OIST
OKINAWA INSTITUTE OF SCIENCE AND TECHNOLOGY
GRADUATE UNIVERSITY

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OF SCIENCE AND TECHNOLOGY
GRADUATE UNIVERSITY

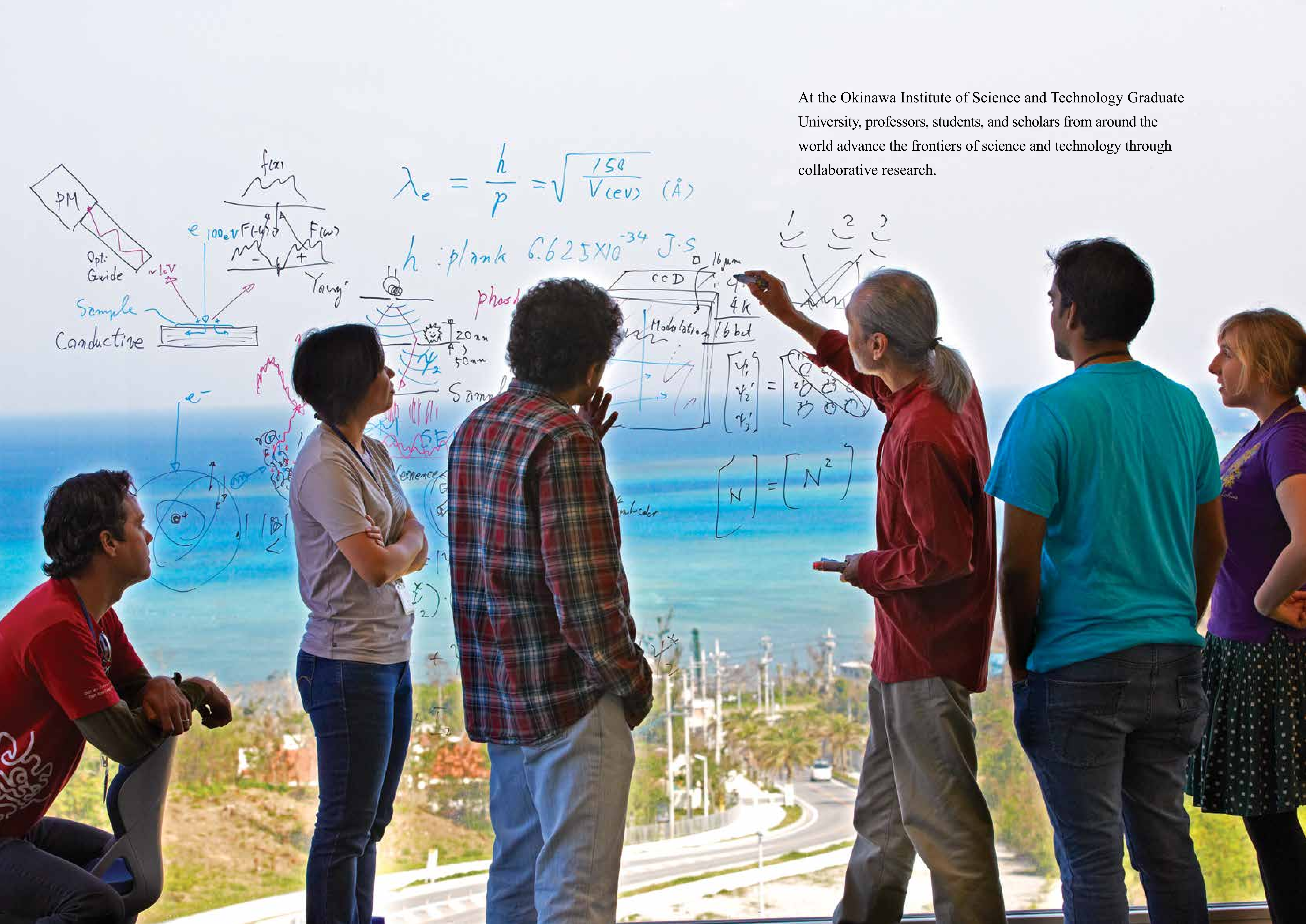
Welcome to OIST

a university for the future

沖縄科学 技術
大学院大 学

Nestled against a forested hillside on the west coast of Okinawa, a new world-class graduate university is forging the next era of interdisciplinary education and research.

At the Okinawa Institute of Science and Technology Graduate University, professors, students, and scholars from around the world advance the frontiers of science and technology through collaborative research.

