rise of high-technology companies focusing on R&D, including Tata Consultancy Services and Vaman Technology.

Wither universities? The nation's university system, comprised of 200 universities and 1,200 colleges, has seemingly grown weaker as the nation's scientific capacity has grown stronger.

It's not entirely clear why this is so. Nevertheless it is true that as India has sought to build a strong foundation for science-based development, its universities have lost some of their lustre and prestige. Part of the problem lies in the heavy investments that have been made in India's central universities and institutes of science and technology, which have received funding far exceeding the funding levels of the less prestigious institutions of higher education.

Another part of the problem is a consequence of a large number of Indian students pursuing their education in universities in the United States and Europe. This provides educational options for students who come from financially well-off families, and thus eases the pressure on India's universities to provide high-quality education.

Improved living standards are placing additional pressures on India's resources.

And part of the problem is a reflection of India's universities' disconnect with the larger society. The universities' "ivory tower" mentality, reinforced by an aging faculty, has allowed the nation's institutions of higher education to become more like observers than participants in the country's recent reforms to promote science-based development.

Similarly, India's growing emphasis on turning scientific knowledge into products and services that enhance the economy has potentially minimized the importance of the basic sciences, which is where the universities' greatest strength as research institutions reside.

Moreover, more promising career opportunities in other fields – for example, business and finance – have led to an internal brain drain, raising fears that the nation's most scintillating students are not pursuing careers in science. As Prime Minister Manmohan Singh

India, which has some 18% of the world's population, produces just 4.5% of the world's greenhouse gases. Approximately, 6% of India's energy is produced by renewables, largely traditional biomass.

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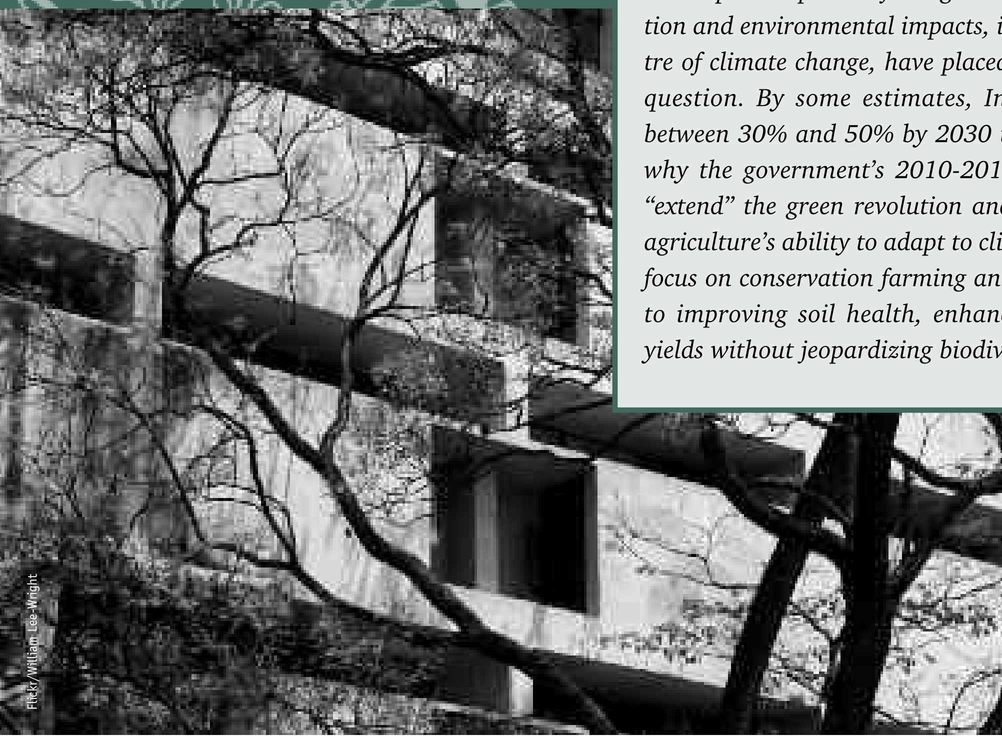
INDIA AND AGRICULTURE

The first green revolution, which took place in the 1960s, enabled India to escape the spectre of hunger and malnutrition. Yet, growing population and environmental impacts, including water shortage and the spectre of climate change, have placed India's future ability to feed itself in question. By some estimates, India will have to increase its yields between 30% and 50% by 2030 to meet the needs of its people. That's why the government's 2010-2011 budget includes USD86 million to "extend" the green revolution and another USD43 million to enhance agriculture's ability to adapt to climate change. The overall strategy will focus on conservation farming and calls for special attention to be paid to improving soil health, enhancing water conservation and raising yields without jeopardizing biodiversity.



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has noted: "I am concerned that our best minds are not turning to science, and that those who do, do not remain in science."

From Imitation to Innovation. India's enormous success in advancing its scientific and technological capabilities has largely focused on initiatives that draw on existing knowledge to re-engineer products and services that were first developed elsewhere.

This aspect of India's success should not be surprising. Think of it as a form of leap-frogging that begins with small, steady steps that conform to the nascent capabilities of a developing country's scientific and technological expertise. The strides then become bigger and more robust as the nation gains strength in science and technology.

Turning to the science and technology developed by others, in fact, is a tried and true practice tested by the annals of history. It's something that the United States did in the 18th and 19th centuries when it "borrowed" European technology. Nevertheless, as India's capabilities have grown, so too have calls for India to become more innovative and to pursue cutting-edge technologies that carry greater value and wealth. Critics, in short, contend that India should focus increasingly on strategies designed to "convert knowledge into commerce."

Such calls for reform are based, in part, on the principle that India's scientific pursuits should not be confined

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India has some 5 million people working in S&T. Yet, its ratio of S&T workers to the overall workforce is about 120 per one million workers. In China, it's 715. In South Korea, 3,700. In the US, 4,600.

to the classroom and laboratory, but should instead be fully integrated into national efforts to grow the economy and combat poverty. The CSIR's Millennium Indian Technology Leadership Initiative, for example, has sought to forge a closer relationship between India's research community and private sector. To date, the initiative has sponsored projects that have engaged more than 200 research groups and 65 industrial partners.

Resource constraints. India's unprecedented "growth burst" is taking place at a time when the world is facing the prospects of natural resource constraints.

Rising demands for water, food and energy, propelled by continual population growth (by 2050 India will have a population of 1.6 billion people) and improved living standards, are placing additional pressures on India's resources. Some experts, for example, contend that domestic agricultural production in India will need to increase an additional 2% a year over the next decade to feed the nation's growing population. That is more than four times the current growth rate in agricultural output. India, it should be noted, covers just 2% of the Earth's landmass and possesses just 4% of the world's water resources. But it must meet the needs of 17% of the world's population.

Meanwhile, energy demand is expected to double by 2030, reaching an equivalent of more than 1,500 tonnes of oil. Today, India imports more than 60% of its oil, a figure that will undoubtedly rise. Almost 75% of all rural residents use wood for cooking and another 10% use dung cakes. But that figure is expected to decline dramatically in the years ahead as Indians adopt more modern sources of energy. Economists estimate that India's installed electric power generation would have to increase to between 650,000 and 950,000 megawatts (MW) by 2030 to sustain an economic growth of between 8% and 9%. This is 5 to 7 times the present generation capacity of 140,000 MW. Will the nation's additional energy supplies be sufficient to meet the nation's rising demand for energy? Will India's potential for economic growth be stymied by energy shortfalls, particularly shortfalls in the availability of electric power?

All of this means that India and other countries with rapidly emerging economies will have to address

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the issue of growth within the context of ever-increasing national and global resource constraints.

This presents opportunities as well as challenges. As former CSIR director general R.A. Mashelkar (TWAS Fellow 1993) contends, unlike rich countries in the North, countries like India are well-positioned to develop a sustained policy for science-based development based on the principle "more for less for more."

Because of its history of impoverishment and its past reliance on local innovation, India may be able to develop policies based on the innovative production of low-cost goods and services that can attract customers of limited means across the globe. That strategy, in fact, has propelled the success of India's efforts in ITs, pharmaceuticals and space technology.

Yet the challenge of growing resource scarcity is likely to remain stubbornly in place. The fact is that the rapid pace of economic growth experienced by Europe and the United States in the 19th and 20th centuries occurred at a time when abundant resources were the rule. In contrast, countries such as India, China and Brazil are experiencing their unprecedented eras of growth at a time when resources are increasingly limited and expensive.

India reflects the new world of science rapidly rising across the globe.

And those left behind. While India's increasing high-tech capabilities, especially in information and communications, have captured the world's attention, it is important to remember that the majority of the population have yet to gain full access to the economic bounty that the nation's growing S&T capabilities have created. As stated earlier, more than 40% of India's population – some 400 million people – continue to earn less than USD1.25 a day, and about one-third of the population is illiterate. More than half of the population are farmers and, despite the rapid growth of cities, some 60% of all Indians continue to live in rural areas, where economic growth has failed to keep pace with urban areas.

The Indian government recognizes the challenges posed by the imbalances in economic growth that seem to have widened over the past two decades by embracing a policy of "inclusive growth". This policy calls for taking steps to ensure that the quality of life improves for all Indians and, most notably, for those living in the remote rural areas and the urban slums that have been largely left behind in the country's ongoing efforts to create wealth and boost the economy.

To address the needs of these citizens, India has developed a wide range of initiatives, including:

- The Mahatma Gandhi National Rural Employment Guarantee Act (NREGA) that guarantees up to 100 days of paid work at 100 rupees (USD2) a day for people living in rural areas to improve village infrastructure. In 2009, some 50 million households participated in the programme.

India has some 11 million students currently pursuing degrees in higher education. Experts estimate they will need some 80 million students by mid century to meet the growing demand for education workers.

DUAL DISEASE BURDEN

When it comes to public health, India, like many developing countries, increasingly faces a "dual disease burden." That is, it must continue to address the challenges posed by infectious diseases, mostly associated with poor people and largely neglected in international research (at least until recently), while recognizing that the challenges posed by 'lifestyle' diseases historically associated with people in rich countries are on the rise.

For example, India has the highest incidence of tuberculosis in the world, accounting for one-third of the total global burden for this disease. It carries half of the global disease burden for leishmaniasis (a parasitic disease that affects some 12 million people worldwide) and has an estimated 2.3 million cases of HIV/AIDS. While some 75% of Indians have access to safe drinking water, such water-borne diseases as hepatitis, cholera, jaundice and typhoid affect nearly 40 million Indians.

At the same time, one million Indians die each year of smoking-related diseases. Meanwhile, the incidence of heart disease, cancer, diabetes and mental illness are all rising sharply. Public health experts estimate that one-half of all deaths in India are now due to such life-style ailments as heart disease and hypertension.

India has dramatically improved its public health system over the past decade. It has a pool of well-trained doctors capable of treating a large number of patients and with broad knowledge of a wide range of ailments. However, there are just 645,000 doctors in India or 0.6 per 1,000 people. By some estimates, India has a shortage of 600,00 doctors and one million nurses. It thus faces enormous public health challenges not just in upgrading its medical research capabilities but also in the training of the next generation of doctors, nurses and other health practitioners to meet the health needs of its population.

- Broad-based infrastructure development for water access and improved sanitation.
- Rapid extension of IT facilities in poor villages and communities.
- Rising investments in primary and secondary education.
- And tapping the country's vibrant democracy to give poor people a strong voice in shaping India's efforts to harness science and technology for equitable economic growth.

