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Building a Future On Science

Brazilian neuroscientist Miguel A. L. Nicolelis taps into the chatter of neural populations to drive robotic prosthetics. Now he hopes to tap the potential of his country's population by building them a network of science cities

By Christine Soares

In a tiny, darkened room on the Duke University campus, Miguel Nicolelis looks on approvingly while a pair of students monitors data streaming across computer screens. The brightly colored dashes and spikes reflect the real-time brain activity of a rhesus macaque named Clementine, who is walking at a leisurely pace on a little treadmill in the next room. Staticky pops coming from a speaker on a back wall are the amplified sound of one of her neurons firing.

“This is the most beautiful music you can hear from the brain,” Nicolelis declares with a smile.

The run-through is preparation for the next big demonstration of work toward mind-controlled human prosthetics that first garnered worldwide headlines for Nicolelis and his team in 2003. Back then, the group showed that they could listen in on brain signals generated by a monkey using a joystick to play a video game and translate that biological code into commands for a mechanical arm to perform the same motions. Now the group intends to make robotic legs walk under commands from the motor cortex of a monkey strolling along like Clementine. This time the scientists also want to feed sensor data from the robot feet into the monkey’s brain, so she can “feel” the mechanical legs’ strides as though they were her own. To raise the stakes still further, the monkey will be at Duke in North Carolina, but the robotic legs will be half a world away at the Advanced Telecommunications Research Institute International in Kyoto, Japan.

The complexity of the experiment presents potential obstacles, Nicolelis admits, but satellite transmission delay of the signals traveling to and from Japan is no longer among them. One of the young men in the room, Ian Peikon, found a way to reduce the delay to a negligible 120 milliseconds. “And he’s an undergraduate,” Nicolelis adds, delighting in the opportunity to illustrate a favorite point—that you don’t need a Ph.D. to participate meaningfully in science. The allusion is to a larger personal philosophy that has been driving the 46-year-old neuroscientist’s pursuit over the past five years of a very different kind of ambition, perhaps on a par with uploading sensations to the human brain.

Convinced that science is a key capable of unlocking human potential well beyond the rigid hierarchies of academia—and outside the traditional scientific bastions of North America and Europe—his other big project has been nothing less than a quest to transform the way research is carried out in his native Brazil. In the process, he believes, science can also leverage economic and social transformation throughout the country.

The heart of Nicolelis’s vision is a string of “science cities” built across Brazil’s poorest regions, each centered on a world-class research institute specializing in a different area of science or technology. A web of education and social programs would intimately involve surrounding communities with each institution while improving local infrastructure and quality of life. And the presence of these knowledge-based oases would spark a Silicon Valley–style clustering of commercial scientific enterprise around them, jump-starting regional development.

Nicolelis is used to initial skepticism, even from peers, elicited by the grandeur of the scenario. “Up until a few months ago Brazilian scientists were the biggest doubters of all,” he says. Now many observers in Brazil and abroad acknowledge that the momentum his plan has attained in a short time suggests Nicolelis may be on to something.

An Idea Becomes Concrete

By last August the nonprofit foundation that Nicolelis and his partners formed in 2003 to build a proof-of-concept neuroscience institute in northeastern Brazil had raised $25 million, much of it in a large endowment from the widow of billionaire Edmond Safra. On a hilly 100-hectare site in the coastal farming town of Macaíba, three core elements of a “campus of the brain” were also complete. The bright white structures include a 25-lab research building, a free clinic specializing in maternal and child health, and a school that will offer twice-weekly science and art classes to 400 local children, aged 11 to 15, in the first quarter of 2008.

In the larger port city of Natal, 20 kilometers away, another science school has been up and running since last February with about 600 students, along with a suite of labs equipped for Nicolelis’s Parkinson’s disease research using transgenic mice. A third neuroscience lab run by Nicolelis’s group, established at the Sírio-Libanês Hospital in the southern city of São Paulo in exchange for the hospital’s sponsorship of the Macaíba clinic, is focused on clinical application of the prosthetics research.

The Macaíba site itself was donated by the state government of Rio Grande do Norte and still lacks a paved access road, but the foundation already has plans for a 5,000-student school, additional lab space, a larger health center, a sports facility and an ecological park to complete what will be the main campus of the International Institute of Neuroscience of Natal (IINN). The Brazilian federal government pledged $25 million toward finishing the complex after President Luiz Inácio Lula da Silva visited the campus in August with his chief of staff and minister of education in tow. Nicolelis had given what he calls "the most important PowerPoint talk of my career" to the president, who is universally known as "Lula," a few weeks earlier.

Back in his spacious office overlooking the leafy Duke campus, Nicolelis recalls that first encounter as feeling slightly surreal. "You know I give lectures all over, but all of a sudden you're talking to the guy who can actually change a lot of stuff. And the cool thing is we were talking about science—not talking about building a bridge or a road, we were talking about how to massively educate kids in a country like ours using science as a driving force." After Lula's visit, Nicolelis's group began discussions with Brazil's minister of education about creating a science curriculum for 354 new national technical high schools. "If this works, we'll be up to one million students in two years," Nicolelis says excitedly.