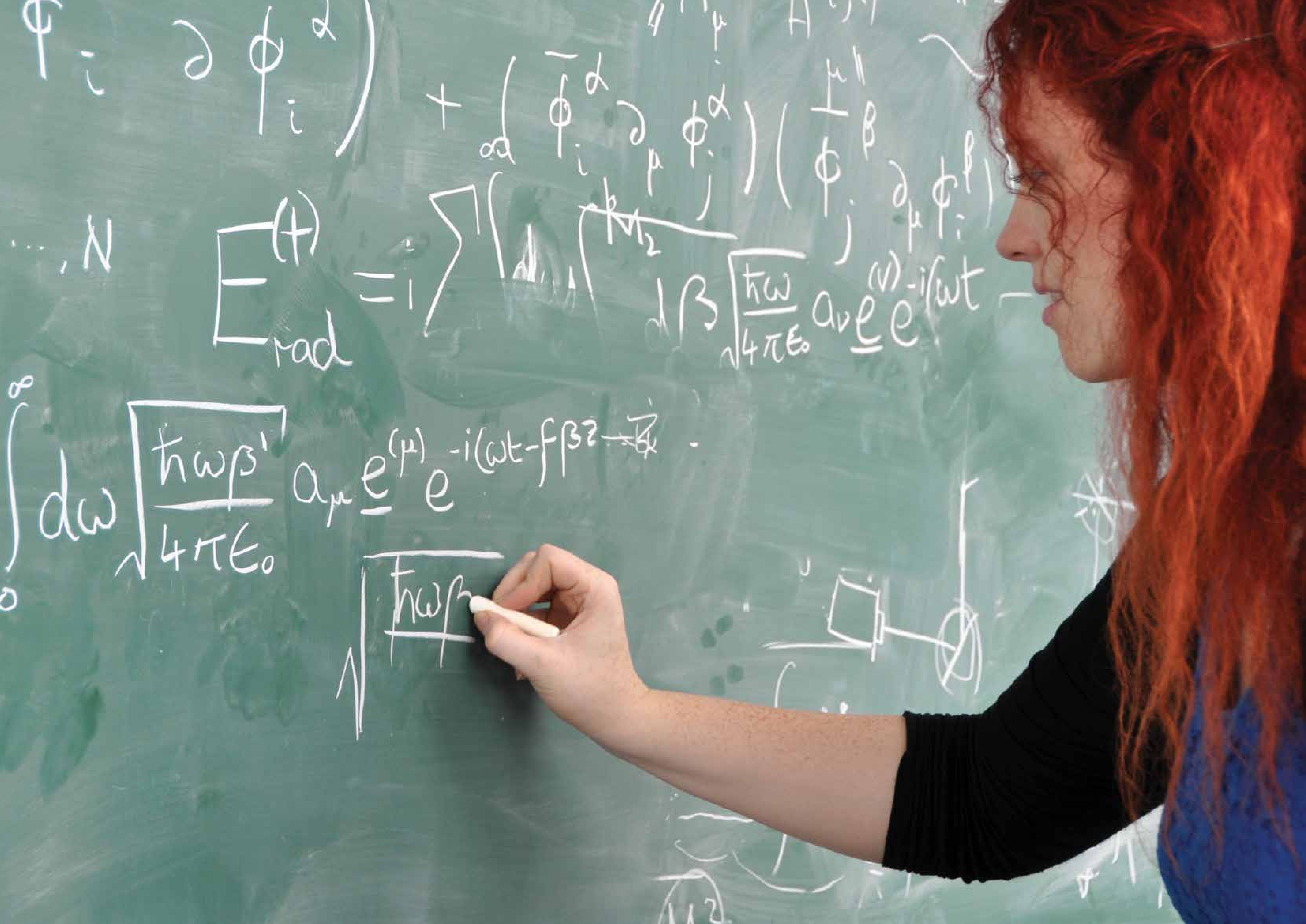


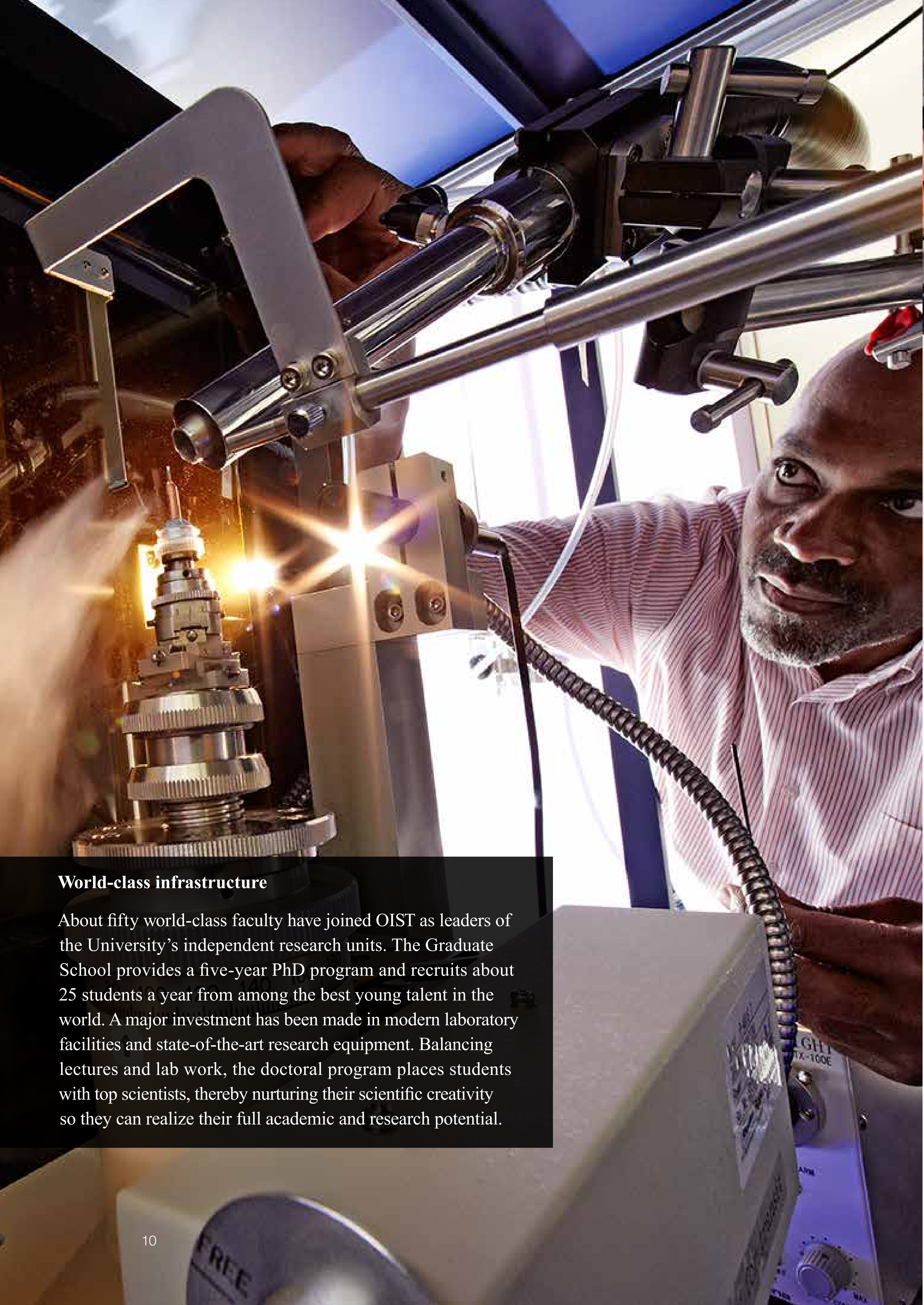
Welcome to the future of research and education

沖縄科学技術
大学院大学

No boundaries

OIST is pioneering change in the global practice of education and research. The absence of academic departments, a policy of broad access to all research equipment, and shared common space for faculty-led research units from widely differing disciplines remove traditional barriers to collaboration and promote cross-disciplinary research opportunities. While students receive strong training in their discipline of choice, their studies also include courses that fall outside of their area of specialization. Students are required to do at least one of their three rotations in a laboratory conducting research outside of their core discipline.





World-class infrastructure

About fifty world-class faculty have joined OIST as leaders of the University's independent research units. The Graduate School provides a five-year PhD program and recruits about 25 students a year from among the best young talent in the world. A major investment has been made in modern laboratory facilities and state-of-the-art research equipment. Balancing lectures and lab work, the doctoral program places students with top scientists, thereby nurturing their scientific creativity so they can realize their full academic and research potential.

GRADUATE STUDIES
Students enjoying a break with Provost Robert Baughman at the OIST Center Court.

The OIST Graduate University

OIST is forging a new path of graduate education—and its students help to create it.

OIST's founders recognize that great discoveries lie at the intersections of major sciences, when researchers make novel connections between disparate disciplines. Accordingly, OIST has built a graduate program for students to grow highly competent in their core discipline and conversant with others.

