SPECIAL ISSUE

STARS OF SOUTH AMERICAN SCIENCE

Growing resources for research and development are creating opportunities across the continent, but many countries still struggle to build their programmes.

Like the night sky, the overall sweep of science in South America can look pretty dark. Brazil is the only country on the continent that spends more than 1% of its gross domestic product on research and development, and even that investment sits far below what other countries of similar means are ploughing into science.

But take a closer look at the continent's scientific enterprise, and bright spots emerge. At the start of the FIFA World Cup in Brazil, with billions of people focusing on South America, *Nature* examines a part of the world that has spent too long on the sidelines of science.

A graphic tour on page 202 details the inputs and products of research and development on the continent. The region faces many challenges in terms of building a strong scientific workforce and boosting resources, but investment and publications are climbing. A News Feature on page 204 profiles several key institutions and research groups — from agricultural specialists in Colombia to RNA experts in Argentina — who have gained worldwide recognition.

An Editorial on page 188 calls on international colleagues to help build South American science in ways that do not cause young researchers to leave permanently. On page 213, a Comment describes one such success: the Pew Latin American Fellows Program, which each year sends about ten top graduates to work in North American labs. More than 70% return to their native countries, bringing with them the expertise they have gained. That initiative is a part of broader efforts, described in a News Feature on page 207 that examines how countries are trying to repatriate scientists who left to train abroad.

As economies on the continent heat up, they are devoting greater resources to research, increasing the need for better infrastructure and policies to support science. In a Comment on page 209, research leaders describe how they hope to navigate this growth, and how science can help to expand their countries' economies sustainably. Ideas range from creating a science ministry to using research to find new commercial uses for the fruits of the Amazon.

Many researchers in South America maintain a cautious outlook — they have lived through periods of intense economic and political strife in the not-too-distant past. But they also harbour the hope that the continent's science is headed for a winning season. ■

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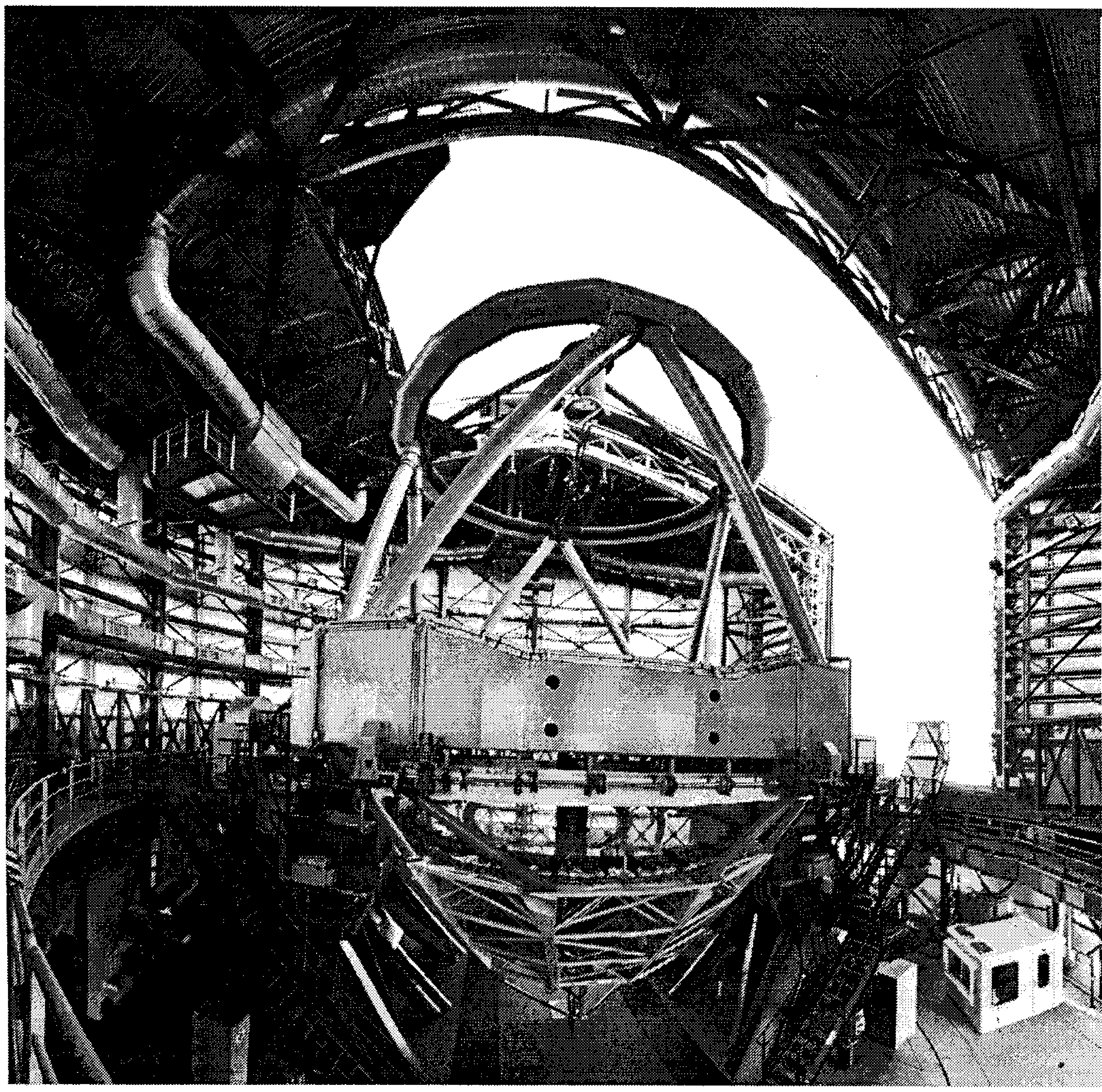
Big *players*

Despite myriad problems in many countries, pockets of excellence thrive in South American science.

IT MAY SEEM HERETICAL TO SAY SO IN THE LAND OF THE BEAUTIFUL GAME, but science in Brazil beats the World Cup — at least in a financial match-up. Government and businesses there invest some US$27 billion annually in science, technology and innovation, dwarfing the price tag for the football tournament, which tops out at about $15 billion.

Science in Brazil and many other countries in South America has come a long way since the dark days of the dictatorships just a generation ago. In Argentina, the number of science doctorates jumped nearly tenfold between 2000 and 2010; Peruvian scientists tripled the tally of articles they produced over the same period; and science funding is climbing in most countries.

South American science still has far to go if it hopes to catch up with other continents. By many measures — such as investments, patents and education — the countries there lag behind other nations with similar levels of gross domestic product (GDP). There is looming instability in countries such as Argentina and Brazil, where recent protests reflect deep social and economic divisions — problems that plague much of South America. But amid the concerns, there are many bright spots in the world of science. Here, Nature highlights several examples of outstanding researchers and institutions in the region.



The European Southern Observatory operates the Very Large Telescope in northern Chile.

B. TAFRESHI/ESO

CHILE

UPWARD TRAJECTORY

BY MICHELE CATANZARO

When Mario Hamuy finished his university degree in Chile in 1982, he was one of just a handful of students in the country interested in pursuing graduate studies in astronomy. Now, more than 25 Chilean students join such programmes each year and Hamuy directs the Millennium Institute of Astrophysics in Santiago, home to 95 students and faculty members.

During the course of Hamuy's career, Chile has emerged as a major player in the world of international astronomy, in no small part because of the extraordinary collection of telescopes housed in the country's highlands.

"Astrophysics has come to the forefront of Chilean science thanks to the increase in human resources and to the fact that we have the cleanest sky in the world," says Dante Minniti, an astronomer at the Pontifical Catholic University of Chile in Santiago.

Although Chile invested just 0.44% of its GDP in scientific research in 2011, the latest year for which figures are available, funding for astrophysics has steadily grown, from $2 million in 2006 to $6.8 million in 2010. Over the same period, the number of faculty positions has almost doubled. And the country's publications in astronomy have risen more than fourfold during the past decade.

The quality of the work has improved as well. Chile ranks highly in terms of citations per paper in space science, and some of its scientists have made important discoveries. In the early 1990s, Hamuy made a key contribution that helped others to measure the accelerating expansion of the Universe and win a Nobel Prize in 2011. And Minniti is one of the leaders at the VISTA infrared survey telescope at the European Southern Observatory's Paranal Observatory in northern Chile, which has created a catalogue of more than 84 million stars in the central parts of the Milky Way.

