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TWAS newsletter

THE NEWSLETTER OF THE THIRD WORLD ACADEMY OF SCIENCES

TWAS 20th Anniversary Conference

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AT THE OPENING CEREMONY OF TWAS'S 9TH GENERAL CONFERENCE AND 14TH GENERAL MEETING IN BEIJING, CHINA, C.N.R. RAO, TWAS PRESIDENT, AND LU YONGXIANG, PRESIDENT OF THE CHINESE ACADEMY OF SCIENCES AND VICE PRESIDENT OF TWAS, SHARED THE PODIUM. RAO PRESENTED A ROUND-UP OF THE PAST AND PRESENT OF THE ACADEMY, WHILE LU OUTLINED HIS VISION OF THE FUTURE OF TWAS, PROVIDING BACK-TO-BACK 'KICKOFF' VIEWPOINTS TO THE ACADEMY'S 20TH ANNIVERSARY CELEBRATION.

C.N.R. RAO

TWAS Yesterday and Today

On 15 October 2004, just one day before the opening of the TWAS 9th General Conference and 14th General Meeting held in Beijing, China successfully launched the manned spacecraft, *Shenzhou-V*.

This event – and the launch several days later of a second Earth resources satellite as part of a collaborative initiative between China and Brazil – is evidence of the great strides that the Chinese scientific community has made in recent years.

TWAS and the Chinese scientific community are old friends. It is a friendship that TWAS cherishes – not only because of the help that China has provided to our Academy over the years, but because of the critical role that China has played in science-based development throughout the developing world.

The Academy first met in the Great Hall of the People in 1987, marking the first time TWAS held a conference away from its secretariat in Trieste. We were less than four years old then – a fledgling organization, with fewer than 120 members, exploring ways to raise our profile and influence.

We may have been small in numbers and resources, but we had a compelling vision – and it was that vision that pushed us forward in a world largely indifferent to our cause.

As the Academy's twenty-year history reveals, TWAS has made significant contributions towards realizing its vision, and today the Academy continues to help shape the advancement of science and science-based development in the South in many different ways:

- Our membership now totals more than 700 – representing a large and growing pool of

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eminent scientists throughout the developing world who provide a strong voice in support of our activities and goals.

- Our capacity building initiatives rank among the most important in the developing world.
- Our prizes are among the most coveted in the South.
- Our exchange programmes have been instrumental in strengthening South-South and South-North partnerships.
- Our affiliated organizations – the Third World Network of Scientific Organizations (TWNSO), the Third World Organization for Women in Science (TWOWS), and the InterAcademy Panel on International Issues (IAP), all of which operate under the administrative umbrella of the Academy – are making important contributions to science both in their own right and in partnership with TWAS.
- Our publications are increasingly recognized as valuable sources of information on science in the developing world, both in the South and North.
- And our role in such international scientific events as the World Summit for Sustainable Development (WSSD) in Johannesburg (2002) and the World Summit on the Information Society (WSIS) in Geneva (2003) and Tunis (2005) is making the Academy a prime player in international science circles.

With such programmes in place, TWAS has truly become the voice for science in the developing world.

That does not mean that TWAS has neglected its major role in supporting the basic sciences. Indeed the 20th anniversary conference held in China presented evidence of the Academy's continual focus on assisting developing world scientists in their efforts to pursue excellence in science.

Like all previous TWAS conferences, a central feature of the conference was the official awarding of the TWAS Prizes. We were honoured to have China's President Hu Jintao personally present these awards. President Hu Jintao's speech at the opening ceremony of the conference to an audience of 3,000 in the Great Hall of the People (see pages 8-9), provided the most compelling highlight of what has come to be regarded as TWAS's most successful conference to date (for a detailed summary of the conference, see pages 10-19).

We therefore extend our hearty thanks to the Chinese government – and to the Chinese Academy of Sciences – which not only provided financial support for the event, but also served as the local organizers. They have been true partners in this effort. It is no exaggeration to say that the meeting would not have taken place without their assistance.

In the same way, we must thank our various partners for the success that the Academy has achieved over the past two decades. Thus, in a real sense, the TWAS 9th General Conference and 14th General Meeting, which marked the Academy's 20th anniversary, was not only a celebration of our accomplishments but also a symbolic reaffirmation of the enduring value of cooperation.

First and foremost, this means acknowledging the role of the Italian government, which has generously supported TWAS since the Academy's inception.

We are also thankful to UNESCO, which provides us with critical help in overseeing

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personnel and budget matters and which works closely with us on a host of programmatic activities.

In addition, we extend our sincere appreciation to our programmatic funders, including the Swedish International Development Cooperation Agency (Sida-SAREC), the Kuwait Foundation for the Advancement of Sciences (KFAS), the OPEC Fund for International Development, and a host of other major foundations and donors – a list that I am happy to report has been expanding each year.

We hope that we have justified their investment and we look forward to continuing our close relationships with these and other institutions in the future.

The Academy also looks forward to building its endowment fund through additional contributions and interest earned on the principal. We are now three-quarters of the way towards our target of US$10 million. I firmly believe that we can reach this goal – and even exceed it – in the next few years. That is why, in Beijing, the TWAS Council agreed to increase the target for the endowment fund to US$15 million and set 2008 as the year we hope to reach this goal. The list of governments that have made donations to the endowment fund is lengthy and growing, and we thank them all for the confidence that they have displayed in the Academy's future.

As we celebrate the Academy's 20th anniversary and look back over our past successes, we are also keeping a keen eye on the future.

The countries of the South must progress by charting a course of science-based development best suited to each nation. It is important that they do not blindly copy what is fashionable in the advanced countries without fully understanding all aspects of the relevant problems and strategies required.

With the right strategies and policies in place, and with help and advice from organizations like the Academy, it is my fondest hope that many developing countries will be well on their way to becoming developed in the next 20 years.

On this 20th anniversary of our Academy, therefore, we have a dream that:

- Developing countries will increase their investment in research and development to at least 1 percent of their gross domestic product within the next 5 years.
- Poverty and malnutrition will be eradicated in 10 years.
- Polio will be eliminated in the next 5 years.
- Safe drinking water will be provided to every human being in the next 5 years.
- Illiteracy will be eliminated in the next 5 years.

We clearly have a lot of work to do. But through commitment and collaboration, especially South-South collaboration, I am confident that the work of the Academy over the next 20 years will be even more significant than our acheivements of the previous 20 years – ultimately advancing our goals in ways that will make our 40th anniversary even more of a celebration than this joyous occasion.

C.N.R. Rao
President
Third World Academy of Sciences

LU YONGXIANG

TWAS Today and Tomorrow

The convening of the 14th General Meeting, 9th General Conference and 20th anniversary celebrations of TWAS, and the 8th General Assembly of TWNSO in Beijing generated great excitement among Chinese scientists and was a great inspiration to the entire Chinese scientific community.

China has always sought to promote scientific collaboration for development. For example, in 1987, the Chinese Academy of Sciences launched its South-South Cooperation Fund that has since enabled more than 600 scientists from developing countries to travel to China for collaborative research with our scientists. In addition, the fund has enabled more than 5,000 Third World scientists to attend symposia, workshops, seminars or training courses held in China.

Since its inception 20 years ago, China has also maintained close ties with TWAS. More than 100 scientists from different research institutes and universities across the country have been elected TWAS Fellows.

In a message written in March 2001, former Chinese President Jiang Zemin praised the contributions of TWAS to advancing the development of science in Third World countries. The address of President Hu Jintao at the opening ceremony of the TWAS 9th General Conference in Beijing reaffirmed the Chinese government's deep concern and continued support for the development of science and technology in all Third World countries (see pages 8-9).

In the past 20 years, TWAS has played a critical role in promoting South-South and South-North cooperation. Today, in the context of an increasingly globalized and yet polarized world – in this era of knowledge-based economies – TWAS should accept higher

WHAT'S IN A NAME?

A proposal to rename the Third World Academy of Sciences (TWAS) was vigorously debated at the TWAS general assembly in China. The name-change put on the table for discussion was The World Academy of Sciences, which would enable the Academy to keep its acronym – TWAS. The acronym, in many ways, has become the Academy's brand name, and is referred to more often than the full name itself. Proponents of the new name also suggested that the Academy, which represents 80 percent of humanity and which now has more than 700 members from over 80 countries, is an organization that has become truly global in scope. However, a number of members expressed reservations about changing the name without canvassing the full membership for their opinions. They were concerned that the Academy's name carried both historical and emotional weight and should not be changed without deep reflection and consideration. The discussion in Beijing clearly indicated the need for additional dialogue before a decision is made. As a result, the TWAS Council agreed to circulate an announcement describing the proposed name-change in the TWAS Newsletter *and to hold another round of discussions at the next general meeting of the Academy, scheduled to take place in Trieste, Italy, on 22-24 November 2004.*

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expectations for itself and embrace a new, greater mission. I would like to take this opportunity to present the following proposals on the future development of TWAS:

- *TWAS should help devise a 'road map' for scientific globalization.* It should explore more effective pathways of cooperation for the creation, development and sharing of knowledge and technology between the North and the South, and seek to transform heated international economic competition into calm collaborative efforts for sustained development. At the same time, the Academy should promote access to scientific and technological information as an indispensable right that helps advance economic growth and national security. TWAS should also voice strong support for giving developing countries the freedom to pursue their own policies and programmes in ways that promote the development of their own science and technology infrastructure and expertise.

- *TWAS should help establish effective mechanisms for nurturing scientific exchanges, cooperation and shared development among developing countries.* Scientific capacity throughout much of the developed world remains weak. Countries in the South are often handicapped by inadequate investments in research and development, poor scientific infrastructures, chronic brain drain problems, insufficient intellectual property rights protection, and weak technology transfer programmes that fail to reap the full commercial benefits of research.

- *TWAS should investigate new opportunities and challenges faced by developing countries as a result of the latest scientific and technological innovations and identify ways of meeting these opportunities and challenges.* A multi-faceted technological revolution led by rapid advances in information technology and biotechnology is having a dramatic impact on our global economy. Driven by scientific advances, a full range of new high-tech industries will spring up in such areas as information and communication technology, biotechnology, nanotechnology, advanced materials and manufacturing, renewable energy resources, the environment, and space and marine technologies, all of which will lead to the sustained growth of the global economy. Developing countries must take advantage of this opportunity to increase their competitiveness and reduce the gap in material well-being between themselves and developed countries.

- *TWAS should advocate and popularize the concept of cultural diversity.* Scientific research thrives in a free and open environment where multiple cultures interact. Therefore, nurturing cultural diversity and different ways of scientific thinking will create new opportunities for scientific innovation. TWAS fellows should encourage international exchanges of information and personnel and promote the blending of various cultures through global scientific inquiry. These efforts, in turn, will improve cross-cultural understanding, creating an atmosphere more conducive to the development of science and technology.

- *TWAS should organize an in-depth study on the conditions of, causes for, and solutions to the 'poverty' of scientific knowledge in developing countries.* 'Knowledge poverty' is an important factor that restricts economic growth throughout the South. The key to accelerating development in developing countries is to launch a war against knowledge poverty, invest in human capital and knowledge infrastructure, and upgrade peoples' ability to generate, absorb and apply information.

- *TWAS should take the lead in discussing and planning strategies for scientific cooperation and exchange between countries of the South, specifically by voicing its support for reliable funding sources and the mobility of personnel.* Such a programme should comply with the conditions and concerns of developing countries while conforming to international practices.

The Chinese Academy of Sciences was greatly honoured to host TWAS's 9th General Conference and 14th General Meeting – twin events marking the 20th anniversary of the creation of TWAS. Let us pay our highest respect to the founder of TWAS, Nobel Laureate Abdus Salam, as well as to all the scientists, government officials, associates and friends who have made contributions to the foundation and development of the Academy, which has emerged as one of the most important institutions for the promotion of both science and science-based development not just in the South but throughout the world. ■

Lu Yongxiang
President, Chinese Academy of Sciences
TWAS Vice President

SCIENCE FOR ALL

HU JINTAO, PRESIDENT OF CHINA, PRESENTS A BROAD-RANGING VIEW OF THE ROLE OF SCIENCE IN THE SOUTH.

On 15 October 2003, China successfully launched the *Shenzhou-V* spacecraft, sending the first Chinese astronaut into orbit. This represents a major contribution of the Chinese people to the world's aerospace programme, and marks another important step for the Chinese people in scaling the summit of world science and technology.

Today, the vital role that scientific and technological innovation play in promoting economic and social development is increasingly recognized. Put simply, science and technology fuel economic growth and social development.

Equally important, breakthroughs in science and technology deepen our understanding of nature and ourselves. Science education, moreover, enhances both our overall knowledge and the cultural and moral aspects of our societies. In addition, technological innovation and industrialization promote economic growth now and in the future.

In brief, advances in science and technology increase the ability of humankind to understand and exploit nature, and open up new spheres for the creation of happy, comfortable and rewarding lives.

Our modern, science-based civilization moves forward due to the joint efforts of all nations and provides a sterling demonstration of human creativity driven by the interaction and integration of the diverse wisdom and cultures of the world.

Every great civilization has influenced and contributed to the advancement of science and technology. History shows that the exchange of information among different civilizations stimulates human creativity as a whole and thus substantially promotes scientific and technological progress.

In today's world, the rapid development of information technology has made human interaction on a global scale easy and convenient. We should take advantage of electronic communication tools to strengthen exchanges and cooperation in science and technology in order to make our world even more creative and prosperous.

The Chinese government, therefore, places great importance on international scientific exchange and cooperation. We currently have scientific exchange programmes with more than 150 countries and

regions, and have signed agreements for scientific cooperation with nearly 100 countries. Exchange and cooperation between China and other developing countries in science and technology has been rich, diverse and fruitful.

Therefore we will continue to promote multi-form, multi-level and multi-channel scientific exchange and cooperation programmes with other countries by encouraging both governmental and nongovernmental initiatives.

Largely through their own efforts, some developing countries have recently made remarkable progress in science. However, largely due to historical factors, a wide gap continues to exist between developing and developed countries, not only in terms of economic development, but also in cultural attitudes towards science and technology.

We must do all that we can to close this gap. Developing countries must learn from developed countries and move as quickly as possible towards scientific development. Indeed developing nations could actually surpass today's science and technology leading nations by learning, importing, digesting and assimilating advanced scientific knowledge from the developed countries – but only if they do so relentlessly and systematically.

Although developed countries are leading the way, the diversity and complexity of science and technology provide the South with many opportunities to develop. We can find niches in some areas by taking advantage of our own strengths. For each developing country, a scientific development strategy adapted to its own unique national circumstances should be pursued that takes advantage of its scientific talents, domestic markets and local resources.

With 1.3 billion people, China is the most populous country in the world. Over the past 25 years, China has greatly advanced its economic and social development, leading to sustained improvements in the living standards of its people.

One of the most important reasons for our success is the great attention we have paid to the powerful role of science and technological innovation in economic and social development.

China has embraced a national strategy for rejuvenating the country through science and education. This strategy attaches importance to both fundamental research and the development of applied technologies that are critical to economic and social development.

On the one hand, we focus on high-tech research; on the other, we seek to quickly disseminate advanced 'applied' technologies throughout all sectors of the economy. We also seek to learn about and import advanced technologies from other countries while simultaneously enhancing our own innovative capacities.

We know that to achieve our goals, we must tenaciously pursue policies that serve our people and the global community – policies that put science and technology to work for the benefit of all humankind.

Hu Jintao
President
The People's Republic of China

THE THIRD WORLD ACADEMY OF SCIENCES (TWAS) CELEBRATED ITS 20TH ANNIVERSARY IN GRAND STYLE. THE SITE WAS BEIJING, CHINA, AND THE SETTING WAS THE GREAT HALL OF THE PEOPLE, WHERE MORE THAN 3,000 PEOPLE WERE IN ATTENDANCE, INCLUDING 200 MEMBERS OF THE ACADEMY.

Standing before 3,000 people in the Great Hall of the People in Beijing on 16th October, China's President Hu Jintao presented the opening address to the 9th General Conference and 14th General Meeting of the Third World Academy of Sciences (TWAS). The event, which took place from 16th to 19th October 2003, marked the 20th anniversary of the Academy.

TWAS AT TWENTY

Earlier that morning, China and the world welcomed China's first astronaut, Lieutenant-Colonel Yang Liwei, back to Earth after a successful 21-hour journey in which he circled the globe 14 times logging more than 600,000 kilometres along the way. The space capsule *Shenzhou-V* (meaning 'divine vessel') landed at the projected site in North China's Inner Mongolia, about 1,500 kilometres from Beijing.

The coincidence of China's first manned space flight and the 20th anniversary of TWAS served as an unintentional but fitting reminder of how far science and technology have come in the developing world since TWAS's inception in 1983.

Yet, much of the discussion at the TWAS anniversary conference focused on the additional work that needs to be done to ensure that science and technology continues to spur sustained development in nations throughout the South and not just among a select number of developing countries.

In his address, President Hu Jintao noted that "TWAS has made outstanding contributions to the development of science and technology in the South," and that he expected the Academy "to play an even greater role in the global science in the years ahead."

Highlights of the TWAS 9th General Conference and 14th General Meeting included:

- The formal ceremony welcoming TWAS's newest members – the 'class of 2002', consisting of 43 scientists from 19 countries. At the same time, the membership approved the election of 49 new members from 21 countries. Included in this class of 2003 are scientists from Tajikistan and Uzbekistan, marking the first time that scientists from these nations have been elected to the Academy. The new members will be formally welcomed into the Academy at the 15th General Meeting scheduled to take place at the TWAS secretariat in Trieste from 22 to 24 November 2004. TWAS's total membership now stands at 710. For additional information about

OPENING SESSION

In addition to President Hu Jintao, the opening session of the TWAS general assembly included presentations from Xu Guanhua, China's Minister of Science and Technology; Wang Quishan, Acting Mayor of Beijing; Thomas Östros, Sweden's Minister of Education and Science; Jane Lubchenco, president of the International Council for Science (ICSU); Yves Quéré and Eduardo Krieger, co-chairs of the InterAcademy Panel on International Issues (IAP); and Gabriele Menegatti, Italy's ambassador to China.