"We want our students to achieve first class research outcomes, to creatively address important scientific questions, and to grow to their full potential as independent scientists playing lead roles in research. We encourage an international perspective and growth that is unrestricted by the traditional boundaries between disciplines," said Prof. Jeff Wickens, Dean of the OIST Graduate School.

Before they begin, students are assigned an experienced faculty member as mentor to guide their course of study and help them choose a thesis lab. Small class sizes and collaborative principles let the students shape how classes are taught. And if OIST doesn't offer recommended courses, the student works with a tutor in guided independent study or with visiting professors in special topics.

In each of three terms, students conduct a research project in a new lab. Usually two rotations fall within the chosen field—perhaps theoretical and experimental physics—and one far outside it, like ecology.

"Rotations are designed for the student to learn, as an insider, to speak the language and apply the techniques used in a research unit. We challenge them to go beyond their comfort zones, to learn research by doing research and gain first-hand experience working alongside leading scientists and faculty members," says Wickens. "This opens up future possibilities for meaningful interactions with researchers in different fields, leading to new possibilities from cross-fertilisation of ideas and collaborative projects."

In the second year, students define their PhD directions and labs. Throughout the program, the OIST philosophy of research is promoted by offering equal access to research equipment. This encourages interaction and collaboration within and between disciplines as a way to find new solutions and discover new knowledge. Most graduates live in the campus village initially, further strengthening the OIST community with plenty of opportunities for socializing.