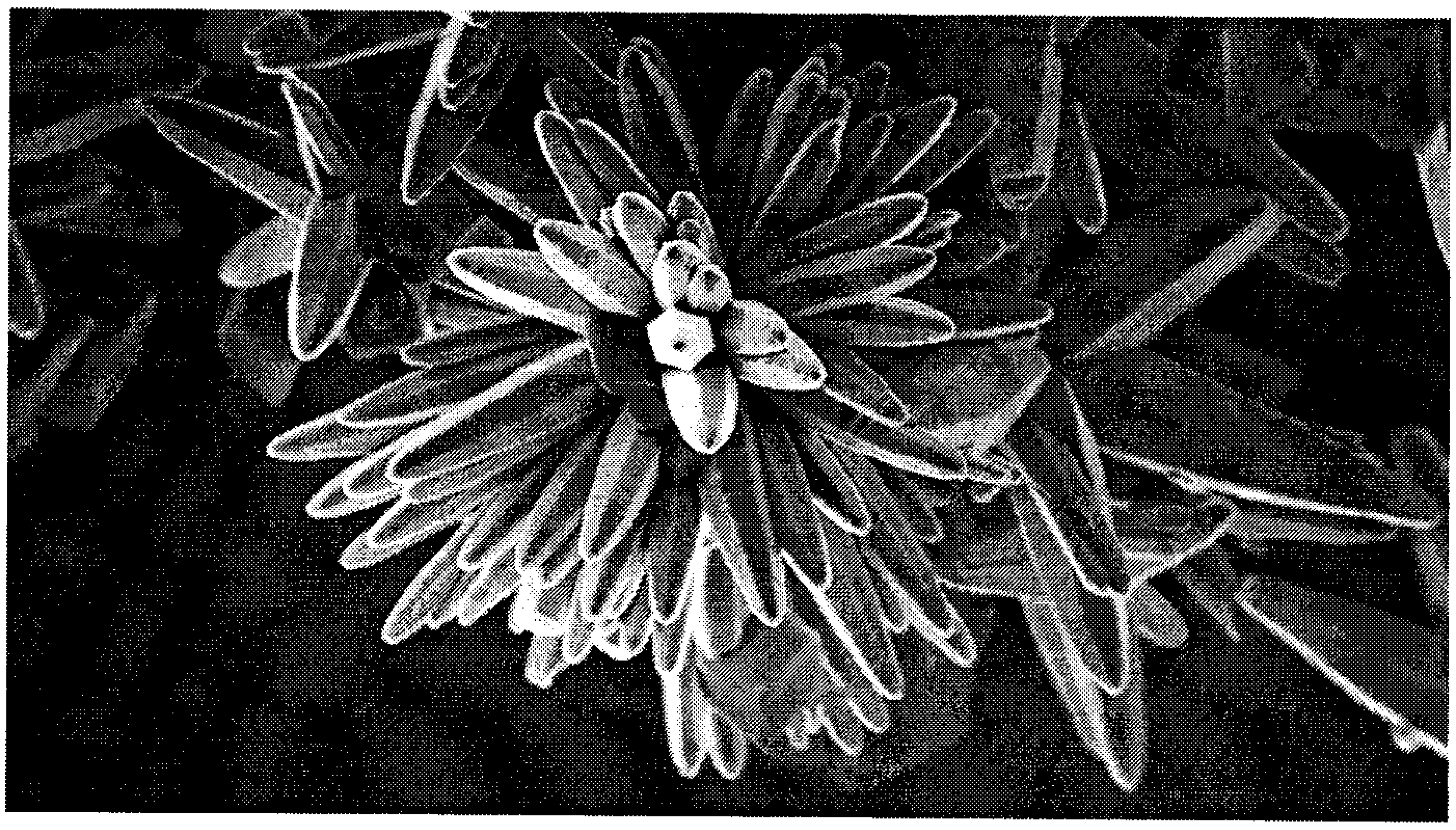
Chile's skies have been attracting international telescopes since 1964. By 2020, when the European Extremely Large Telescope is due to be completed, the country is expected to host 70% of the global observation surface for large optical and infrared telescopes.

By contract, Chilean astronomers get 10% of the observation time on each telescope installed in the country. But some astronomers say that this is too little, considering how much the country provides for the organizations running the telescopes.

"This country has given enormous advantages to the international consortia, ranging from full tax exemption to diplomatic status: it's time that Chile participates in a more active way," says Mónica Rubio, director of the astronomy programme of the Chilean funding agency CONICYT.

A unanimous aspiration of Chilean scientists, says Rubio, is not just to use observatories but also to build them, through local companies and engineers. Another plan Rubio is working on is developing the Atacama Astronomical Park, a 36,347-hectare protected area around the Atacama Large Millimeter/submillimeter Array, which CONICYT plans to use to attract future telescopes from Brazil and the United States, and maybe also from China, South Korea and Thailand.

But many astronomers are worried about the governance of science in Chile. CONICYT has lacked a director since José Miguel Aguilera resigned eight months ago, and the country's new president, Michelle Bachelet, has frozen plans to create a science ministry (see *Nature* **507**, 412–413; 2014). "It's a good moment for Chilean astronomy, but keeping the momentum will require more sustained support from the government," says Minniti. ■



CDFM/FAPESP

A ZnO semiconductor from a FAPESP-funded project.

BRAZIL

SÃO PAULO'S HEAVY HITTER

BY GIULIANA MIRANDA

Although Brazil rivals Europe in size, much of the leading research in South America's largest country emanates from an area the size of the United Kingdom. São Paulo, in southern Brazil, is the richest of the country's 26 states and publishes more than half of Brazil's scientific articles. One of the main reasons for its success is the São Paulo Research Foundation (FAPESP), the state agency that promotes research and education. In 2013, the agency invested $512 million in science funding, more than many nations in the region. (At the federal level, Brazil's National Council for Scientific and Technological Development has a budget of about $650 million for science, technology, and innovation in 2014.)

Created in 1960, FAPESP has a stream of funding guaranteed by the constitution of São Paulo, which requires that 1% of the tax revenue goes to the foundation. Its success in fostering research and education inspired other Brazilian states: all but one now has a similar agency, and most have guaranteed funding linked to taxes.

FAPESP directs 37% of its funding to basic research in fields ranging from climate change to particle physics. About 10% goes to infrastructure and the rest is channelled to applied research. Nearly one-third of its total budget is devoted to medical research.

"One difference in FAPESP's work is that we invest a lot in basic science," says Carlos Henrique de Brito Cruz, FAPESP's scientific director. "We believe in balance."

The most recent large project approved for funding is the Long Latin American Millimeter Array radio telescope, a joint project between Brazil and Argentina that will receive $12.6 million from the agency and an equal amount from Brazil's science ministry. FAPESP's board is considering a $40-million investment in the Giant Magellan Telescope, which would give São Paulo astronomers access to the facility, planned for construction in Chile.

Science officials in other nations can only look with envy at the agency's guaranteed funding. "FAPESP is a very interesting model for us because São Paulo is one of the few states in the world where support of research is linked directly to GDP," says Martyn Poliakoff, foreign secretary and vice-president of the Royal Society in London.

Regional agencies such as FAPESP play a very important role in Brazil, says Wanderley de Souza, a biomedical scientist at the Federal University of Rio de Janeiro and a member of the Brazilian Academy of Science. "They can make research happen even if the federal funding gets scarce."

Brazil struggles with vast economic differences among its various regions, and that is reflected in regional science budgets. FAPESP has the biggest budget of all the regional agencies, but that does not reduce federal investments in the state, says Clelio Campolina, the minister of science, technology and innovation. "We want to improve other states, but also reward excellence," he says.

FAPESP's rapid growth has raised some concerns among scientists in São Paulo who complain about an increase in bureaucracy. But agency officials defend its performance and say they are working to improve its procedures.

It's all part of an effort to produce high-quality work, says Brito Cruz. "We want the best projects." ■

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COLOMBIA

GROWTH CENTRE

BY LISA PALMER

In the Cauca Valley of western Colombia, a herd of hefty cows at Petequi farm munches away on lush grass that looks as if it has grown there forever. But the plants are relative newcomers. They are cultivars of African super grasses, bred for enhanced nutrition and hardiness by researchers at the International Center for Tropical Agriculture (CIAT), less than 50 kilometres to the north.

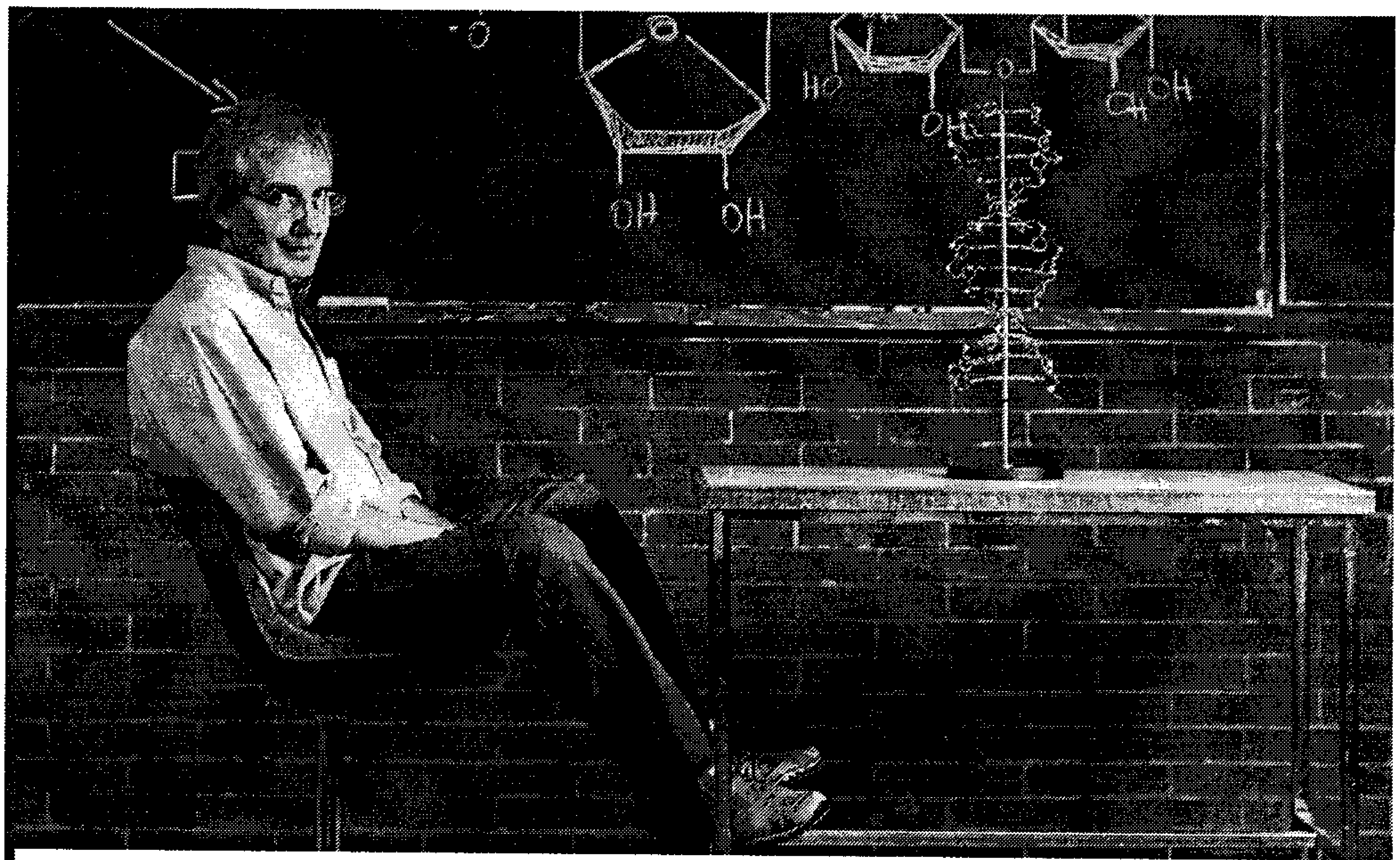
Cows at Petequi once took four years to reach market weight. Now they fatten up in just 18 months. The story is much the same throughout the South American *cerrado*, or savanna. The improved grasses have revolutionized tropical forage across the continent thanks to the combined work of researchers at CIAT and the Brazilian Enterprise for Agriculture Research, a state-owned Brazilian company, says Eduardo Trigo, an agricultural economist and science adviser to the Argentine ministry of science, technology and innovation in Buenos Aires. "CIAT has been one of the key actors in the development of the South American *cerrado*," he says.