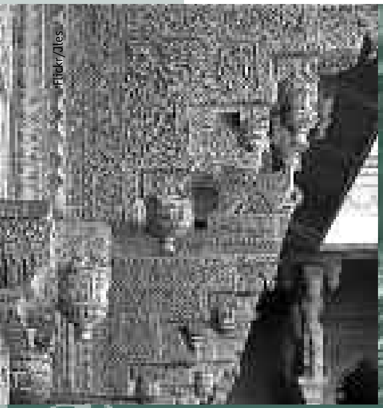
As India's Department of Science and Technology noted a quarter century ago in its 1983 policy statement, the goal of India's science and technology policy should seek to "uplift the Indian people and indeed all of humanity" as a key element to advance the lofty goal of building "the India of our dreams."

That dream has become a reality for an increasing number of Indians. Yet a great deal of work still needs to be done if it is to be shared by all of the nation's citizens.

SCIENCE FOR WHOM?

As a rising global economic power and an emerging international hub of scientific excellence, it is difficult to describe the full range of scientific activities taking place in India today. In many ways, India reflects the new world of science that is rapidly rising across the globe – a world in which the once sharp lines of demarcation between the developed and developing countries are blurring.

When observers look at where India has been and where it is heading, they see a rapidly emerging economic and scientific powerhouse that is successfully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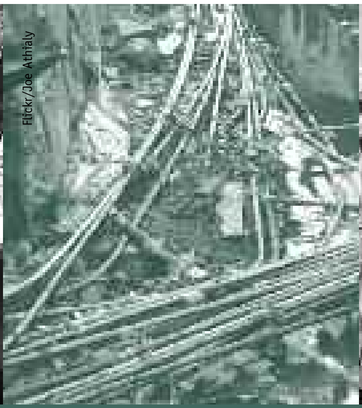
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drawing on its expanding capabilities to build a vibrant society characterized by prosperity and confidence.

Over the past 60 years, India has indeed experienced slow but steady progress – and has done so at an ever-faster pace. It achieved self-sufficiency in food production and has enacted policies and programmes that largely meet the basic needs of its citizens for safe drinking water and sanitation, healthcare and housing, even if the implementation of these programmes has often been patchy and uneven. Building on this success, it subsequently developed high-level capabilities in information technology, software development, pharmaceuticals and a growing number of manufacturing sectors.

But enormous challenges remain if India is to become a full-fledged leader in international science and in the global market place. It must significantly enlarge its pool of scientific and technological personnel. It must strengthen its scientific infrastructure. It must develop more effective strategies for converting its scientific expertise into goods and services that boost the economy. It must revitalize university research. And it must seize the opportunity afforded by a world of limited resources to take advantage of its proven ability to make more for less, turning its liabilities into assets.

India's scientific capacity, in fact, is increasingly being developed in a multilayered fashion. Capacity is growing most notably in federal government agencies and large multinational corporations. Yet it is also emerging at a subnational level in the country's states and regions. And it is being propelled, in part, by an increasing number of non-profit organizations with growing knowledge of science, technology and development, including the Swaminathan Research Foundation and the Centre for Science and the Environment (CSE). A system that is this diverse and that is expanding on so many fronts is likely to be sustainable and resilient. Progress may not be linear but it will certainly continue to take place.

India has a complex web of S&T organizations that are moving ahead at a breakneck speed.

SCIENCE FOR ALL?

The long-standing question of whether India will ever emerge on the world stage standing front and centre as a powerful nation has largely been answered. In that sense, India is indeed on a roll.

But whether that future will be inclusive of all its citizens remains an open question. In fact, the nation's "internal divide" will likely be one of the most critical challenges facing India in the years ahead.

Will India rise as one nation or two? Will the enormous wealth, created in large measure by its scientific and technological prowess, generate wealth for all of its citizens or just for some? Will science and technology be used not just to create a global powerhouse but a nation of comfort and security for all?

If India is able to respond successfully to all of these challenges, it will not only have created a just and prosperous society but also a new paradigm for growth. ■

S&T IN INDIA: INSTITUTIONAL PROFILES

India has one of the world's most extensive and complex national systems for science and technology. While the government plays a central role in the health and vitality of the system, long traditions of scientific autonomy, openness and international exchange, combined with recent investments in the nation's scientific enterprise, have created an endless mosaic of highly productive and highly visible scientific institutions. What follows is a sampling of these institutions that is designed to give readers a sense of the world-class science taking place in India today.

DEPARTMENT OF SCIENCE & TECHNOLOGY

The Department of Science & Technology (DST), which was established in May 1971, is responsible for the coordination and promotion of science and technology in India. DST seeks to build scientific and technological capacity by providing grants to individual scientists and supporting research institutions and laboratories. DST plays a central role in nationwide discussions taking place at the crossroads of science and society, most notably through its science communications initiatives. It is a lead agency for India's information and communication efforts; conducts extensive surveys examining the state of science and technology in India; is one of the foremost organizations in fostering international activities and exchanges in science and technology; and focuses special attention on scientific issues related to innovation and gender and regional equity. DST is the major source of funding for TWAS's 21st General Meeting in Hyderabad. For additional information, see *www.dst.gov*.

INDIAN NATIONAL SCIENCE ACADEMY

The Indian National Science Academy (INSA), which was established in 1935, has a current membership of 790 fellows and 95 foreign fellows. INSA has collaboration and exchange programmes with 46 academies around the world. Its principal objectives are to promote scientific knowledge and public awareness of science in India; enhance and safeguard the interests of India's scientists and present their work to the nation and international scientific community; strengthen ties between INSA and other learned societies and, more generally, science and the humanities; and publish proceedings, journals and other scientific material. INSA has focused special attention on the needs of young scientists. It is a member of the IAP, the global network of science academies, and the International Council for Science (ICSU). It also works closely with the InterAcademy Council. INSA is serving as the main host for TWAS's 21st General Meeting in Hyderabad. For additional information about INSA, see *www.insa.nic.ac*.

HYDERABAD EYE RESEARCH FOUNDATION

The Hyderabad Eye Research Foundation (HERF) serves as the research arm of the LV Prasad Eye Institute (LVPEI). HERF's research focuses on the role that molecular genetics plays in inherited eye diseases. Staff scientists have devised molecular diagnostic tools for the early detection of eye infections, deciphered the biochemical drivers of cataracts, and explored how stem cells might help in the reconstruction of damaged ocular surfaces. These initiatives have been supported by the Department of Biotechnology, Department of Science and Technology, Council of Scientific and Industrial Research, and the Indian Council of Medical Research (ICMR) in India, and the National Institute of Health's Eye

Institute in the United States. HERF has also partnered with the University of Hyderabad, Birla Institute of Technology and Science in India, and the University of New South Wales in Australia to allow research scholars from LVPEI to earn PhDs. HERF is serving as the local host for TWAS's 21st General Meeting. For additional information, see *www.lvpei.org*.

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

The Council of Scientific and Industrial Research (CSIR), which was created in 1942, is dedicated to strengthening India's extensive network of industrial research and development (R&D) laboratories for the purposes of advancing sustainable and inclusive growth. The laboratories, which total nearly 40 in number, are located throughout the country. They are engaged in R&D activities in a broad number of fields, ranging from aerospace to health-care to sustainable energy to advanced structural design to ceramics and leather production. With a workforce of more than 17,000 people, CSIR is one of India's leading institutions for innovation and its researchers are among India's leaders in securing international patents. It is particularly interested in linking research to the marketplace and helping to create broad skill sets and a strong infrastructure in science and technology for the purposes of facilitating innovation. CSIR also offers grants and fellowships and recognizes young researchers through its coveted Shanti Swarup Bhatnager prize in the basic and applied sciences. For additional information, see *www.csir.res.in*.

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INDIAN COUNCIL OF MEDICAL RESEARCH

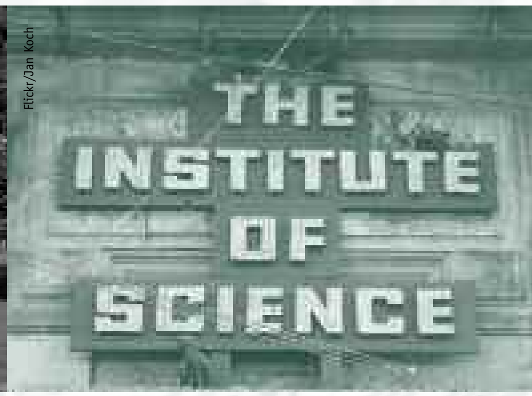
The Indian Council of Medical Research (ICMR), whose roots lie in the creation of the Indian Research Fund Association in the early 20th century, helps to coordinate and advance medical research and practice in India. Its broad portfolio of issues parallels the nation's most significant health challenges and health-care priorities. ICRM's efforts range from examinations of communicable and non-communicable diseases to mental, maternal and child well-being to improving environmental and occupational health to the gathering of critical health statistics. The council's ultimate goal is to reduce India's disease burden and promote national health and well-being. The council supports 29 medical research institutes, centres and units across the country that pursue broad-ranging research on such critical issues as nutrition, reproductive health and oncology, and on such diseases as tuberculosis, leprosy, malaria and HIV/AIDS. ICMR also promotes capacity building in the medical sciences through grants to individual, universities and research centres. For additional information, see *www.icmr.nic.in*.

INDIAN AGRICULTURAL RESEARCH INSTITUTE

Launched in 1905 at Pusa, Bihar, in northeast India and relocated to Delhi in 1936, the Indian Agricultural Research Institute (IARI) is the nation's premier centre for agricultural research, education, training and field demonstrations. IARI played a key role in India's "green revolution" in the 1960s, which led to the development of high-yielding varieties of rice, wheat and other food commodities. It is currently conducting world-class research on plant genetic resources and examining system-wide approaches to farm management to promote sustainable agriculture. The goal is to harness science, traditional knowledge and management for ensuring bountiful harvests without placing undue stress on the environment. More than 700 students, seeking doctorate and masters' degrees, attend the institute. For additional information, see *www.iari.res.in*.

BHABHA ATOMIC RESEARCH CENTRE

The Bhabha Atomic Research Centre (BARC) is the nation's pre-eminent centre for advanced research and development in nuclear science and engineering. Research at BARC spans a broad spectrum of fields, ranging from nuclear reactor design and installation to fuel fabrication and the chemical processing of depleted fuel. BARC also conducts research on the development of radioisotope application techniques in medicine, agriculture and manufacturing. Spectroscopy, solid-state physics, chemical and life sciences, reactor engineering and instrumentation, and radiation safety rank among its major fields of study. The centre bears the name of Homi J. Bhabha, the famed Indian nuclear physicist who guided India's nuclear research and development programme from its inception in the mid 1940s until his death in 1966. For additional information, see *www.barc.ernet.in*.



Flickr/Jan Koch

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

With campuses in Mumbai, Pune, Bangalore and soon Hyderabad, and additional research facilities throughout India, the Tata Institute of Fundamental Research (TIFR) is a world-renowned institute operating under the umbrella of the Department of Atomic Energy. It conducts basic research in physics, chemistry, biology, mathematics and computer science, and directs masters and doctorate programmes in the same fields. TIFR houses a linear particle accelerator for the study of heavy ion atomic interactions, and has a nuclear magnetic resonance facility for the study of complex molecules. Field stations include the world's largest meterwave radio telescope at a facility north of Pune, as well as a cylindrical radio telescope and a high-energy cosmic ray laboratory in Tamil Nadu. It operates high-energy cosmic ray and gamma ray laboratories in Madhya Pradesh and a national balloon facility in Hyderabad considered among the best in the world. Like Bhabha Atomic Research Centre, TIFR was founded by Homi J. Bhabha. For additional information, see *www.tifr.res.in*.