Although located in Japan, OIST is truly international. Education and research are conducted in English, and the academic year starts in September. Students are encouraged to develop professional skills, travel internationally to keep abreast of new developments, disseminate their research findings, and tap into the extensive networks connected with the OIST faculty members. This will develop future career opportunities in leading research institutes and universities worldwide.

"What makes this model so exceptional is the student-centered approach," explains Wickens. "We recognise that students are individuals and design their programs of study with them, according to their unique needs and scientific aims. We provide the resources, guidance and support they need for each step they take toward achieving their goals in research and scholarship."

FEMTOSECOND SPECTROSCOPY UNIT

Ultra-fast lasers are revealing the behaviors of electrons at the femtosecond timescale, a millionth of a billionth of a second.

Shared goal, opposite approaches

Dani's investigations of nano-scale materials help applied material scientists like Qi brighten the future of solar cells.

When Professor Yabing Qi, head of the Energy Materials and Surface Sciences Unit, tells people he's developing flexible, lightweight solar cells that are inexpensive to produce and easy to use, their first question is: what's the catch?

"There's no catch," says Qi. "It's just a matter of time before organic solar cells are coating windows and powering houses in both developing and developed countries."

Today's solar cells are often made of silicon—a rigid, inorganic material that is costly and slow to produce. Qi belongs to a network of researchers who are developing low-cost, flexible solar cells out of organic materials. The panels are easily made by coating plastic sheets with an organic semiconductor solution using a machine much like an inkjet printer. The plastic sheets can then be applied to nearly any surface. Windows are a popular choice.

"Going green is not just about using renewable energy, but also about identifying smarter ways of tapping into natural resources," says Qi."We don't need sophisticated equipment of millions of dollars' worth to produce our solar cells, which significantly reduces production costs."

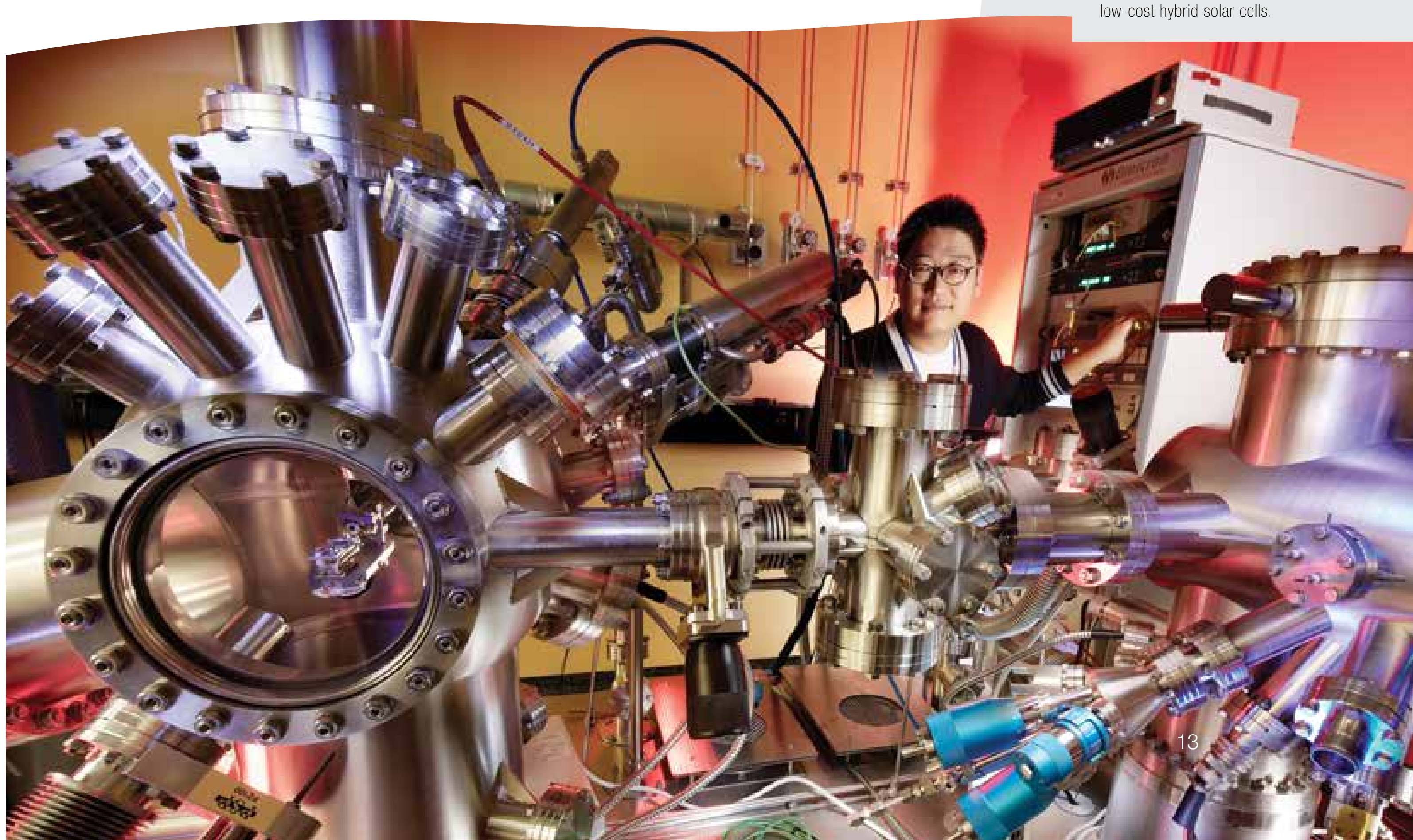
While the technology needed to produce these organic solar panels is relatively simple and inexpensive, their development wouldn't be possible without a fundamental understanding of how electrons and photons interact with each other. At OIST, Keshav Dani, head of the Femtosecond Spectroscopy Unit, is interested in just that.