Established in 1967, the Colombian facility was one of the first members of the CGIAR consortium of international agriculture research centres. CIAT employs 325 scientists and has an annual budget of $114.4 million, paid for by the multi-donor CGIAR fund and by other international donors.

Aside from its work on grasses, CIAT has focused on breeding improved varieties of beans, rice and cassava — staple crops that are important to the food security of the rural poor. "Genetic improvement of these crops has proved to be a powerful weapon for combating hunger and poverty," says Ruben Echeverría, director-general of CIAT. For example, beans developed by CIAT from Latin American varieties are now feeding up to 30 million people in Africa, according to the centre.

Some 70% of rice in South America, and 90% of cassava in Asia, can be traced back to CIAT's breeding programme. "Cassava is now a multibillion-dollar business for starch production in Asia, providing income to smallholders," says Andy Jarvis, leader in policy research at CIAT.

The centre has also helped to grow expertise on the continent and elsewhere; since CIAT opened, some 13,000 researchers have trained there. Its facilities have been instrumental in building capacity for plant physiologists in the poorer countries of the Andean region, says Trigo. ■



Alberto Kornblihtt: RNA pioneer.

ARGENTINA

THE RNA SLEUTHS

BY ALESZU BAJAK

Molecular biologist Alberto Kornblihtt likes to put things in perspective. "We may be on the periphery of scientific research," he admits from his office in Buenos Aires. "But it's not an impossible place to do science." In fact, he and his community of researchers in alternative RNA splicing — a field he helped to create — have shown that they can do world-class research despite tight government budgets and three-month delivery times for reagents that can cost three times as much as they would in the United States or Europe.

Like Kornblihtt's lab, alternative RNA splicing makes use of constrained resources in innovative ways. Through varied patterns of cutting and rejoining, a single transcribed gene can give rise to many different messenger RNAs, thus permitting a single gene to express different proteins. Kornblihtt found one of the first cases of this process in humans while he was a postdoctoral fellow in the United Kingdom. He moved back to Argentina in 1984 and has assembled a group of researchers that continues to explore this realm.

It has been a good year for his group. Kornblihtt and his doctoral student Ezequiel Petrillo published a paper in *Science* in April on how light affects alternative splicing in plants (E. Petrillo *et al. Science* http://doi.org/s2d; 2014). And last month, Gwendal Dujardin, a postdoctoral fellow from France (a rare sight in an Argentine lab), published a splicing study in *Molecular Cell* (G. Dujardin *et al. Mol. Cell* **54**, 683–690; 2014).

The work is all part of a continuum, says Kornblihtt. He considers scientific research in his native Argentina to be part of a long tradition that started with Bernardo Houssay and Luis Leloir, twentieth-century Nobel laureates whose names now adorn avenues, museums and universities across the country. "The scientific institutions they founded led to generations of disciples that continue to do the science of today," he says.

Kornblihtt carries on that tradition, in part by teaching an introductory course on molecular biology at the University of Buenos Aires. "That course has been a nursery for many young Argentine scientists," he says. It lures in many students, says Diego Golombek, a biologist at the National University of Quilmes in Buenos Aires. "Imagine that on the first day of classes, young students find themselves before the country's most well-known researcher teaching molecular biology classes with an absolutely contagious enthusiasm," he says. "He's had an influence over the new generations of biologists."

Petrillo, who has just left Argentina for a research post at the Medical University of Vienna, says that he will sorely miss the camaraderie of the tight-knit group of RNA researchers from labs and universities all over Buenos Aires. The RNArgentinos, as they call themselves, have for years organized informal seminars and get-togethers to share ideas, concerns, protocols and techniques.

Kornblihtt recognizes that Argentine scientists cannot all work in their home country and he encourages his students to "seed the world" as postdocs abroad. But he asks his university students to complete their PhDs in Argentina. "It's not necessary to leave the country to get a doctorate," he says. "We have a strong science ministry, lots of scholarships and subsidies and new research buildings. The structure to do science in Argentina is not precarious. It has many pillars." ■

VERA ROSEMBERG

HOMEWARD BOUND

South American efforts to repatriate scientists are paying off.

BY BARBARA FRASER

When Andrea Bragas left Argentina in 2000 for a postdoctoral fellowship at the University of Michigan in Ann Arbor, she did not know where she would eventually end up. Although the terms of her fellowship obliged her to return home, Argentina's economy was heading for a crisis and there was no guarantee of continued government funding, much less a job when she came back.

But the gamble paid off. By 2004, Argentina's economy had started to rebound and the president was pledging new investments in science and technology. Bragas returned to teach at the University of Buenos Aires and is now a nanoscientist at CONICET, Argentina's National Scientific and Technical Research Council.

Across South America, thousands of researchers have similar stories. Countries that saw some of their most promising scientists flee during decades of dictatorships or economic crises are now reversing the brain drain, luring researchers home with offers that range from short-term teaching and research fellowships to fully equipped labs and competitive salaries.

"Unlike financial capital, which is hard to recover once it has left the country, intellectual capital returns with interest," says Lino Barañao, Argentina's science and technology minister. "A scientist who has spent some years outside the country has training, networks of contacts and access to top institutions — and from a productivity standpoint can be more valuable than one who has stayed in the country."

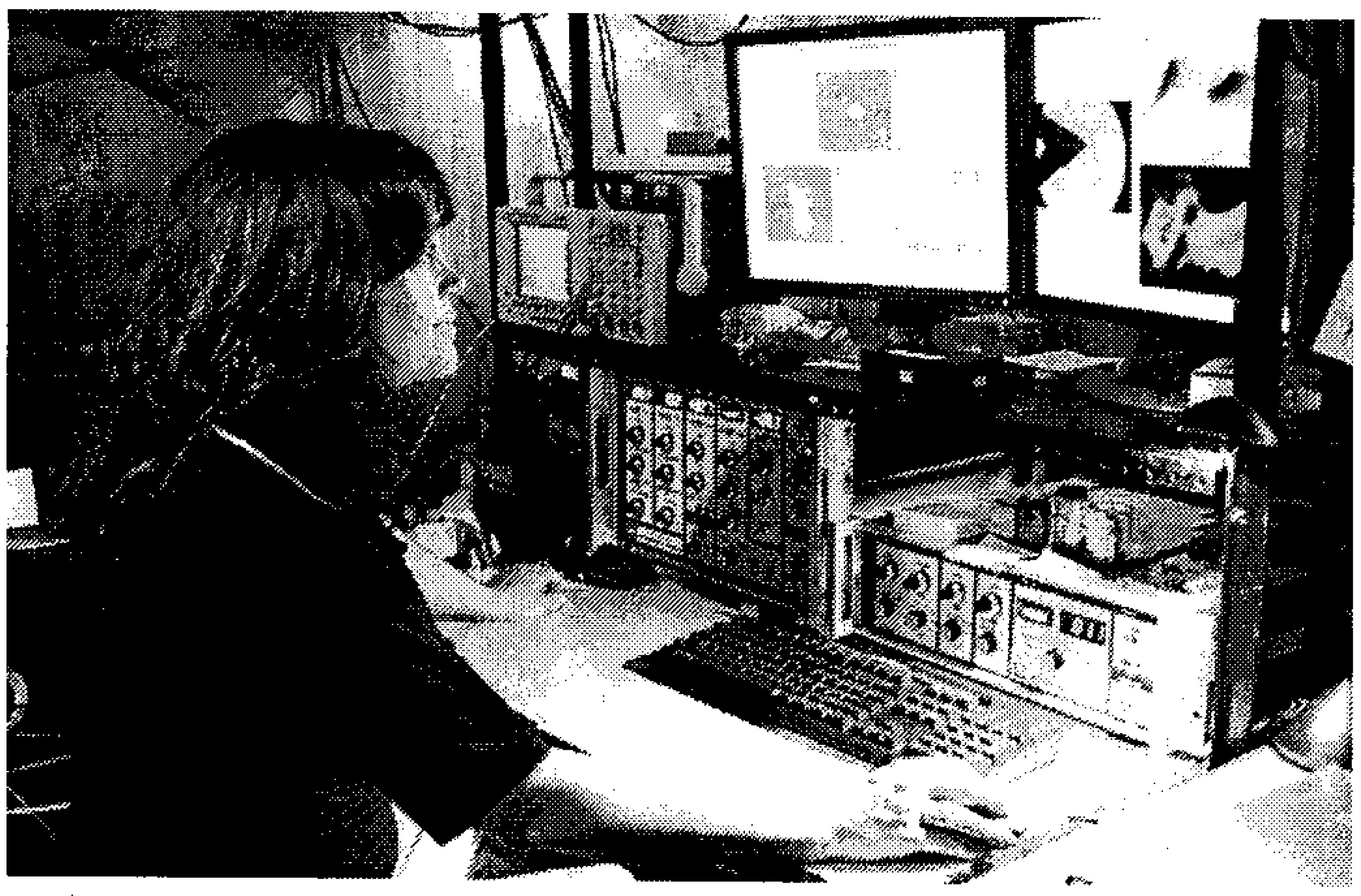
Brazil was one of the first South American countries to invest in building a base of researchers. When Lindolpho de Carvalho Dias attended the first Brazilian Mathematics Colloquium as a student in 1957, he was one of about 50 participants in a country that had few universities and no graduate programmes in science.