INDIAN INSTITUTE OF SCIENCE IN BANGALORE

Inspired by Jamsetji Nusserwanji Tata, founder of the Tata Group, and established in 1909, the Indian Institute of Science (IISc) in Bangalore is India's oldest and most prestigious centre for research and postgraduate study in science and engineering. Its first Indian director was Nobel laureate C.V. Raman. Today, IISc has some 50 departments. Its 400-member faculty provides instruction and guidance to

2,000 students, chosen on a highly competitive basis. About 200 doctorate and masters' degrees are awarded each year in a broad range of fields related to the biological, chemical, mathematical and physical sciences, and electrical and mechanical engineering. IISc is home to the JRD Tata Memorial Library, one of India's leading science and technical libraries, and hosts a supercomputer facility. The institute actively promotes collaborations with the private sector. For additional information, see *www.iisc.ernet.in*.

JAWAHARLAL NEHRU CENTRE FOR ADVANCED SCIENTIFIC RESEARCH

The Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) is a multidisciplinary research institute devoted to world-class research and training in science and engineering. Established in 1989 by the Department of Science and Technology, the centre's research covers a broad range of fields. The institution is divided into seven units: chemistry and physics of materials, engineering mechanics, evolutionary biology, molecular biology and genetics, theoretical sciences, educational technology and geodynamics. JNCAR also has two off-campus units at the Indian Institute of Science in Bangalore focusing on chemical biology and condensed matter theory. The centre's 40-member faculty provides instruction to 150 students seeking masters and doctorate degrees. CNR Rao, TWAS's immediate past president, is JNCAR's founding chair. For additional information, see *www.jncasr.ac.in*.

MS SWAMINATHAN RESEARCH FOUNDATION

The MS Swaminathan Research Foundation (MSRF), which was established in 1988, is one of India's most renowned non-profit research centres dedicated to utilizing science and appropriate technology for sustainable development. MSRF focuses on such broad social issues as poverty, gender inequality, empowerment and resource management. Major research areas include coastal systems, biodiversity, biotechnology, ecotechnology and food security. Specific issues shaping its research and development agenda include agrodiversity, medicinal plants and fisheries. The foundation also devotes a great deal of attention to education and public communication and has gained international attention for its creation of village resource centres. MSRF's headquarters is in Chennai but it also has regional centres in Tamil Nadu, Pondicherry, Kerala and Orissa. TWAS Founding Member, MS Swaminathan, for whom the foundation is named, serves as the chairman of the board of trustees. For further information, see *www.mssrf.org*.

GENERAL ELECTRIC JOHN F. WELCH TECHNOLOGY CENTRE

The John F. Welch Technology Centre, established in 2000, is a multidisciplinary research and development centre with state-of-the-art laboratories focusing on such fields as mechanical and chemical engineering, ceramics and metallurgy, polymer science and process modelling. The centre, which employs 4,000 researchers and engineers, is GE's largest integrated multi-disciplinary research and development centre outside the United States. GE researchers in India, who work closely with their counterparts in the United States, China and Germany, have contributed to the design of the world's most efficient gas turbine and the development of a smart axle counter system for the Indian railway's signalling system. To date, the centre has filed more than 185 patents. For additional information, see *www.ge.com/in/company/jfwtc*.

RANBAXY LABORATORIES

With sales of USD1.5 billion, Ranbaxy Laboratories Ltd, which was incorporated in 1961, is India's largest pharmaceutical company. It produces a wide range of affordable generic medicines for customers in more than 125 countries. Employing 1,200 scientists (and 13,000 employees in all), Ranbaxy views its R&D capabilities as key components of its business strategy. It is concerned with developing novel drug delivery systems (through, for example, innovations in inhalation and gels) and, increasingly, on new drug discovery research (focusing on therapies for infectious, metabolic, inflammatory and oncologic diseases). It has begun phase-III clinical trials for a new anti-malaria drug and is profiling inhibitors for type-2 diabetes. Ranbaxy has forged partnerships with India's leading academic institutions and, in 2008, entered into an alliance with Daiichi Sankyo Company Ltd, in Japan, placing the joint venture 20th in size among international pharmaceutical firms. For additional information, see *www.ranbaxy.com*.

DR REDDY'S LABORATORIES

Dr. Reddy Laboratories, established in 1984, currently sells pharmaceuticals in more than 60 countries, concentrating on markets in the United States, Europe and Russia. Its core businesses focus on global generics, pharmaceutical services and active ingredients and proprietary products. It pursues R&D for drug discovery in such areas as metabolic disorders, cancer, cardiovascular diseases, infections and inflammatory disorders. The company, which employs more than 10,000 people, has eight US Food and Drug-inspected plants – six in India, one in Mexico and one in the UK – that produce active pharmaceutical ingredients, and seven FDA-inspected certified plants – five in India and two in the UK – that manufacture patient-ready medications. It also has three technology development centres – two in India and one in the UK. The company also supports an in-house research foundation and an institute for life sciences. Dr. Reddy's overall goal is to translate basic biology into innovative pharmaceuticals products and services that can be sold at an affordable price. In the first quarter of 2010, the company generated USD363 million in revenues and after-tax profits of USD45 million. For additional information, see *www.drreddys.com*.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INFOSYS TECHNOLOGIES

Infosys Technologies began with an initial investment of USD250 in 1981. Today, with a workforce that exceeds 110,000 people and annual revenues approaching USD5 billion, it is global leader in information technology consultancy. In 2007, it received 1.3 million job applications and hired less than 3% of the applicants. Infosys, which has offices in more than 30 countries and development centres in India, Australia, Canada, China, Japan and the UK, offers a complete range of services for business strategies, product engineering and information technologies that include systems integration, software and infrastructure development, and testing and validation. Specific areas of consultancy include aerospace and automotive, energy and utilities, life sciences and health-care, and media and entertainment. In 2009, the Infosys Science Foundation announced the creation of Infosys Prizes to honour the achievements of Indian scientists in a broad range of fields. For additional information, see *www.infosys.com*.

WIPRO TECHNOLOGIES

With nearly 110,000 employees and 72 development centres in more than 50 countries, Wipro (an acronym for Western India Products Ltd), which began as a vegetable oil trading company in the late 1940s, is among the world's leading information technology services companies. Wipro, which generates more than USD6 billion in annual revenues, focuses on a broad range of issues, including financial services, transportation, manufacturing, health-care, energy and media. It currently has more than 800 clients and has worked with some of the world's largest international corporations. Wipro moved into the information technology sector after IBM was asked to leave India in 1977. It began developing its own computer in 1979 (the first India company to do so) and then, in the early 1980s, computer chips (also the first Indian company to do so). Wipro's current R&D activities include cloud and social computing, green technologies, information management and security. For additional information, see *www.wipro.com*.

UNIVERSITY OF HYDERABAD

The University of Hyderabad, which was established in 1974, is one of the nation's leading teaching and research institutions. Although primarily focused on post-graduate training, it recently began to enrol undergraduates. Its student body totals 3,500, and it has a faculty of 250. The University is divided into a large number of schools, ranging from the performing and fine arts, to the humanities and social sciences, to administration and management, and to mathematics and the basic sciences. It also promotes interdisciplinary studies, continuing education and partnerships with the private sector, and participates in a number of international cooperation activities with European universities. The 'Study India Program' offers foreign students the opportunity to spend a semester or summer at the university. For additional information, see *www.uohyd.ernet.in*.

ANNA UNIVERSITY

Anna University, established in 1978, is one of India's foremost technical universities. Located in the southern state of Tamil Nadu, it offers undergraduate and post-graduate degrees in engineering, science and technology. It also promotes research in a broad range of technical fields, and encourages cooperation between academia and industry. It consists of four main institutions: School of Architecture, College of Engineering, Madras Institute of Technology and Alagappa College of Technology. It also has a large number of centres and institutes in fields ranging from biotechnology to energy and environmental studies, to nanoscience and nanotechnology, and to ocean management. The university graduates 65,000 engineering students each year. For additional information, see *www.annauniv.edu*.

JADAVPUR UNIVERSITY

Jadavpur University ranks among India's leading universities in interdisciplinary research. It is especially noted for its excellence in engineering. The university enrols more than 10,000 students and awards over 250 PhD degrees each year. Its faculty of engineering and technology focuses on such disciplines as architecture, civil, mechanical and metallurgical engineering, computer science and pharmaceuticals. Its faculty of science focuses on biotechnology, chemistry, geology, mathematics and physics, and its faculty of arts on the teaching and research of languages, history, literature and philosophy. The university is currently engaged in more than 350 research projects funded by national and international agencies. For additional information, see *www.jadavpur.edu*.

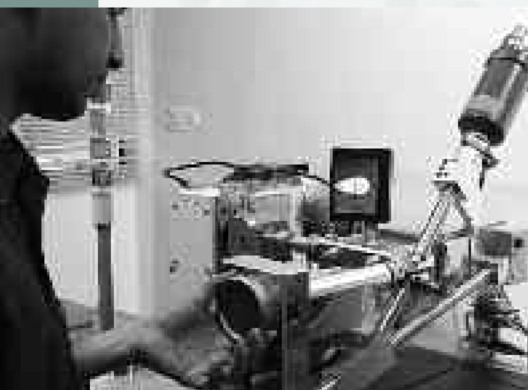
JAWAHARLAL NEHRU UNIVERSITY

The Jawaharlal Nehru University (JNU), established in 1969, is dedicated to pursuing the principles that guided the governance philosophy of Indian's first prime minister, Jawaharlal Nehru. These principles include national integration, social justice, secularism, democracy, international understanding and scientific approaches to the problems of society. Today the total enrolment stands at 5,500 students. The University reserves 22.5% of each incoming class for students from underprivileged castes and ethnic groups. Some 10% of its student body comes from foreign countries. The University prides itself in its student/faculty ratio, which is 10 to 1. JNU is comprised of 10 schools that range from arts and aesthetics to computer and systems sciences to international studies. There are also four centres in a diverse range of fields: sanskrit studies, law and governance, molecular medicine and nanosciences.

JNU also serves as the home of Jawaharlal Nehru Institute for Advanced Studies, which hosts more than 50 fellows. For additional information, see *www.jnu.ac.in*.

INDIAN INSTITUTE OF TECHNOLOGY IN KHARAGPUR

The Kharagpur Institute of Technology (IIT Kharagpur), established in 1951, was the first of India's prestigious institutes of technology (currently totalling 15 in number), and it remains one of the top engineering schools in India today. It currently has 19 academic departments, 8 multi-disciplinary centres and 13 schools of excellence. The campus, located on an 8.5 square mile campus 120 kilometres west of Kolkata, is part of a self-contained city of some 20,000 people. IIT Kharagpur has 2,000 employees, including 470 faculty members, and 5,500 students (undergraduate and graduate) living on campus. It is also home to the Vinod Gupta School of Management, the Rajiv Gandhi School of Intellectual Property Law, the Ranbir and Chitra Gupta School of Infrastructure Designing and Management and a School of Medical Science and Technology. For additional information, see *www.iitkgp.ac.in*.



Flickr/Abhishek Kumar

S.N. BOSE CENTRE

S.N. Bose National Centre for Basic Sciences (SNBC), established by the Department of Science and Technology in 1986, is one of India's leading research institutes in the basic sciences. It is especially well known for its PhD programmes in the physical and chemical sciences. The Centre consists of departments in the theoretical sciences, material sciences, astrophysics and cosmology, and chemical, biological and macro-molecular sciences. It also has units in nanoscience and nanotechnology and materials science. Among the specific areas of interest are electronic structure and the physics of materials; soft condensed matter and complex systems; non-equilibrium statistical mechanics; the physics of mesoscopic and nanoscopic systems; quantum optics and mechanics; cosmology; differential geometry; and probability theory. For additional information, see *www.bose.res.in*.