TWAS's membership, see *www.twas.org* under the 'Membership' link.

• Election of the TWAS Council for 2004-2006. The new council consists of: C.N.R. Rao, president, and Jacob Palis, secretary general, both of whom were re-elected; José L. Morán López (Mexico), who was elected treasurer replacing Ali Abdullah Al-Shamlan (Kuwait); vice presidents: Lydia P. Makhubu (Swaziland), representing the African region; Ismail Serageldin (Egypt), representing the Arab region; Abdul Hamid Zakri (Malaysia), representing central and south Asia; Lu Yongxiang (China), representing east and southeast Asia; Jorge E. Allende (Chile), representing Latin America and the Caribbean region; plus council members: Ali Al-Shamlan (Kuwait), Eugenia M. del Piño Veintimilla (Ecuador), Federick Ian B. Kayanja (Uganda), Mohamed Ataur Rahman (Pakistan), and K.R. Sreenivasan (USA). For more information about the TWAS Council, see *www.twas.org* under the 'Council' link.

• The official launching of TWAS regional offices in Rio de Janeiro, Brazil; Alexandria, Egypt; Bangalore, India; and Nairobi, Kenya, which joined the already functioning regional office in Beijing, China. These offices will be asked to organize meetings, identify promising scientists within their regions, and engage the public and media in scientific issues of importance to their societies. In brief, the offices will seek to raise the level of activities and the public profile of the Academy in the regions in which they are located. The TWAS secretariat will provide each office with up to US$10,000 annually to help defray overhead and programmatic costs. For more information about TWAS's regional offices, contact *info@twas.org*.

• The organization of a session devoted to the history of TWAS on the occasion of its 20th anniversary that included presentations from the Academy's 'founding fellows' – Muhammad Akhtar (Pakistan); Mambillikalathil Govind Kumar Menon (India); and Autar Singh Paintal (India) – who reminisced about TWAS's past and marvelled at how far the Academy has come

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over the past two decades. All paid homage to Abdus Salam, the Pakistani-born Nobel Laureate, who spearheaded the creation of the Academy and served as its president during the first decade of its existence. Paolo Budinich, who worked closely with Salam in efforts to launch both the International Centre for Theoretical Physics (ICTP) in the 1960s and then TWAS twenty years later, spoke about the creation of these two organizations in his Abdus Salam Medal Lecture. He also described how ICTP and TWAS have helped lay the foundation for the development of the Trieste System, a constellation of science research centres in Trieste dedicated to the promotion of science in the developing world. The Trieste System has earned an international reputation for its contributions to scientific capacity building in the South and for its ability to build strong South-South and South-North linkages in science and technology. A history of the first 20 years of TWAS has been drafted and will be published later this year.

- The holding of the Third World Network of Scientific Organizations' (TWNSO) 8th General Assembly. At the assembly, it was announced that TWNSO has added two new members – the Ministry of Education in Cameroon and the Academy of Scientific Research and Technology, Egypt. That brings TWNSO's total membership to 160 organizations – largely ministries of science and technology, research councils, and science academies in the developing world. At the programmatic level, TWNSO has been active in a number of South-South and South-North partnerships, including a grants programme for developing-world institutions to pursue joint research projects (supported by the OPEC Fund). It has also engaged in broad-ranging initiatives examining 'best practices' in the application of science and technology to address critical economic, environmental and social issues in the South. Partnering institutions in this effort include the United Nations Development Programme's (UNDP) Special Unit for Technical Cooperation among Developing Countries (TCDC), the United Nations Environment Programme (UNEP), Global Environment Facility (GEF) and the World Meteorological Organization (WMO). For additional information, see *www.twnso.org*.

FIFTY TIMES FOUR

At the TWAS 20th anniversary conference, Brazil, China, and Mexico announced that they would each sponsor 50 research fellowships a year under the TWAS research fellowship programme. These nations join India, which agreed last year to sponsor 50 fellowships annually in the field of biotechnology. This initiative, now the world's largest South-South exchange research programme, promises to grow even larger in the years ahead as additional nations come on board. For additional information, contact info@twas.org.

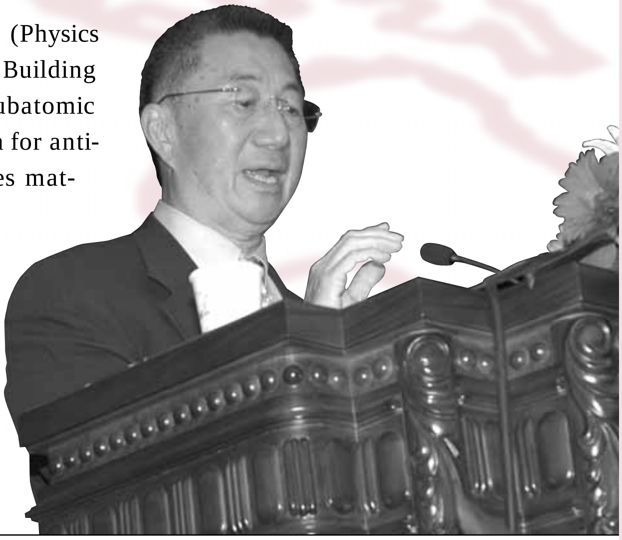
• TWNSO also held a special ministerial session examining the state of science and technology and, more specifically, governmental science policies in the developing world. Fifteen ministers of science and technology, including officials from China, Jordan, Nigeria, North Korea, and Rwanda, participated in the event. All spoke of the need to deepen South-South scientific cooperation through exchange programmes and joint research projects. "Science and technology is at the core of our knowledge economy," noted Roberto Amaral, Brazil's Minister of Science and Technology at the time, "and developing nations must do all that they can to invest in such endeavours to ensure their long-term economic and social well-being." Xu Guanhua, China's Minister of Science and Technology, observed that his nation's ability to sustain a rapid rate of economic growth over the past two decades has been based on a strong foundation in science and technology – a foundation consisting of vastly improved policies (enabling research to take place in an environment that promotes and rewards excellence); increased funding (the government's annual budget for science and technology has more than doubled over the past 5 years and now amounts to 1.2 percent of China's gross domestic product); the promotion of national laboratories and universities that extol excellence; sustained investments in such key development sectors as agriculture, energy and health; and the active encouragement of South-South and North-South scientific collaboration. For selected summaries of the ministers' comments, see pages 20-23.

BEIJING DECLARATION

TWAS's 14th General Meeting and 9th General Conference ended with the approval of the Beijing Declaration, which called on the Academy to expand its role as the 'voice of science in the South'. The full text of the declaration may found on pages 49-51.

• Participation in a nationwide 'popular' science programme, broadcast 'live' on the internet and the following day on CCTV (China's Central Television network). The programme, entitled 'Science and Society', featured a distinguished panel that included C.N.R. Rao, president of TWAS; Bruce Alberts, president of the US National Academy of Sciences; and Noble Laureate Hartmut Michel (Chemistry 1988). Special focus was placed on the challenging career options that await students who choose to study science. Science, all the presenters noted, is the shared legacy of all nations and its future depends on contributions from all parts of our globe. It is a field, the presenters concluded, in which personal rewards and social benefits often find themselves in harmony.

• A lecture by Nobel Laureate Samuel C.C. Ting (Physics 1976). The talk, 'In Search of the Fundamental Building Blocks of Nature', focused on the discovery of such subatomic particles as leptons and quarks and the current search for antimatter. The Big Bang theory, explained Ting, requires matter and antimatter to be present in equal amounts at the very beginning of the universe. However, cosmic antimatter cannot be detected on Earth because matter and antimatter would annihilate each other in the atmosphere. Ting went on to describe an international project, of which China is a part, to search for antimatter using special detection equipment – alpha magnetic spectrom-



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eters (AMS). The first AMS, launched in 1998, is the only large-scale experiment on the international space station and it marked the arrival of state-of-the-art particle physics detection technology in space. A new AMS, based on the latest superconductor technology, is now being prepared, in part by the Chinese Academy of Sciences' Landing Vehicle Technology programme. Nobody is sure what the AMS will discover, explained Ting, but technological development is firmly rooted in basic scientific research. "If a society restricts itself to technology transfer, then clearly, after some time, there will be nothing left to transfer if no new insights and phenomena are discovered by basic research," said Ting. As an example, Ting highlighted one spin-off from the latest AMS – an electronics system that runs ten-times faster than current space electronics systems.

• The organization of a special session on the Severe Acute Respiratory Syndrome (SARS) outbreak in China that, during the winter of 2002 and early spring 2003, afflicted more than 8,000 people worldwide, some 5,000 of whom resided in China. SARS killed nearly 10 percent of its victims. Discussions focused on the early incidence of the disease and the global response that eventually halted its spread. During the session, Zhong Nanshan, director of the Guangzhou Institute of Respiratory Diseases, who was among the first researchers to identify the clinical existence of SARS, outlined the treatments that were administered to SARS patients in China and current guidelines for dealing with any future infections. Christophe Fraser, a researcher at Imperial College, London, UK, who is an expert in the mathematical modelling of disease epidemics, highlighted the importance of tracing SARS patients' contacts and rapidly isolating those who display symptoms of the disease. In the case of SARS, symptoms appear before a patient is infective. Therefore transmission of the disease can be prevented by the centuries-old strategy of separating patients from the general population. Both speakers agreed that, because of the detection measures that have been put in place, another major worldwide SARS epidemic is unlikely. Nevertheless the threat of future global epidemics – or pandemics – instigated by yet unknown bacteria and viruses remains real. SARS, the speakers observed, provided a significant warning of the risks to public health posed by the densely populated, 'jet-setting' world in which we live. For further details, see 'Session on SARS', pages 30-33.

ENDOWMENT FUND

The TWAS endowment fund, launched in 1993, has now reached US$7.5 million, three-quarters of its way toward its original target of US$10 million. In Beijing, the TWAS Council agreed to raise the target to US$15 million and cited 2008 as the year that it hoped the Academy would reach this goal.

• Five presentations by renowned experts that summarized major scientific advances in their respective fields and that sought to forecast areas in which future advances are most likely to take place. Jorge E. Allende (Chile), in 'Challenges of the Post Genomic Era', suggested that biological research is experiencing a paradigm shift from a reductionist view to a holistic and integrated analytical approach – a trend that he believes will increasingly involve mathematics. Phillip Griffiths (USA), in 'Mathematics for a New Millennium', echoed this sentiment, contending that mathematics will be integrated into virtually every aspect of modern science, reenforcing its role as the universal language of science (for further details, see pages 39-45). Anthony Cheetham (UK and USA), 'Chemistry in the 21st Century', and Narendra Kumar (India), 'Physics of the Future', examined the future of chemistry and physics respectively, envisioning increasingly important benefits from the development of such fields as nanotechnology, which will depend, in part, on more a profound understanding of both disciplines (see 'Small Scales…Big Opportunities', pages 34-38). And Yiyi Li (China), in 'Material Processing and Computer Simulation', explored technological progress in her native country and analysed how recent developments in computer software, for example, have been applied to the construction of precision valves used in industrial steel production.

CONGRATULATORY MESSAGES BOOK

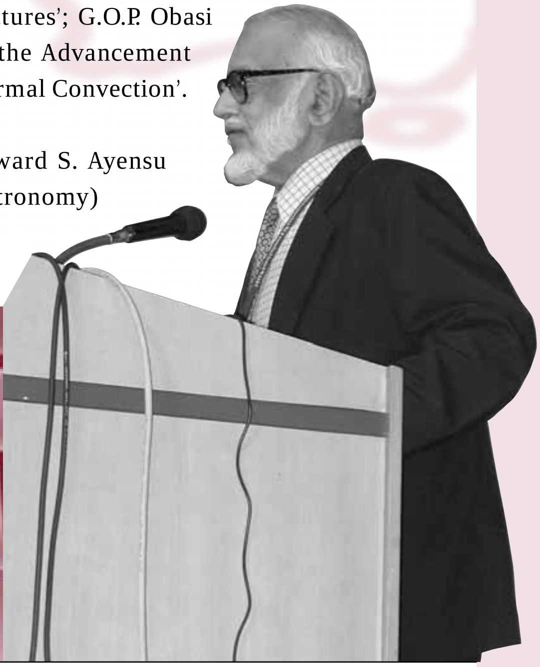
As part of its efforts to celebrate its 20th anniversary, TWAS published a book of congratulatory messages. The book includes good wishes for the Academy's continued success sent by more than 100 prominent individuals, including three heads of state, eight ministers, and 12 heads of international organizations.

• Lectures by the 2003 TWAS Prize winners: Wang Zhizhen (China), 'Thiol-Protein Oxidoreductases as Molecular Chaperones'; Peng Shie-Ming (Taiwan, China), 'From Metal String Complexes to Metal Wires'; Ranulfo Romo (Mexico), 'Sensing Without Touching: Psychophysical Performance Based on Cortical Microstimulation'; José A. de la Peña (Mexico), 'Stable Representations of Quivers'; and Deepak Dhar (India), 'Sandpile Models of Self-Organized Criticality'. The presentations, which ranged from an examination of the assembly and disassembly of proteins to the creation of molecular metal wires and their potential application to the development of molecular switches, reflected the breadth of excellence in research now taking place in the developing world. For a full list of the lecturers and their topics, see *www.twas.org*.

• An announcement of the names of the 2003 TWAS Prize winners: Fu Ting-Dong (China) for agricultural sciences; Mayana Zatz (Brazil) for basic medical sciences; Rafael Palacios de la Lama (Mexico) for biology; Eluvathingal Devassy Jemmis (India) for chemistry; Kaigala Venkata Subbarao (India) for earth sciences; Welington Celso de Melo (Brazil) for mathematics; Rodolfo Gambini (Uruguay) for physics; and Mayra de la Torre (Mexico) for engineering sciences. The prizes will be presented at TWAS's 15th General Meeting to be held from 22-26 November 2004 in Trieste.

• Presentations by the 2003 TWAS Medal Lecture winners: Chunli Bai (China) on the 'Characterization and Preparation of Two-Dimensional Nanostructures'; G.O.P. Obasi (Nigeria) on the 'Contribution of the Earth Observing System to the Advancement of the Atmospheric Sciences'; and K.R. Sreenivasan (USA) on 'Thermal Convection'.

• Announcement of the 2004 TWAS Medal Lecture winners: Edward S. Ayensu (Ghana, biology); José L. Morán López (Mexico, physics and astronomy) and Sheikh Riazuddin (Pakistan, biotechnology).



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In Beijing, TWAS members also a received a draft copy of the Academy's third Strategic Plan covering the years 2004-2006. The plan, which acknowledges the growing influence of TWAS in the global scientific community, concentrates on a number of targeted initiatives designed to strengthen the Academy's impact in the years ahead. The preface noted that the first plan (1994-1996) "focused largely on formalizing procedures and practices and on devising strategies for individual and institutional capacity building." The second plan (1997-2000) "concentrated on building scientific capacity in the South; facilitating South-South and South-North cooperation in science and technology; and reaching out to other scientific bodies and international organizations to forge effective partnerships for science-based sustainable development."

The Academy's third strategic plan, in turn, calls on TWAS to broaden its influence even further by devising and implementing strategies that will enable the Academy to pay greater attention to problem-solving and demand-driven research. Goals include:

• Raising the membership of TWAS to 800 by 2008 and making special efforts to recruit a larger number of female scientists, scientists from least developed countries (LDCs) and social scientists.

• Responding to the needs of young scientists by continuing to strengthen the research grants programme and by increasing the number of fellowships for doctoral candidates and postgraduate studies.

• Enhancing South-South cooperation, especially by fostering greater collaboration between scientifically proficient countries and scientifically lagging countries in the South. Efforts will be made to increase the number of postgraduate and visiting fellowship programmes in order to help nurture the exchange of individual scientists in the South and lay the groundwork for joint research projects among scientific institutions in the developing world.

• Harnessing science and technology for sustainable development through South-South and South-North partnerships. This goal will be advanced by strengthening the Academy's partnerships with the International Science Council (ICSU) and the Initiative for Sustainable Development in Science and Technology (ISTS) at Harvard University and developing programmes with Leadership in Environment and Development (LEAD), headquartered in London, that are designed to bring the scientific and economic development communities closer together.

In discussions among TWAS members that took place during the Academy's General Assembly, several major 'look-ahead' themes were raised.

TWAS's newly elected vice president, Jorge E. Allende, for example, noted that the Academy should place increasing emphasis on science education as part of a larger strategy to promote public understanding of science and to gain greater citizen support for scientific research. Jacob Palis, TWAS's secretary general, noted that TWAS should continue to emphasize the need to support science in the least developed countries (LDCs) and not to focus exclusively on the South's most scientifically proficient countries. "If the Academy doesn't try to help the least fortunate among us," he noted, "then who will?" Palis also emphasized the importance of the Academy's South-South fellowship programme. "The willingness of Brazil, China, India and Mexico to fund 50 fellowships a year for students from developing countries to study at universities in the South outside their own countries," he observed, "marks a historic step forward for South-South cooperation that is likely to have a profound impact on science in the years ahead."

Ana Maria Cetto (TWAS Fellow 1999) asserted that TWAS should make a special effort to ensure that the publications and research findings of Southern scientists are integrated into global research agendas. "Too often," she observed, "research in the developing world is relegated to a junior, subsidiary status in international science initiatives despite the fact that a growing body of world-class work is being done in Southern institutions."

Meanwhile, both Manuel Limonta (TWAS Fellow 1995) and Juan Roederer (TWAS Associate Fellow 1991) urged the Academy to incorporate science management into its research and training activities. "As both funding and accountability increase," Roederer said, "it is important that scientists have the skills not only to do research but to manage it, particularly as projects become larger, more complex and more interdisciplinary. Unfortunately, that kind of training is often not available in graduate school. TWAS should help fill this important void in the skill-set of scientists – especially scientists in the South – by organizing training workshops for learning and applying management skills."