But the government was taking major steps to close the education gap. In the early 1950s, it created the National Council for Scientific and Technical Development (CNPq) and launched a higher-education campaign. Since then, Brazil has paid to send students abroad for graduate study, with the commitment that they would come back to teach and do research. Many of those who returned became staff members in new graduate programmes and the country has ramped up its production of scientists and engineers. The number of doctorates awarded in those fields per year nearly doubled between 2001 and 2011.

As a measure of the country's scientific growth, the mathematics colloquium currently draws about 1,000 participants a year. And research institutes in Brazil now attract both home-grown and foreign talent, adds Dias, who has served as director of the CNPq and as executive secretary of the Ministry of Science and Technology.

Like Brazil, Argentina has long sent students abroad for graduate education. But the country has only recently devoted sustained and coordinated funding to provide opportunities for returning researchers like Bragas. The science ministry now runs a programme called RAICES ('Roots') to encourage researchers to return home with offers of fully equipped laboratories and salaries comparable to those in the United States and Europe.

So far, 1,062 Argentinean scientists have returned. Most have gone to public universities or research centres, although Barañao expects that to change as Argentina's private technology sector cranks up. The employer usually provides laboratory facilities, and RAICES pays moving costs and subsidizes salaries for a few years. As an added incentive, it also helps with placements for spouses.



UNIV. BUENOS AIRES EXACTAS COMUNICACIÓN

Andrea Bragas in her nanotechnology laboratory.

In Chile, the Millennium Scientific Initiative — launched in 1999 — has set up centres of excellence and offers study-abroad fellowships with a commitment to return home to work. It has also established a programme called ChileGlobal, which lets Chilean scientists network at home and abroad through seminars and other activities.

Countries with smaller science budgets are also experimenting with ways to repatriate researchers through fellowships, networking and incentives. In March, Colombia's Department of Science, Technology and Innovation announced the US$9-million 'It's Time to Return' repatriation programme. The initiative offers research posts in various fields, and hopes to lure back 500 Colombian PhD holders in its first two years.

Although brain-drain-reversal programmes take different forms, Barañao says that the key is to harness the expertise, contacts and experience of researchers outside the country — many of whom were educated at least partly at the taxpayer's expense — while expanding research facilities and opportunities at home.

Ultimately, the long-term success of these efforts may depend on the willingness of governments and companies to increase research investments, which have been climbing only modestly relative to gross domestic product in most South American countries. "You have to create a competitive research environment with top-quality, interdisciplinary research centres," says Barañao. "Even if you offer a good salary or pay relocation expenses, without those conditions, a good researcher won't return." ■

Barbara Fraser *is a freelance writer in Lima.*

learn how to coax stem cells — either from human embryos or from reprogrammed adult cells known as induced pluripotent stem (iPS) cells — to develop into the right sort of replacement cell. It also takes time to work out how to get these cells to integrate into the host tissue and to function. And the steps required to work out how many replacement cells need to be delivered, and how to deliver them safely, cannot be rushed.

The eye and spinal cord are relatively isolated systems. Much will be learnt from them, but the brain and heart are altogether more complicated. Fixing damage in these systems is crucial, however, because together they provide the biggest disease burden in developed countries.

Happily, clinical trials are on the horizon. Treatments for Parkinson's disease are just a few years away from clinical testing. And some for Huntington's disease may not be far behind.

Taking any radical therapy into humans requires caution. Ideally, researchers should be able to use data from a patient in one trial to refine the approach for one in another. So a decision by the Global Force for Parkinson's Disease, or G-force, to bring together teams from Europe, the United States and Japan to define standards for cell preparation and patient selection and monitoring for future trials is particularly welcome (see page 195).

The G-force seems to have learnt the lessons of moving research to the clinic too fast and in isolated teams. Multiple trials of cells derived from fetal brains to treat Parkinson's disease began in the late 1980s, but stopped in 2003 because the outcomes were an uninterpretable mishmash. And trials using adult stem cells to treat heart failure have shown wildly varying outcomes (see *Nature* **509,** 15–16; 2014), perhaps owing in part to a lack of good preclinical data. But systematic research has now shown that heart cells derived from human embryonic stem cells can engraft into damaged primate hearts and synchronize their beats to it, at least to some extent. Some of the monkeys developed arrhythmias, showing that the technique still needs improvement. The principle of the therapy has been proven, however, which gives confidence that clinical trials may become possible.

"News reports need to be careful not to overhype the potential of cellular therapies."

Designing trials to agreed standards will ensure that researchers can understand why any one patient benefited, or failed to benefit, from the treatment. This will magnify the efficiency of the trials and speed up the development of therapies. It is a model that deserves to be widely copied.

News reports need to be careful not to overhype the potential of cellular therapies. As the field inches towards clinical testing, it is important that researchers clearly communicate to the media what the therapies are likely to achieve — and what they are not. Early trials are unlikely to show cures, but that does not diminish their value: even small improvements in quality of life are important to a person with a serious disability. A blind person who becomes able to discern light from shade, a paralysed person who regains some feeling in a limb and a person with advanced Parkinson's disease who can walk independently, if not normally — each will think it worthwhile.

Like all new therapies, stem-cell repair will improve through trial and error. These approaches promise more trial and, hopefully, fewer errors. ■

Open goal

International researchers can help to improve the scientific enterprise in South America.

Productivity in offices and labs around the world will probably slip a little during the next month, as football fans tune in to watch the 2014 FIFA World Cup, which starts in Brazil this week. Four years ago, nearly half the world's population tuned in at some point during the tournament. And as the world focuses its attention on Brazil, *Nature* has taken the opportunity to widen the view with our special issue on science in South America (see page 201). The package of articles and commentaries details some of the success stories on the continent as well as the substantial challenges faced by researchers there as they seek to build scientific institutions in the wake of decades lost to dictatorships.

They need not struggle alone. From London to Boston to Tokyo, individual scientists and larger organizations in the developed world can offer significant help to South American countries. When *Nature* asked leading South American scientists what kind of assistance would bring tangible benefits, the answers invariably clustered around two key requests to their international colleagues: host young scientists in your laboratories, and come to visit South American researchers.

The flow of students from South America to the United States and Europe has grown in recent years but remains a trickle. Brazil sent fewer than 11,000 undergraduate and graduate students to the United States in 2013 — less than Turkey and Vietnam, countries with much smaller populations and economies. The tally for all students sent to US universities from Latin America and the Caribbean was less than one-third of the number sent by China.

Many South American scientists called on their northern colleagues to recruit more graduate students and postdoctoral scientists from the continent. Even short visits of three to six months can help to train a young scientist. But the exchanges have to be done in a way that does not contribute to the brain drain that has lured many leading researchers to permanent positions in the United States and Europe (see pages 207 and 213). One solution is to provide start-up funds for researchers returning to South America. For example, after postdoctoral training in the United States, Lino Barañao received support from the Rockefeller Foundation to establish his lab at home in Argentina, where he is now the minister of science, technology and innovative production.

Travel needs to go both ways. According to South American researchers, too few scientists visit their continent to spend time in labs, give lectures and attend meetings. Even virtual visits, through video conferences, would help.

The networking requests go beyond the wish to trade research methods and results. Scientists in South America want to know how to select the best people and how to improve coordination between universities and industry. Many called for help in improving science-evaluation processes (see page 209). In Brazil, for example, assessments too often reward quantity over quality.

Investments in sending researchers back and forth can yield long-term dividends. In 1990, Argentine molecular biologist Eduardo Arzt started a fellowship at the Max Planck Institute for Psychiatry in Munich, Germany. After returning to Argentina, Arzt continued to collaborate with Max Planck colleagues — a connection that was key when the society was looking to expand its international programs. In 2011, it established its first South American partner institute in Buenos Aires, run jointly with Argentina's Council for Scientific and Technological Research, and with Arzt as director. Several of the research groups at the institute are led by Argentine scientists lured back from overseas by the opportunity to do top-tier science.

Football fans in South America are used to seeing top players leave for abroad. Efforts to reverse the flow, in science as in sport, face great challenges. But they are a worthwhile goal. ■

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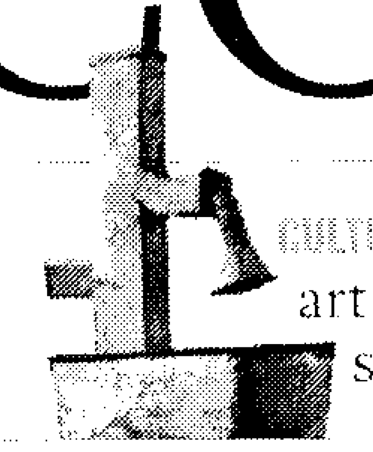
COMMENT



