FAR-FLUNG PHYSICS

The International Centre for Theoretical Physics was set up to seed science in the developing world; 100,000 researchers later, it is still growing.

BY KATIA MOSKVITCH

The dust in Kathmandu cloaks everything. It carpets the streets with a dingy layer. Women cutting waist-high grass are wearing face masks to keep it out. And it settles on the dilapidated buildings of Tribhuvan University (TU) — the biggest scientific establishment in Nepal.

Narayan Adhikari, however, has managed to stay clean. Clad in an impeccable white shirt and black trousers, he adds his motorbike to a collection of some 20 others parked haphazardly in front of a 3-storey building, the university's physics department. Before entering his tiny lab, the 44-year-old researcher removes his shoes to keep the dirt out. In the lab are a dozen desktop computers, which the department received in 2009 — before that, there were none. Power blackouts happen every day, lasting for up to 16 hours, and the Internet connection works "maybe one day a month", Adhikari says.

Despite this, for the past eight years Adhikari and his students have been producing a stream of theoretical-physics papers on the properties of materials such as atom-thick graphene. It is a rare — if not unique — achievement for a physics lab in Nepal, and Adhikari's contributions are also helping to build up his department as a whole, by boosting the number of PhD students being trained there. "Doing physics in a country like Nepal is a real challenge," he says.

Adhikari's accomplishments are rooted in more than his own determination and wit; they also draw on support from the International Centre for Theoretical Physics (ICTP), an organization based a world away in the picturesque Italian seaside town of Trieste. Set up in 1964 by Pakistani physics Nobel laureate Abdus Salam and Italian physicist Paolo Budinich, it aims to advance theoretical physics in the developing world. Salam, who died in 1996, wanted the centre to be "a home away from home" for researchers from the poorest regions of the world. After they passed through the ICTP's programmes of training and research, he hoped that alumni would establish scientific communities in their home countries, rather than settling abroad as so many scientists did. Adhikari, who completed the ICTP's one-year postgraduate-diploma programme in 1998, is one of the institute's success stories.

GLOBAL REACH

Adhikari is hardly the only one. In the 50 years since it was established, the ICTP has trained more than 100,000 scientists from 188 countries through its workshops and courses. Researchers who studied there have contributed to major discoveries in fields ranging from string theory and neutrino physics to climate change, and have racked up a trophy cabinet of academic prizes, including shares in a pair of Nobels. Most physicists credit the institute with stemming the brain drain and bolstering academia in the developing world. The institute is "widely admired", says Martin Rees, an astrophysicist at the University of Cambridge, UK, and former head of the Royal Society in London, who hopes that it will "inspire the creation of similar institutions covering other scientific fields".

The ICTP has evolved over time. What started out as a small project focused narrowly on Salam's discipline — high-energy physics — has morphed into a broader programme. In 1998, the institute expanded its brief to include mathematics and Earth-systems physics, including climate and geophysics, and in 2014 it added quantitative life sciences. The institute is still changing. In the past two years it has opened satellite campuses in Brazil, Mexico and Turkey, and it is currently establishing branches in Rwanda and China. Plans to expand into more countries and disciplines are being considered.

But some worry about the organization's future. The main provider of the ICTP's funding, the Italian government, has started to baulk at shouldering most of its costs, and some scientists are concerned that expanding could dilute the quality of ICTP-fuelled research. "In the last few years ICTP has started many new things," says Chris Llewellyn

Tribhuvan University in Kathmandu has built up its physics department with support from the International Centre for Theoretical Physics.

CENTRAL DEPT OF PHYSICS, TRIBHUVAN UNIV.

Smith, a theoretical physicist at the University of Oxford, UK, and former head of CERN, Europe's particle physics laboratory near Geneva, Switzerland. "If they try to take on even more and be too ambitious with new ideas, they might let go of what they've got."

CURIOUS CHILD

Adhikari could be a poster child for the ICTP. The youngest of six siblings, he was born to farming parents in a village near Nepal's second-largest city, Pokhara, and grew up with paraffin-oil lamps and no running water at home. His father was literate, his mother was not — but both parents supported his desire to study. "I am very curious to unearth the secrets of nature — so I love physics," he says. He worked as a teacher for three years to earn enough money to study at TU.

In 1996, having completed his undergraduate and master's degrees in physics, Adhikari won a place on the ICTP's diploma programme. When he travelled to Trieste, aged 27, he felt as if he had landed on a different planet. "I was astonished by the Western world — there was no dust in the air!" he says. Adhikari met Nobel laureates and other distinguished physicists, who come to the ICTP to collaborate and teach.