When TWAS was launched in 1983, science and technology in virtually every nation of the developing world was in a dismal state. Annual government investments in science and technology were typically below 0.1 percent of the gross domestic product; the number of developing-world scientists who migrated to developing countries exceeded those who chose to remain in their native lands; universities were poorly equipped and professors chronically underpaid;

SCIENCE IN AFRICA

A parallel event, 'Harnessing Science and Technology for Sustainable Development in Africa,' held on Monday 20 October, one day after the official close of the conference, brought together some 50 participants from African ministries, research councils and academies of science, to identify strategies for improving support for science in Africa. Mohamed Hassan, TWAS's executive director, and Turner T. Isoun, Nigeria's minister of science and technology, co-chaired the event. Among the topics discussed were the need to promote concrete initiatives with long-term economic and social impacts and the lack of science academies in the vast majority of African nations. Indeed only nine of Africa's 53 nations have merit-based science academies. With assistance from TWAS, the African Academy of Sciences is seeking to remedy this problem through the creation of the Network of African Science Academies (NASAC). Participants also discussed the recent US$4.2 million grant from the World Bank to the government of Uganda as part of a larger effort to build biotechnology research capacity in that country and ultimately throughout Africa. The grant was largely due to the efforts of the Millennium Science Initiative. For additional information, see www.msi-sig.org.

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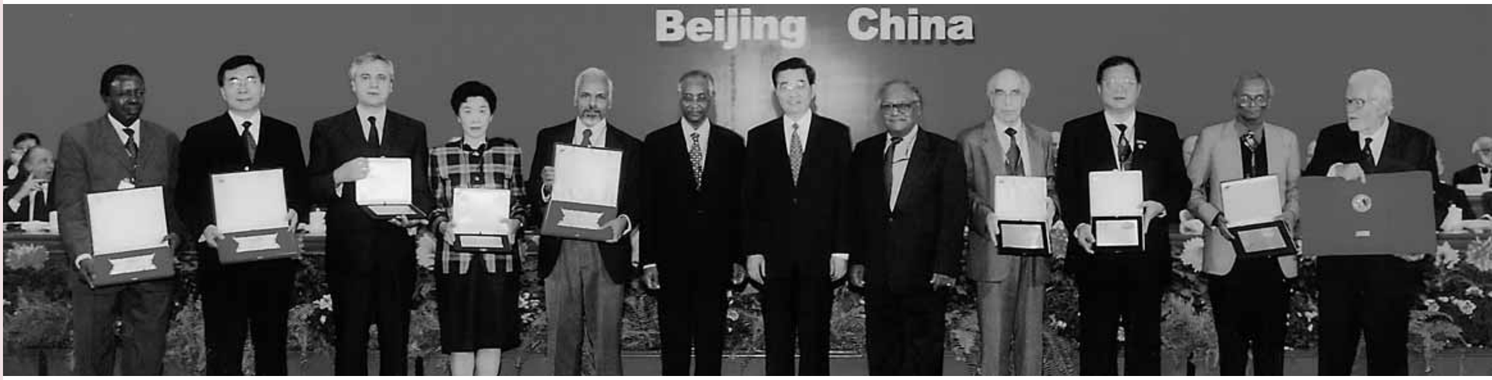

and government officials tended to believe that science was a luxury, not a necessity, and that technologies could be purchased abroad more cheaply than they could created at home.

Over the past 20 years, and particularly over the past decade, much has changed – and changed for the better – for science and technology in the South, especially among the developing world's larger and more prosperous nations. Whether improved economic conditions have spurred investments in science or science has sparked economic growth is beside the point. The likelihood is that both these forces have worked in tandem to the benefit of each.

The most important factor is that investments in science and technology have increased substantially, especially among select nations in the South, and that the results of this sustained effort are paying handsome dividends. Several developing countries – for example, Brazil, China and India – now invest more than one percent of their gross domestic product in science and technology and enjoy annual rates of economic growth that far exceed any levels of growth that they have achieved in the past.

While the brain drain problem continues to plague many developing countries, the number of native-born scientists who choose to remain at home, at least in some nations – for example, in Brazil, China, India and Mexico – has risen. At the same time, programmes designed to keep expatriate scientists in contact with their colleagues at home have increased in number and effectiveness. Universities have also improved, as reflected in the quality of their teaching and research. And advances in communication technologies have truly created a global forum for the rapid exchange of information and ideas among those connected to the internet – regardless of whether their offices and laboratories are in Boston, Beijing or Bogotá.

The bottom line is this: Virtually no country today views science and technology as a luxury and virtually all countries are making efforts to integrate science and technology into their strategic plans for sustained economic and social growth.

As a result, the critical issues that TWAS has tackled over the past two decades have shifted

IN MEMORIAM

TWAS lost twelve of its members during the past two years. Satish Dhawan (Fellow 1985, India); Triloki N. Khoshoo (Fellow 1994, India); Miguel Layrisse (Fellow 1995, Venezuela); Elizabeth Mann Borgese (Associate Fellow 1985, Germany); José L. Massera (Fellow 1992, Uruguay and Italy); César Milstein (Associate Founding Fellow, United Kingdom); Chang-Lin Tien (Associate Fellow 1993, USA); Hugo Aréchiga (Fellow 1996, Mexico); Mohamed M. Mahmoud (Fellow 1989, Egypt); Thomas Odhiambo (Founding Fellow, Kenya); Marcel Roche (Founding Fellow, Venezuela); and Andrés O.M. Stoppani (Fellow 1988, Argentina). The Academy extends its condolences to the family and friends of each of our departed members.

somewhat. In response, the Academy has sought to meet these new challenges by expanding the purpose and range of its programmes.

For these reasons, TWAS has paid increasing attention to the needs of the least developed countries (LDCs). It has sought to foster even stronger initiatives for South-South cooperation, particularly between the South's scientifically proficient nations and those that remain scientifically impoverished. It has forged programmes designed to put science to work to address critical social, economic and environmental issues in the South. And it has taken steps to develop South-North scientific partnerships that nurture an environment in which all parties contribute equally to global research efforts.

Against this backdrop, the world continues to change at an unprecedented rate. Non-stop change, in turn, has had a dramatic impact on how science is carried out even as science itself radically alters the societies in which it operates. This 'feedback loop' is likely to affect both society and science in as-yet-unknown ways in the years ahead.

"Competition has usurped compassion in our age," noted Rao at the opening session of the conference. "If science is to make a difference, it must learn how to balance the intense competitive environment in which it operates with a sense of compassion that will enable science to address the real problems of real people, especially people in the least developed countries."

"We cannot make all poor countries rich," he added, "but the global scientific community, working in concert with organizations like TWAS, can help provide people throughout the world with the goods and services that they need to live reasonably comfortable lives."

At the same time, a mastery of science – both in terms of acquiring knowledge and applying it – can help instil in citizens across the South the dignity and confidence that they need to compete successfully in our increasingly globalized world.

Rao proudly observes that "TWAS has made great contributions to the world of science during its first two decades," but that "its work is by no means done." In fact, the Academy now stands ready to build on its foundation of success and to extend its reach directly into the societies where its scientists live and work. "The measure of our future success," he concludes, "will largely depend on the degree to which we help our fellow citizens improve their lives and achieve their 'place in the sun'." ■

FUTURE GATHERINGS

The TWAS Council has decided to hold Academy general assemblies once every three years instead of once every two years, as has been the case over the past two decades. The change is designed to help lighten the secretariat's work load in the face of the Academy's ever-expanding operations. The TWAS 15th General Meeting will take place in Trieste on 22-24 November; the TWAS 16th General Meeting will take place in Alexandria, Egypt, in late 2005; and the TWAS 10th General Conference and 17th General Meeting is tentatively scheduled to take place in Mexico in late 2006.

A MEETING OF MINISTERS

THE TWNSO MINISTERIAL SESSION HAS BECOME ONE OF THE HIGHLIGHTS OF THE BIENNIAL TWAS GENERAL CONFERENCE AND TWNSO GENERAL ASSEMBLY. THIS YEAR'S TOPICS: FUNDING AND CAPACITY

In Beijing, 11 ministers of science and education took part in the session 'Government Investment in Science and Technology Capacity Building'. Below are brief extracts of what several ministers had to say about the state of science and technology in their respective countries – viewpoints that shed light on the state of science and technology in the developing world as a whole.

REBUILDING RWANDA

As a small country of just 26,000 square kilometres and 7 million people, Rwanda has few natural resources on which it can depend. Therefore, the government is determined to develop its scientific and technological capacities as part of a larger strategy designed to enhance the socio-economic development of the country. In 1999, five years after the genocide, the Rwandan government moved from a state of emergency to a plan for development. Examples of the scientific capacity building efforts that are now taking place throughout Rwanda include the establishment and strengthening of key institutions of higher learning, including the National University of Rwanda and the Kigali Institute of Science, Technology and Management. We are also using information and communication technologies in education to promote distance learning for teachers throughout the entire educational system and e-learning to assist students in higher education. The African Virtual University *(www.avu.org)* is one example of this effort. Rwanda's main development reports, *Vision 2020* and the *National Investment Strategy*, call for the creation of a knowledge-based economy founded on the use of information technology and the application of science through the provision of computers to all primary and secondary schools, the training of a critical mass of scientists, and the building of an adequate science and technology infrastructure that draws on government investment and bilateral cooperation, particularly South-South cooperation. ■

Eugen Munyakayanza
Minister of State for Primary and Secondary Education
Ministry of Education, Science and Technology Research
Kigali, Rwanda

JORDAN: INVESTING IN SCIENCE

Research and development depend on human capital and, in this regard, Jordan's human capital is considered a valuable asset. Our nation enjoys an adult literacy rate of 90 percent, a youth literacy rate of 99 percent and high levels of enrolment in secondary and tertiary education (76 and 33 percent, respectively). Yet, the number of Jordanians involved in research and development remains low. For example, the Jordanian workforce has just three research scientists per 1,000 people compared to six in Egypt and more than 60 in such developed countries as Australia and France. To improve this situation, Jordanian universities have launched a faculty-enhancement plan that provides scholarships to distinguished graduates to attend leading international universities for their doctorate degree. Upon their return, they join the teaching staff at a Jordanian university. As an additional incentive towards excellence, financial prizes are awarded to distinguished research faculty members at universities and the nation's most promising student researchers. The Jordanian government has also taken steps to develop the nation's information and communication technology (ICT) capacity. Yet the job is by no means complete. In a recent report, Jordan ranked 14th out of 80 countries in assessing the priority that governments give to ICT, but we ranked just 58th out of 80 countries in the use of personal computers. To accelerate our nation's access to ICT and other scientific capacity building efforts, Jordan is establishing a Commission for Scientific Research whose purpose will be to harmonize the research efforts of our universities, research institutions and the private sector.

Mohammad Hamdan

Mohammad Hamdan
Minister of Higher Education
and Scientific Research
Amman, Jordan

CUBA'S SCIENCE CULTURE

For many years, international restrictions have prevented Cuba from importing the latest scientific equipment. As a result, we have been forced to modernize our technological infrastructure on our own. We have done this by relying on our principal resource: human

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Fidel Castro Diaz-Balart

potential. This determined and unrelenting effort has generated many positive outcomes: for example, many Cuban-based developments in biotechnology, including such new products as a recombinant hepatitis B vaccine and a recombinant epidermal growth factor for treatment of patients suffering from severe burns. In another measure of success, Cuba now generates 95 percent of the electricity that it uses from its own oil reserves. Deep sea oil exploration, conducted in collaboration with foreign oil companies, now plays a critical role in helping assimilate high technologies into national scientific capacity. In addition, the production of solar panels designed for use in optoelectronic equipment means that isolated rural communities – including some 2,000 schools – now have electricity. Cuba's achievements can be traced to 1961 when we attained virtually 100 percent literacy among our population. As one of our country's most eminent poets, Jose Marti, once wrote: "To be educated is to be free." We now have more than 200 institutions devoted to science and technology, of which 118 have research facilities. We also have a trained scientific workforce of more than 64,000 people. That amounts to more than 13 scientists for each 1,000 workers, a figure comparable to some developed countries.

Fidel Castro Diaz-Balart
Scientific Advisor to the President
of the Council of State
Havana, Cuba

MODERNIZING MALAYSIA

The government of Malaysia is convinced that investments in knowledge-seeking activities, as well as the development of scientific talent, are not luxuries but pre-requisites for progress. Human capital has become the core source of wealth of the 21st century and its development cannot be left to chance. To nurture this potential among our people, the government of Malaysia has committed itself, by 2010, to increase research and development spending from the present 0.5 to 1.5 percent of our gross domestic product, and to increase the scientific workforce from 1.5 to 6 people per 1,000 workers. To achieve these twin goals, we recognize that our education and training systems must promote a culture of creativity, experimentation, risk taking, entrepreneurship and, above all, life-long learning. In addition, we must promote a 'culture of science' so that our young people see the benefits of learning science and engineering, which will be critical for many jobs in the future. The knowledge economy also places a high premium on our ability to collaborate. Given our limited resources, with regard to both trained manpower and finance, it is imperative that Malaysia – and indeed all other developing countries – pool their expertise in areas that generate maximum benefits for all. Broad-based collaboration, including with industry, can help ensure that the cost of providing the necessary infrastructure is not prohibitive. To develop scientific and technological capacity, countries such as Malaysia must concentrate on those sectors where we are already strong and where opportunities for growth and leadership are most promising. Our challenge is not how well we adapt information and communication technologies and biotechnology to enhance the productivity of our traditional sectors, such as agriculture, but how well we can harness them to address pressing problems such as poverty. I believe that these are the key elements to which developing countries must give high priority in their investment portfolios. ■

Hieng Ding Law
Minister of Science, Technology and the Environment
Kuala Lumpur, Malaysia

SCIENTIFIC CAPACITY IN NORTH KOREA

In smaller developing countries, advancements in science and technology require a relatively greater amount of investment. In the Democratic People's Republic of Korea, for example, we are now striving to build our research and development capacity, especially in those fields that are necessary for the future of our country. Wars, the counterproductive policies of a few developed countries, and repeated natural disasters have placed obstacles on the road to scientific and technological development in our country. We have, however, successfully overcome these obstacles in several areas. In the life sciences, for example, we have bred rice with improved photosynthetic efficiency. We have also made significant advances in the basic sciences, including developing a new theoretical clarification of high-temperature superconductors. We have achieved these advances by believing in ourselves, by having the political willpower to develop our own science and technology capacities, and by prioritising our science and technology investments according to the requirements of our economy. In the future, we will seek to collaborate more actively with TWAS and further develop exchanges and cooperation in the field of science and technology among developing countries on the basis of our experience and the lessons we have learned. ■

Pyong Y. Rip

Pyong Y. Rip
President of the Academy of Sciences with ministerial status
Pyongyang, Democratic People's Republic of Korea

SOUTH AFRICA'S STRATEGY

The training of scientists and the creation of scientific institutions are both long-term investments. How to shorten this investment cycle is one of the critical challenges faced by developing countries. Fifty years ago, developing countries had very little science and technology capacity. Emphasis was placed on developing colleges and universities, government research and development facilities, and agricultural research stations and extension programmes. Investment in science and technology capacity must, however, address the full spectrum of skills and infrastructure. More recently, therefore, efforts have included training for scientists and science teachers, providing financial services for science and technology spin-off companies, developing markets for knowledge-intensive goods and services, and creating networks for the sharing and dissemination of scientific knowledge. When reinforced by targeted government intervention, this leads to an enabling environment for the maintenance of a productive and competitive science system. In this context, I wish to draw your attention to the *National Research and Development Strategy* adopted by the government of South Africa in 2002. The strategy calls on the South African government to double its investment in research and development over the next 6 years. This would raise the national investment in research and development to above one percent of our gross domestic product. The burden of investing in science and technology in the developing world lies primarily with national governments. By the same token, we must recognize the importance of collaboration and partnerships with advanced economies and the pivotal role of assistance from the international development community. ■

Buyelwa Sonjica
Minister of Arts, Culture, Science and Technology
Pretoria, Republic of South Africa

SCIENCE AND TECHNOLOGY IN CHINA

DELEGATES AT THE TWAS 9TH GENERAL CONFERENCE WITNESSED FIRST-HAND HOW QUICKLY THE NATION'S CAPITAL HAS BEEN TRANSFORMED INTO A WORLDCLASS METROPOLIS. BEIJING AND OTHER CITIES IN EASTERN CHINA HAVE BENEFITED FROM POLICIES THAT HAVE LED TO DRAMATIC INCREASES IN FUNDING – NOT JUST FOR ECONOMIC DEVELOPMENT BUT FOR SCIENCE AND TECHNOLOGY.

The TWAS 9th General Conference was devoted, in part, to an in-depth examination of the work and accomplishments of China's scientists and scientific agencies, particularly those forming the Chinese Academy of Sciences network. Here's a brief sampling of what was presented during the meeting, which included a morning session devoted exclusively to 'Science in China'.

GOVERNMENT SUPPORT

The day before TWAS's 9th General Conference in Beijing was officially opened, China became the first developing country to launch a manned space flight. The successful return to Earth of the *Shenzhou-V* rocket made headlines around the world.

Among the major reasons behind such advances in science and technology (S&T) in China, explained **Xu Guanhua** (TWAS Fellow 2001), the Minister of Science and Technology, have been far-reaching reforms in S&T funding throughout the country. Between 1990 and 2002, for example, the proportion of China's gross domestic product spent on research and development doubled from 0.6 percent to 1.2 percent. Furthermore, industries are now major players in research and development investment, which is reflected in the fact that 60 percent of the Chinese government's expenditure is targeted towards industrial projects. Indeed, Xu explained that China now has 53 high technology industrial development parks, 25,000 S&T enterprises and more than 3 million well-paid positions in the high-technology sector. "In addition," said Xu, "there are some 300 venture capital firms and 865 productivity promotion centres located throughout the nation."

In the future, China plans to accelerate the development of its S&T infrastructure by providing increased support to laboratory scientists – including incentives for those returning from abroad – and funds to improve the investment environment for small- and medium-sized enterprises seeking to transform S&T advances into practical applications.

"During the next 5 to 10 years we aim to consolidate our innovation and development procedures, especially in the areas of biomedicine and the modernization of traditional Chinese medicines; transportation, including electric vehicles and high-speed trains; and information technology," explained Xu.

"The conventional path for developed countries is to have undergone industrialization before the development of information technology," he added. "China does not have to go this route. We will promote industrialization through 'informatization'."