INDIAN INSTITUTE OF TROPICAL METEOROLOGY

The Indian Institute of Tropical Meteorology (IITM), established in 1962, is one of India's premiere research institutes for the study of meteorology and atmospheric science. IITM, which now operates under the Ministry of Earth Sciences, seeks to advance understanding of fundamental atmospheric challenges and, more specifically, the mechanisms that drive monsoons and weather- and climate-related processes in tropical regions. IITM focuses a great deal of its research on the ocean-atmosphere climate system. It also oversees an extensive training programme for junior-level scientists and research fellows. The institute's research divisions include forecasting, climatology and hydrometeorology, instruments and observational techniques, and climate and global modelling. Its research programmes range from seasonal prediction of mean monsoon rainfall to thunderstorm dynamics to urban air pollution. IITM has more than 100 faculty members. For additional information, see *www.tropmet.res.in*.

JULIA MARTON-LEFÈVRE, DIRECTOR GENERAL OF THE INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN), HAS BEEN A LEADING FIGURE IN THE SCIENCE, EDUCATION AND DEVELOPMENT COMMUNITIES WHERE SHE HAS HELD A BROAD RANGE OF EXECUTIVE POSITIONS IN INTERNATIONAL INSTITUTIONS DEDICATED TO CAPACITY BUILDING AND SUSTAINABLE DEVELOPMENT.

Before coming to IUCN, Marton-Lefèvre was rector of the University for Peace (UPEACE) in Costa Rica. Earlier, she held positions as executive director of LEAD International in London and executive director of the International Council for Science (ICSU) in Paris. She is a member of a number of boards, councils and committees, including the China Council for International Cooperation on Environment and Development, Oxford University's James Martin 21st Century School and the Clinton Global Initiative's Energy and Climate Change Working Group. She has held board memberships in the International Institute for Environment and Development, Earth Charter International, World Resources Institute, Lemelson Foundation and the InterAcademy Councils' (IAC) Panel on Promoting Worldwide Science and Technology Capacities for the 21st Century.

DIVERSITY LOST AND FOUND

The United Nations has designated 2010 the International Year of Biodiversity (IYB) as the centre piece of a larger effort to raise broad public awareness about this critical issue. In an hour-long interview with the editor of the TWAS Newsletter, *Marton-Lefèvre describes what she hopes will be accomplished during the high-level, year-long discussions focusing on biodiversity protection, conservation and sustainable use. Edited excerpts follow.*

Could you please give us some background on the Convention on Biodiversity?

The Convention on Biodiversity, signed by more than 150 countries at the Earth Summit in Rio de Janeiro in 1992, placed biodiversity issues front-and-centre on the global environmental agenda. More importantly, it provided an international legal framework for protecting biodiversity.

Discussions moved forward in 2002 at the World Summit for Sustainable Development (WSSD) in Johannesburg, South Africa, when the Convention's signatory nations agreed to significantly reduce biodiversity loss by 2010.

The Convention on Biodiversity deserves a great deal of credit for raising awareness about this issue, especially among national governments and international organizations. However, the language that has been used by the Convention and others to describe the issue has been vague and abstract. Moreover, discussions on the topic have often been disconnected from the everyday problems faced by most people. As a result, both political leaders and the public have had a difficult time understanding the importance of biodiversity to their more immediate concerns, and how the loss of biodiversity could impact their economic and social well-being.

That is why I have suggested that experts should speak more about nature and habitat, and less about biodiversity, when addressing political leaders and the public. As the Brundtland Commission's report, *Our Common Future*, published more than two decades ago, observed: the essential issue is "environmentally sound development."

Equally important, as the Convention on Biodiversity clearly stated, ultimate responsibility for progress in biodiversity conservation and sustainable use resides largely with national governments.

While there has been some progress, it has been uneven, depending in large part on the commitment and measures taken by national governments and a broad range of stakeholders within each country, including nongovernmental organizations and the private sector.

For all of these reasons, proponents of biodiversity have fallen short of what they have hoped to accomplish. By all accounts, biodiversity loss has not been curtailed. In fact, it has accelerated, in part due to inadequate and ineffective policies, and in part due to increased pressures that have been placed on natural resources as a consequence of continual population growth and economic development.

What do you hope will be accomplished during the International Year of Biodiversity?

Those involved in the International Year of Biodiversity hope to advance the issue in a number of ways. In the broadest sense, what we would like to do is turn the rhetorical discussions and legalistic frameworks that have been developed over the past two decades into an effective action-oriented strategy that achieves convincing results across the globe – results that can quickly take hold and that resonate with the public.

First, at a very basic level, we hope that we can become more effective in convincing the public that everyone depends on nature (and, consequently, biodiversity) for his or her well-being. Put another way, experts in the field need to do a better job of explaining, in plain language, what is at stake if we fail to reverse current trends in biodiversity loss.

Second, advocates of biodiversity conservation hope that they can effectively describe the deep and fundamental connections between the need for biodiversity conservation and sustainable use over the long term and the more short-term economic concerns that, by necessity, take precedence in society.

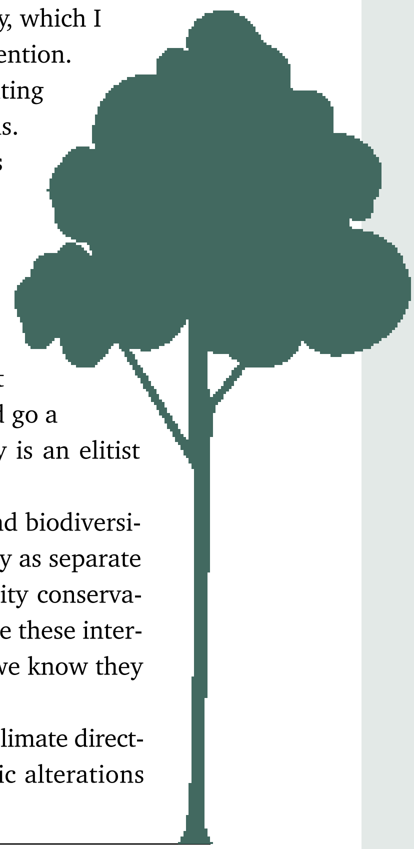
People intrinsically understand that nature bestows untold benefits that we all value and cherish as human beings – clean air and water, beautiful vistas and recreational opportunities, and even the joy of witnessing wild animals run free in habitats largely untouched by humans.

But what the public often fails to fully appreciate are nature's direct and enduring contributions to a nation's overall economy and the financial well-being of its citizens. Significant habitat and biodiversity loss will increase the cost of a broad array of ecosystem services, ranging from access to clean drinking water, to the protection of coastal environments in the face of storm surges and sea level rise, to timber supplies placed at risk as a result of deforestation.

Economists have recently developed analytical techniques for assessing the value of – that is, assigning monetary worth to – ecosystem services. These frameworks, moreover, have become more sophisticated and refined over time. Some economists now estimate that damages done to ecosystem services, due to biodiversity loss, cost the global economy between USD1.35 trillion and USD3.1 trillion each year.

These estimates tell us two things. First, the economic impact of biodiversity loss is significant. And second, in light of the broad range in estimates, it shows the losses are difficult to measure. Indeed, as ecological economists have often noted, ecosystem services historically have been viewed as free goods – or externalities – that lie outside conventional methods of determining national wealth.

There are, in fact, a number of reports that will be published this year, under the banner of The Economics of Ecosystems and Biodiversity (TEEB) initiative, sponsored by the United Nations Environment Programme (UNEP), the European Union and Germany, which I hope will help bring the financial costs of biodiversity loss to the public's attention. Equally important, TEEB is designed to create mechanisms for fully integrating the economic value of ecosystems into national and global accounting systems. The ultimate goal is to augment, or even replace, such methodologies as gross domestic product (GDP) with analytical techniques that can assess the worth of natural capital.



New systems of accounting are extremely important. But they will not be sufficient to achieve significant progress in biodiversity conservation and sustainable use. It is critical that we present the issue in more personal and less abstract terms, and that we clearly present the short-term, and not just the long-term, impacts both to our environment and economy. This could go a long way in overcoming the public perception that the issue of biodiversity is an elitist concern of little consequence to the average person.

Third, I hope that we will be able to draw the issues of climate change and biodiversity loss more closely together. Until recently, the two have been treated largely as separate issues. If we are to develop and enact effective public policies for biodiversity conservation, we will need to move beyond a 'silo' mentality that has led us to examine these interrelated challenges as if they are isolated from one another when, in reality, we know they are not.

We are well aware, for example, that changes in habitat due to changes in climate directly impact the well-being of numerous species and often precipitate dramatic alterations in both living conditions and migration patterns. We also know that changes in habitat adversely affect the ability of ecosystems to capture carbon dioxide and other greenhouse gases. In fact, experts estimate the destruction of tropical rain forests (6 million hectares are being lost each year) is responsible for some 20% of global greenhouse gas emissions. That is higher than the level of emissions generated by the transportation sector. Consequently, examining the relationship between climate change and biodiversity loss is essential for acquiring a greater understanding of the full scope of these 'twin' challenges.

Fourth, and perhaps most importantly, I hope that the events related to the Year of Biodiversity, particularly the high-level diplomatic meeting on biodiversity that will take place during the UN General Assembly in New York City in September, followed by the Biodiversity Convention in Nagoya, Japan, in October, will lead to new and innovative strategies based on specific targets for species and habitat conservation. We need to develop realizable goals that the public can understand and support. One critical way to do this is to establish clear benchmarks that enable us to measure our progress (or our lack of progress) in meeting the targets. This includes a firm commitment to halt biodiversity loss by 2020. I am confident that we can – and will – make significant progress on this front, hopefully this year.

Could you describe the scope of the biodiversity challenge?
We know that we are losing biodiversity. Yet we don't have precise figures on the rate of loss. That should not be surprising. After all, the best scientific estimates place the total number of species on Earth at about 10 million (indeed estimates range between 2 and 100 million). Yet, to date, we have identified only 1.4 million species. This lack of knowledge, however, does not mean we cannot detect trends.

IUCN publishes the *Red List of Threatened Species* each year. Last year, we surveyed some 50,000 species. This is a tiny but revealing sample. Here's what we have found. According to the most recent survey, more than 17,000 of the sampled species are threatened, including 12% of the birds, 21% of the mammals, 27% of the coral reefs and 30% of the amphibians. Moreover, as I mentioned previously, the rate of biodiversity loss is accelerating. According to the *Living Planet Index*, published by WWF–World Wildlife Fund for Nature, the world's sea grass beds have been depleted by 30% and mangrove forests by 20% over the past three decades. Perhaps even more disturbing, the *Index* shows that populations of wild species have declined 30% since 1970. Overall, scientific studies and fields surveys suggest that the current rate of species extinction is 1,000 times higher than the fossil record.

Why should people care about the biodiversity loss?
As I mentioned earlier, there are ethical and aesthetic reasons. As I look out my office window here in Gland, Switzerland, I can see the snow-capped peaks of the Alps. In the summer, I swim in Lake Léman. Much of this landscape lies in areas protected by the government. It gives me great personal pleasure not only to have access to these areas but also to know they will be there for generations to come.

Tens of millions of people feel the same way about their surrounding environment, especially if they live in a place as beautiful as I do. People also experience immeasurable joy and satisfac-


Flickr/Martin Loetzsch

tion in knowing that far-away special landscapes, whether the Imfolozi Wilderness Area in South Africa or Yellowstone National Park in the United States, will remain pristine environments for future generations to discover on their own – in person, in books, in movies, or on the internet.