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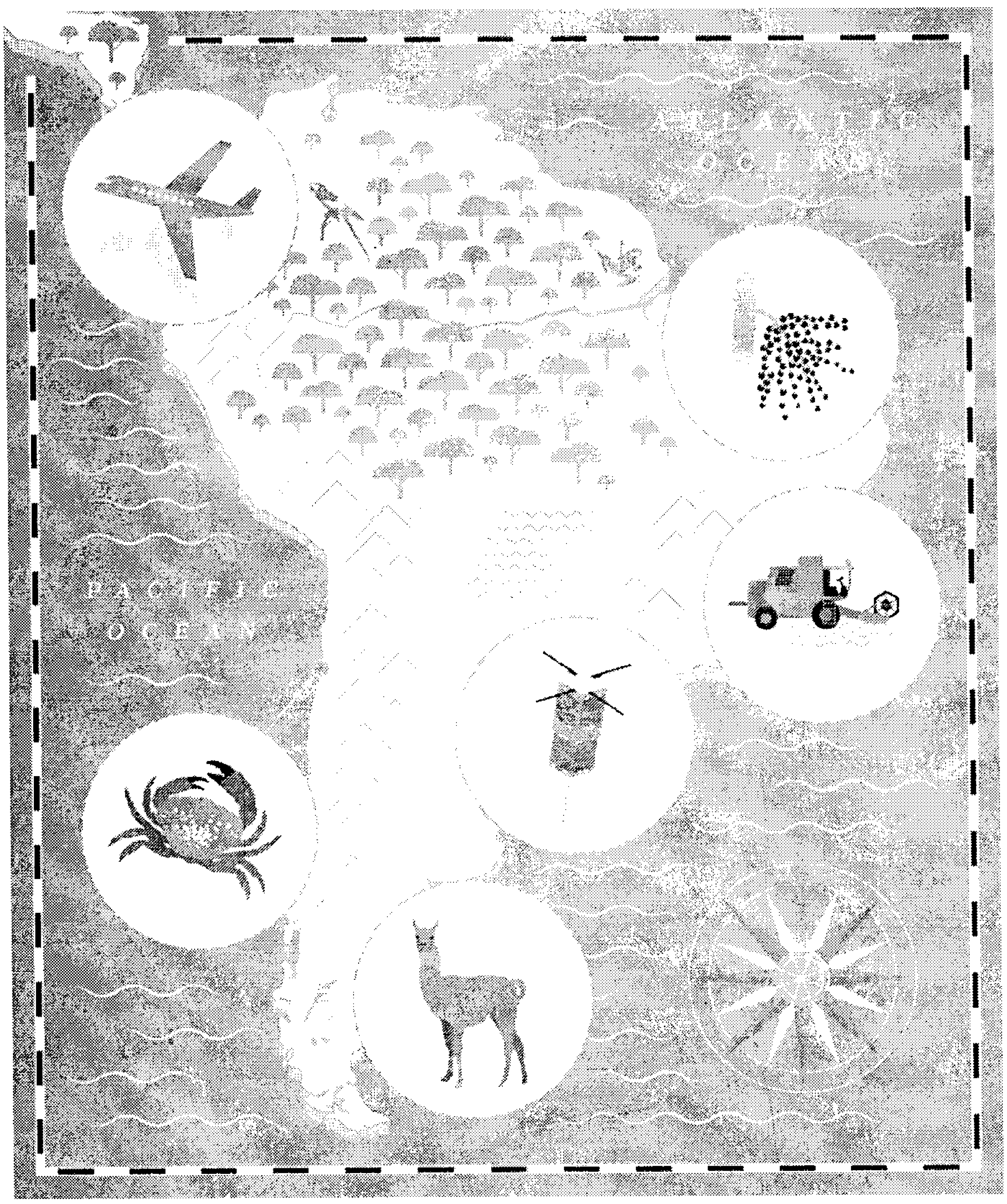

Architects of South American science

Ten research leaders call for policies to build science, and ways to build science into policy.

ARGENTINA

Strengthen networks

Eduardo Arzt *is director of the BioMedicine CONICET–Partner Institute of the Max Planck Society, Argentina*

Regional and cross-continental networks strengthen science in South America. They encourage young scientists to return home, motivate governments to invest in their own science, and fill gaps in core technologies such as advanced microscopy and proteomics, which require sophisticated instruments. A number of initiatives in recent years illustrate several creative approaches.

One model relies on partnerships with other prestigious institutes. For example, Uruguay's Pasteur Institute in Montevideo was founded in 2004 through an agreement with its counterpart in Paris, and the Biomedicine Research Institute of Buenos Aires, inaugurated in 2011, is a partner institute of the German Max Planck Society. Both institutes have recruited dozens of young researchers and built dedicated laboratories. They have also appointed international boards of scholars to offer advice and evaluate the quality of the science. This positive feedback loop should motivate similar evaluation schemes across other institutions.

Other programmes also foster collaborations between scientists in South America and scientists in North America and Europe. In April, Argentina became an associate member state of the European Molecular Biology Laboratory (EMBL). Symposia have already been organized, and Argentinian scientists now have access to the EMBL's state-of-the-art resources.

The Millennium Science Initiative (active in Chile and Brazil), the US National Institutes of Health's Fogarty International Center, the Howard Hughes Medical Institute, the Pew Charitable Trusts (see ▶

SOUTH AMERICAN SCIENCE
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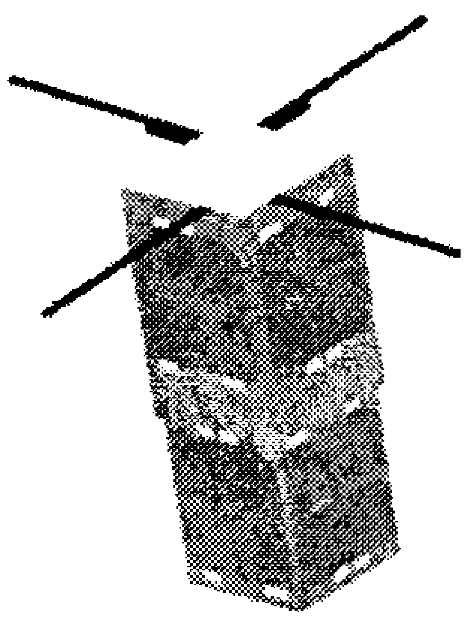
▶ page 213) and the Partner Groups of the Max Planck Society all sponsor individual scientists to help to create a critical mass in fields such as molecular biology, neuroscience and nanotechnology.

Regional entities have recognized the benefits of such programmes. The multinational South American trade group MERCOSUR, through its fund FOCEM, provided US$7 million to build a biomedical research network spanning six institutions in Argentina, Uruguay, Brazil and Paraguay. The network will foster research, training and technology transfer in molecular medicine. National governments will chip in a further $3 million.



These networks are building momentum in the region's science. As they begin to bear fruit, the time is right to build on them and not become complacent.

PERU

Build research capacity fast

Gisella Orjeda *is president of the National Council for Science, Technology and Technological Innovation, Peru*

It is an exciting time for science in Peru. After years of neglect, the budget of the National Council for Science, Technology and Technological Innovation (CONCYTEC) has grown 20-fold in just 18 months to almost US$110 million, and it will continue to grow at the same rate. For the first time, Peru has a president who is prioritizing science and innovation. Journalists are trying to grasp and explain new concepts.

Now Peru needs highly qualified scientists and scientific managers. We must learn how best to organize calls for proposals, allocate funds, build programmes and reach companies. Then we must work out how to build prosperity with our new-found knowledge.

CONCYTEC establishes and promotes national policies for science, technology and innovation, and funds research. We work with local governments, the private sector, scientific institutes, universities and colleges. This is a big task for an organization of 148 people that until 2012 had an annual budget of just $6.3 million and almost no information about the set of institutions that produce, transfer and use knowledge.

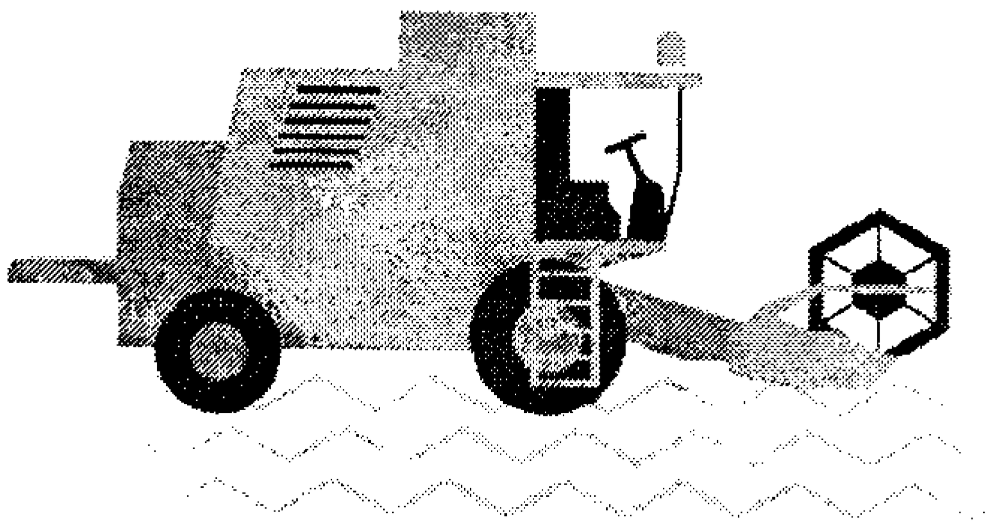
We are building these capacities: defining evidence-based policies and priorities, adhering to conflict-of-interest guidelines, and establishing a merit-based review of proposals and incentives for innovation. We are eliminating rigid rules for immigration, buying scientific equipment and hiring qualified personnel.

I returned to Peru eight years ago, after spending ten years in France, because I wanted to make a difference in my country. After publishing the potato genome in *Nature* in 2011, I never imagined that I would have to leave science to lead science, but I have no regrets. It is thrilling to be at the helm of CONCYTEC as we face the formidable challenge of constructing a knowledge-based economy.