Between 1990 and 2002, China doubled its spending on R&D from 0.6 to 1.2 percent of its gross domestic product.

THE GENOME AND BEYOND

Following the success of the Human Genome Project, in which China was the only developing country to participate, **Yang Huanming**, director of the Beijing Genomics Institute, explained that China was now sequencing the genomes of many other species, mainly domestic animals and plants. "The genome mapping of the chicken and soybean are well underway, the first stage of the pig genome has been completed, and our scientists have sequenced the entire genome of indica rice," Yang noted.

Yet, as Jorge Allende (TWAS Fellow 1985) so eloquently put it in his presentation on 'The Challenges of Post Genomic Biology' in the 'Future of Science' session of the conference: "The genome is a masterful symphony. We are now at the stage of discovering the individual musical instruments, the genes, and what sounds each one can make. We are still a long way from being able to hear the melodious harmony and the dramatic tempo of the movements that these instruments make when, together, they play the score written in the genome to generate the pulsating music of life."

Chinese scientists are currently involved in several projects designed to decipher this 'musical code'.

One of these projects, the Hap Map project, is an effort to search the human genome for so-called 'haplotypes,' blocks of DNA that tend to pass from generation to generation without splitting. Scientists believe that single nucleotide polymorphisms – in other words, changes in the individual letters of the genetic code – within these haplotypes are at the root of such ailments as heart disease and asthma, the incidence of which varies between different races. The Hap Map project, therefore, includes the study of three major populations: northern Europeans, the Yoruba of Nigeria and an Asian sample of Japanese and Han Chinese.

"We have successfully engaged the communities, obtained their informed consent and begun sample collection," said Huanming.

Like the Human Genome Project, the Hap Map project is an international effort. Data, therefore, is made freely available to scientists everywhere. Unlike the Human Genome Project, however, to which China contributed just one percent of the final output, this new collaborative venture will benefit from a 10 percent contribution from China.

COMPUTER CULTURE

The Chinese government's focus on 'informatization' has seen the information and communications technology sector become one of the country's leading industries.

[CONTINUED PAGE 26]

"Over the past five years, our information industry has grown at 25 percent each year," said **Li Guojie** (TWAS Fellow 2001 and a member of the Chinese Academy of Engineering), "and annual sales for electronic information products manufactured in China now total about US$170 billion."

Indeed, between 1997 and 2002, China increased its production of computer chips from 1.3 billion to 8.5 billion, and expectations are that, by 2010, China will be producing 50 billion chips a year, equivalent to 5 percent of the global market.

Included among these chips is the Godson-I CPU (central processing unit) chip, the first to be wholly developed in China. Hardware support for this chip wards off computer viruses and other hostile attacks, making it especially suitable for use in such areas as e-government. An upgraded version of the chip, the Godson-II, should be commercially available in 2004.

China is now ranked second in the world in terms of its number of networked computers and internet users.

In addition, China is now ranked second in the world in terms of its number of networked computers (more than 20 million) and internet users (60 million). One impediment to the uptake and use of computers in China is the need to recognize the tens of thousands of Chinese characters, as compared to the 26 letters used in the English alphabet.

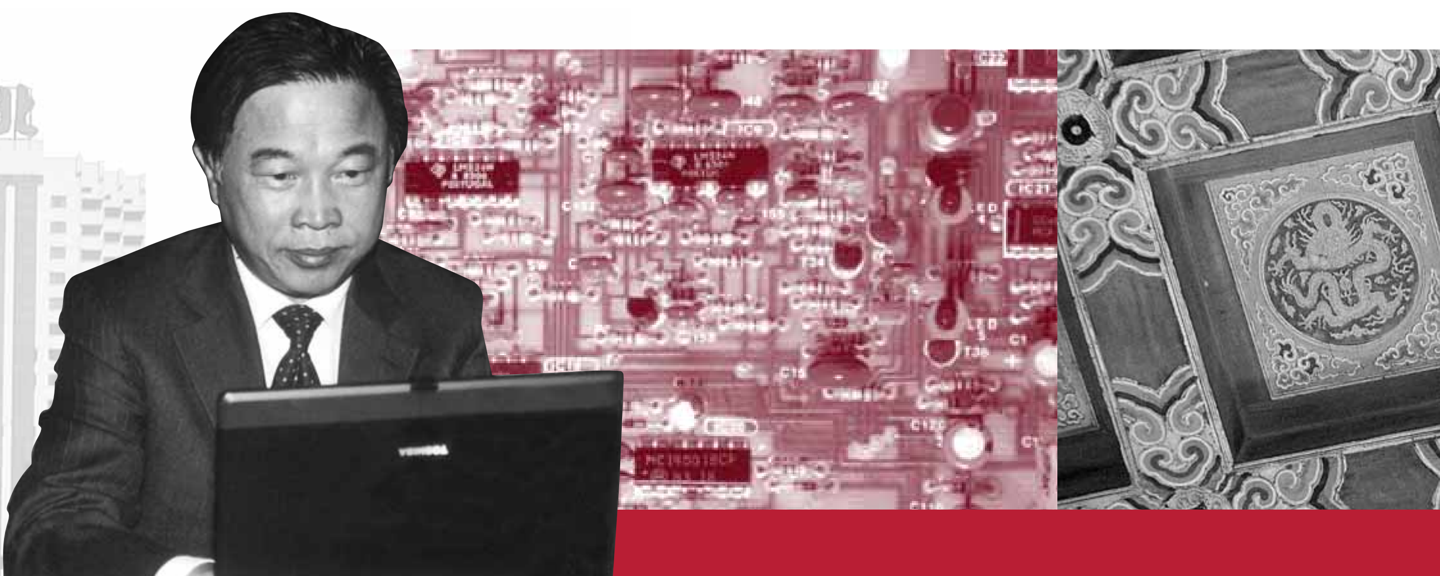
Driven by this concern, China is the world leader in the development of optical character recognition software. "As early as 1985, the Chinese Academy of Sciences' Institute of Automation developed the first software for online handwritten Chinese character recognition," explained Guojie. "Over the past decade, this software has been upgraded from its 1.0 version to the current 10.0 version, which is now being used by such companies as Microsoft and Motorola. It can recognize more than 10,000 Chinese characters with an error rate as low as 1 in 10,000."

Advances have also been made in Guojie's own field of artificial intelligence. In an application, for example, that has implications for the film and entertainment industries, computer recognition of the characters making up the text of Chinese folk tales can now be automatically converted into animated cartoons.

MEGA-MOLECULES

Proteins rank alongside DNA and RNA as the most important biological molecules. They form a major part of the structural constituents of cells, regulate gene expression and, as enzymes, catalyse thousands of cellular processes.

Although they have a wide array of functions, proteins are composed of chains of just 20 relatively simple components – amino acids. Despite this apparent



simplicity, proteins have a complex, three-level structure, the intricacies of which determine the function of these 'mega-molecules'.

The first structural level is simply the order of the amino acids that make up chains known as polypeptides. A protein's secondary structure depends on the order in which these chains are linked together to form complete proteins. Finally, the chain folds in and around itself, producing the three-dimensional, third-level structure.

These folds are then held together by strong disulphide bonds between pairs of amino acids. The folds also bring together groups of amino acids that are otherwise separated along the chain to form the 'active sites' of enzymes or to provide structural strength to the protein molecule.

Although scientists have known for several years how to determine the sequence of amino acids in any given protein, understanding how they are folded has remained elusive. The work of **Wang Zhizhen**, for which she received the 2002 TWAS Prize in Biology, sheds light on this dilemma.

Some years ago, researchers showed that protein folding was not spontaneous, but required the assistance of two other types of proteins – 'foldase' enzymes and molecular chaperones. These chaperones help stabilize and orientate proteins that are being folded, while the foldases do as their name suggests and catalyse the reactions that hold the protein folds together. One of the two types of foldase known, for example, is protein disulphide isomerase (PDI), which helps make the strong disulphide bonds between amino acids.

Using a series of elegant experiments, Zhizhen, of the Chinese Academy of Sciences' Institute of Biophysics, Beijing, has shown that PDI is not only a foldase, but also acts as a chaperone.

First, she showed that, under mild denaturing conditions, PDI protected the integrity of a protein that contained no disulphide bonds. This led Zhizhen to consider that the PDI was acting simultaneously as a foldase and a chaperone. She then knocked out the active foldase site and tested the modified protein's activities on a snake venom protein that contained seven disulphide bonds. Once again, despite being inactive as an enzyme, the PDI maintained the integrity of the venom protein – thus demonstrating its chaperone qualities.

Thanks to Zhizhen's research, not only do cell biologists now have a greater understanding of the processes involved in building proteins, but these processes may one day be harnessed to create new drugs. ■

A detailed description of the state of science in China may be found in a book published in conjunction with the TWAS's 20th anniversary conference:
Science Progress In China
(Beijing: Science Press, 2003).

TWAS 9TH GENERAL CONFERENCE & 20TH ANNIVERSARY CELEBRATIONS
TWAS 14TH GENERAL MEETING
TWNSO 8TH GENERAL ASSEMBLY

Beijing, China, 16-19 October 2004

北京国际会议中心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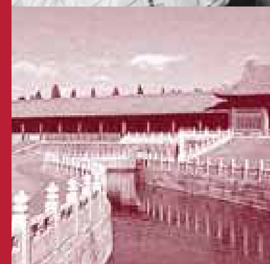
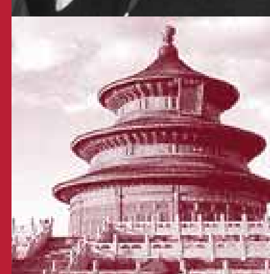
Meeting


TWNSO





SESSION ON SARS

ONE OF THE MOST HIGHLY ANTICIPATED SESSIONS OF THE TWAS CONFERENCE IN BEIJING FOCUSED ON SCIENTIFIC ANALYSES OF LAST WINTER'S GLOBAL SARS EPIDEMIC - A POST-EMERGENCY CHECK-UP OF WHAT WENT RIGHT AND WHAT WENT WRONG IN COMBATTING THE VIRUS.

Last winter and early spring, the sudden appearance and spread of Severe Acute Respiratory Syndrome (SARS) posed a threat to global health, infecting over 8,000 people in more than 30 countries, killing nearly 800. The epidemic, which centred on China and other east Asian countries, nearly caused the postponement of the TWAS 9th General Conference and 20th anniversary celebrations. Eventually, after the World Health Organization (WMO) declared China SARS-free, the meeting was given a green light. It was fitting, therefore, that one of the conference sessions should focus on the newly identified virus.

The global SARS epidemic is now believed to have begun in mid-November 2002 in China's Guangdong province – probably as a result of a virus 'jumping' from an animal host, the masked palm civet cat (*Paguma larvata*), to humans.

During the height of the epidemic, schools and offices were closed, busy roads in major cities were deserted, and people who ventured out in public did so only wearing a protective mask. The disease spread more than sickness – it generated fear as well. People, in fact, were terrified of this unknown or 'emerging' disease. As Zhong Nanshan, director of the Guangzhou Institute of Respiratory Diseases, pointed out in his presentation, many people expressed relief if an illness – no matter how serious – turned out not to be SARS. Zhong cited the example of a banner hung outside a Beijing apartment. It read: "Congratulations to Mr. Zheng on being diagnosed SARS-free". It also had this postscript: "Just typical pneumonia!"

Indeed, a major problem faced by doctors dealing with the SARS epidemic was accurate diagnosis of the new disease. The symptoms – including a temperature above 38°C (100°F), signs of respiratory illness such as coughing and shortness of breath, and x-ray evidence of pneumonia – can easily be confused with such diseases as influenza and the 'typical pneumonia' highlighted in Mr. Zheng's banner. In fact, before the SARS acronym (which stands for Severe Acute Respiratory Syndrome) became the accepted terminology, the emerging disease went by the name of 'atypical pneumonia'.

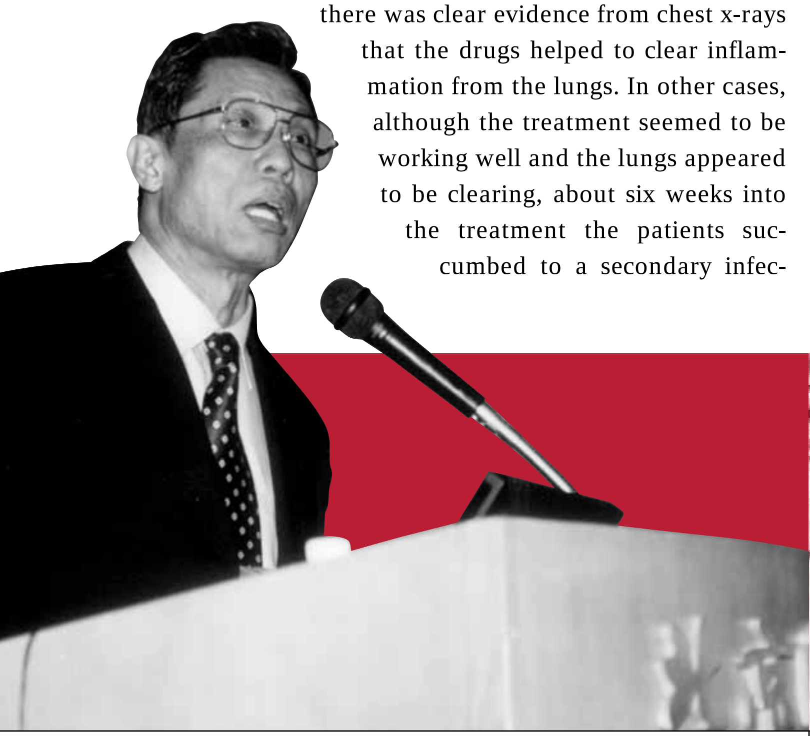
As with any disease, accurate diagnosis is the first step towards devising an appropriate response. In the case of SARS, however, doctors were initially in the dark not only as to the cause of the disease, but also how to treat it. Was the disease caused by a bacterium, for example, that could be countered with antibiotics, or a virus that would require an entirely different range of drugs to treat it?

The important first clue to the identity of the disease-causing agent was that it did not respond to antibiotics. A virus was suspected – and the previously unknown virus, now known as the SARS coronavirus (so-called because it appears to have a 'halo' or 'corona' around it when viewed with an electron microscope), was eventually identified in February 2003.

TREATMENTS

By this time, doctors in China and elsewhere had been testing various treatments. According to Zhong, who was among the first researchers to identify and describe the clinical existence of SARS, several treatments proved effective to varying degrees. Antiviral drugs such as interferon and the 'broad spectrum' ribavirin proved moderately effective, as did injecting patients with antibodies to the virus extracted from the blood of people who had recovered from the disease.

Another treatment, the use of anti-inflammatory corticosteroids, had mixed results. In some patients, there was clear evidence from chest x-rays that the drugs helped to clear inflammation from the lungs. In other cases, although the treatment seemed to be working well and the lungs appeared to be clearing, about six weeks into the treatment the patients succumbed to a secondary infection of *Aspergillus* – a fungus that usually does not infect humans but which can gain a foothold in immune-compromised patients.



These results highlighted another feature of SARS – the fact that it causes acute immunodeficiency. Unlike the long, slow development of immunodeficiency experienced by HIV/AIDS patients, however, a characteristic of SARS patients is that such a condition appears quickly.

A much more effective treatment for SARS proved to be a combination of traditional Chinese and modern medicines, explained Zhong.

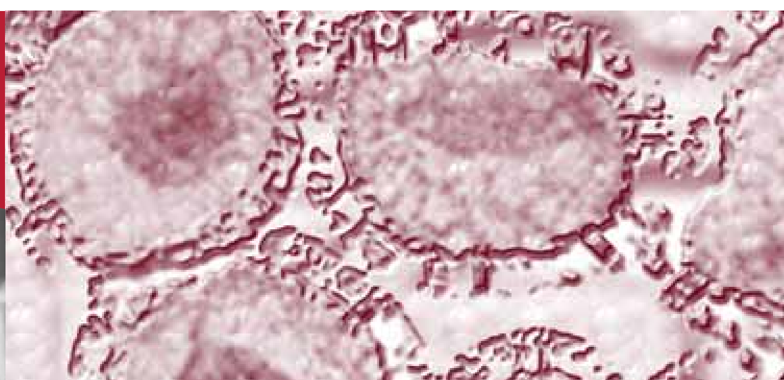
Controlled studies were carried out in 11 Chinese hospitals with promising results. "This integrated treatment was better than a single treatment," claimed Zhong, "It provided relief from such symptoms as shortness of breath, and reduced the size of the lumps found in the lungs of typical SARS-infected patients."

Zhong also explained that treatment alone is not enough to control any future SARS epidemic. The key, he said, is to identify infected patients as quickly as possible. This could be helped, he said, if people in large cities receive the influenza vaccine, as this would reduce the number of people reporting fevers and make it easier to spot true SARS cases. SARS patients could then be isolated and treated, continued Zhong, and any people with whom they had been in contact traced and tested.

MODELS

The second speaker in the TWAS conference session on SARS was Christophe Fraser of the Department of Infectious Disease Epidemiology, Imperial College, London, UK.

Fraser agreed that, in order to prevent the epi-



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demic from spreading, it was important to trace patient contacts. However, he also admitted that, except in exceptional circumstances, this was very difficult. As an example of such exceptional circumstances, Fraser noted that of nearly 8,500 cases of SARS, more than 1,700 were healthcare workers who had been in close contact with other SARS patients.

"Every infectious disease has its 'basic reproduction number' or 'R_0' – the number of people infected by an infected person," continued Fraser. "If the R_0 value can be brought down to less than one, then an epidemic can be brought under control."

Indeed, this is what happened during the SARS epidemic. At the beginning, the R_0 value was between two and three, whereas by the end it had dropped to just 0.3.

The R_0 value is just one input of biological and sociological data that Fraser relies on in his disease epidemiology models – mathematical models that can quickly help determine whether disease-control measures are sufficient to prevent the growth of an epidemic. "We can build a model or computer simulation using as much information as we have," said Fraser. "Then we can alter any unknown parameters to try to tailor the model to the way the epidemic is actually unfolding."