The social components of Nicolelis's plans that are taking shape alongside the scientific facilities are absolutely integral to the institute's purpose in his view. "What we took [to Natal] is not only the idea of doing science at an international level, as we do here [at Duke], but the idea that we let that become part of a school, of a women's clinic, that we merge a scientific enterprise with society." He is keen for scientific research at the IINN to focus on how the brain learns, for example, so that new insights can be incorporated into teaching methods in the schools. Given the importance of early brain development, the clinic will also offer a human milk bank for new mothers who cannot produce their own and will fill an unmet need in the region for neuropediatric treatment. "So it's a huge experiment that links neuroscience with education and health services," he explains.

The plan has continued to evolve ever since it was conceived with two other Brazilian scientists at Duke as a way of raising the caliber of science in Brazil. "It was about repatriating people and reversing the brain drain," Nicolelis says of the idea that he and his postdoctoral fellows Cláudio Mello* and Sidarta Ribeiro had in 2002 to establish a world-class neuroscience institute in Brazil.

"But we also knew that it had to be a driving force for social change, to demonstrate that, with opportunity, talent anywhere will have a shot." They named the nonprofit they founded to execute their plan the Alberto Santos-Dumont Association for the Support of Research (AASDAP), after the Brazilian who went to Paris in the 1890s to pursue his dream of flying and succeeded.

Meeting Global Standards

In 1989, when Nicolelis and his wife, Laura de Oliveira, left Brazil so that Nicolelis could pursue a neuroscience career, both had medical degrees from the University of São Paulo in Brazil's largest city, and Nicolelis had completed his Ph.D. at the same institution under the guidance of a prominent Lou Gehrig's disease researcher, César Timo-Iaria. But the country had just emerged from two decades of rule by a bureaucratic military regime, research funding was minuscule, and young scientists had few prospects for work. Once in the U.S., Nicolelis also encountered doubts that a Brazilian-trained scientist could amount to much. "What or who of any significance has ever come out of the University of São Paulo?" he says he was asked repeatedly in job interviews.

Starting out at Philadelphia's Hahnemann University, Nicolelis soon became a pioneer in techniques for eavesdropping on hundreds of neurons at once in attempts to decode the fundamental language of the brain. Widely recognized today as one of the world's leading neuroscientists, he credits his own professional success with fueling his conviction that promising young scientists should not have to leave Brazil to realize their full potential.

In the time that he has been away, conditions for Brazilian scientists have improved, although the nation's 2006 public and industry spending on research and development of $14.5 billion is still considerably less than the amount invested by many of the other emerging economies with which Brazil is often compared [see sidebar on next page]. Lula has endorsed science and technology as avenues for Brazil's development and recently announced a $23-billion boost to the research budget over the next three years.

The president's embrace of science is undoubtedly encouraged by some recent high-profile demonstrations of the fruits of research spending, notes physicist Sergio Mascarenhas de Oliveira, director of the Institute for Advanced Studies of São Carlos, part of the University of São Paulo. Mascarenhas praises the national agricultural research corporation, Embrapa, in particular for its leadership in developing ethanol and other biofuels as well as staking out tropical agricultural biotechnology as an area where the country can establish expertise. In 2000 a consortium of some 30 Brazilian laboratories produced a genome sequence of Xylella fastidiosa, an important citrus crop parasite, and several other projects to sequence crop plants, such as sugarcane, are under way. "Embrapa is in the process of changing our [nation's] export commodity from raw materials to applied science," Mascarenhas says. "What Brazil still doesn't know how to do is to transform research from the university into products and venture capital," he adds, blaming the weakness in part on an ivory-tower culture in Brazil's largely university-based research community.

Not surprisingly, some of those scientists were dubious of the Natal project, Mascarenhas recalls. Nicolelis's concept of a network of independent research centers, inspired by Germany's prestigious Max Planck institutes, is unusual for Brazil. The AASDAP motto, "The Future of Science in Brazil Starts Here," definitely did not help, Mascarenhas notes. And if the approach alienated some Brazilian scientists, the decision to locate the first institute in the impoverished hinterland of Natal also mystified many of them. Nicolelis thinks that the institute's social and economic influence will be most visible in the communities around Natal and Macaíba, and that the region is exactly where such transformation is most needed.

Moreover, the seaport and an airport that receives nonstop flights from Europe should make the location a promising one for commercial science, he says. The federal government has declared the area a free-enterprise zone, and AASDAP staff is now negotiating the creation of a 1,000- to 2,000-hectare biotech park, which Nicolelis hopes will attract businesses focused on products for export, such as pharmaceuticals and biofuels. Meanwhile he is in talks with several other states interested in hosting the next three institutes, whose specialty areas will likely be bioenergy, microelectronics and environmental science.