BRAZIL

Boost pro-forest economics

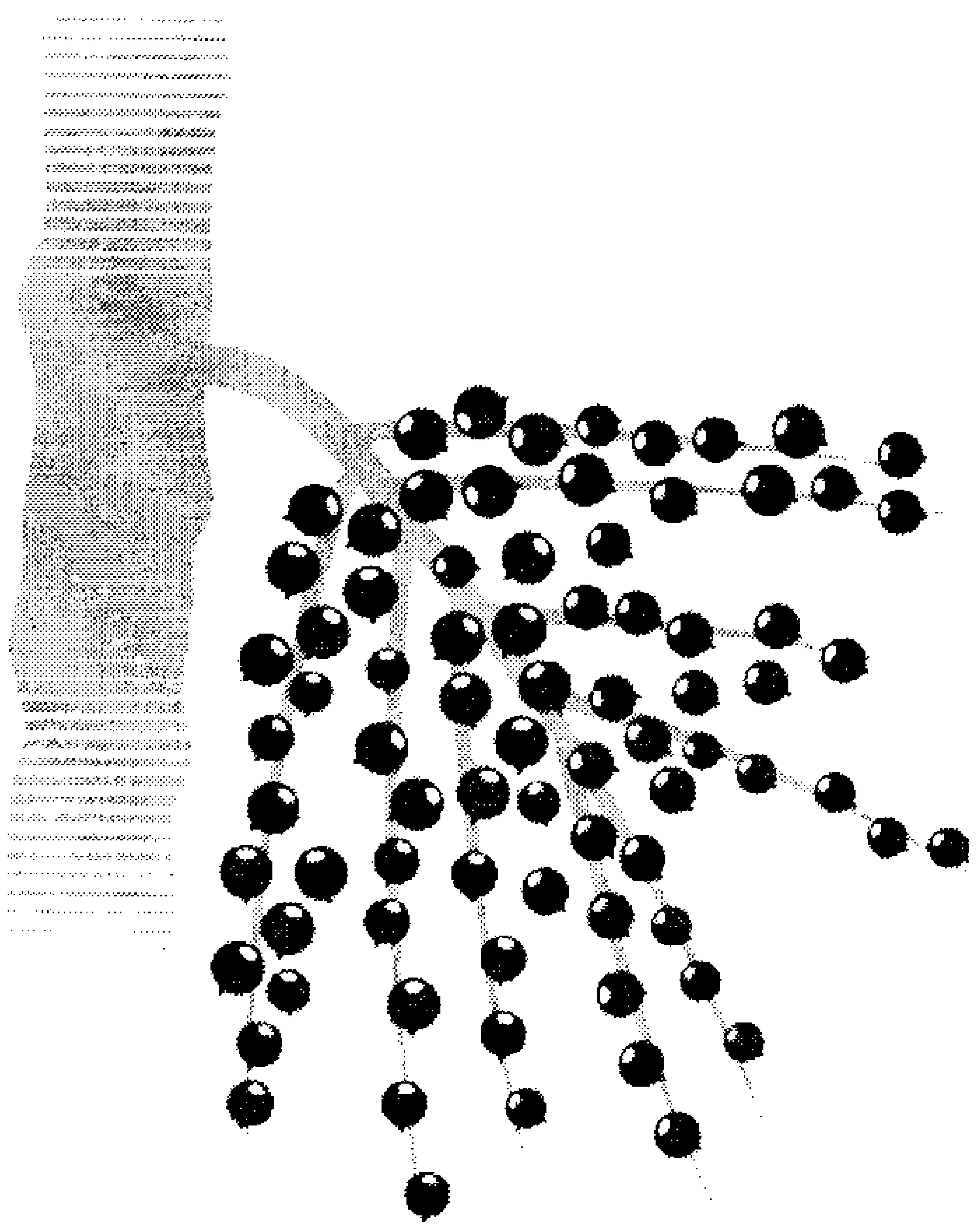
Carlos Nobre *is national secretary for research and development policies at the Ministry of Science, Technology and Innovation of Brazil*



The deforestation of the Amazon must stop: when forests are cleared for agriculture, cattle ranching and logging, the damage is felt environmentally, economically and socially. But simply curbing deforestation is not enough: sustainable-development strategies must also improve well-being for local communities.

Unfortunately, the global economy places a higher premium on meat and soya beans than on forests. Creating a new economic model for the Amazon forest will therefore take two transformations; both require science.

One strategy is to add value to locally harvested products. A good example of such a bioindustry is the açaí fruit of the palm tree *Euterpe oleracea* that grows in the Amazon. Until around 20 years ago, the dark berries were a food staple consumed only by the local population. Today, açaí fruit is used in produce including food, nutritional supplements, cosmetics, dyes and industrial oils around the world. Annual pulp production exceeds 200,000 tonnes and contributes more than US$2 billion to Brazil's economy, second only to beef and tropical timber.



Local açaí producers can make more than $1,000 per hectare in annual profit, 5–10 times more than from soya and at least 15 times more than from cattle. Embrapa — the Brazilian Agricultural Research Corporation — has used açaí to produce a dye for bacterial plaque that is now ready for commercial use in toothpaste and mouthwash.

More research is needed to identify uses for new and known natural products, and to scale up production. In a decade or two, it should be feasible to increase the exploitation of dozens of forest products.

A second strategy is to make better use of the large areas of already cleared forest — estimated at more than 750,000 square kilometres in the Brazilian Amazon alone — to reduce the need to clear even more. A nationwide Low Carbon Agriculture Program aims to more than double cattle occupancy per hectare within a decade. Field research conducted by Embrapa and the Brazilian cosmetics company Natura showed that oil-palm plantations on smallholdings could be integrated with other crops, such as nitrogen fixers, to obtain yields comparable to those of large-scale plantations.

Both these transformations require educating the rural and urban populations to change their ways. Technical programmes to increase agricultural productivity must reach hundreds of thousands of farmers. Isolated traditional populations will need help to reap value from collecting and selling products of biodiversity. Doing so will rely on modern communication — a new government-owned telecommunications satellite is set to start operations in 2016 to bring high-speed Internet to communities in the Amazon.

"In a decade or two, it should be feasible to increase the exploitation of dozens of forest products."

CHILE

Empower coastal research

Juan Carlos Castilla *is professor emeritus at the Pontifical Catholic University of Chile*

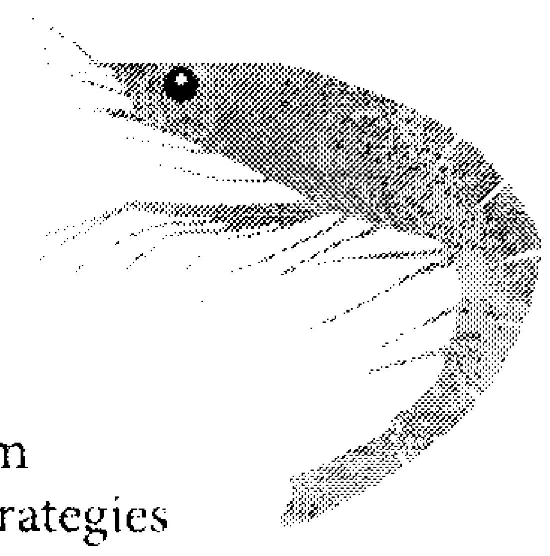
Rich countries can protect vast areas of their seas. Australia bans fishing in 345,000 square kilometres of the Great Barrier Reef; California protects about 16% of its coastal waters, some 2,200 km^2. This approach will not work in the parts of the developing world where people's livelihoods depend on coastal fishing. A promising alternative is community-centred stewardship, boosted by research and education.

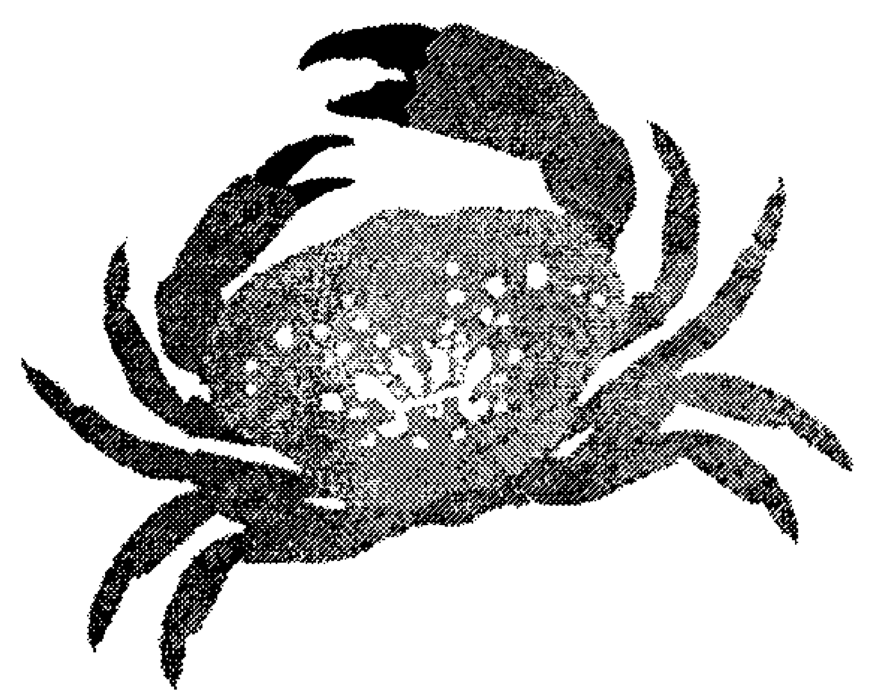
The Chilean government grants coastal communities exclusive territorial use rights in fisheries (TURFs) to extract seafood from a designated area, in exchange for a management plan that limits the annual catch proportion of algae and benthic organisms (bottom-dwelling animals including molluscs, shrimp and crabs). Around 500 of these co-management areas encompass more than 1,100 km^2. The areas are only 4–10 km apart, so larvae and young animals from one area can disperse into another.

This system of fishery co-management was established in 1991. Communities differ in their performance, but results reported in 2012 revealed a desirable by-product: TURF areas show robust increases in the biodiversity of invertebrates, algae and rockfishes compared to uncontrolled areas.

Co-management empowers people to care for their resources. If a port or power plant begins operations nearby, communities demand that any damage to their area is assessed and compensated.

In unmanaged areas, the coast is overfished. TURFs are not enough. One strategy is to develop communal-management approaches for specific resources in the areas that can be fished by anyone. Regulations in Chile that came into force last year will set a total allowable catch for key species, attempting to account for a marine stock's reproductive, growth and mortality rates. A network of no-take areas between TURFs would also help. Ocean life in the no-take areas could help to restock depleted populations.





We must learn from experience, documenting and assessing the effects of ecosystem management. If these strategies fall into place, communities can continue to fish, protect biodiversity and safeguard coastal ecosystems.

ARGENTINA

Fuel public–private consortia

Lino Barañao *is Minister of Science, Technology and Innovative Production, Argentina*

After a decade of policies aimed at boosting research, science in Argentina is starting to have positive effects on economic development and society. Now, greater involvement from the private sector is required.

Five years ago, the Argentinian government launched the Sectoral Funding Strategy to promote public–private consortia. From 2008 to 2013, more than 5,000 companies, including 80 start-ups, received a total of US$800 million as grants or loans with below-market interest rates. The government also created programmes for postdocs and established researchers to gain experience in private companies. The number of scientists in industry increased from 7,200 in 2003 to 12,300 in 2012, and is expected to rise to more than 18,000 by 2020.

Projects funded by the strategy must combine a key enabling technology (such as biotechnology, nanotechnology, or information and communications) with a strategic area (such as health, energy, or environment and social development). They must also provide a business plan to bring an innovative product or service to market within five years. Some projects have already moved beyond proof of concept, including production of human growth hormone in the milk of transgenic cows and nanotechnology systems for drug delivery. Another example is Satellogic, a company that is developing nanosatellites for imaging. It is about to launch its third prototype and has already received private investment.