Such models showed that, at least in Hong Kong, people admitting themselves to hospital more quickly had little effect in slowing the SARS epidemic. "Instead, if our assumptions are correct," said Fraser, "it was changes in the behaviour of the population that resulted in reduced contact rates, as well as improved isolation of hospitalised patients, that resulted in epidemic control. Attributing changes to single public health interventions is difficult, though, and more work needs to go into looking retrospectively at each measure."

Modelling can also examine what Fraser described as "what if…" scenarios.

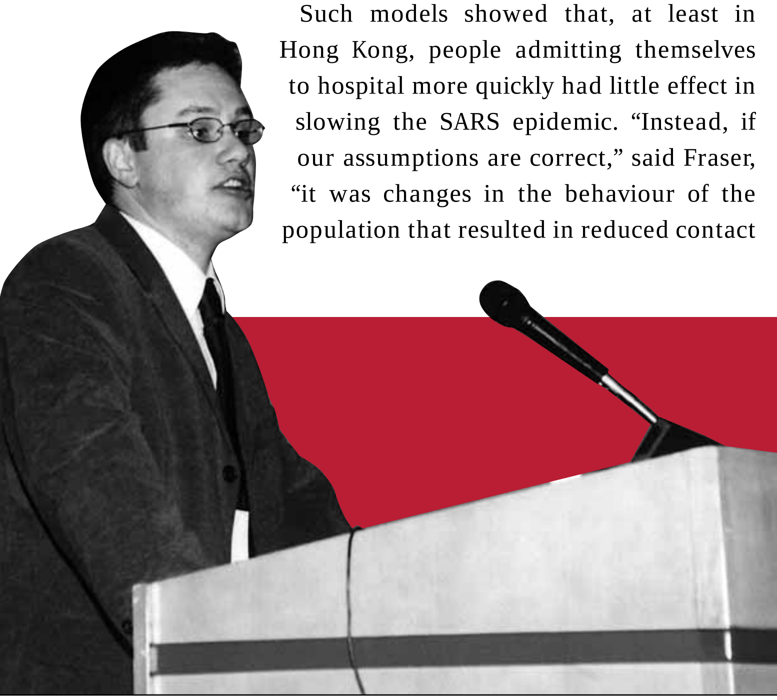
"The SARS virus had some, but luckily not all, of the attributes that could have lead to a catastrophic pandemic," he warned.

The SARS virus had some, but luckily not all, of the attributes that could have lead to a catastrophic pandemic.

Unfortunately, Fraser noted, such catastrophic pandemics are not as unusual as we think. In 1919, for example, a strain of influenza spread across the globe killing at least 40 million people, while HIV/AIDS – first detected only 20 years ago – has become one of the most widespread infectious diseases ever. HIV/AIDS has killed some 30 million people worldwide and, at the end of 2003, researchers estimated that an additional 40 million people were living with the disease.

One reason why influenza and AIDS continue to threaten human health around the globe is that, in both cases, a high proportion of transmissions occur before symptoms become obvious – a parameter known as θ (theta) that Fraser can insert into his models. Fortunately, in the case of SARS, most people develop symptoms ten days after close contact with an infected individual, but do not begin to 'shed' the virus and become infective until three or four days later, so θ is low.

"By isolating 90 percent of patients as they develop their first symptoms, we can contain SARS," explained



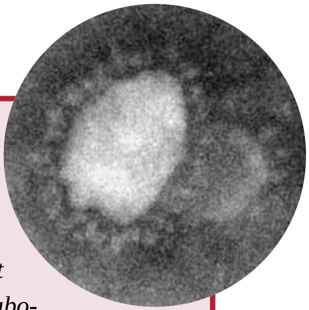
Fraser. "That's not the case with diseases like AIDS or influenza where the ability to infect others occurs before symptoms become apparent." As a further example, smallpox has an R_0 value between that of SARS and influenza and Fraser's models suggest that, should the disease again break out, it is unclear as to whether isolating 90 percent of symptomatic patients would contain its spread.

When contact tracing is used as a means to control an epidemic, both SARS and smallpox can be contained. Again, however, because of their high θ values, influenza and AIDS cannot. Instead, echoing the advice of Zhong Nanshan, Fraser's models suggest that the way to contain SARS, smallpox and any future 'emerging disease' would be to include both patient isolation and contact tracing in the disease control action plan. Fraser also recommends estimating the value of θ as early as possible in an outbreak to determine whether these measures are likely to succeed alone.

His research also highlights the urgent need for control strategies to be devised for potential novel strains of influenza that may emerge from bird reservoirs, such as the recent H5N1 'chicken flu' outbreak in parts of Asia. Isolation and contract tracing are unlikely to be effective against influenza, however, so other measures such as travel restrictions, rapid vaccine development and the prophylactic use of antiviral drugs must be considered.

"Implementing patient isolation and contact tracing procedures would require greater emphasis on 'health protection' and the creation of isolation facilities which, in many countries, are few and far between," added Fraser.

Despite these gloomy predictions, it seems unlikely that SARS will again threaten the global community. For example, there is little risk that patients cured of SARS and released from hospitals will spread the disease. In a study described by Zhong, Chinese scientists followed 60 former patients who had close contact with nearly 160 other people over the following three month period – none of whom became infected. "Unlike typical pneumonia, antibodies to the SARS coronavirus also remain at a high level in the blood for at least 6 months," added Zhong, implying that, once recovered, SARS patients are likely to have developed a lifetime immunity.



VACCINE TRIALS

Since the TWAS general assembly met in Beijing last October, work to develop a vaccine against the SARS virus has continued in laboratories in Europe, North America and China. This February, a team of scientists from a private company, Sinovac Biotech in Beijing, in collaboration with scientists from the Chinese Academy of Medical Scientists, announced that they had won approval from the State Food and Drug Administration to begin human trials of their candidate vaccine. The vaccine, which contains an inactivated form of the virus, has been shown to be safe in animal trials and will initially be administered to just 30 healthy human volunteers in March. Blood tests will then determine if the volunteers mount an immune response to the virus.

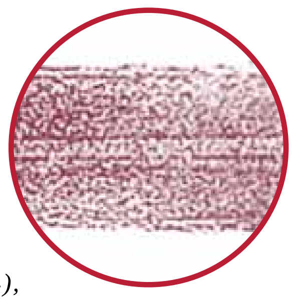
Previously, almost all vaccines manufactured in China were based on Western products. With the development of the Chinese anti-SARS vaccine after just 9 months of research, all that has changed. The approval of the anti-SARS vaccine for clinical testing demonstrates that China now has an efficient vaccine research system. However, Yin Hongzhang of the State Food and Drug Administration cautions that: "Although these vaccines might enter clinical testing at an early date, their effectiveness and safety will only be determined after years of research."

The United States and Canada also aim to begin human trials of their candidate SARS vaccines later this year.

Still, Zhong did not rule out the possibility of isolated cases, especially with the return of winter in southeast Asia and the return of the masked palm civet to the diet of the local people – a prediction that has since turned out to be true as some isolated cases were reported earlier this year. However, thanks to the surveillance and reporting systems that have been put in place by the Chinese and other national authorities, a return to the global epidemic seen last winter is regarded as unlikely.

SMALL SCALES...BIG OPPORTUNITIES

LIKE OTHER TWAS CONFERENCES, THE PROGRAMME FOR THE 9TH GENERAL CONFERENCE INCLUDED A MIXTURE OF POLITICS, POLICY DISCUSSION AND, OF COURSE, SCIENCE. ALTHOUGH NO SPECIAL SESSION WAS ORGANIZED ON THE SUBJECT, THE RAPIDLY DEVELOPING – AND POTENTIALLY LUCRATIVE – SCIENCE OF NANOTECHNOLOGY FEATURED PROMINENTLY. HERE IS A ROUND-UP OF WHAT WAS PRESENTED.

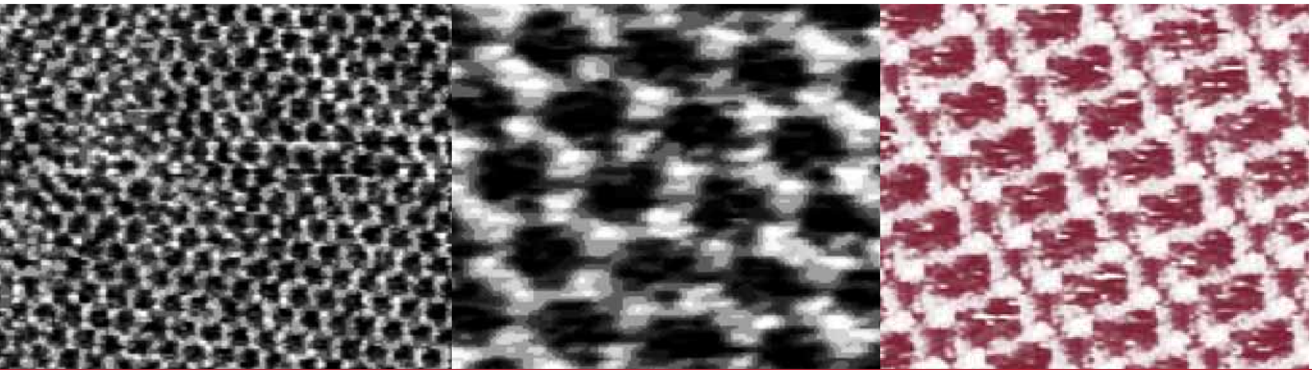


Four speakers focused at least part of their talk on nanotechnology. Significantly, two of these speakers, Anthony K. Cheetham (TWAS Associate Fellow 1998) and Narendra Kumar (TWAS Fellow 1994), presented their papers during the 'Science of the Future' session, discussing the current situation and projected major developments in the sciences of chemistry and physics respectively. In addition, Bai Chunli (TWAS Fellow 1997) spoke about the 'Characterization and Preparation of Two-Dimensional Nanostructures' in his TWAS Medal Lecture, and during the 20th Anniversary Lecture, TWAS President C.N.R. Rao described the latest results from research on nanomaterials being carried out at the Jawaharlal Nehru Centre for Advanced Scientific Research in Bangalore, India.

Chemistry textbooks once informed us that there were two forms of crystalline carbon – graphite, with carbon atoms arranged in layers, and diamond.

In 1985, a third form of crystalline carbon was discovered. Almost spherical in shape and each composed of 60 carbon atoms, the new arrangements have been named 'buckyballs' or 'fullerenes', named after the architect of the geodesic dome, R. Buckminster Fuller.

Shortly after, in 1991, another form of crystalline carbon was discovered – hollow cylinders. These so-called 'nanotubes' have novel properties, particularly with regard to their lightness, strength and surface area. Such properties will allow these structures to be used in a variety of commercial applications, but it is



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their electrical conductivity properties that give nanotubes the potential of becoming tiny alternatives to the silicon chip.

Welcome to the age of nanotechnology.

In his 'Physics of the Future' presentation at the TWAS 9th General Conference, Narendra Kumar, Director of the Raman Research Institute, Bangalore, India, made a bold prediction. Humankind, he said, has progressed through the ages of wood, stone, bronze, iron and silicon, and may now be entering the 'carbon age' – that is, the age of all-carbon nanotubes and fullerenes.

Humankind may now be entering the 'carbon age' – the age of nanotubes and fullerenes.

"Unlike the other periods of the technological advancement of humankind, however, it's not just the basic material that matters, but how it is organized or assembled on the nanometric scale," he added.

A nanometre is 1 x 10^{-9} of a metre, or one millionth of a millimetre, and roughly equivalent to the distance between ten atoms in a crystal lattice. To visualize this, consider that the width of an average human hair is 80,000 nanometres, a strand of spider silk is 7,000 nanometres wide, and the DNA double helix measures 2 nanometres across.

Nanotechnology deals with structures between about 1 and 100 nanometres in size. A buckyball itself has a diameter of 1 nanometre.

It is these tiny dimensions that give nanoparticles their unusual properties. For example, changing the size of nanocrystals can change the reactivity of a material. Physical properties, including the wavelength at which the crystals absorb and emit light, can change too.

Indeed, the celebrated British physicist, Michael Faraday (1791-1867), is believed to have been the first scientist (albeit unwittingly) to have produced nanoparticles. His solutions of colloidal gold prepared under different conditions – still preserved to this day in the museum of the Royal Institution, London, UK – display different colours depending on the different wavelengths of light they emit. Catalytic and biological properties can be altered also – properties that, in some circles, have created fears about the technology as the toxicology of some nanocompounds could differ from their 'regular-sized' counterparts.

In his presentation 'Making and Manipulating Nanomaterials through Soft Chemistry', C.N.R. Rao put the potential of nanotechnology into context.

"Moore's Law says that the size of things decreases by half every three to four years. By 2010, computer chips will therefore be in the nano-range. In other words, it will be like having the storage capacity of a thousand compact discs in something the size of a wrist watch."

But nanotechnology has potential applications in more than just computers, as Anthony Cheetham, Director of the Materials Research Laboratory, University of California, Santa Barbara,

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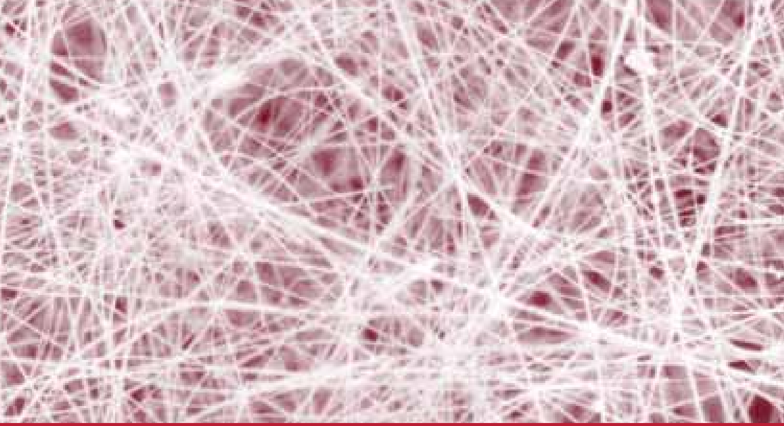
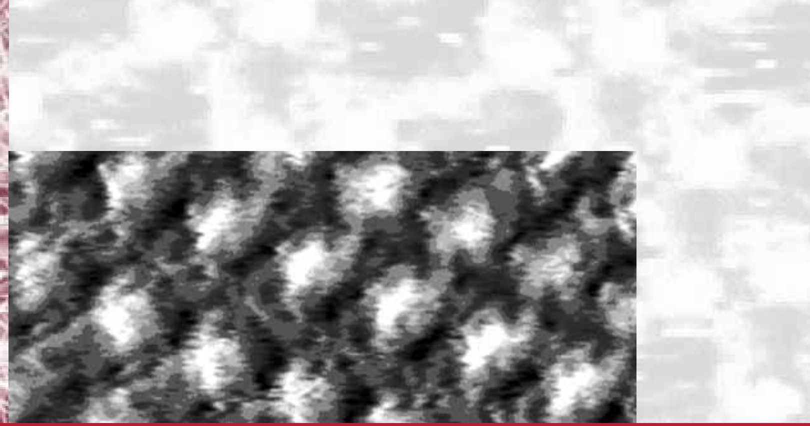
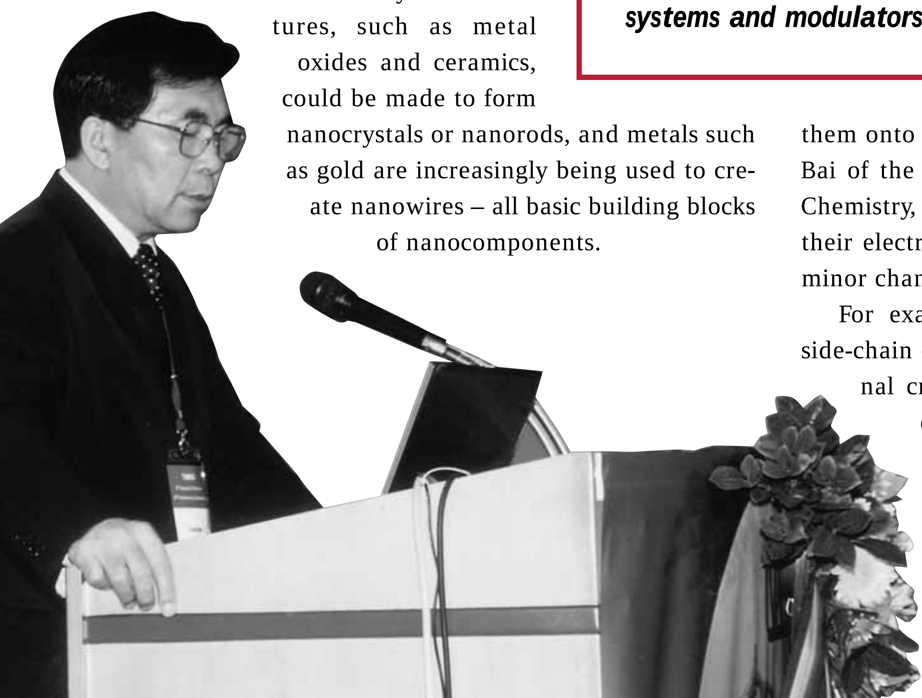




explained in his ‘Chemistry in the 21st Century’ paper. Several years after the discovery of nanotubes, explained Cheetham, scientists were able to make nanotubes with both single and double walls.

“These are both stronger and lighter than steel,” he said. “They can also display excellent insulating and conducting properties, and have the potential to be used in a variety of situations, including reinforced composites, sensors, transistors and data storage, photovoltaic cells and water purification.”

Perhaps contradicting Kumar’s claim about the forthcoming ‘carbon age’, Cheetham described how carbon is no longer considered unique, and that any material that could form layered structures, such as metal oxides and ceramics, could be made to form nanocrystals or nanorods, and metals such as gold are increasingly being used to create nanowires – all basic building blocks of nanocomponents.



Nanocrystals could become essential components in molecular devices used in fluorescent signalling systems and modulators.

NANOCRYSTALS

As with Faraday’s gold particles, crystals of other compounds can be created in different size ranges depending on the starting materials, explained Rao. For example, depending on whether the starting material is gallium acetylacetonate, gallium cupferron or gallium chloride, uniform crystals of gallium nitride of between 5 and 500 nanometres can be created.