After finishing the diploma, he did a PhD at the Martin Luther University of Halle-Wittenberg in Germany, simulating the behaviour of polymers and other materials. This was followed by postdocs in the United States and Germany. "Our life was good, and there was clean drinking water," says Adhikari's wife, Sabitra. "But one day Narayan told me: 'We have to go back.'" Adhikari had always felt strongly that he wanted to use his knowledge "to make Nepal a better place", he says — and this aim was reinforced during his diploma at the ICTP.

When Adhikari rejoined TU in 2006, he set about building his own research group. He had no problem finding willing students; what he did not have was books, the Internet, a good electricity supply or any equipment. That ruled out experimental physics, but it allowed him to continue his theoretical work, which he did by buying a suite of desktop computers with funding from the ICTP.

Soon Adhikari was publishing his studies, which modelled the properties of materials ranging from water to polymers and solids such as graphene. In the past two years, for example, he has explored[1,2] how graphene might be used to store energy by decorating it with metal — a study that he estimates took three times as long as it would have in the West, because of the power cuts that routinely stopped work. "The conditions were so difficult that sometimes I was afraid that I'd never achieve anything in Kathmandu," he says. "But I just kept thinking that I had to continue, because it'd be great to develop science in Nepal." At the time, few scientists at TU were publishing consistently in international journals, but Adhikari's enthusiasm seeped into the rest of his department. In the 40 years before 2006, just 4 students had completed a PhD there; ambitious graduates usually went to Europe or the United States. Since Adhikari joined, 22 students have been admitted to the PhD programme and other researchers have published more, too. "What he has helped us to achieve is really remarkable," says Binil Aryal, head of physics at TU.

THE GREATER GOOD

But does Nepal need a theoretical-physics department? After all, the country has more urgent issues: its population struggles with malnutrition, its infrastructure is falling apart, and its air quality ranks among the worst in the world. "In developing countries like Nepal, the government does not allocate sufficient budget for R&D because of much more pressing problems and priorities," says Ganesh Shah, Nepal's science minister from 2008 to 2009.

Shah and Adhikari say that building up the intellectual capacity of the country will drive its economic development. "Investment in science, technology and innovation is required to create jobs and reduce poverty and improve the living standards of the people," says Shah.

KATIA MOSKVITCH

Narayan Adhikari (centre, in pale blue shirt and black trousers) with students from the physics department at Tribhuvan University.

When he was science minister, he tried to allocate more funding for basic research, he says — but with limited success. The Nepali government invested 0.3% of its gross domestic product in research and development in 2010, similar to that of other developing countries in south Asia but well below the nearly 2% invested by China. Theoretical physics is a lot easier and cheaper to set up than some other fields, Shah points out.

Adhikari is paid by the university, but he still receives some support from the ICTP. Until this year, his students had to fly to computing facilities in Kolkata, India, every time they had a complex computation to perform. Not anymore. Gopi Kaphle, one of Adhikari's PhD students, proudly shows off a shoebox-sized computer. "It performs computations about ten times faster than the machines we used to have," says Kaphle. Because calculations on the new computer must run without interruption, the ICTP also funded a solar panel on the roof of the department, to deal with Nepal's power cuts.

This year, Adhikari decided that he wanted to expand into relatively simple, tabletop experiments in nanoscale materials. "We have to be able to do experiments; it's the next step forward," he says. To try to negotiate the funds, he returned to the ICTP. He arrived at the headquarters in Trieste in late September, just as the centre was getting ready to celebrate its 50th birthday.

BREAKING DOWN BARRIERS

The seeds of the ICTP were planted after the Second World War, when physicists including Albert Einstein, Robert Oppenheimer and Niels Bohr championed the concept of a United Nations-backed centre to promote peaceful nuclear-physics research. Initially, this led to the creation of the International Atomic Energy Agency (IAEA). But for Abdus Salam, a science prodigy from Pakistan who had been made a physics professor at Imperial College London by the age of 31, that was not enough.

Speaking to the IAEA's General Conference in 1960, he outlined his idea for an IAEA-backed organization that would promote theoretical-physics research in the developing world and bridge East and West in the cold war. In the audience was Paolo Budinich, head of physics at the University of Trieste, who shared the dream. The two men initially encountered resistance to the idea of building a new centre; critics argued that it would be easier and cheaper for developing-world physicists to visit existing labs in the developed world. But Salam and Budinich won the argument, not least after they secured the financial backing of the Italian government and the support of the IAEA and the United Nations Educational, Scientific and Cultural Organization (UNESCO). They chose to locate the centre in Trieste, which was politically symbolic because it sat right next to the Iron Curtain that divided East and West.