But there is more at stake than beautiful mountain vistas, enjoyable swims in pristine freshwater lakes and the ability to experience unique environments in other countries. The world's 1.1 billion poorest people – those earning less than USD2 a day – derive half of their welfare directly from nature. Coral reefs alone generate USD170 billon a year in ecosystem services and support the livelihoods of 500 million people.

For poor people, nature is not just a source of aesthetic pleasure or an ethical imperative. It is a matter of day-to-day survival. Such ecosystem services as wild harvests, crop pollination, provisions for clean water and adequate sanitation, and the natural buffers they provide from hurricanes and storm surges play a direct role in their well-being. In many developing countries, damage to the local environment has an immediate adverse impact on personal welfare and security. And, for poor people living in rural environments, nature is also the key source of their cultural identity. That is what is often meant by an indigenous culture – a culture where the social environment cannot be separated from the natural environment.

What measures do you think need to be taken to protect biodiversity?

We need to set targets both for the preservation of species and for the protection of habitat. For species preservation, this will require signing (and, more importantly, enforcing) binding international agreements to stop species loss by 2020. To achieve this goal, concrete measures must be agreed upon at the international conferences scheduled for New York and Nagoya, with full implementation beginning no later than 2015.

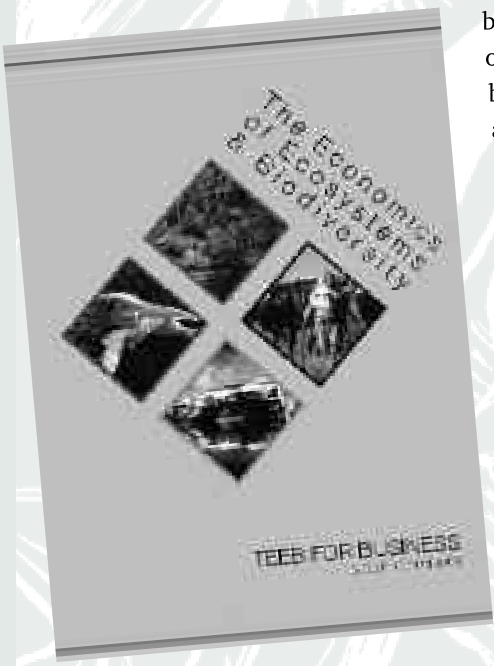
For habitat protection, this means setting aside at least 15% of the Earth's lands and seas as protected areas. That is the ambitious target that the IUCN has proposed. Today, approximately 12% of the world's lands and seas receive some kind of legal protection from development. But only about 1% of the seas, which cover three quarters of the Earth, are protected. This means that just 4% of the world's total surface is currently protected.

IUCN

IUCN (the International Union for Conservation of Nature), which was founded in 1948, seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. IUCN builds on the strengths of its members, networks and partners to enhance their capacity and support global economic and environmental sustainability. IUCN is comprised of more than 1,000 government and NGO member organizations, and almost 11,000 volunteer scientists in more than 160 countries. The organization's global headquarters is located in Gland, Switzerland. For additional information, see www.iucn.org.

It is important to remember that habitat protection is not new. Think of the gaming preserves for European royalty dating back to the Middle Ages. The history of national parks as 'peoples' parks' – that is, land set aside in perpetuity for human recreation and enjoyment of a nation's citizenry, as well as for animal, plant and environmental protection – dates back less than 150 years. Yellowstone National Park, created in 1872 in the United States, is often cited as the world's first national park. Today, there are an estimated 7,000 national parks across the globe.

Over time, we have become more sophisticated in devising strategies for protected areas. Under current laws and regulations, they are no longer confined to places where humans are entirely kept at bay, except as visitors. In fact, IUCN lists six distinct categories of protected areas, ranging from places largely devoid of all human contact to places where there are houses, roads and even commercial establishments, but where restrictions are nevertheless placed on development to ensure that the natural and cultural identity of the area remains intact. National parks have been placed in category II. That means they have not been materially altered by human habitation, but that the presence of humans can be found – and is indeed common. Anyone who has been to a national park has come across lodges, restaurants, trails and lookout posts that reveal an undeniable human presence in a largely natural setting.



Where do you hope efforts to help conserve biodiversity will be five years from now?

I anticipate that stricter laws and regulations will be put in place for protected areas and that provisions for protecting habitat and species will be enforced by international frameworks, perhaps under the jurisdiction of the UN. These laws, however, will not be mandated by international organizations but instead developed in consultation with national governments. The governments, in turn, will act through a consensus forged with all members of their society, including nongovernmental organizations, indigenous populations and the private sector. I anticipate that large, well-financed programmes will be established not only for protecting habitat and species but also for restoring ecosystems. Humans have altered and extensively damaged so much of nature that it will be necessary to engage in large-scale projects of recovery and restoration. Finally, I anticipate that there will be large-scale campaigns designed to promote changes in lifestyle, especially among developed countries. Unprecedented economic growth in China, India, Brazil and other large developing countries will be placing added stress on the world species and habitat. However, it is important to recognize that it is the unsustainable patterns of production and consumption that have taken hold in developed countries over the past three centuries that largely account for the losses in species and habitat that we face. My hope is that changes in lifestyle, marked by more efficient production and less rampant consumerism, will not only prove doable but will ultimately be embraced as a benefit, and not as a burden, to those of us fortunate enough to live in wealthy societies.

The possible future scenarios I have described will require two additional critical elements to succeed. First, there will have to be significant reforms in governance that allow international organizations to assume greater responsibilities in policy development and enforcement. The

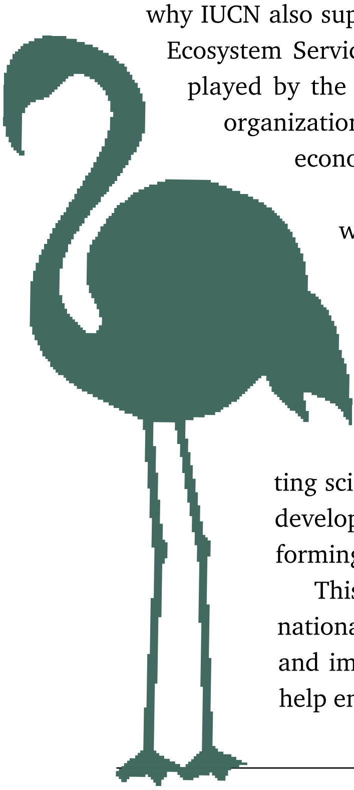
role of national government will not be diminished when it comes to laws and regulations influencing the lives and well-being of their citizens. However, when it comes to such 'borderless' issues as species and habitat protection and climate change mitigation, we will need to empower international organizations to devise strategies and set targets that will help us achieve our shared goals.

And, second, such efforts will raise the profile of science but it will do so in a unique way, marking an important change in the relationship of science to society. As in the past, scientific research will be essential to assess the scope of the problem, identify trends, create evidence-based strategies to meet the challenges, and determine whether the measures are proving successful.

However, it is important to realize that successfully addressing questions of biodiversity and habitat loss will involve the social sciences as much as the natural sciences, and that progress will necessitate broad-based partnerships that welcome people in many different fields of study and walks of life to participate in the discussions.

These goals, of course, will not be achieved without additional funding, especially for developing countries. That is why IUCN has called on the 30 member states of the Organization for Economic Cooperation and Development (a network of the world's richest countries) to contribute 0.2% of their GDP to biodiversity conservation efforts in developing countries.

The goals will also require measures to strengthen the science-policy interface. And that's why IUCN also supports the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Such an organization would play a similar role to the one played by the Intergovernmental Panel on Climate Change (IPCC), the international organization that reviews and assesses the most current scientific, technical and socio-economic information for understanding climate change issues.



Abdus Salam, the founder of TWAS, who I was privileged to know and work with early in my career, was fond of saying that science is the heritage of all humankind and therefore all nations should share in its exploration, discoveries and benefits. I am sure that Salam would also agree that nature is not only an essential aspect of our heritage but also an integral aspect of our future – and that all of humanity shares "a common concern" for biodiversity, as the Convention of Biodiversity stated in 1992.

Salam, I am sure, would also readily agree that if we succeed in putting science to work in protecting nature and in promoting sustainable economic development (in part, through species and habitat conservation), we will be performing a great service for humanity.

This is the spirit that I hope will guide discussions not only during the International Year of Biodiversity but also in the years beyond, as we seek to devise and implement strategies for biodiversity conservation and sustainable use that help ensure global well-being for current and future generations. ■

RISKS AND BENEFITS IN MEDICAL IMAGING

RECENT ADVANCES IN MEDICAL IMAGING TECHNIQUES HAVE SAVED UNTOLD LIVES BY ENABLING DOCTORS TO MAKE MORE ACCURATE DIAGNOSES FOR SERIOUS ILLNESSES. BUT THERE IS GROWING CONCERN THAT THE OVERUSE OF SUCH PROCEDURES IS PLACING PATIENTS AT UNNECESSARY RISK OF CANCER FROM RADIATION EXPOSURE.

Marlen Pérez Díaz, professor of medical physics at Cuba's Central University of Las Villas, has a passion for finding the right balance between benefit and risk for patients undergoing medical imaging scans.

A recent study published in the *Archives of Internal Medicine* found that, in the United States, the number of computed tomography (CT) scans has increased threefold since 1993, reaching 70 million scans in 2007. Another study in the same journal concluded that, because of a lack of standardization, patients receive a wide variety of radiation doses. A 2007 article in the *New England Journal of Medicine* contended that as many as 50% of all CT scans are not sufficiently justified on medical grounds.

Such statistics come as no surprise to Marlen Pérez, a professor and researcher at Central University 'Marta Abreu' of Las Villas, Santa Clara, Cuba, who specializes in radiation dose optimization in medical imaging. "Most doctors really need to think more about radiation dosages when ordering CT scans," she says.

Pérez is a member of the Organization for Women in Science for the Developing World (OWSDW, formerly TWOWS), a Trieste-based organization that works closely with TWAS (see box, p. 39). Pérez visited

Trieste earlier this year as an associate fellow of the Abdus Salam International Centre for Theoretical Physics (ICTP).

TOO MUCH OF A GOOD THING?

"I went into the field of medical imaging because I wanted to help people," Pérez says. "I soon understood that not enough attention was being paid to radiation dosages."

Pérez is among a growing number of scientists and health-care technicians who believe that technological advances in medical imaging are outpacing safety protections in medical physics – a field which includes medical imaging (*e.g.* X-rays, nuclear medicine and CT scans) for diagnosis, and radiation therapy (*e.g.* in treating malignant tumours).

> ***CT scans represent one of the most significant recent advances in medical science.***

The realization that much remained to be accomplished in the optimization of radiation dosage convinced her to concentrate on medical physics for her PhD, which she received in 2003 from the Institute for Nuclear Science and Technology, in Havana. She had earned a BSc in nuclear physics engineering in 1993 and a master's degree in nuclear and radioactive installations in 1998 from the same institution.

"CT scans represent one of the most significant recent advances in medical science," notes Pérez. The cross-sectional images that they provide are much more detailed than traditional X-rays. That makes the image not only clearer but also more convenient to use.

As a result, doctors are ordering more and more scans to be conducted. Yet their usefulness has tended to obscure the risks that are involved. Most patients don't know that the radiation dose of an average CT chest scan is equal to some 500 chest X-rays. Such exposure poses significant risks for cancer, especially when patients receive a number of scans over time.