“The different sized crystals each have a different quantum confinement,” added Rao. In other words, although the crystals are chemically identical, their electronic and optical properties change according to their size.

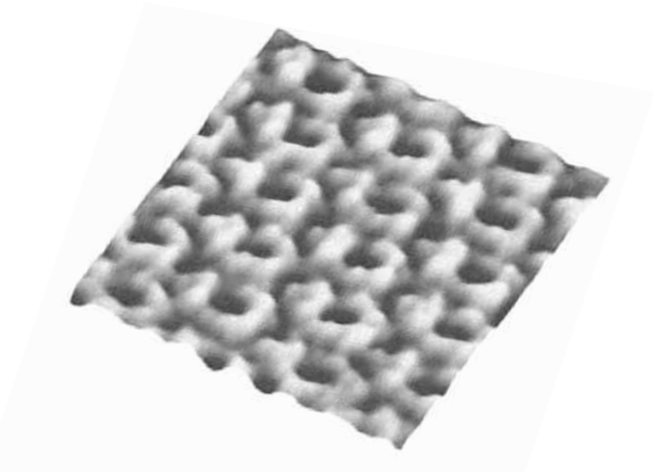
Nanocrystals, however, usually occur as powders or in solution. To use them in devices, they need to be organized into thin layers, or so-called two-dimensional arrays. This is typically done by coating them onto an inert substrate, or chip. Furthermore, as Bai of the Chinese Academy of Sciences, Institute of Chemistry, explained, the crystals’ shape, and therefore their electrical properties, can be changed by making minor changes to the compound being deposited.

For example, an organic compound featuring a side-chain of 12 carbon atoms (12TEB) forms hexagonal crystals when self-assembled on a graphite chip, whereas 14TEB, which has a side-chain just two carbon atoms longer, forms a parallelogram-shaped crystalline structure.

Again, although differences in the chemical properties of 12TEB and 14TEB are minor, the properties of their nanocrystals vary because of their shape.

With some further development, such nanocrystals could become essential components of molecular devices used in fluorescent signalling systems and modulators, essential parts of computer modems.

One application for such layered nanocrystals is solid state lighting, based on light emitting diodes, or



LEDs, which produce light more efficiently than the commonly used incandescent or fluorescent lamps. The wavelength of the light emitted by an LED can be controlled either by altering the size of the crystal or by adjusting the voltage applied to the device.

Such technology is already being put to use in growth chambers designed for growing plants for experimental purposes in space, where both size and weight place restrictions on the apparatus. Not only are the small sizes of the devices conducive to launching the growth chambers into orbit aboard the space shuttle, but they can be tailored to produce only the wavelengths of light needed by the plants, further increasing their efficiency.

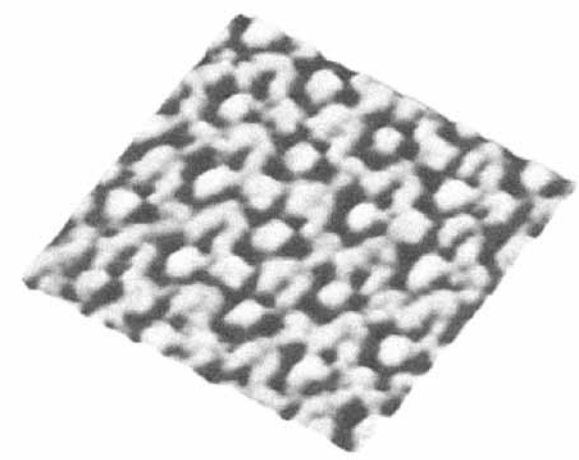
NANOWIRES

Efficiency savings can also be made when connecting all these nanodevices together via nanowires. A one nanometre-diameter gold wire, for example, has a much higher electrical conductivity than a standard gold wire. The practice of producing nanowires, however, is not so simple.

"Building electronic devices demands precise control of the structure and arrangement of nanowires," explained Bai, "but controlling their arrangement is especially difficult."

Bai has pioneered one way of controlling the formation of nanowires using multicomponent thin layers. Monomers of diacetylene, for example, are applied to a surface in narrow lines separated by an inert spacer compound. The diacetylene monomers are then polymerised and the spacer compound rinsed away. The rows between the polymerised diacetylene can then be filled with a functional compound such as phthalocyanine, metal-, semiconductor- and inorganic nanoparticles. In this way, controllable nanowires and quantum dot patterns can be prepared, which are useful in the fabrication of nanoelectric and optical devices.

Rao, too, has been investigating different ways to make nanowires based on such semiconducting compounds as silicon nitride and the sulphides of iron and hafnium. As with nanocrystals, different properties can be conferred on the wires depending on their sizes that, in turn, depend on the reaction conditions during their synthesis. Still, the organization of these nanowires, which are often produced in haphazard clusters, presents technical difficulties.



One way around this is to 'draw' individual nanowires onto a chip, and Rao has converted an instrument used to analyse nanocrystal structures into one that can create nanowires. The atomic force microscope (AFM) works by moving a pointed cantilever slowly across the surface under investigation. Minute movements in the tip of the cantilever, caused by atomic interactions, are registered depending on the structure of the molecules below it. Computer soft-

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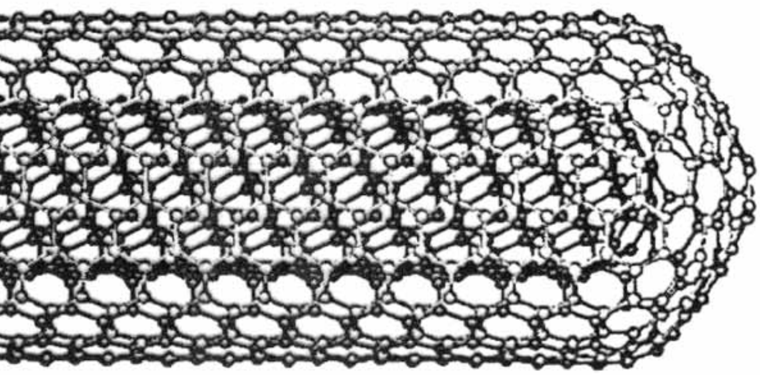
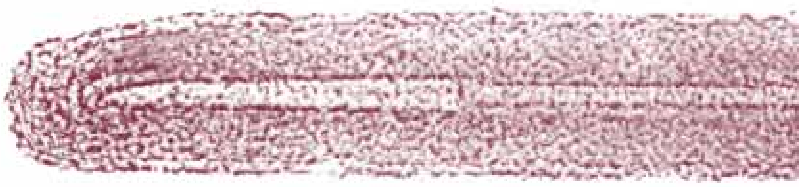




ware converts these movements into an image of the surface.

Rao and his team introduced a droplet of water filled with nanoparticles of gold onto the AFM cantilever. When the cantilever was drawn across a chip, a meniscus formed that left a trail of gold particles 30 nanometres wide in its path. The cantilever was basically acting like the nib of a fountain pen and the gold particles as the dyes in an ink that effectively produced a nanowire. “Next time I’ll write out ‘TWAS’,” said Rao, highlighting the versatility of the process to form complex patterns.

APPLICATIONS

Bai also presented another application of nanotechnology. A sandwich of crystals of nickel atoms between atoms of copper has a uniform cyclindrical shape that, depending on the conditions under which they are produced, can be ‘tuned’ to have different diameters and lengths.

“This array has a remarkably enhanced coercivity, a measure of magnetic strength,” explained Bai. “It is in the order of 490 Oersted, compared to just 0.7 Oersted for bulk nickel. This gives the sandwich a high bit density, so it may be suitable for ultra-high density magnetic recording media.”

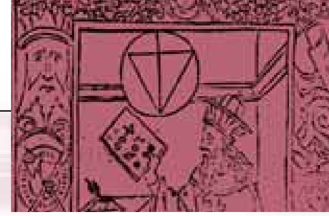
In fact, the storage density would be around 70 Gigabits per square inch, which is much higher than that of current commercial hard drives (around 3.7 Gigabits per square inch) and well beyond the projected limit of 40 Gigabits per square inch for continuous magnetic films.

That means Rao’s prediction of the information contained on a thousand CDs being compressed into the size of a wrist watch may be on its way to being realized.

In the meantime, there is a trickle of ‘nanoproducts’ entering various markets. Sunscreens with nanoparticles of ultraviolet-absorbing zinc and titanium oxides, for example, have been commercialized. “DNA labelled with nanocrystals of gold for biorecognition assays is also near commercialization,” informed Cheetham, “and nanocrystals of aluminium are being used in rocket fuels.”

These are still early days in the nanotechnology revolution, however, and advances such as the use of synthetic DNA to direct the assembly of nanoparticles atom by atom, and intra-molecular manipulations, an area Kumar described as ‘moletronics’, or the production of ‘nanocomposites’ that mimic the strength and lightness of such natural materials as bones and teeth, are still several years away.

There is clearly great potential in the discovery and application of nanomaterials. The good news is that, as the work of Bai, Rao and others shows, a lot of pioneering research is being carried out in developing countries. Investigations into the world of the nanoscale, therefore, provide enormous opportunities for Third World countries to develop their own nanotechnology programmes that could enable them to compete favourably with more advanced countries in the North. ■



MATHEMATICS FOR A NEW MILLENNIUM

IN THE SESSION DEVOTED TO 'SCIENCE OF THE FUTURE', PHILLIP A. GRIFFITHS (TWAS ASSOCIATE FELLOW 2000), DIRECTOR OF THE PRINCETON INSTITUTE FOR ADVANCED STUDY, PRINCETON UNIVERSITY, USA, EXPLAINED WHY HE BELIEVES MATHEMATICIANS WILL INCREASINGLY INTERACT WITH SCIENTISTS FROM OTHER FIELDS.

Over the past few years, there have been three main aspects of change in mathematics and its relationship to the other sciences:

- *The solution of some of our oldest mathematical problems.*
- *The crossing of internal barriers between mathematical subfields.*
- *The interaction between mathematics and the other sciences.*

NEW SOLUTIONS TO OLD PROBLEMS

The past century was a productive period for solving long-standing mathematical problems. Two of the more interesting achievements relate to the proofs of problems that were more than 300 years old. Both proofs occurred toward the end of the century and succeeded only because of the mathematical advances that preceded them.

The first is the solution of Fermat's Last Theorem by Andrew Wiles, which made news around the globe in 1993.

This example is interesting because of Pierre de Fermat (1601-1665), an amateur mathematician who published no papers. It is also interesting because of Wiles, who worked alone on the problem for 7 years. Finally, it is interesting because of the problem itself.

The solution depended on fundamental advances in number theory by many mathematicians over a period of 350 years, and especially during the last half-century.

The theorem was written in 1637 when Fermat was studying an ancient Greek text on number theory. He

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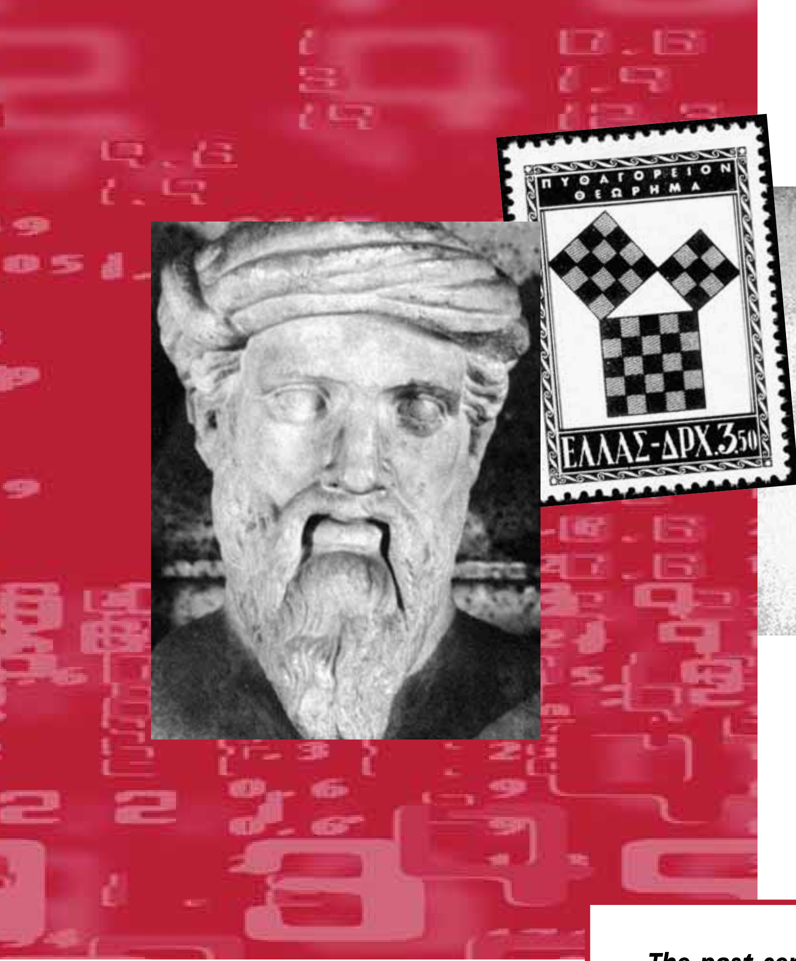


came across the Pythagorean equation most of us learn in school: $x^2 + y^2 = z^2$. Even today, countless schoolchildren learn to say: “The square of the hypotenuse equals the sum of the squares of the other two sides.”

The past century was a productive period for solving long-standing mathematical problems.

Of particular interest are solutions to the Pythagorean equation in whole numbers, such as the 3-4-5 right-angled triangle. When Fermat saw this, he noted that for any exponent – or power – greater than two, the equation could not have solutions in whole numbers. He also wrote that he had discovered his own proof, but that the margin of his notebook was too small to contain it. No such proof has ever been found, but Fermat made many such marginal notes – which may have been jokes or insults to his fellow mathematicians. Over the centuries all Fermat’s notes have been answered – except this one, Fermat’s Last Theorem.

Andrew Wiles first came across Fermat at age 10, in a library in Cambridge, England, where he grew up. He vowed that some day he would prove this Last Theorem. As a young mathematician, however, he was advised not to spend his time on this problem, and he decided to work instead in an area of algebraic number theory known as Iwasawa theory. But he never forgot about Fermat.

In 1986 he learned of a breakthrough: a colleague had linked Fermat’s Last Theorem to another unsolved problem – this time in algebraic geometry – posed in 1955. To summarize a very complex sequence of reasoning, this linkage showed that proving the first problem would essentially prove Fermat’s Last Theorem as well.

After Wiles had presented his results, a small but crucial error was found during the refereeing process that led to another year’s work. Again, there seemed to be no solution. But again, Wiles found the answer. He called this last insight “the most important moment of my working life. It was so indescribably beautiful, it was so simple and elegant and I just stared in disbelief for twenty minutes.”

Today it seems highly unlikely that Fermat completed his own proof in the 17th century since Wiles’ work made use of an enormous and elaborate formal structure, including whole sub-fields of 19th- and 20th-century mathematics that didn’t exist in Fermat’s time.

The second problem is Kepler’s Sphere Packing Conjecture.

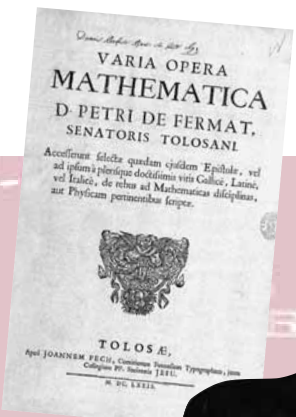
Like the Fermat problem, it was only in the last few decades that sphere packing could have been solved in the way it was. Even so, it took the mathematician Thomas Hales 10 years to do so.

The question was posed in the latter half of the 16th century, when Sir Walter Raleigh was looking for a quick way to estimate the number of cannonballs that could be stacked on the deck of a ship. The query was passed on to Johannes Kepler (1571-1630), the German astronomer, who was already interested in how spheres could be arranged to minimize the gaps among them. But Kepler could find no system more efficient than the way sailors normally stack cannonballs, or grocers stack oranges: a system known as 'face-centered cubic packing'. Kepler declared that this technique was the best one possible, but he was not able to prove it.

By the end of the 19th century the Kepler conjecture was sufficiently important for another famous mathematician, David Hilbert, to include it in his list of 23 great problems to solve.

The problem is difficult because of the immense number of possibilities that must be eliminated. By the mid-20th century, mathematicians had discovered how to reduce this difficulty to a finite problem, but the problem was still too complex to compute.

Even for Hales, with modern computers, the challenge was immense. His equation has 150 variables, each of which must be changed to describe every conceivable stacking arrangement. The proof, explained in a 250-page argument that contains 3 Gigabytes of computer files, relies extensively on methods from the theory of global optimization, linear programming, and interval arithmetic. Even so, the proof has recently created some lively controversy, not over its mathematical analysis, but because the elimination of the huge number of other possibilities has not yet been justified to the satisfaction of the mathematics community.



Like Fermat's Last Theorem, sphere packing sounded simple, but it baffled mathematicians for nearly four centuries. Moreover, both problems had subtle difficulties that led numerous mathematicians to believe they had found solutions that ultimately turned out to be false.

It is also worth noting that the topic of sphere packing belongs to a very important area of mathematics that lies behind error-detecting and error-correcting codes. These are the codes that are used to store information on compact disks and to compress information for transmission around the world. In today's information society, it is difficult to think of a more significant application of mathematics. From a grocer's display of oranges to the storage of information on a computer disk may seem like a huge leap, but for a mathematician these different areas of human activity are part of the same systematic logic.

CROSSING INTERNAL BARRIERS

These two proofs could be described as intellectual exercises of great precision, abstraction, and, some would say, beauty. But mathematics has a dual nature, which is part of the reason for its vitality. In addition to its intellectual and aesthetic qualities, mathematics is tremendously useful in the real world.