The New Science City

As a means to promote regional economic development, the strategy of clustering high-tech businesses around major research institutions in the hope of spurring innovation has never been more popular. Local and national governments, especially across Asia, are spending billions to build such science parks and "cities" as they peg their development goals to science.

In 2006 China declared its plan to construct 30 new science cities and to raise its annual research spending to more than $100 billion by 2020. At that point, the government expects 60 percent of the country's economic growth to be based on science and technology. India, where a small number of elite universities have become hubs for technology clusters, as in Bangalore, is also betting on a continued tech boom. Although their approaches differ, what many of these nations have in common is an overt goal of luring a diaspora of scientists trained in the West to bring their expertise back home, notes Marina Gorbis, executive director of the Institute for the Future (IFTF), a think tank in Palo Alto, Calif. "The example most often cited is Taiwan," she says, "where the whole semiconductor industry is based on expats who stayed here in the Silicon Valley for 20 years, then went back. We're seeing it happen in China, too: professors going back and establishing their labs, and they're bringing their students and contacts and becoming magnets." Nicolelis is probably one of a handful of Brazilian scientists with the stature to play the same role in his country, Gorbis adds.

She and IFTF research director Alex Soojung-Kim Pang led a yearlong project to produce the "Delta Scan," a broad analysis and forecast of science and technology trends commissioned by the British government. In it, they flagged Brazil as a possible world scientific leader by 2025 and the Natal initiative as an example of the direction the country will need to take to get there. The potential for transdisciplinary research within and among AASDAP institutes is an important advantage in Gorbis's view. And Nicolelis's own emphasis on collaboration between his Duke lab, the IINN sites and international partners embodies a globally networked style of working that Delta Scan authors considered essential to Brazil's ability to produce world-class research. Pang also sees the IINN's launch, enabled primarily by international donations at first, as the shape of things to come elsewhere. "The other interesting story," he notes, "is the rise of private capital in supporting these kinds of centers and supporting what we would normally think of as big science projects." The next evolution in science-based development, Pang observes, is a less structured and less government-driven "innovation zone" arising from the joint efforts of entrepreneurs, philanthropists and researchers.

Harvesting Human Potential

Whether the Natal model can help Brazil catch up to the countries pouring many times more resources into science and technology remains to be seen. As the world's fifth largest nation in land area and one exceptionally rich in diverse natural resources, Brazil has long been described as "the country of the future," possessing nearly all the ingredients needed to become an economic powerhouse. Most analysts cite the country's own legal system as being one of the biggest obstacles to Brazil's reaching its full potential.

Bureaucracy, burdensome taxes, and weak enforcement of antitrust and intellectual-property laws are blamed for stifling the population's natural entrepreneurial dynamism. A poor school system and high illiteracy rates are the other major barriers to progress most often named.

In that light, the most unorthodox aspect of the Natal project could be its greatest strength. Nothing like the educational effort on the scale envisioned by Nicolelis has ever been tied to a science-city initiative. "A few give it lip service," Pang says, "but even then they're mainly talking about university-level education."

In Nicolelis's view, reaching children well before college age is crucial. He believes that science education strengthens critical thinking skills in general, and he plans to use improvements in the children's regular school performance as a benchmark for the effectiveness of the supplementary classes at institute science schools. If some of the kids become interested in pursuing science and technology careers, they will find plenty of opportunities in the knowledge economy. "Ninety-nine percent of scientific work doesn't require a Ph.D.," he insists.

But he is careful to clarify that he is not trying to create a nation of scientists. "We are trying to create a generation of citizens capable of leading Brazil," Nicolelis explains. "These kids already have the hopes—now what they need is the tools." Whether they want to be doctors, architects, pilots or president, he is confident that the experience of hands-on scientific inquiry can instill a feeling of empowerment that the children will carry into adulthood and use to carry their country into its long-awaited future.

**Erratum: Cláudio Mello was an associate professor of neuroscience at Oregon Health & Science University, not a postdoctoral fellow at Duke as stated in the article, when he, Ribeiro and Nicolelis launched their initiative to build a neuroscience institute in Natal. We regret the error.* —The Editors

More To Explore

Brazil Institute Charts a New Hemisphere Marcia L. Triunfol and Jeffrey for Neuroscience.
Mervis in Science, Vol. 303, pages 1131–1132; February 20, 2004.

Marcela Ferrer et al. The Scientific Muscle of Brazil's Health Biotechnology. in Nature Biotechnology, Vol. 22, supplement, pages DC8–DC12; December 2004.

Supplement to the Economist. Dreaming of Glory: A Special Report on Brazil. April 14, 2007.

Delta Scan: The Future of Science and Technology, 2005–2055.

Institute for the Future. http://humanitieslab.stanford.edu/deltascan/Home

International Institute of Neuroscience of Natal English-language Web site: www.natalneuro.org.br/_eng/index.asp