The dramatic increase in the use of CT scans during the past decade, and the fact that physicians rarely keep track of patients' cumulative doses, prompted the International Atomic Energy Agency (IAEA), in 2009, to caution against unwarranted risks of multiple scans. In April, the agency launched a project to provide every patient with a 'smart card' containing information on radiation doses received.

"Every medical use of radiation," Pérez points out "whether for diagnosis or therapy, involves a certain degree of risk." Her goal, Pérez says, is to fine-tune guidelines to "minimize patients' radiation exposure, while at the same time maintaining the best possible

image quality so that the chances of a correct diagnosis are not diminished". To do this, she and her colleagues rely on both mathematical models and experiments.

PRINCIPLES FIRST

Pérez explains that "there are two general principles that doctors and technicians follow to assure that patients are properly protected from radiation: justification and optimization."

Any medical procedure involving radiation must be first *justified* in terms of the benefits outweighing the risks of the exposure to radiation; then protection needs to be *optimized* so that dosage and exposure is as low as can be reasonably achieved. Finally, all doses should fall below 'reference levels', Pérez says. "These are not 'limits' *per se.* Rather they serve as guideposts for optimizing the results while minimizing the risks."

Every medical use of radiation involves a certain degree of risk.

The problem, Pérez observes, is that most practitioners focus exclusively on the first principle – justification. "More attention needs to be paid to optimization and reference levels," she says.

Whether it is for nuclear medicine (NM) imaging or CT scans, for diagnosis of the bones, heart, kidneys or brain, the challenge for Pérez and her colleagues is to "find the ideal compromise between image quality and radiation risk to the patient."

But obtaining standardized radiation values, Pérez explains, is complicated by the fact that typical doses differ from country to country, and even from institution to institution. The values depend on such wide-ranging variables as the type of equipment and radiopharmaceutical used and patient size.

"The IAEA recommends reference values for imagining doses," she says. "But they also recommend that these standards be adjusted to take into account the specific circumstances in each country." For example, she explains that Cubans tend to be both shorter and slimmer than their US counterparts, and the equipment used in the country tends to be older (and thus less sophisticated). Cuba also produces its own radiopharmaceuticals (radioactive agents used as tracers for diagnosis in nuclear medicine). These factors must all be carefully considered when determining doses.

"IAEA radiation dose recommendations are based on models for typical adults, but they do not assure an optimized dosage in all cases", says Pérez. "On the other hand," she adds, "the biological effects of radiation in medical diagnosis are probabilistic, not deterministic."

Pérez believes that there has been insufficient interest in optimizing dosage for diagnosis. "Most doctors simply do not have dose optimization in mind," she says, "and so they are not thinking of all the variables involved".

Specifically, the idea in image optimization is to obtain the best image quality possible – with low levels of "noise" or static; no "artefacts" (spurious images, caused by interference, as on a TV with poor reception, which can lead to diagnostic errors); and good contrast and resolution – with the lowest possible levels of radiation.

Optimization is crucial, Pérez says, because studies suggest that it can reduce radiation doses by about 20–70% in many situations. Researchers in Cuba, she notes, have managed to lower the amount of radiation used for kidney diagnosis by 50% in the past decade.

LAB PHANTOMS

In their efforts to determine optimum radiation dosages, Pérez and her colleagues begin with mathematical models. Before moving on to clinical trials (once safety values are adequately determined), they perform experiments with 'tissue-equivalent' materials – called 'anthropomorphic phantoms' – that simulate human organs.

"Phantoms are designed to have properties similar to human tissue," she explains. They are used in both research and teaching, as well as to evaluate the performance of imaging and radiation therapy equipment. Phantoms are available for various body parts and sections, including phantom hands, torsos, knees and feet. A phantom head, for example, is a life-size head form constructed to simulate the radiation absorption of human tissue. Internal containers may be positioned within the form to simulate tumours.

Phantoms are important in optimization research, says Pérez, because they provide a valuable half-way step between mathematical models and working with real people. "The problem," she continues, "is that they are expensive, which means that few centres in Cuba can afford their own."

Pérez relates that her lab recently found a solution to this problem through South-South cooperation. "We collaborated with the nuclear energy department of the Federal University of Pernambuco, Brazil, which has very good quality phantoms. We did the mathematics here, and they provided us with the measurements that were made using these phantoms."

COMPRESSING IMAGES

Pérez is also researching with her students the optimization of image compression for both MRI (magnetic resonance imaging) and CT scans. The goal is to determine "the minimal bit rate that still ensures an accurate detection of the pathology involved – for example, the lesions indicating multiple sclerosis (MS)".

The technology involved is basically the same as that which is relied on when using a personal computer to download or email photos in jpeg format. For

GENDER BALANCE

Pérez joined the Organization for Women in Science for the Developing World (OWSDW, formerly known as the Third World Organization for Women in Science, TWOWS), in 1998. OWSDW's main objectives are to promote women's leadership in science and technology in the South and to strengthen their participation in science-based development. Launched in 1993, OWSDW currently has more than 3,000 members from over 80 countries in the South. Its secretariat is hosted by TWAS, which played a key role in its establishment and provides most of its core funding. The organization's 4th General Assembly and International Conference was recently held in Beijing and will be reported on in a future edition of the TWAS Newsletter. *For more information about OWSDW, see www.womenscience.org.*

Pérez currently serves as a member of OWSDW's national chapter in Cuba, which, she says, organizes a number of meetings every year. She strongly supports the organization's efforts to improve opportunities for women in science. "Cuba sets a very good example in this regard," she proudly notes, "because more than half of the workers in technical fields are women."

health professionals, the compression of image data from X-rays, CT scans and MRI is likewise important because it reduces the need for archival space and speeds data transmission. The challenge, Pérez explains, arises because conventional compression technology involves some loss of data, which – in the case of the high-resolution medical images – reduces the chances that a physician will make a correct diagnosis based on the scans.

"Obtaining the optimum compression of CT and MRI scans", Pérez says, "means finding the best balance between image quality and maximal compression".

TEACHING INSPIRATION

Born in 1970, in Santa Clara, Cuba, Pérez became interested in science as a young girl, thanks to a "wonderful physics teacher, Anibal Hernández Perdomo" in secondary school who, recognizing her abilities and enthusiasm, asked her to be his classroom helper. "This teacher changed my life," she says.

The radiation dose of an average CT chest scan is equal to some 500 chest X-rays.

With her teacher's encouragement, Pérez participated in science competitions with students in other schools. That, in turn, further sparked her interest and gave her a strong sense of the challenges and possibility of discovery offered by the sciences.

"When I completed secondary school," Pérez recalls, "I passed a competitive exam that allowed me to attend a special high school in Santa Clara, where we were taught the usual curriculum in the morning, but devoted our afternoons to specialized subjects – in my case, physics." There, she says, she received a "sound preparation in math and physics" – and discovered her vocation. "I knew then what I wanted to do when I grew up. I told my parents, 'I *will* be a physicist'."

Another physics teacher whom she remembers, Wilfredo Rivero, had won a research fellowship to go to Germany – an illustration of the opportunities available for researchers. "He transmitted his enthusiasm and love of the subject to his students."

Pérez considers the years in which she attended primary and secondary school to have been the "golden age of public education in Cuba." The nation's educational system declined somewhat in the 1990s, she says, after the collapse of the USSR (bringing an end to Soviet financial assistance to the country). But Cuba, she notes, has "recently been making strides to reach this high educational level once again".

As an undergraduate, a growing desire to address social problems led Pérez to pursue a master's degree in medical physics. "I began to understand how physics could help people," she says.

In addition to her research, Pérez is now a teacher herself. "I teach about 130 hours of undergraduate courses per semester in biomedical engineering – four two-hour classes a week – for example, on bioinstrumentation and medical image analysis. I also teach three courses per year in the MSc degree programme on the physical principles of medical imaging, radiation protection, and the biological effects of ionizing and non-ionizing radiation. In total, I teach about 70 students a year." She also supervises students' PhD and master's theses.

PUBLIC HEALTH-CARE

Cuba enjoys excellent health statistics, particularly for a developing country. Life expectancy is 78. The under-5 mortality rate is 5 per 1,000 live births – comparable to the United States (where the figures are 79 and 8, respectively). An interesting difference is that the US spends over USD7,000 per person a year on health-care, whereas Cuba spends less than USD300.

Pérez is justifiably proud of her country's accomplishments and notes that "medical radiation physics and biomedical engineering are core components of Cuba's advances in public health-care."

She cites the founding of the National Institute of Oncology and Radiobiology in Havana in the 1960s as "a milestone" in the development of nuclear medicine in Cuba. "Today," she says, "radio-diagnostic services, including static, mobile and dental equipment, mammography and fluoroscopy, are available throughout the country." Cuba also has CT scanners in all the provinces, 20 gamma cameras, 11 radiation therapy machines and 13 MRI scanners.

In the past few years, she says, the government has boosted the country's capacity in medical physics. For

example, the National Programme for Medical Images has offered a master's degree programme in medical images technologies (MIT) since 2005.

"To be eligible for the programme," Pérez explains, "candidates must complete an undergraduate degree in nuclear physics, nuclear engineering, electronic engineering or telecommunications." For students wishing to pursue a career installing and maintaining equipment, the programme offers a technical diploma.

Students obtaining a master's in MIT may go on to pursue an MSc in medical physics, offered by the Higher Institute of Technologies and Applied Sciences, Havana, in collaboration with the IAEA and a network of research and health centres in Cuba and Spain. Some centres and universities also offer master's degree programmes in biomedical engineering.

"Cuba will need an estimated 600 additional engineers and physicists to work in the health-care system by 2015", Pérez says, "to complement the work of 9,000 doctors." To meets this need, the government has set several goals for the next 5 years. These include: that 2% of Cuba's engineering students (about 270 students) pursue studies in biomedical engineering; 40 students per year study nuclear physics, nuclear engineering or nuclear chemistry; and 50% of the latter be employed by the national health system or in research centres working in medical physics. The government also hopes to increase the number of master's degrees and PhDs in medical physics and related technical sciences.

MARVELLOUS IDEA

Pérez describes her stay in Trieste as an ICTP junior associate as "paradise" – in part because she could work without distractions. "When I am home, my time is divided among so many responsibilities," she says. "But here, I can concentrate solely on my research."

She explains that the first time she came to the centre in Trieste, she met a Brazilian scientist working in her field. This led to a research project with colleagues at the Federal University of Pernambuco in Brazil. Besides having access to more modern equipment, she says, "I met people with a great deal of experience, with whom I could exchange information and ideas." She relates the irony of meeting a Cuban scientist at ICTP who attended her seminars here, something that would have been unlikely to take place in their home country.

"Organizations like TWAS and ICTP are so valuable", Pérez says, "because of the contributions they make in helping scientists from developing countries through exchange and cooperation programmes." About TWAS, she adds, "it is really a marvellous idea" to build scientific capacity in the South as a way to sustainable development. ■

IMPROVING HEALTH IN TANZANIA

THE IFAKARA HEALTH INSTITUTE (IHI) BEGAN AS A FIELD RESEARCH INSTITUTE SPONSORED BY THE SWISS. TODAY, IT IS TANZANIA'S FOREMOST HEALTH RESEARCH INSTITUTION.

IHI's history dates back to the late 1940s. By then, European missionaries, including a group from Switzerland, had lived in Ifakara for more than a quarter century. The village also had a reasonably well-equipped hospital, St. Francis, which had evolved from a maternity clinic founded by nuns in 1937.