The researchers in Dani's Unit investigate interactions between electrons and photons in many materials. One of their main interests is the properties of titanium dioxide, a semiconductor that absorbs photons to produce electrons and holes. These electrons and holes, or negative and positive charges, can help generate an electrical current in a solar cell, among other commercial and scientific uses.

However, negative and positive charges are notorious for attracting one another, and their affinity hinders the efficiency of organic and regular solar cells. Dani's Unit uses ultra-short pulses of light to produce electrons and holes in titanium dioxide to better understand how to keep these opposites from attracting. Their fundamental research will aid applied material scientists like Qi in developing more efficient solar cells.

ENERGY MATERIALS AND SURFACE SCIENCES UNIT

Qi's lab is using organic materials to develop efficient, low-cost hybrid solar cells.



NEURONAL MECHANISM FOR CRITICAL PERIOD UNIT

Songbirds learn to make sound in a similar way to humans. By studying the early development stage in songbirds, scientists unravel why it is difficult to learn new things when we are older.

Our plastic brains

By studying how birds learn their songs, Yoko Yazaki-Sugiyama is discovering what makes young brains so absorbent.

When we are young, our brains bend like flimsy plastic at the whim of our sensory environments. We see this extreme malleability in our children, but less often in our adult selves: why is it so much harder to adapt to a new environment when we're fifty than when we're five?

Professor Yoko Yazaki-Sugiyama, head of the Neuronal Mechanism for Critical Period Unit, studies how this 'critical period' of malleability in the young is orchestrated in the brain. But instead of delving into the complex neural networks of the human brain, she studies songbirds.

"When a young zebra finch learns a song from its father, neural pathways in its brain form to commit the song to memory, and the same thing might happen in a baby's brain when they learn to speak," she explains. These similarities allow her to find parallels between the critical period in each species. "But exactly where or how this occurs is still a mystery—one that I want to uncover."

She's doing so by monitoring and controlling neuronal activities of specific areas of bird brains to explore how changes in neurons drive the malleability in bird behavior. Her findings will help her answer the next big question: why we lose that malleability as we mature.

Smart robots, healthy minds

Using robots, rats, and computational neuroscience to learn how life adapts to the world.

Considering the brain's complexity, it's no surprise that research in Kenji Doya's Neural Computation Unit spans theory, biology, and engineering. In one project, Doya studies artificial systems by building autonomous robots that can learn from experience, to see how they face basic challenges.

Life has two essential drives: to sustain itself and to reproduce. The "Cyber Rodent" robots he designed are equipped with a wide-angle camera, proximity sensors working as "whiskers," and an infrared communications port for copying the essential parameters of its program. They roam their space searching for batteries to sustain their life and for mates to copy their "genes" with.