In 2012, Argentina's national research council, CONICET, and its national petroleum company, YPF, came together to create a joint company called Y-TEC. The firm, which employs more than 70 researchers, is developing technologies to exploit unconventional oil such as shale and renewable energy, and has already submitted six patent applications, three of which are licensed.

In developing countries, the science and technology sector cannot focus only on cutting-edge technologies; it must also promote social inclusion. The latter is illustrated by the Guanaco Project in the Andes, which is developing textiles for the 'responsible luxury' market. Guanacos, close cousins of llamas and vicunas, produce a fibre superior to cashmere.

In the past, science had only a cultural role in Argentina. Now it is contributing to a knowledge-based economy as a means to achieve a more just society.

BRAZIL

Reward quality not quantity

Sidarta Ribeiro *is director of the Brain Institute at the Federal University of Rio Grande do Norte, Brazil*

In the past decade, the Brazilian government has put substantial resources into education and science. It has: established a minimum wage for school teachers; allocated 1.2% of the gross domestic product to fund research; and launched the Science without Borders scholarship programme to attract foreign talent to the country and to help promising Brazilian researchers to train abroad.

"Independent international evaluations at universities and research institutes might be the key."

Two of the biggest remaining barriers to improving the nation's research are performance evaluation and rewards. Valuing quantity over quality is so ingrained in Brazil's scientific culture that it is nicknamed *numerologia* (numerology), a pun on the mystical belief in the power of numbers.

The official Qualis system for the evaluation of scientific papers and journals — which carries heavy weight in grant and job applications — encourages Brazilian researchers to publish as many papers as possible, regardless of the international impact of their research. Qualis does recognize different tiers of journals, but the categories are so broad as to be almost meaningless — a paper published in a journal such as *Nature* or *Science* and one in a highly specialized journal might be counted equally. Rather than gathering a full set of experiments into a coherent story, scientists gain more recognition in the system by breaking related work into multiple papers.

Independent international evaluations at universities and research institutes might be the key to rewarding innovation and cutting-edge science more effectively.

VENEZUELA

Respect science and scientists

Claudio Bifano *is president of the Venezuelan Academy of Physical, Mathematical and Natural Sciences*

Much of Venezuela's technology and scientific capacity, built up over half a century, has been lost in the past decade. We need to restore respect and funding to basic research to halt the brain drain and reverse this catastrophic trend.

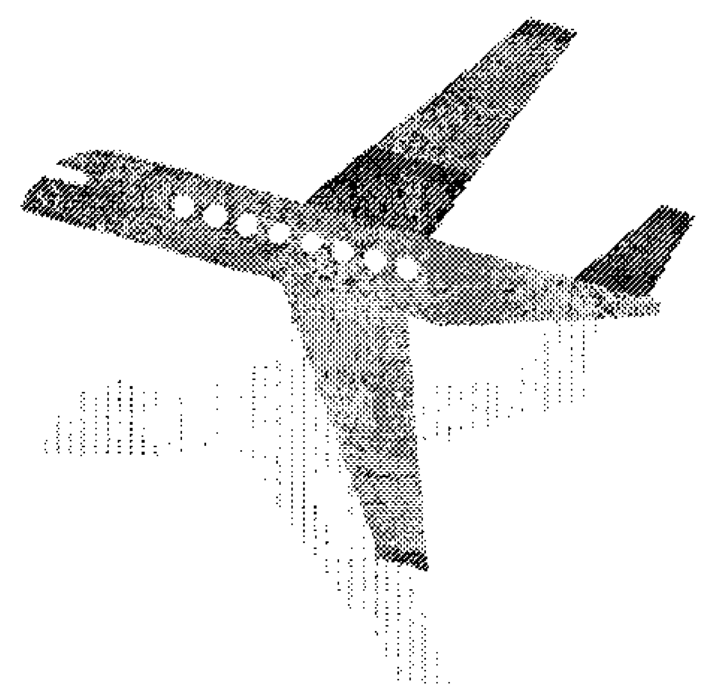
In recent years, Venezuela has invested more than 2% of its gross domestic product (GDP) in science and technology, and boasts a workforce of about 13,000 scientific researchers. But the number of publications in international journals declined by 40% in 2008–12, from roughly 1,600 to 1,000. The total number of publications in 2012 matched that of 1997, when the country had fewer than 3,500 researchers, and a science and technology budget of just 0.3% of the GDP.

According to a 2011 survey, 51% of Venezuelans over 25 years old living in the United States have finished university (compared to 13% of the US Hispanic population and 29% of all US residents). The online publication *Piel-Latinoamericana* reports that 1,100 of 1,800 physicians who graduated from medical school in Venezuela in 2013 have left the country. In other words, educated Venezuelans are fleeing — or are being forced out. For example, in 2003, roughly 1,000 professionals, mostly physical scientists and engineers, were fired from Venezuela's petroleum research and development institute, INTEVEP. International agencies report that no patents have been granted since that time.

Since 1999, the Venezuelan government has imposed a political model called socialism of the twenty-first century. I and others find it based mainly on authoritarianism, with some ideas from Marxist philosophy and extreme populism. Science, according to the minister for science and technology, is for the solution of societal problems. The National Science, Technology and Innovation Plan (2005–30) says that science must be conceived as a process that involves new participants, such as the holders of traditional and local knowledge.

To achieve this goal, the Ministry of Science, Technology and Innovation supports projects submitted not only by scientists but also by those without scientific training and by organizations such as community councils, environmental groups and associations geared towards the social services. Funded programmes include one that distributes computers to school children and missions for a remote-sensing satellite and a data-transmission satellite. These may be laudable projects, but they are not science.

Allowing those who lack scientific training to access public funds for scientific research trivializes science.



BRAZIL

Banish bureaucracy

Jose Eduardo Krieger *is provost of research at the University of São Paolo, Brazil*

Brazil needs a better environment for knowledge creation and innovation. Bureaucracy currently holds back research. Fixing this will require changes to institutional policy and national legislation.

At the University of São Paulo, for instance, we began a major initiative in 2011 to enable scientists to focus on what they do best, rather than wasting time filling in forms. The university is the largest research institution in South America, responsible for about 20% of all papers published in Brazil every year. The institution's 6,000 scientists win almost half of the US$450 million that the state of São Paulo awards to support research.

But most Brazilian grants do not cover overhead or indirect costs, such as facility maintenance. So our universities lack the support offices that North American and European researchers rely on to help with ordering equipment and reagents, paying invoices, financial reporting, contract negotiation and account monitoring. Every researcher must set up these systems individually.

By the end of this year, the University of São Paulo will roll out a digital platform to assist researchers with procurement, accountability and operations. We are also creating a network of trained project managers to assist specialized schools and large research groups. These measures follow a $100-million, four-year effort by the university to reorganize its research enterprise. More than 100 research support groups have been created, each with a technician, to encourage scientists to organize themselves into interdisciplinary clusters.

These strategic moves will be complemented by improvements in the regulatory laws currently under discussion in the Brazilian Congress. These should allow equipment and consumables for academic research to be imported more quickly and easily — giving our scientists more time for research, and helping them to compete with their peers in North America and Europe.

CHILE

Base policy on evidence

Pablo C. Guerrero *is assistant professor at the University of Concepción, Chile;* Mary T. K. Arroyo *is director of the Millennium Institute of Ecology and Biodiversity, Chile*

Chile needs a system for formulating public policy on the basis of sound scientific information. The government's decision in March not to create a ministry of science passed up a valuable opportunity for that.

The current disconnect between science and policy within the government is worrying, as two recent examples show. First is the devastating fire that swept through parts of the city of Valparaíso in April. For decades, authorities ignored ecologists' warnings about expanding highly flammable eucalyptus plantations that are now near many cities in central Chile, and where the Valparaíso fire started.

"The current disconnect between science and policy within the government is worrying."

Second, Chile has experienced seven earthquakes measuring magnitude 7 or more in the past decade. Here, too, scant attention was paid to scientists' predictions about the accumulation of seismic strain.

Some have suggested that Chile's highly regarded science-funding body, the National Commission for Scientific and Technological Research (CONICYT), could regain its past influence and advise on public policy once more. To do so it will need to adjust its current emphasis on impact factors and international recognition of basic science. CONICYT should give explicit credit to basic-science problems that are relevant to the concerns of Chileans, such as the availability of water resources in a changing climate and innovative ways to use minerals. ■