Rudolf Geigy was the first researcher to set foot in Ifakara. He did so in 1949. Eight years later, he opened the Swiss Tropical Institute Field Laboratory (STIFL) in Ifakara. In 1990, the Tanzanian Ministry of Health endorsed the integration of STIFL into the country's National Institute for Medical Research (NIMR). The following year, STIFL was renamed the Ifakara Centre and designated an affiliate of NIMR. And, in 1996, it was finally made into a trust: the Ifakara Health Research and Development Centre (IHRDC). It assumed its current name – Ifakara Health Institute (IHI) – in 2008.

Today, IHI employs nearly 600 staff in six sites across Tanzania: Ifakara, Bagamoyo, Dar Es Salaam, Rufiji, Mtwara and Kigoma. Its annual budget, standing at USD20 million, is projected to rise to nearly USD28 million by 2011-2012.

WHAT IHI DOES

IHI is more than just a research institute. It also engages in research training, seeks ways of turning scientific knowledge into health benefits and assesses national health policies.

A Board of Trustees, chaired by officials from the Commission for Science and Technology, manages the institute. Other board members hail from Tanzania's Ministry of Health and Social Welfare, the National

Institute for Medical Research, Swiss Agency for Development and Cooperation, Swiss Tropical Institute and representatives from nongovernmental organizations (NGOs) and local government.

WORLD-CLASS RESEARCH

While IHI is primarily known for its malaria research, its research portfolio evolved over many years. Projects were determined by available funding and the individual interests of the researchers. Over time, however, IHI has increasingly sought to address critical societal problems and, more specifically, to address Tanzanian health issues on a broader front.

This shift from pure to applied research is reflected in the institute's strategic plan for 2008–2013, which outlines four thematic areas for IHI's research operations:

- **Biomedical and environmental research,** encompassing the study of modes of transmission, immunology and molecular biology with a particular focus on malaria.
- **Intervention, efficacy and effectiveness**, including clinical trials, surveillance of disease patterns and evaluation of the effectiveness of treatments.
- **Health systems**, seeking to improve the efficiency of Tanzania's health programmes.
- **Programme monitoring and evaluation**, addressing one of the most important goals of the institute: to examine which interventions work and why.

IHI is more than just a research institute.

These four thematic areas are complemented by cross-cutting priorities. One such priority is neonatal and maternal health, where success is proving elusive. Mortality rates for children under five years of age in Tanzania have fallen by a third since 2000, but maternal mortality has remained at the same level since the 1990s.

NET BENEFITS

Research into the nature, prevention and treatment of malaria has been at the core of IHI's activities since its founding in the 1950s.

IHI's malaria research ranges from clinical trials of new malaria vaccines to monitoring the impact and safety of existing drugs. The institute also conducts studies on how malaria is transmitted. Ifakara housed the first African malaria vaccine trial from 1992 to 1994. In May 2009, IHI researchers inoculated the first child in an international Phase 3 trial of RTS,S, the most sophisticated malaria vaccine to date. This is the first step in a study that will include up to 16,000 children across Africa.

in Ifakara has helped shape World Health Organization (WHO) protocols on the best ways of treating and preventing malaria in poor regions.

IHI is also well known for the Kilombero Net Project (Kinet), which set a new standard for the use of insecticide-treated bed nets to fight the killer disease. The project began in 1996 with a six-month study of local attitudes towards the use of bed nets to combat malaria. Using social marketing, the researchers sensitized communities to the benefits of nets and succeeded in selling 65,000 nets in the valley over the following three years.

The Kinet project led to a 27% reduction in child mortality. On a national scale, this would translate into 30,000 children saved each year. The Kinet experience

JOINING THE BATTLE

The prevalence of HIV in Tanzania's population is about 7%. Although much lower than some other countries in sub-Saharan Africa, it still makes AIDS the leading cause of death among adults. Tanzania's government began rolling out a national treatment plan in 2004. Supported by such global HIV/AIDS programmes as the Global Fund and Pepfar, established by former US president George W. Bush, the plan offers treatment and care to a large number of Tanzanians. Yet it is still woefully inadequate, especially in terms of reaching the many million Tanzanians that live in rural settings.

Little is known about the best way of providing antiretroviral (ARV) treatments in rural areas. To address this issue, in 2004 the Swiss Tropical Institute began constructing Tanzania's first rural HIV care and treatment centre (CTC) in Ifakara, in collaboration with the St. Francis Designated District Hospital, IHI and Tunajali Family Health International, a US-based charity.

In addition, the Chronic Disease Clinic Ifakara (CDCI) is IHI's first official foray into HIV/AIDS

research. It aims to implement and improve care and treatment according to the National AIDS Control Programme (NACP); support programme outreach with an advocacy and referral system to satellite sites; and build a platform for capacity building and knowledge transfer within the health-care system and local community.

CDCI offers voluntary testing and counselling as well as dispensing ARVs. It sees up to 120 patients and carries out 30 to 40 HIV tests every day. The centre has enrolled 4,500 people with HIV infection, 3,200 of who are being examined on a monthly basis. About 60% receive anti-retro viral treatment.

IMPROVING ACCESS

The cost of health-care is a major constraint for the success of health programmes. To help ensure poor or vulnerable people receive adequate health-care, Tanzania's government introduced the Community Health Fund in the mid-1990s.

The fund is a form of health insurance that allows households to pay an agreed-upon sum of money each year in return for access to free basic medical services. Funds are kept in the district headquarters. Each health-facility governing committee can apply to and draw cash from the funds to purchase drugs and medical supplies or carry out renovations.

Membership in the community health fund, which is voluntary, provides a good way for poor people to offset the risk of having to come up with out-of-pocket payments when they fall sick.

Research into the prevention and treatment of malaria is at the core of IHI's activities.

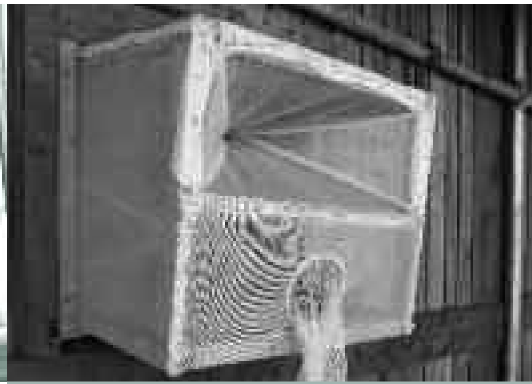
Nevertheless, the scheme's success has sometimes been limited. A 2007 IHI study found that one barrier to participation was the perception that the quality of health services being 'bought into' was low. Unless facilities are improved, many people will not see the benefits of joining.

There are ongoing efforts to improve the quality of health-care being offered by the facilities. IHI is also testing a micro-financing scheme targeting women groups in Kilombero and Ulanga. The groups receive from 2.5 to 3.0 million Tsh (USD2,000 to USD3,000) to invest in activities that will improve their income and hence access to health-care.

BRINGING RESEARCH TO POLICY

While IHI always enjoyed a high profile in global health research circles, until recently it was virtually unknown in its own country. In November 2008, Jakaya Kikwete became the second Tanzanian president to visit IHI in Ifakara. President Julius Nyerere was the first. To the staff'ss surprise and chagrin, the president said that he had not heard of IHI until a foreign colleague had congratulated him on the institute's excellent work.

Since Kikwete's visit, connections between IHI and the government in Dar Es Salaam have grown exponentially. The institute is routinely consulted on matters of health policy, and its former director, Hassan Mshinda, has been placed in charge of the country's key science advisory body, the Commission for Science and Technology (COSTECH).


For its part, IHI is coordinating its research agenda with Tanzania's growth strategy *Vision 2025,* and with the global Millennium Development Goals (MDGs).

MAKING AN IMPACT

The Interdisciplinary Monitoring Programme for Antimalarial Combination Therapy (IMPACT) is one of IHI's programmes designed to inform government policy. IMPACT evaluates the rollout of effective – but costly – artemisin-based combination therapies (ACTs) to fight malaria in Tanzania.

ACTs are the gold standard in malaria treatment. They were introduced in 2007 in Tanzania to replace sylphadoxine pyrimethamine (SP), which had been used previously. In clinical studies, ACT has a much higher success rate in combating malaria than SP, which was reflected in testing carried out by IMPACT programme officials. ACT achieved an efficacy rate of more than 90%, compared with less than 60% for SP.

An effort to investigate the effects of the new malaria regimen is the '*A*rtemether/*L*umefantrine *I*n *V*ulnerable populations: *E*xploring the health impact' (ALIVE) programme. This programme focuses on evaluating the effects of the treatments in children under the age of five.

The outcomes of both the IMPACT and ALIVE programmes will not be limited to Tanzania. They will be of use in other African countries wanting to make sure health investments achieve the greatest possible impact.

BRINGING SCIENCE TO THE PUBLIC

Having recently forged strong links with the Tanzanian government, IHI is also looking beyond the policy-making community to the intended beneficiaries of the institute's efforts – the public.

One initiative under discussion is to add value to IHI's extensive data sets by placing them in a central repository. The repository would be open to public searches. IHI researchers would facilitate the process by creating a simple interface to help people find the data they need.

"The expected audience includes district managers, policy makers, scholars, and other interested parties,"

INNOVATIVE EXPERIENCES IN SCIENCE AND TECHNOLOGY SERIES

Previous case studies in this TWAS profile series of research institutions in developing countries include the Centre of Biotechnology of Sfax (Sfax, Tunisia), the Institute of Medicinal Plant Development (Beijing, China), the Malagasy Institute for Applied Research (Antananarivo, Madagascar), the National Institute of Biodiversity (Santo Domingo de Heredia, Costa Rica) and the Central Drug Research Institute (Lucknow, India). The series was initially funded by a generous grant from the David and Lucile Packard Foundation. To review the case studies online, see www.twas.org. For a print copy of the booklets, contact info@twas.org.

says Henry Mwanyika, an IT researcher working at IHI. Funding for the database initiative has not been obtained, but advocates are hopeful that it will soon be forthcoming.

TRAINING

When the IHI was launched in the 1950s, all trained scientific staff were European. This has changed over time. Today, IHI trains much of its scientific staff in-house. But filling IHI's rapidly growing staff needs has not been easy. In 1981, the institute had a staff of nine, one of whom was an academic. Today, the staff number nearly 600 of whom about 100 are academics.

Since it is not a university, IHI does not award degrees. And Tanzania's own university system is not equipped to fully train the top-class researchers required by an institute of IHI's calibre.

The solution is to partner with academic and funding institutions to create a talent pool upon which the institute can draw. This has advanced efforts for North-South collaboration at IHI, as PhD projects are often 'twinned' with projects in the funder's country, leading to close working relationships.

"We've drawn on funding from a variety of sources to get people trained in other institutions, both local and international," says IHI's director Salim Abdulla. "That has created opportunities that wouldn't otherwise exist."

In addition to training researchers, IHI also plays a key role in the training of health professionals in Tanzania. The Tanzanian Centre for International Health, located adjacent to IHI in Ifakara, sprung from the Rural Aid Centre set up by IHI's founding director Rudolf Geigy. It was handed over to the Tanzanian government in 1978.

The Rural Aid Centre has evolved into a public-private partnership between the Tanzanian Ministry of Health, Novartis Foundation for Sustainable Development and the Swiss Tropical Institute. The centre,

IHI plays a key role in the training of health professionals in Tanzania.

which is now called the Tanzanian Training Centre for International Health, offers courses in partnership with Columbia University, in the US, and the University of Athens, in Greece. From the centre's creation through 2008 it helped train more than 1,700 health professionals for Tanzania.

PRICE OF SUCCESS

IHI receives core funding from development agencies and the Tanzanian government. But most of its budget comes from competitive grants. In 2008–2009, the institute's grant income was USD16.4 million, compared with USD3 million for programme support.