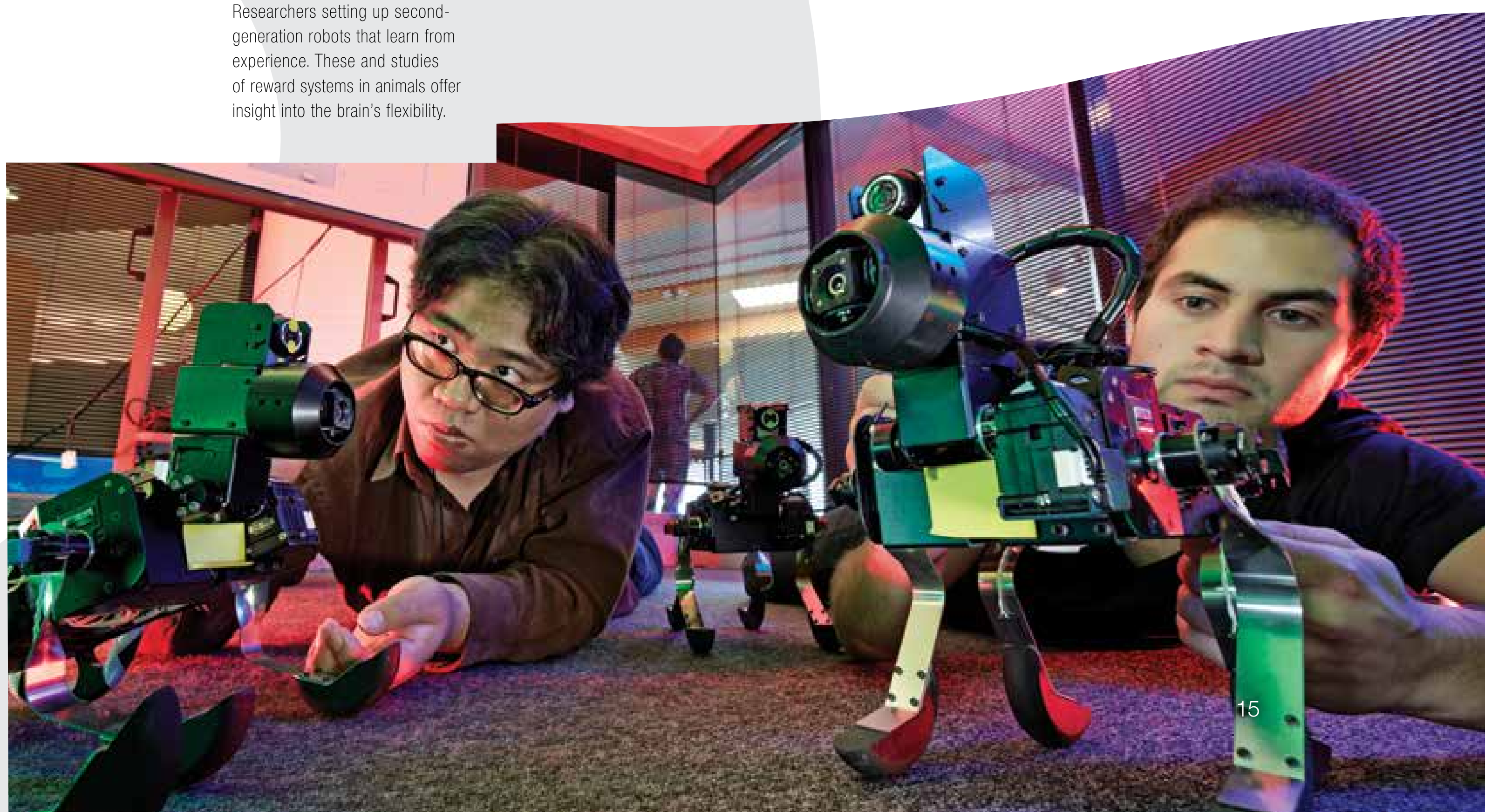
Doya and colleagues encoded the definition of the "reward" for the robot and the parameters of learning into their genes. They also introduced random mutations in copying and selection based on the sender's energy level. Generations later, the robot rats acquired the right levels of rewards for finding a battery or a mating partner in their sights, and proper time constants for learning from the past and predicting the future. Some colonies evolved into two subpopulations: one focused on recharging, the other more eager for mating. "This was some unexpected evolution," says Doya, "but the right mix created a good balance." Balance is also crucial to reward levels: too much reward from a visual cue and a robot will run out of power while contentedly looking at a battery. Too little and it won't bother to recharge.

"We can learn a lot from robots that do not learn well," says Doya. One example was a robot that learned to just stay still, even though a battery could be seen in the distance. By analyzing the parameters of the robot, Doya found a very small setting of the parameter that specified how long delayed reward the robot should take into account. "How does our brain set the time frame for planning ahead?" That question led Doya's neurobiology team to focus on the function of serotonin, a neurotransmitter that has been implicated in depression, but its exact role was unclear. Through experiments with real rodents, his team revealed that serotonin in the brain plays a critical role in the regulation of the patience for forthcoming rewards.

The Unit has ongoing joint research with industry partners to create more independent, adaptive brains for their robots. Lab members have now built second-generation robots with advanced eating and mating behaviors.

NEURAL COMPUTATIONAL UNIT

Researchers setting up second-generation robots that learn from experience. These and studies of reward systems in animals offer insight into the brain's flexibility.



MARINE BIOPHYSICS UNIT
Mitarai's team with some of the instruments involved in monitoring marine health in Okinawan waters.

Making connections above and beneath the waves

Okinawa's first comprehensive project to wire the ocean will monitor marine health, track marine life, and help marine agencies.

Travel deep beneath the waves to a field of hydrothermal vents and you'll find a community of clams, snails, worms, and crabs. You'll find a similar community at the next field, perhaps 2 or 200km away. How do individuals find their way to these habitats when there are no sulfuric oases in between?