When the institute opened in 1964, it rapidly established itself as a place for high-level research and training, welcoming scientists from both sides of the Iron Curtain and from farther afield. The centre, which initially offered scientists a two-to-three-month grant to work in Trieste, "was like a source of oxygen to Third World scientists", says Abdelkrim Aoudia, a geophysicist from Algeria who works at the ICTP.

Even in the institute's early days, many Nobel laureates served as visiting professors. When, in 1979, Salam shared a Nobel prize with Sheldon Glashow and Steven Weinberg for the unification of electromagnetism and the weak nuclear force, the organization's prestige skyrocketed. Speaking at the anniversary celebrations, Salam's son Ahmad, an investment banker at EME Capital in London, wiped away tears as he remembered the sacrifices his father made while he set up the centre — not least spending little time with his children. "He had a much bigger mission in life," said Ahmad.

Today, around 2,500 developing-world scientists visit the ICTP each year. About 50 of these enrol in the one-year diploma, an intense predoctoral education programme taught by experts from around the world. (The institute identifies students through both an application process and the recommendations of researchers and teachers.) Many of the rest — including Adhikari — are part of the Associates Scheme, which supports scientists from developing countries to make regular visits to the ICTP, where they network and update their skills. What makes the institute successful, say those involved, is its focus on nurturing talented scientists and keeping them connected to the international community, while encouraging them to continue research at home.

BRAIN GAIN

That approach is working, says Fernando Quevedo, the ICTP's director. Three-quarters of the students who have completed the diploma programme have received PhDs, or are working towards them, and more than half of those who complete PhDs go back to their home countries (see 'Sticking with science'). More than 90% of associates remain in their home countries for their careers. Some, inevitably, do end up abroad, but even in those cases, the ICTP often claims success. One of the world's leading string theorists, Argentinian Juan Maldacena, who works at the Institute for Advanced Study in Princeton, New Jersey, attributes his achievements in part to the ICTP, because of the training that he and his master's supervisor received at the centre.

The ICTP's journey has not been entirely smooth, however. "When Salam passed away, ICTP had a period to recover from the founder's death, but they managed," says David Gross, a string theorist at the University of

California, Santa Barbara, who often visits the institute. Keeping the money flowing has been difficult — especially in light of the institute's growth into new fields.

The satellite campuses that it has been launching, mostly supported by the host countries, are designed to improve postgraduate education in physics and mathematics, as well as to conduct research and training in topics that serve regional interests and strengths. The centre in São Paulo, Brazil, for instance, focuses on pure theory, whereas the one in Chiapas, Mexico, includes climate and renewable energy. When it comes to further expansion, Quevedo says, the institute insists on quality over quantity and is careful to evaluate each proposal. It has also made it a priority to recruit more women into its programmes. Since 2001, the average proportion of female scientists visiting or studying on its campus has been 20%, but the balance is better in the 2013–14 diploma programme, in which half of the participants are women.

All of these activities take money. The Italian government still covers about 80% of the Trieste centre's annual budget of about €30 million (US$37 million), with a major chunk of the rest provided by the IAEA and UNESCO. (UNESCO has also had responsibility for the centre's administration since 1996.) "Italy deserves a lot of credit for sticking with the organization over the years through all their financial crises," says Gross. But the government is keen for the ICTP to find new funding sources, and in 2013 the institute created an office dedicated to seeking additional funding from elsewhere. With many applications for every available training slot, "the main challenge is to attract funds to be able to fund more students", says Quevedo.

The centre has also had to adapt to geopolitical changes. Back at the start, when it was important to bridge the East–West divide, the institute offered neutral ground for Soviet and US physicists. Today the bridges are built between developed countries in the global north and more impoverished or politically isolated ones in Africa, South America and south Asia. The institute is one of very few places to have helped scientists from North Korea to meet and study with other researchers, for example, says ICTP cosmologist Paolo Creminelli. "These researchers represent a connection between North Korea and the rest of the world."

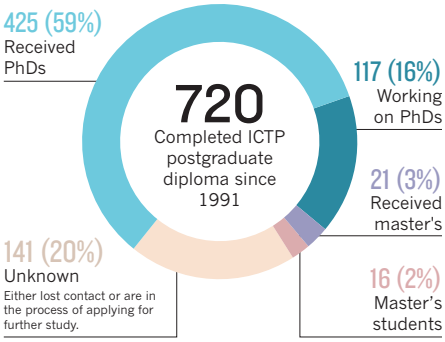
Elsewhere, several other institutions have been built on the ICTP model, including the International Centre of Physics (CIF) in Bogota, which since its establishment in 1985 has supported physics research in Colombia and surrounding countries. There is a great need for ICTP-type programmes in natural sciences, engineering and other technical sciences, says Torsten Wiesel, president emeritus of Rockefeller University in New York City, who has worked to advance developing-world science. "The world needs more programmes reaching out over the borders into countries of need," he says.