Attracting grant funding has not been a problem for the institute – quite the opposite, in fact. Grant income is expected to increase to USD18 million by the end of 2010, and could grow to USD25 million by 2012–2013.

Reasons for IHI's success are twofold. First, because the institute was never set up as a government institution with a large amount of core funding, fundraising has been one of its highest priorities. "We either win funding or we don't exist," says Salim Abdulla. The other reason is that IHI has worked very hard to diversify its funding portfolio, approaching new partners all the time.

But success has been both a blessing and a curse. Between 2003–2008, IHI's income from grants rose from USD3 million to USD16 million, placing a huge strain on the institute's scientific infrastructure. According to its strategic plan for 2008–2013, IHI will seek to slow the rapid influx of funding and ensure that the grants, which are awarded, include a higher percentage for overhead. For now, the overhead sought ranges from 8% to 15% of the total request. This is much lower than the overhead received by most research organizations in developed countries. In the UK, for example, government funding agencies usually pay researchers 40% overhead.



EFFECTIVE PARTNERSHIPS

IHI would not be where it is today without its fruitful partnerships with foreign institutions and funders.

Not surprisingly, IHI's most important partnership has been with the Swiss Tropical Institute. Until 1981, STI and a private foundation, the Basel Foundation, covered all of the institute's expenses.

STI still co-finances many of IHI's research projects. Moreover, since 2008, STI provides 400,000 Swiss Francs (USD370,000) to the institute in core funding from the Swiss government. In addition, STI provides IHI 100,000-200,000 Swiss francs a year out of its own pocket for non-earmarked block grants.

IHI has worked hard to make sure that it stays Tanzanian at its core.

STI also contributes in-kind to the IHI. For example, it is giving the institute the equivalent of 300,000 Swiss francs over the next 3 years for administrative assistance, largely by paying the salaries of personnel who are seconded to IHI.

IHI has also received funding from a variety of sources, including the Wellcome Trust in the UK, Bill and Melinda Gates Foundation, Canada's International Development Research Council (IDRC), Biotechnology and Biological Sciences Research Council (BBSRC) in the UK, International Atomic Energy Agency (IAEA), Novartis Foundation, UK's Comic Relief Charity, the European Union and the Global Fund to Fight HIV, Tuberculosis and Malaria.

STRIKING A BALANCE

Research institutes in developing countries that depend on external funding often face a dilemma. Taking on contract research can be lucrative. But if such contracts dominate the research agenda, an institute's own scientists can lose their unique voice and become mere technicians and enablers.

IHI has worked hard to make sure that it stays Tanzanian at its core, despite the majority of funding coming from abroad. "It's not about whether we are asked to do something, or if we are saying what we want to do. It's about who we are," says Abdulla.

One way to avoid losing local identity is to run auxiliary studies when conducting research that has external direction. For example, the institute's prestigious RTS,S malaria vaccine trial is a form of contract research. But IHI scientists are conducting additional studies alongside it that cater to their own interests and address local needs. That way, IHI can combine an international profile with local interests.

FUTURE BRIGHT

All things considered, the future looks bright for IHI. There is no sign that the interest from funders will diminish, and IHI's growing relationship with Tanzania's government is likely to strengthen its mission to bring health benefits to the country's entire population.

IHI's extraordinary transformation from a European field station to a Tanzanian centre of excellence has come to symbolize the very best of North-South cooperation in science and has begun to bridge the chasm between science and policy-making not only in Tanzania, but across the African continent. ■

PEOPLE, PLACES, EVENTS

FELTRINELLI PRIZE 2010

• *Accademia Nazionale dei Lincei* in Rome, Italy, has awarded TWAS the 2010 Feltrinelli Prize for it contributions to building scientific capacity in the developing world. The international prize is conferred on individuals or institutions that have made outstanding contributions to knowledge or to addressing critical social challenges. It is sometimes referred to as Italy's Nobel prize. The prize includes €250,000 cash award and is given in memory of Antonio Feltrinelli, an Italian business leader and artist who died in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1942. Since 1950, the award has been given to more than 25 people and institutions, including the *Fondazione Giorgio Cini*, a non-profit cultural institution based in Venice dedicated to restoring the Island of San Giorgio Maggiore, and the Remedial Education Center in Gaza. Fore more information, see www.twas.ictp.it.

PALIS ELECTED TO LINCEI

• **Jacob Palis** (TWAS President and Fellow 1991) has been elected a foreign member of the *Accademia Nazionale dei Lincei* in Rome, Italy. Palis is professor of mathematical sciences at the *Instituto Nacional de Matematica Pura e Aplicada* in Rio de Janeiro, and president of the


Jacob Palis

Brazilian Academy of Sciences. He has also served in various capacities at the International Mathematical Union (IMU), the International Council for Science (ICSU) and the scientific council of the Abdus Salam International Centre for Theoretical Physics' (ICTP), ETH-Zurich, and, currently, at *Collège de France*. In addition to his election to *Lincei*, Palis has been honoured with membership in the Brazilian, Indian, Chilean, French, German, Mexican, Norwegian, Russian and US national academies of sciences.

RUHR UNIVERSITY BOCHUM

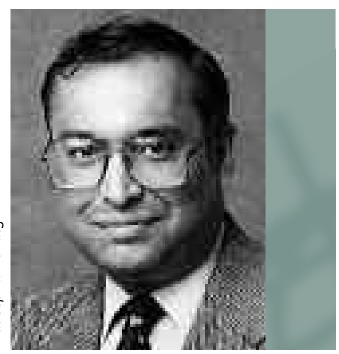
• **Padma Shukla** (TWAS Fellow 2007) has received the first "international chair" at the Ruhr University Bochum (RUB) for his long-standing contributions to the university's efforts to promote international relations. Shukla will assume the role of university "ambassador"


Padma Shukla

for the next five years. He has been asked to advance international and interdisciplinary networking and increase RUB's reputation abroad. The distinction of "international chair" includes an annual stipend of €20,000 for travel and material expenses. Shukla has been a professor of physics and astronomy at RUB since 1973 and a guest professor at the University of Umea in Sweden. He has received over 25 awards and honours for achievements in science and has published more than 1,000 articles in international scientific journals.

GRANT FOR NANOSTRUCTURES

• **Pradeep K. Rohatgi** (TWAS Fellow 1989), a distinguished professor of engineering at the University of Wisconsin-Milwaukee (UWM), USA, has been named director of the newly launched Center for Advanced Materials Manufacturing (CAMM) at UWM. The Center re-


Pradeep K. Rohatgi

ceived a USD1.2 million federal grant to help transfer UWM research in nanostructured materials to industry. The Oshkosh Corporation and other firms will work with CAMM to help scale up production.

YOUNG SCIENTISTS' CONFERENCE

• **TWAS-ROSSA** (Regional Office for Sub-Saharan Africa) will hold

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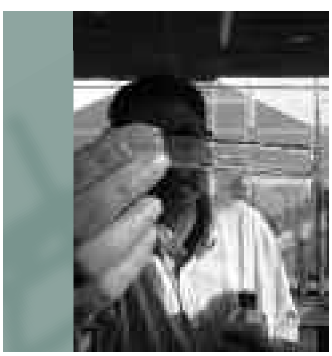
The Role of Networkink

its fifth Young Scientists' Conference in Nairobi, Kenya, from 6-8 December 2010. The theme is "Exchanging Knowledge on Climate Change Impacts and Vulnerability in Africa: The Role of Networking." The conference will provide a forum for scientists to share their research findings on climate change in the region and outline effective networking mechanisms for the advancement of climate change research. For additional information, see www.nairobi.twas.org.

TWAS-ICIPE PARTNERSHIP

• TWAS and *icipe* (African Insect Science for Food and Health) in Nairobi, Kenya, have entered into a partnership to promote insect science for food security and health in Africa and other developing regions. As part of the agreement, *icipe* joins the TWAS-UNESCO Associateship Scheme. It is also the first institution in Africa to become a partner in the TWAS Fellowship Programme. The collaboration will allow the centre to share its expertise with the associates and young researchers who will be hosted there. It will also enable researchers at the centre to benefit from knowledge and resources in other developing countries. For more information, please see www.icipe.org.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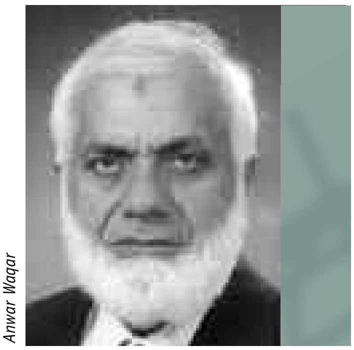
IN MEMORIAM

• **Sang Soo Lee** (TWAS Fellow 1988) died on 7 May at age 84. Lee was professor emeritus in the Department of Physics at the Korea Advanced Institute of Science and Technology (KAIST) in Seoul. During his long and illustrious career, Lee held a number of prestigious positions, including director general of the Office of Atomic Energy, Korea, and council member of the United Nations University (UNU) in Japan. He also served as president of KAIST, the Korea Physical Society, and the Optical Society of Korea. For his outstanding contributions to the field of physics, Lee received the Medal Moran for Distinguished Scientific Achievement, Korea, the Presidential Award of Science, Korea, and the Medal Mugunghwa (Magnalia), the highest medal the Korean Government gives to a Korean civilian for distinguished service in science.


Sang Soo Lee

• **Anwar Waqar** (TWAS Fellow 1991) died on 14 June at age 68. He was senior professor of cell and molecular biology at the Dr. Panjwani Centre for Molecular Medicine and Drug Research (PCMD), International Center for Chemical and Biological Sciences, at the University of Karachi in Pakistan. He contributed greatly to strengthening the PCMD throughout his career. In recognition of his accomplishments, he received many honours, including the rank of National Professor by Pakistan's Higher Education Commission, the Sitara-i-Imtiaz, Tamgha-i-Imtiaz, Convocation Medal from Flinders University in South Australia and the 7th Khwarizmi International Prize from Iran. He was a member of a number of prestigious organizations, including the Pakistan Academy of Medical Sciences, the Institute of Biology, London, and the World Academy of Art and Science and the Islamic World Academy of Sciences.


Anwar Waqar

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 900 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.

In 1988, TWAS facilitated the establishment of the Third World Network of Scientific Organizations (TWNSO), a non-governmental alliance of some 150 scientific organizations in the South. In September 2006, the foreign ministers of the Group of 77 and China endorsed the transformation of TWNSO into the Consortium on Science, Technology and Innovation for the South (COSTIS). COSTIS's goals are to help build political and scientific leadership in the South and to promote sustainable development through broad-based South-South and South-North partnerships in science and technology. ···› **costis.g77.org**

TWAS also played a key role in the establishment of the Third World Organization for Women in Science (TWOWS), which was officially launched in Cairo in 1993. TWOWS has a membership of more than 2,500 women scientists from 87 developing countries. Its main objectives are to promote research, provide training, and strengthen the role of women scientists in decision-making and development processes in the South. The secretariat of TWOWS is hosted and assisted by TWAS. ···› **www.twows.org**

Since May 2000, TWAS has been providing the secretariat for the InterAcademy Panel on International Issues (IAP), a global network of 100 science academies worldwide established in 1993, whose primary goal is to help member academies work together to inform citizens and advise decision-makers on the scientific aspects of critical global issues. ···› **www.interacademies.net/iap**

The secretariat of the InterAcademy Medical Panel (IAMP), a global network of 65 medical academies and medical divisions within science and engineering academies, relocated to Trieste in May 2004 from Washington, DC, USA. IAMP and its member academies are committed to improving health worldwide, especially in developing countries. ···› **www.iamp-online.org**

www.twas.org