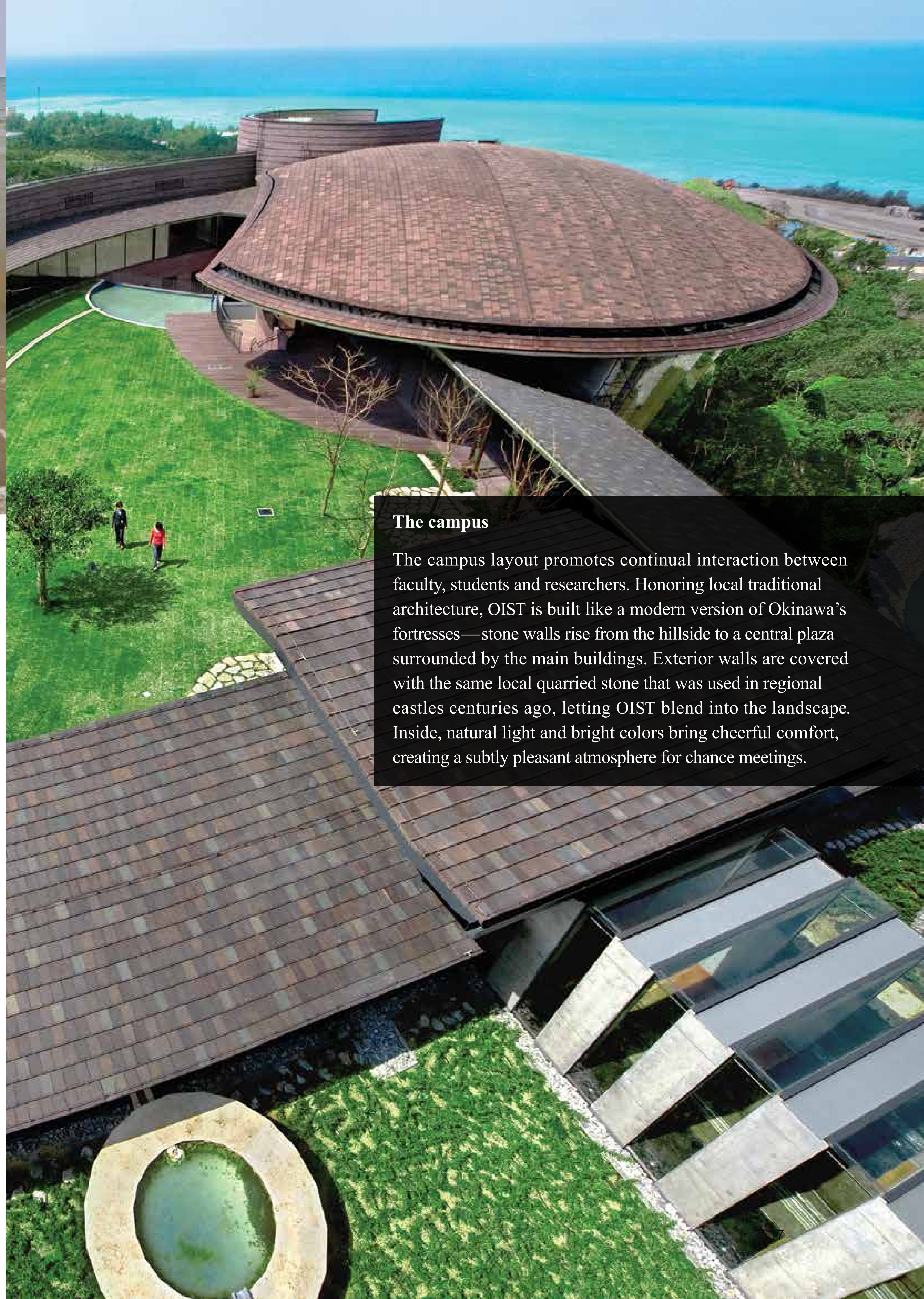
Part of the answer lies in the waywardness of youth. Starfish, corals, sea snails, barnacles, and many other marine animals start out as larvae, drifting with ocean currents until they settle and transform into adults. Discovering how these animals reach their destinations, be it a coral reef or a black smoker chimney, interests Satoshi Mitarai, who heads the Marine Biophysics Unit. He, Noriyuki Satoh, Igor Goryanin, and other OIST researchers received a $38M JPY Canon grant to investigate how animals disperse to hydrothermal vents throughout the Okinawa Trough in the East China Sea.

This endeavor requires collaborating with many agencies, and OIST's aim is that these connections provide mutual benefit. For instance, the Japanese Coast Guard helps Mitarai deploy equipment for deep-ocean surveys, and the Coast Guard, in turn, can improve its emergency response by using the detailed ocean circulation models OIST generates from the data.

"Thanks to our collaborators' help, including local fishermen, we can cover a wide geographic range and various ecosystems," says Mitarai. "Without their help, I don't think we could do this."

Closer to OIST, another Mitarai project will track the Kuroshio Current that carries warm tropical water north past Okinawa—and, with it, ocean larvae. While the Kuroshio tends to stream along the continental shelf, its path has been meandering lately. The project's buoys, solar-powered wave glider, camera and other equipment form the first marine array to surround all the Okinawa Prefecture islands, and will monitor the water's health by logging its temperature, oxygen, chlorophyll, and saltiness.