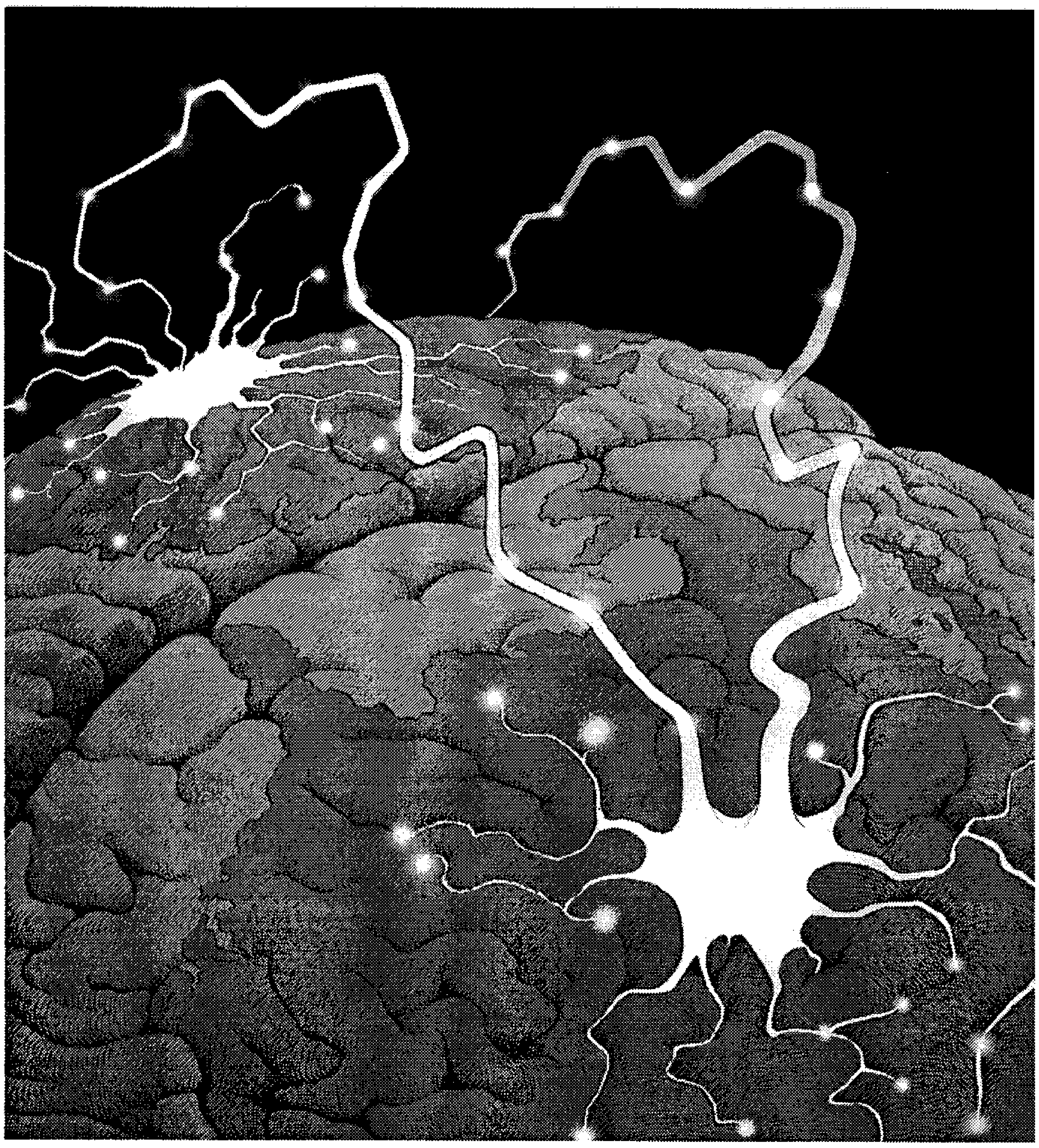


ILLUSTRATION BY DAVID PARKINS

Turning brain drain into brain circulation

Overseas scholarships that encourage scientists to return to their home countries are helping to rebuild science in Latin America, says **Torsten Wiesel**.

It takes a long time for a country to build a strong base in science, but only a short time to destroy it. Germany was a sad example. It was a world leader in the sciences for more than a century, until its science base was demolished during the Nazi era, and the country ceded its position to the United States. It has taken decades for Germany to rise again to its current level of excellence.

The German experience has much in common with the situation in Latin America, where authoritarian regimes came to power in the mid-twentieth century in countries including Brazil, Chile and Argentina. As a consequence, many of the continent's best scientists emigrated to the United States, Europe and Canada. When the dictatorships were finally shaken off in the 1980s and 1990s, the departed scientists were settled in their new homes and had little incentive to return to countries left laden with debt.

Many have forgotten that science in Latin America was once robust. For example, Bernardo Houssay, who won the 1947 Nobel Prize in Physiology or Medicine, directed the Institute of Physiology at Buenos Aires University until 1943, when the government fired him for advocating for democracy; his protégé, Luis Leloir, won the 1970 Nobel Prize in Chemistry. Several emigrants also became laureates, including the immunologist Baruj Benacerraf, from Venezuela, and the biochemist César Milstein, from Argentina.

Against this background, the Pew Latin American Fellows Program was founded to help to rebuild and strengthen biomedical sciences in the region. From its inception, the programme has been linked to the pre-existing Pew Biomedical Scholars Program, which each year provides around 20 promising newly independent US scientists with four-year scholarships, funded by the Pew Charitable Trusts, a non-profit organization based in Philadelphia, Pennsylvania.

In March 1989, at the annual meeting of the scholars programme in Puerto Vallarta, Mexico, a group of these scholars — struck by the lack of resources of their counterparts in Mexico — sought help from Rebecca Rimel, president of the Pew Charitable Trusts. Later, Rebecca and I discussed the best ways to train talented students from Latin America, and our ideas crystallized into the fellows programme.

REPATRIATION RATES

Since the founding of the Pew Latin American Fellows Program in 1991, about ten graduate students each year have been awarded two-year postdoctoral fellowships to work in some of the best labs in North America. It is no surprise that some remain abroad to continue their careers in more developed countries. What is surprising is that more than 70% return to their home countries, which may not always allocate sufficient resources to cutting-edge research (see 'Bringing science home'). For comparison, the Human Frontier Science Program, a multinational initiative that supports the life sciences, also funds postdoctoral fellows worldwide — but fewer than half of those who train in the United States return to their home countries.

Pew fellows who remain in North America have positions in leading universities and several have established joint projects with labs in their home countries, as well as hosting new fellows. The annual

PEW LATIN AMERICAN FELLOWSHIP

Bringing science home

Becoming a great scientist requires exposure to greatness. At a 1997 orientation meeting in Costa Rica for new postdocs, Torsten Weisel, the co-founder of the Pew Latin American Fellows Program, told us that the best scientists are not necessarily more creative or smarter than everyone else, but that they had the opportunity in their junior years to conduct and discuss science in prime environments.

I earned my PhD in 1996 from the University of Chile in Santiago, studying how ions move through proteins extracted from neurons. I wanted to apply that work in living brains. Senior members in my department told me about the Latin American fellows programme and helped me to find a postdoctoral adviser.

Charles Zuker, then at the University of California, San Diego, accepted me into his lab and taught me to study how flies sense the world. It was an amazing experience to be in the Zuker lab when seminal work on taste and pressure receptors was happening. I was part of the team that helped to show how the organization of proteins in photoreceptor cells is essential for flies to see light. I returned home to work as a junior professor at the University of Chile in 1998.

Even now, few institutions in South America provide start-up funds to new faculty members. Most young professors have to join senior laboratories or sit in an empty lab, sometimes for more than a year, before getting their first grant. By contrast, I had a US$35,000 repatriation fund from my Pew fellowship. The money was enough to buy small, essential equipment to start doing some simple experiments soon after I returned: a table-top centrifuge to separate cells into basic components, power supplies, electrophoresis chambers to run gels for DNA analysis, a mechanical shaker to grow bacteria and some reagents.

Since then, I have trained nearly two dozen students to work with flies and have helped four researchers to set up their own labs for fly research in Chile. I have also directed three international courses to train Latin American students to use the insects (and, more recently, worms) as animal models.

And my relationship with Pew continues. I have started collaborations with scientists from other countries whom I met at annual Pew alumni meetings. For the past five years, I have served on the regional Pew committee that selects six Chilean candidates for the fellowship. We look for young researchers who have connected with a great lab and proposed adventurous projects — particularly to work in areas or with animal models that are not available at home. The hope is that they will bring those skills back to their native countries.

Chile has an 80% repatriation rate. That bespeaks both a good selection process and the importance of the start-up money for returning fellows. Scientific agencies and governments in Latin America should try to replicate these measures to help to build a stronger and more innovative scientific community. Jimena Sierralta, University of Chile

meetings are attended by Latin American fellows, biomedical scholars and senior advisers, including Nobel laureates and Howard Hughes Medical Institute scholars. Participants share ideas and start collaborations as a result of the meetings.

SUCCESSFUL SCHOLARS

In a survey sent out in 2013 to 202 alumni of the Latin American fellows programme between 1991 and 2011, an impressive 151 responded. Alumni who have returned to their home countries include department heads and university provosts. Nearly half reported holding a director position, such as department chair or head of an academic discipline. On average, each fellow had published 15 papers, and those who had returned home had trained 13 scientists, from technicians and graduate students to visiting scholars.

Last month, the journal *Cell* highlighted a 2003 Pew fellow, immunologist Dario Zamboni, as one of 40 notable scientists under 40 years old. Zamboni is head of the Innate Immunity and Microbial Pathogenesis laboratory at the University of São Paulo in Brazil. His group is working out how the body responds to intracellular parasites, including the one that causes Chagas disease — a problem in poor, rural areas of South America. Doing science in Brazil involves hurdles that would not exist in the United States, but he is determined to improve the system for other scientists in the country.

Selection of fellows starts with established researchers in Latin America. Argentina, Brazil, Chile and Mexico have national committees of former Pew fellows and senior scientists. Each committee selects six applicants by evaluating research proposals and interviewing a dozen or so of the most promising students. (The chairs of these committees act together as a fifth multinational committee for applicants from the other countries in the region.)

> *"The fellows programme is just a drop in the ocean relative to the need of the entire continent."*

Thirty applications are chosen in total to be evaluated by a central committee of outstanding US scientists with strong ties to Latin America. Several are emigrants from the dark periods in their countries of origin. These committees work hard to select the most promising scholars and send them to the best labs.

The Brazilian state of São Paulo plans to augment the benefits that are open to returning Pew fellows: they can apply for a generous four-year stipend to get their new labs off the ground. The hope is that other nations will use their own resources to extend this initiative to foster their best scientists.

The absolute number of Latin American fellows is small — fewer than 250 in a region with more than 400 million people. But my impression is that they have an outsized influence, shaping expectations of what it means to be a scientist in Latin America, and the fellows' high expectations of themselves.

That said, the fellows programme is just a drop in the ocean relative to the need of the entire continent. This is perhaps especially true now that larger programmes exist in several Latin countries to support the training of scientists abroad and to encourage trained scientists to return home, such as the Brazil Scientific Mobility Program (see page 207).

Nonetheless, like a seed planted in a fertile soil, the Pew programme has flourished over the past 20 years. The plant will no doubt continue to grow and to support its ecosystem. The ultimate success would be that this type of programme is no longer needed because each country would have developed strong, independent scientific establishments. But for now, we need to bolster the support for scientists in emerging countries, in Latin America and elsewhere. ■

Torsten Wiesel *is president emeritus of Rockefeller University in New York City, USA. He won the 1981 Nobel Prize in Physiology or Medicine.*
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