It is effective not just in describing science, but in combining with the sciences to create new insights and whole new sub-fields. For example, the development of Computed Axial Tomography (CAT) and Magnetic Resonance Imaging (MRI) scanning technology was built upon integral geometry. The generation of codes for the secure transmission

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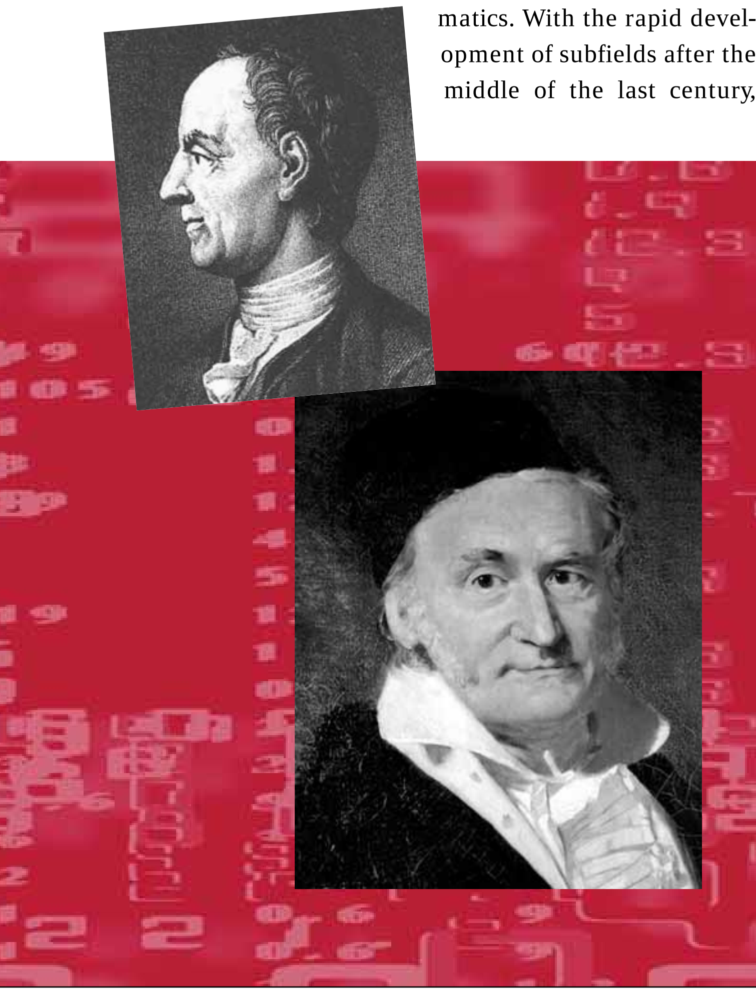
of data depends on the arithmetic of prime numbers. And the design of large, efficient networks in telecommunications uses infinite dimensional representations of groups.

Thus mathematics is both an independent discipline valued for precision and intrinsic beauty, and a rich source of tools for application in the 'real' world. The two parts of this duality are intimately connected. In mathematics, the abstraction is the reality.

A principal reason mathematics is so healthy today is the breakdown of barriers within the field. At first glance, the full body of mathematics, assembled over more than 25 centuries, seems to defy the possibility of unity. Gone are the days when a single giant – a Leonhard Euler (1707-1783) or a Carl Friedrich Gauss (1777-1855) – could command all of mathematics. With the rapid development of subfields after the middle of the last century, mathematics became so specialized that practitioners had difficulty communicating with anyone outside their own specialist subject area.



But this trend toward fragmentation is accompanied by a growing tendency to address interesting problems in an overarching manner. Subfields, once viewed as separate, are now seen as part of a whole as new connections emerge between them.

Mathematics and the other sciences are becoming much more interrelated and interdependent.

Algebraic geometry, for example, the field I am most familiar with, combines algebra, geometry, topology, and analysis. Synergies in this area have played a major role in some of the crowning achievements of pure mathematics and reflect the ability of mathematicians to draw on different subfields and to see their subject as a whole.

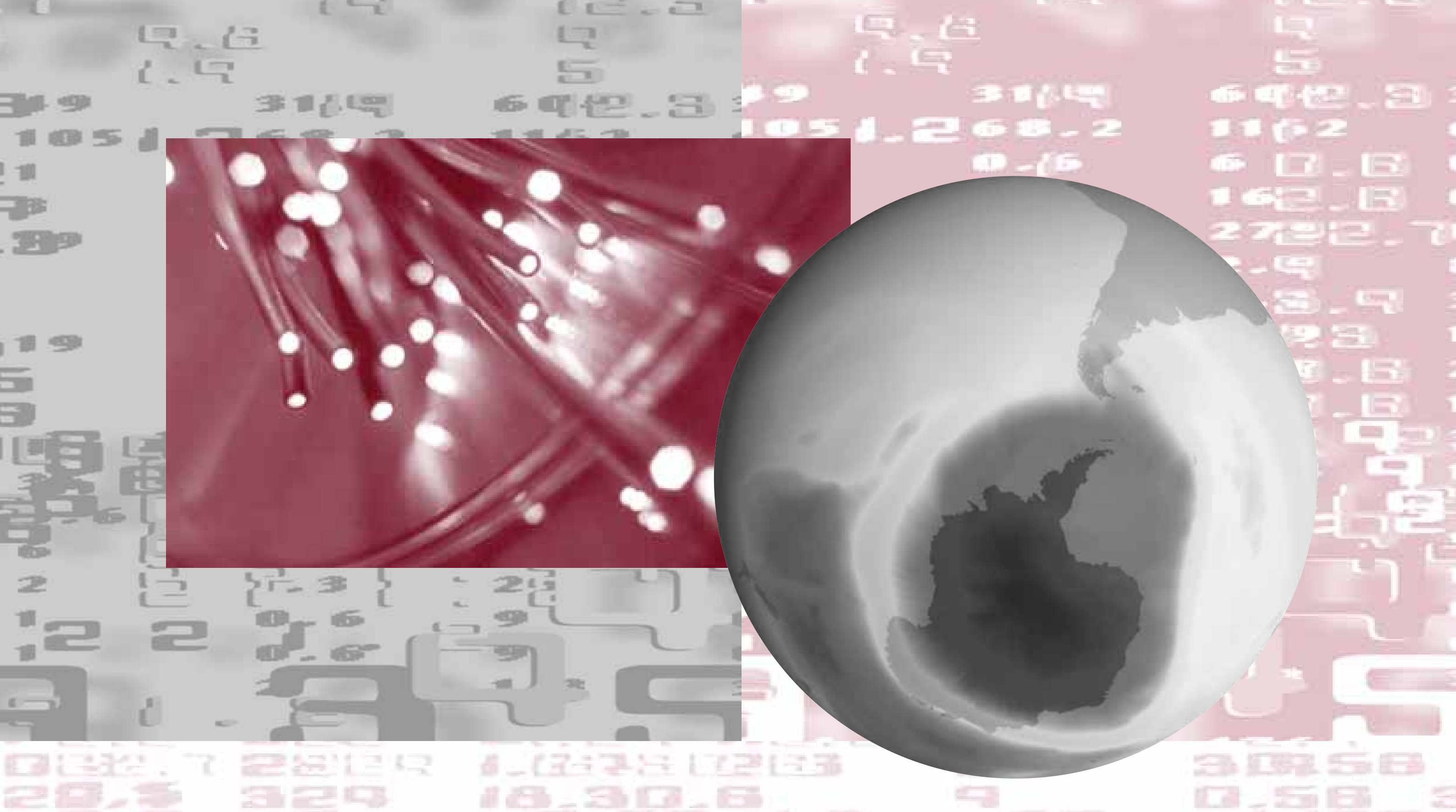
INTERACTIONS WITH OTHER SCIENCES

Beyond the breakdown of internal barriers, mathematics and the other sciences are becoming much more interrelated and interdependent. These interactions are leading both to great insights and fundamental advances in mathematics. They also reflect some important trends in scientific research generally, along with some of the challenges that await us in the 21st century.

The first major trend is in the way we describe research.

Many people assume that basic research is different from applied research. They might say that basic research is the pursuit of knowledge for its own sake, without much thought about how it will be used, whereas applied research is done with specific goals in mind. People still talk about a 'linear model' of research where knowledge moves in one direction from basic research to applied research to development. But this model does not match the real world. Even the simplest research project involves a dynamic flow of ideas and information with multiple feedback loops.

We can think of many examples of how creative research depends on interaction between basic and applied thinking. Louis Pasteur (1822-1895) was often motivated by practical questions from medicine, wine



making and agriculture, and these questions led him to fundamental discoveries about basic biology and disease. Gregor Mendel (1822-1886) was looking for practical answers to improve agricultural crops when he discovered the basic laws of genetics. More recently, the study of basic optics in physics has led to the development of fibre optics – an integral component of modern telecommunications.

Similarly, mathematics is essential to the design of fibre optic cables. The mathematical theory of solitons (pulse-like waves that exist in nonlinear systems) provides excellent models that help design the most efficient light pulses for particular fibre optic functions. So we can see how different fields can provide unexpected insights to produce practical results.

A second major trend in research is the expansion of the scientific process itself.

Until recently, the scientific method was framed by two steps – theory and experiment. Now, with the explosion of computing capacity, we have added the third and very mathematical step of computation. This new step allows us to design mathematical models of systems that are too complex to measure or quantify directly, and to answer questions that were beyond understanding only a few decades ago.

A familiar example that requires extensive computation is the mixing of oceans and atmospheres, which is far more complex than normal diffusion processes such as the spreading of ink through water. A careful examination of the oceans or atmosphere, for example, reveals 'islands' of unmixed fluid that are not penetrated from the outside.

In the oceans, this phenomenon can be a matter of life or death for fish, which depend on the mixing of nutrients, plankton and other fish. In the atmosphere, these islands can determine the spread of pollution and greenhouse gases.

The ozone hole that forms every winter over Antarctica is one of these islands. The hole is surrounded by ozone, and the atmosphere is stirred by turbulence, but the surrounding ozone doesn't enter the hole. This is because it is at the centre of a large vortex, and mathematical models correctly predict that the outer edge of the vortex acts as a barrier to mixing. When warming breaks up the vortex each spring, the barrier disappears and new ozone returns to fill the hole.

Understanding this phenomenon requires all three steps of the scientific process – the theory of fluid mechanics, experiments with atmospheric conditions, and finally computation, which is then checked against the original observations. Such understanding was

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impossible before the advent of modern computing power.

A third broad trend today is the shift towards interdisciplinary research – a shift in which mathematics plays a central role.

Traditionally, academic research institutions are organized by disciplines, and a successful academic career is primarily dependent on success in disciplinary research.

By and large, disciplinary mathematics and science have been spectacularly successful: physicists have explored the building blocks of matter, chemists have learned to create new compounds with specified qualities, and biologists have identified many of the genes and proteins that regulate life. At the same time, new interdisciplinary teams are examining problems, the complexities of which are greater than any single discipline.

For a long time, mathematics has been linked with theoretical physics, and the link has grown stronger over the last two decades. My own field of algebraic geometry, for example, has become an essential tool for theoretical physicists in their search for a unified field theory – or, more precisely, a theory that unifies gravity with the three fundamental forces of physics: the strong nuclear force, the weak nuclear force, and electromagnetism.

Mathematical research leads us not only to theoretical and practical knowledge, but also to better ways of working together.

One interesting candidate for such a unifying theory is 'string theory'. The effort to understand this extremely complex theory has led a group of theoretical physicists deep into mathematics where they have made a series of spectacular predictions about mathematics – predictions that are only now being confirmed.

Another fast-growing new partnership involves collaboration between mathematics and biology. In the 1920s, the Italian mathematician Vito Volterra (1860-1940) studied fish in the ocean and found that the populations of predators and prey could best be described mathematically. Modelling methods developed for populations have since been extended to epidemiology, which resembles population biology since it focuses on the study of diseases in large populations of people.

Most recently, the insights of molecular genetics have inspired scientists to adapt these same methods to infectious diseases, where the objects of study are not populations of organisms or people, but populations of cells. The reason this partnership is successful is that mathematical models offer tools of sufficient power to describe the immense numbers and relationships found in biological systems.

Mathematical models can also contribute to the battle against drug resistance. A major threat to human health in this century will be microbial resistance to drug therapy. Models can point to clear guidelines for the collection and analysis of data, which can then be applied to make drugs more effective.

The fourth major trend is a shift away from the focus on reductionism towards the study of more complex systems.

Scientists have long tried to reduce matter to its smallest parts, and to describe the interaction of these parts with simple laws. While these laws seek to be simple, the world itself is complex. And because the world is complex, there is a demand for more effective mathematical models.

A good example is the use of complexity in the life sciences. We now know that the expression of individual genes is regulated not by one, two, or five proteins, but by dozens, and interactions between molecules in a cell have feedback effects that increase or decrease the expression of other molecules. Attempts to model such cellular systems by computer are now being developed and such efforts have even spawned a new cross-discipline – bioinformatics.

CHALLENGES AHEAD

As we move into the 21st century, there is increasing interest in collaborations between mathematics and the other sciences. These collaborations bring support for mathematics and involve mathematicians in some of the most stimulating questions of modern science. As we move forward, it is essential for the health of mathematics to achieve a balance between pure mathematics and these new partnerships.

As we try to maintain this balance, some difficult challenges await us.

One barrier to interaction is our tradition of isolation. For a long time, many mathematicians have been isolated from other subfields of mathematics, from other fields of science, and certainly from non-academic areas of science. This is beginning to change, and we now have the opportunity to build stronger bridges among different fields and among institutions.

In overcoming this isolation, it is encouraging to look at the rich history of mathematics. We think of Isaac Newton, Leonhard Euler, Carl Friedrich Gauss, Bernhard Riemann, Henri Poincaré and others whose mathematics were integral to studies of the physical world. For most of our history we have participated in the mathematical aspects of other sciences and found them intrinsically interesting.

But in this new century opportunities seem to be much greater. In this regard, universities can learn from the private sector about interactivity. For example, in one of the greatest research institutions in the United States, the old Bell Laboratories, researchers were organized around interesting scientific areas such as telecommunications rather than rigid disciplines. The organizational structure did not determine the science; the science determined the organizational structure. This allowed the freedom and flexibility of thought to pursue problems with great success.

Mathematical and scientific research leads us not only to theoretical and practical knowledge, but also to better ways of working together across boundaries – whether geographical, cultural or institutional.

The challenge for mathematicians will be to strike a balance between the pursuit of their subject for its own sake and the application of mathematics in other areas of science and technology.

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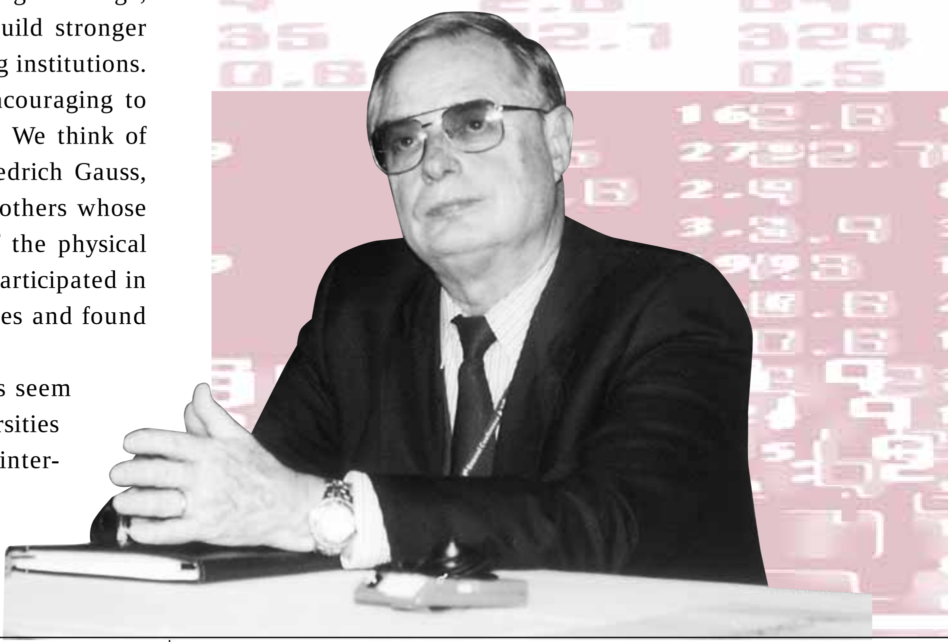
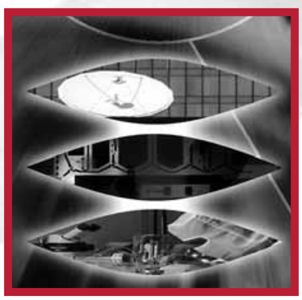


FIRM FOUNDATION

THE NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA (NSFC) WAS FORMALLY ESTABLISHED IN 1986. MODELLED AFTER THE US NATIONAL SCIENCE FOUNDATION, THE NSFC HAS GROWN INTO CHINA'S LARGEST AGENCY FUNDING BASIC RESEARCH. NSFC'S PRESIDENT CHEN JIA'ER EXPLAINS HOW THE FOUNDATION IS ORGANIZED AND THE REASONS BEHIND ITS SUCCESS.



In 1982, a group of Chinese academicians lobbied the government on the need for a Natural Science Foundation of China. The government responded, and in 1986 the NSFC was formally established. It is now the major funding agency for basic research in China. Since 1986, the NSFC's budget has increased from less than US$10 million a year to almost US$300 million, mainly from government sources.

ORGANIZATION

The NSFC is organized with a council that includes a president and seven vice-presidents, each of whom is an expert in his or her scientific field.

Together, they bring to the council first-hand knowledge of a wide range of disciplines. Each of the seven vice-presidents oversees a department responsible for a specific area of science: mathematical and physical sciences, chemical sciences, life sciences, earth sciences, engineering and materials sciences, information sciences and management sciences.

Each department also has an advisory committee composed of experts who prioritise the research programmes. These priorities are published in an annual *Guide to Programmes* so that scientists throughout China can apply for grants. Areas in which the committees concluded that the previous year's applications were weak or derivative rather than innovative are also highlighted in the book, which helps to push research into critical areas.

The foundation's prevailing principle is that science should be guided by transparency, competition and merit. The review process is, in fact, open, ensuring that individual scientists gain support based on the excellence of their research proposals.