Some researchers argue that the ICTP itself should go further. It should "develop research schemes and programmes with direct, specific and relevant applications in engineering, industry and medicine in the developing world", says Estelle Maeva Inack, a condensed-matter physicist from Cameroon who works at the ICTP. Quevedo says that the institute is aware of this need, and that it is one of the reasons for expanding into more applied disciplines. He also points to a popular course on entrepreneurship for physicists, which the ICTP runs in collaboration with partner institutes around the world. "But our main mission is to promote excellence in science in developing countries and we should continue being faithful to this mandate," he says.

That is what got it this far, after all. "The first challenge of every institution is survival," says Quevedo, "and ICTP has survived for 50 years."

STICKING WITH SCIENCE

Most people who get diplomas from the International Centre for Theoretical Physics (ICTP) pursue further study, and more than half who get PhDs return to their home countries.



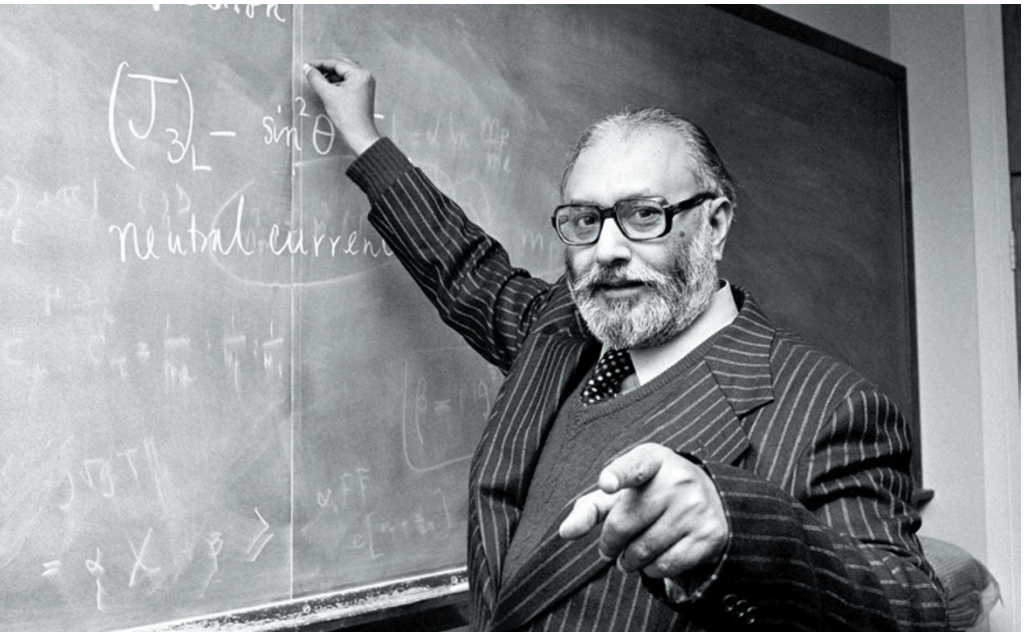
SOURCE: ICTP

HEADING HOME

The anniversary celebrations over, Adhikari talks to his students by phone as he gets ready to leave Trieste. It has been raining a lot in Nepal, which has rendered the solar panels rather useless — and has made work hard for Kaphle, who is getting ready to defend his PhD thesis in a few weeks.

But Adhikari is not put out. His proposal for tabletop physics went down well, and now discussions are under way at the ICTP to see whether he can receive the funds he would like. "I owe a lot to the organization," he says, and he is optimistic that science will appeal to other bright students in Nepal. He wants to see children in villages doing homework on computers, illuminated by electric lights, rather than the oil lamps that he once used. "I hope one day our students in Nepal will be able to find answers to some really big problems in physics."

And there is no reason why they shouldn't, says Gross, with a worldwide pool of talent just waiting to be tapped. "There are brains everywhere, in roughly the same proportion of the population — as long as they get a chance." ■



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Nobel-prizewinning physicist Abdus Salam campaigned for a centre to support developing-world physics.

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1. Pantha, N., Belbase, K. & Adhikari, N. P. *Appl. Nanosci.* http://dx.doi.org/10.1007/s13204-014-0329-y (2014).
2. Oli, B. D., Bhattarai, C., Nepal, B. & Adhikari, N. P. *Adv. Nanomater. Nanotechnol.* **143,** 515–529 (2013).