PROGRAMMES AND PROJECTS

The main mission of the NSFC is to support basic and applied research in China and to foster young talent. This is done through a variety of structured programmes.

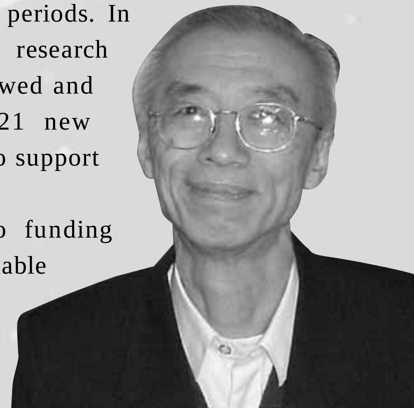
• First in importance is the *General Programme*, which is divided into several sections. The *Project of Free Application* is open to all scientists in China who can apply to carry out projects on any research topic specified in the *Guide to Programmes*. This project alone accounts for 60 percent of the NSFC's budget. Projects typically receive around US$40,000 per year for three years. The General Programme also earmarks funds for the less developed regions of China such as the Inner Mongolia Autonomous Region and Yunnan Province, and for young scientists. In the latter case, applicants must be under the age of 35, lead a team of mainly young researchers, and have their own creative ideas.

• *Key Programme* projects attract more funding (around US$200,000 a year) compared to Projects of Free Application and are designed to foster the exploration of critical scientific problems and newly developing areas of science that require more in-depth research. Some of the projects funded under the Key Programme were initiated by projects funded under the General Programme.

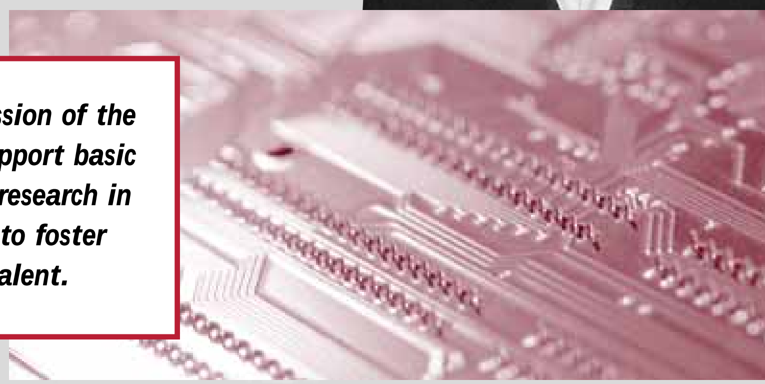
• A *Major Programme* focuses on interdisciplinary and interdepartmental efforts, perhaps involving three or four research groups, aimed at solving major scientific and technological issues or national economic and social development needs. One such example is the modernization of traditional Chinese medicine, which requires collaboration between physicians, biochemists, information scientists and statisticians.

• *Major Research Plans* obtain funding from General, Key and Major Programmes. The modernization of traditional Chinese medicine is also funded under this programme. Other focus areas include the environment and ecology of western China, bioinfomatics, nanoscience and nanotechnology, and the regional response to global climate change.

• *Groups of Scientific Excellence* are well-established scientific groups of six to ten people working on collaborative projects. Since 2000, selected groups are given US$450,000 for three years, renewable for two additional three-year periods. In 2003, 15 of the original 55 research groups had their funding renewed and funding was provided for 21 new groups. There are also plans to support another 40 groups by 2005.



This layered approach to funding ensures that resources are available for all aspects of the nation's scientific infrastructure and enterprises: conventional and cutting edge research; young and experienced scientists; centres of excellence and institutions far from the more developed eastern regions of the country.



The main mission of the NSFC is to support basic and applied research in China and to foster young talent.

The goal is to push the development of institutions that have the wherewithal to compete in the international science arena while providing assistance to those institutions seeking to gain regional and national strength.

INTERNATIONAL COLLABORATION

About five percent of the foundation's total budget is allocated to international cooperation and exchanges. In fact, the Third World Academy of Sciences' conference in Beijing was supported by the NSFC as part of its commitment to encourage high-level academic meetings in China.

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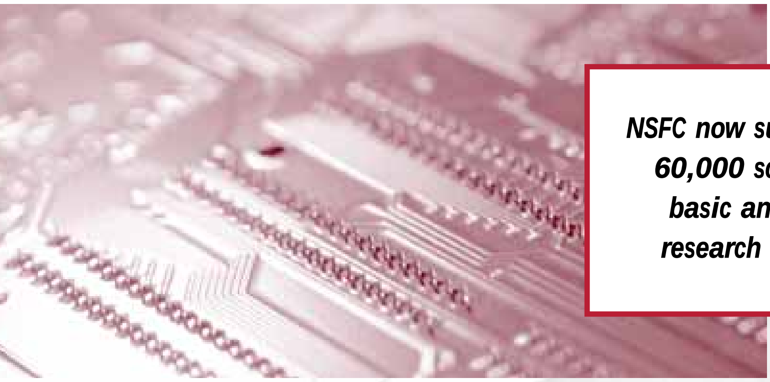
The foundation also supports more than 1,000 Chinese scientists a year to travel abroad to major international conferences, and there is a separate fund for Chinese scholars working abroad in such countries as Germany and the United States to come back to China for periods of one week to a month to lecture or to develop and carry out collaborative research projects.

Another active part of the NSFC's outreach is to fund cooperative research projects. About 200 such projects are currently underway in nearly 40 countries, including bilateral arrangements with the Australian Research Council, the Council for Scientific and Industrial Research (CSIR) in India, and Mexico's *Consejo Nacional de Ciencia y Tecnologia* (CONACYT, National Council for Science and Technology).



NSFC now supports some 60,000 scientists in basic and applied research each year.

The NSFC has also sent some 50 students to the Abdus Salam International Centre for Theoretical Physics (ICTP) at Trieste. The largest share of its budget for international cooperation, however, goes toward funding such major joint research programmes as an antimatter project in collaboration with the European Organization for Nuclear Research (CERN) in Switzerland, which also includes research carried out at ICTP.

SUCCESS

NSFC now supports some 60,000 scientists in basic and applied basic research each year. For the past three years, NSFC-funded scientists have won the Chinese government's highest award for scientific excellence. The foundation's career support for young researchers – whereby they receive larger grants for bigger projects as their work proceeds – is also paying dividends, as can be seen by the fact that almost all the young scientists elected to the Chinese Academy of Sciences over the past five years have been NSFC-funded. In addition, of the papers by Chinese scientists published in *Nature* and *Science* over the past few years, more than 85 percent were supported by NSFC grants. The foundation can also take credit for supporting over 85 percent of the projects in the national Major Research Plan.

Despite these successes, the NSFC still hopes to secure larger budgets in the future. The US National Science Foundation funds some 30 percent of the applications it receives. Studies from the United Kingdom support the view that such a success rate – about one in three – is the threshold for creative research to flourish. With its current budget, however, the NSFC funds less than 6,000 of the 34,000 proposals that it receives each year – a success rate of less than 20 percent.

The openness that the NSFC applies to its grant proposal review process is a valuable lesson that can be learned by other developing countries when allocating their science budgets. Above all, however, government support has been essential to the success of the NSFC and the recent successes of Chinese science in general. Without such long-term support, and without nurturing the careers of young scientists who are dedicated to the development of their own country – by rewarding them for the excellence of their research – the building of scientific capacity in many Third World countries will remain too slow to keep pace with countries in the North and the gap between the rich and poor will continue to widen. ■

BEIJING DECLARATION

The 14th General Meeting and 9th General Conference of the Third World Academy of Sciences (TWAS) and the 8th General Assembly of the Third World Network of Scientific Organizations (TWNSO) have been successfully convened in Beijing, People's Republic of China, during 16–19 October 2003.

We, the participants, focusing on the subject of 'Science for Development'; aiming at scientific advancement, openness, and cooperation; and further enhancing South-South and South-North cooperation,

And having witnessed the launch of China's Shenzhou-V, the first successful manned space capsule designed and built by a developing country, and which serves as a symbol of the impressive growth of science and technology that has taken place in China over the past decade:

CONSIDERING THAT:

1. Science is the heritage of all humankind and political borders should not bind its pursuit and applications. The rights of acquiring and applying scientific and technological research results should be equally accessible to all countries, developed and developing;

2. Science and Technology (S&T) is the paramount force behind the advancement of human civilization. The productivity gains and achievements of humankind have been derived chiefly from scientific discovery and technological and engineering innovations, as well as extensive applications of S&T in the social life of humankind. Today, fully realizing that S&T is a 'double-edged sword,' we should assume greater responsibility in the applications of scientific research to promote peace and prosperity and the sustainable development of our global community;

3. The scientific achievements of humankind result from contributions made by every nation. Third World countries, with their deep-rooted civilizations, not only have great traditions of S&T development but also have made invaluable contributions to the advancement of modern S&T. However, many of these nations still lag far behind the economically advanced world and confront severe challenges related to such issues as the promotion of economic and social development, the elimination of poverty, the rational use of resources, and the protection of ecosystems;

4. The primary task of future S&T development lies in its ability to provide solutions to address these problems and to help promote economic and social development. As the lifeblood for sustainable development, constant and systematic support for basic scientific research and education should remain a fundamental element of governmental policies;

HEREBY DECLARE THAT:

Building S&T capacity is a crucial factor in:

1. Reducing the number of people living in poverty, increasing access to healthcare and thereby promoting social equity and improving the standards of living of all humankind;

2. Protecting the benefits provided by ecosystems, including clean air, soil, water and indeed all the Earth's natural resources;

3. Promoting the sustainable development of human society and the equitable sharing of S&T achievements with present and future generations.

WE ALSO DECLARE THAT:

1. It is essential for the scientific community to strengthen its cooperation with all other sectors of society, to propose targets for sustainable development, and to gradually narrow the gap in scientific and technological capabilities between the developing and developed countries;

2. It is imperative for every nation to attach great importance to the development of science, technology and education, which offers the most direct route for them to become strong and prosperous;

3. It is necessary for every nation to promote international cooperation and exchange in science and technology for the purposes of addressing the South's common problems and for exploring ways to promote our shared desire for development;

AND RECOMMEND THAT:

1. TWAS, and its affiliated organizations (including TWOWS and TWNSO)

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expand their programmes for South-South cooperation by encouraging centres of scientific excellence in the developing world to offer research fellowships to scientists working in universities and research institutes in scientifically lagging nations in the South. South-South fellowship programmes for students to pursue PhD degrees that have recently been initiated by Brazil, China, India, and Iran, under the administrative umbrella of

TWAS, represent a substantial expansion of the Academy's advanced educational training activities. The TWOWS postgraduate fellowship programme, which offers educational opportunities for young university-educated women from the least developed countries (LDCs) who are seeking advanced degrees in science, is also an important step forward for South-South cooperative educational efforts. The ultimate goal is to create a 'pan-South' network of fellowship programmes, which would help ensure that scientists across the globe can reach their full potential. TWAS will seek to have 500 fellowships in place by 2005.

2. TWAS should strengthen and expand its programmes for North-South cooperation by encouraging programmes that foster the exchange of scientists and scientific expertise between the developed and developing world. The ICSU/TWAS/UNESCO/UNU-IAS Visiting Scientists Programme, which enables scientists in the North to make brief periodic visits to institutions in the South, could serve as a model for other like-minded programmes. TWAS should seek to develop programmes that not only encourage the participation of individual scientists but also engage scientific institutions in the North.

3. TWAS and TWNSO should encourage the creation of national science foundations in individual countries throughout the developing world. Foundation-like organizations in the developing world – for example, the National Natural Science Foundation of China, South Africa's National Research Foundation, and the Kuwait Foundation for the Advancement of Sciences – could serve as models for other developing countries.

4. TWAS should explore strategies for strengthening programmes that promote science-based sustainable development. The Academy should continue its involvement in the development of the Consortium for Science and Technology for Sustainable Development, a partnership forged with the International Council for Science (ICSU) and the Initiative on Science and Technology for Sustainability (ISTS). The Consortium aims to develop pro-

grammes that create measurable benchmarks for assessing the progress made in advancing science-based sustainable development. Problem-solving research and scientific capacity building are the two critical elements driving this effort. The project, which was initiated last year and has since established an expert advisory board that includes representatives from the natural and social sciences, has outlined an ambitious agenda. If successful, it could help to dramatically transform the relationship between science and society both in the South and North.

5. TWAS should continue to expand its interaction with the social science and economic development communities as part of its larger effort to increase the impact of science on society. TWAS should seek to strengthen its emerging partnership with ISTS and Leadership in Environment and Development (LEAD) to develop a broad based training programme to help diplomats and trade negotiators achieve a better understanding of science and its potential role in decision making, focusing on such issues as intellectual property rights. Funding for this initiative will be sought over the next year.

6. TWAS and TWNSO, in cooperation with the InterAcademy Panel on International Issues (IAP) and the US Na-

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tional Academy of Sciences, should expand their recent efforts to build the capacity of science academies, especially those in developing countries, and to help them become more effective forces within their societies. These efforts should focus on implementing the recommendations of the IAP/TWAS workshops and conferences that have already taken place to advance this goal. The initial success that has been attained in Africa, Asia and Latin America should serve as a foundation for devising additional mechanisms by which science academies may become instruments of change both within their own nations and among international organizations where inputs from scientific experts could help improve the decision-making process.

7. TWAS should initiate roundtable discussions between the developing world's leading scientists and ministries of science, nonprofit organizations and the private sector to explore ways for better integrating science into broad sectors of society that lie beyond the scientific community. At the same time, TWAS should seek funding to prepare a series of reports for the policy making community in the developing world that examine critical problems facing the South. These reports should be distributed widely throughout the South and North.

8. TWAS, through its recently established regional offices and in cooperation with TWNSO's regional offices, should hold regional meetings that bring together leading scientists and high-ranking public officials to discuss strategies for addressing critical regional issues.

9. TWAS, in collaboration with TWNSO and its members, should implement the recommendations of its reports on safe drinking water and renewable energy in collaboration with local, national and global agencies.

10. Many path-finding research investigations of scientists are not published in front-ranking journals in the North. Yet these are relevant and important, and should be made known to the world. To this end, TWAS should begin publication of periodic 'Research Highlights,' which will summarize these studies in a rigorous and professional manner. TWAS should also support efforts to have these highlighted research reports covered in the world's high-impact journals.

11. TWAS should continue to expand its collaboration with the other scientific institutions that form part of the Trieste System, including the Abdus Salam International for Theoretical Physics (ICTP), the International Centre for Genetic Engineering and Biotechnology (ICGEB), the International Centre for Science and High Technology (ICS) and the InterAcademy Panel on International Issues (IAP). Individually and in concert with each other, these institutions have developed innovative instruments for helping scientific communities in developing countries.

12. TWAS should continue to strengthen its collaboration with the Group of 77 (G-77), the largest group of nations within the United Nations. The Academy served a primary role in the organization of the G-77 South-South High-Level Conference on Science and Technology, held in Dubai in October 2002. It should now seek to pursue other joint activities with the G-77. TWAS should also seek ways to enact provisions of the Dubai Declaration, which voiced strong support to strengthening and expanding the Trieste System. In addition, TWAS should support efforts to make the Trieste System a model that can be emulated by the UN and other international and national institutions worldwide.

Over the past two decades, TWAS has earned the trust of a large number of developing countries and has emerged as the voice of science for development. TWAS believes that it can build on its success to make even greater contributions to the well-being of the developing world in the future.

Agreed to by TWAS Fellows and Associate Fellows in attendance at the 9th General Conference and 14th General Meeting of the Third World Academy of Sciences (TWAS), Beijing, China, 16 October 2003.

WHAT'S TWAS?

THE THIRD WORLD ACADEMY OF SCIENCES (TWAS) IS AN AUTONOMOUS INTERNATIONAL ORGANIZATION THAT PROMOTES SCIENTIFIC CAPACITY AND EXCELLENCE IN THE SOUTH. FOUNDED IN 1983 BY A GROUP OF EMINENT SCIENTISTS UNDER THE LEADERSHIP OF THE LATE NOBEL LAUREATE ABDUS SALAM OF PAKISTAN, TWAS WAS OFFICIALLY LAUNCHED IN TRIESTE, ITALY, IN 1985, BY THE SECRETARY GENERAL OF THE UNITED NATIONS.

TWAS has 710 members from 81 countries, 66 of which are developing countries. A Council of 13 members is responsible for supervising all Academy affairs. It is assisted in the administration and coordination of programmes by a small secretariat, headed by the Executive Director. The secretariat is located on the premises of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. UNESCO is responsible for the administration of TWAS funds and staff. A major portion of TWAS funding is provided by the Ministry of Foreign Affairs of Italy.

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 scholarship.

TWAS was instrumental in the establishment in 1988 of the Third World Network of Scientific Organizations (TWNSO), a non-governmental alliance of 160 scientific organizations from Third World countries, whose goal is to assist in building political and scientific leadership for science-based economic development in the South and to promote sustainable development through broad-based partnerships in science and technology. **www.twnso.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 2000 women scientists from 87 Third World 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 90 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**

WANT TO KNOW MORE?

TWAS offers scientists in the Third World a variety of grants and fellowships. To find out more about these opportunities, check out the TWAS web-pages! Our main page is at:
www.twas.org

FELLOWSHIPS

Want to spend some time at a research institution in another developing country? Investigate the fellowships and associateships programmes:
www.twas.org/Fellowships.html
www.twas.org/AssocRules.html

GRANTS

Seeking funding for your research project? Take a look at the TWAS Research Grants:
www.twas.org/RG_form.html
TWNSO runs a similar scheme, for projects carried out in collaboration with institutions in other countries in the South:
www.twnso.org/TWNSO_RG.html

EQUIPMENT

But that's not all TWAS has to offer. For instance, do you need a minor spare part for some of your laboratory equipment, no big deal, really, but you just can't get it anywhere locally? Well, TWAS can help:
www.twas.org/SP_form.html

TRAVEL

Would you like to invite an eminent scholar to your institution, but need funding for his/her travel? Examine the Visiting Scientist Programme, then:
www.twas.org/vis_sci.html

CONFERENCES

You're organizing a scientific conference and would like to involve young scientists from the region? You may find what you are looking for here:
www.twas.org/SM_form.html