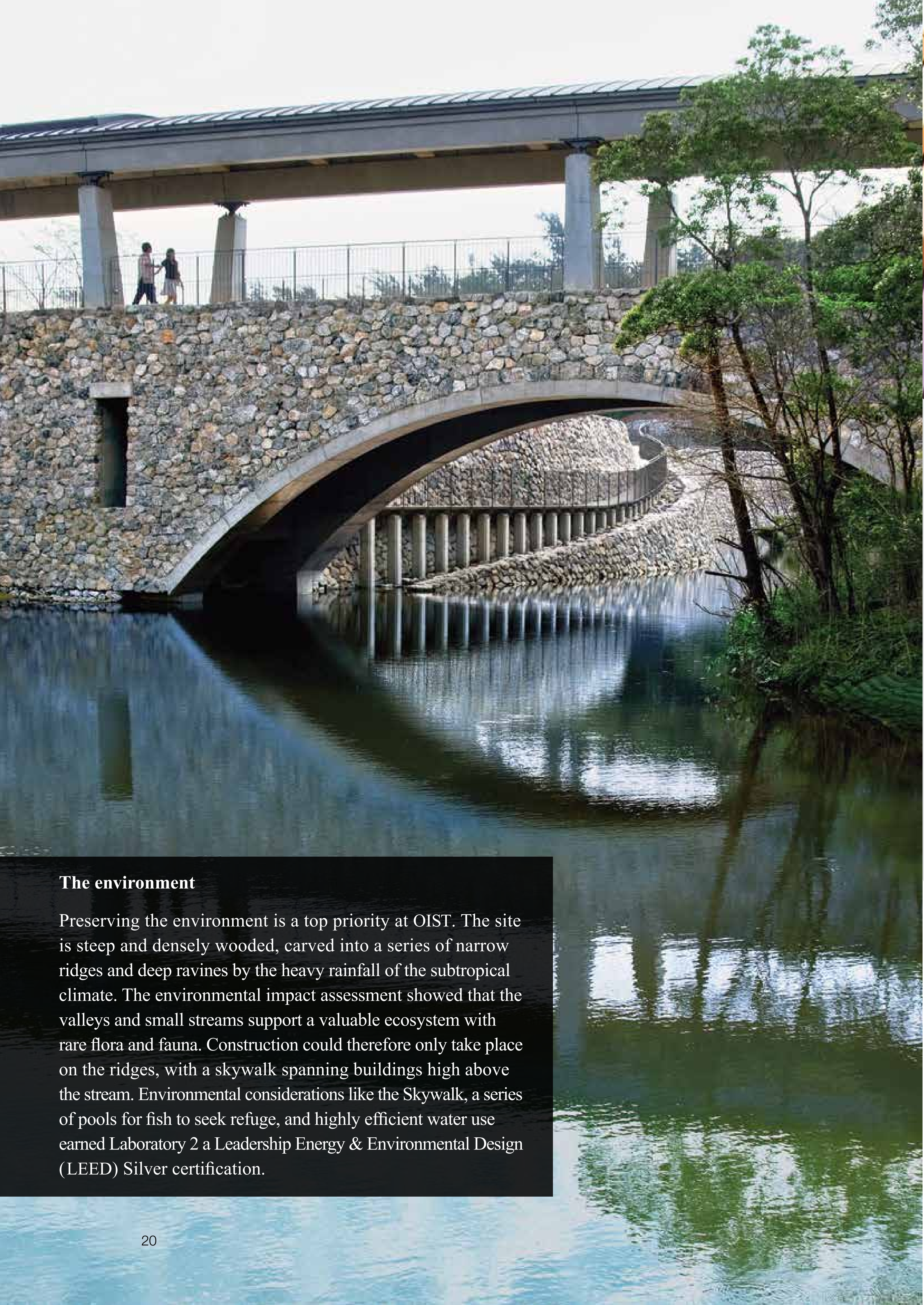
"Combined, this information will give us a large glimpse of complex marine connections around Okinawa," says Mitarai, "We have such great access to coral reefs that it only makes sense to look here first."



The campus

The campus layout promotes continual interaction between faculty, students and researchers. Honoring local traditional architecture, OIST is built like a modern version of Okinawa's fortresses—stone walls rise from the hillside to a central plaza surrounded by the main buildings. Exterior walls are covered with the same local quarried stone that was used in regional castles centuries ago, letting OIST blend into the landscape. Inside, natural light and bright colors bring cheerful comfort, creating a subtly pleasant atmosphere for chance meetings.

OIST President Jonathan Dorfan talking with students on the Skywalk.



The environment

Preserving the environment is a top priority at OIST. The site is steep and densely wooded, carved into a series of narrow ridges and deep ravines by the heavy rainfall of the subtropical climate. The environmental impact assessment showed that the valleys and small streams support a valuable ecosystem with rare flora and fauna. Construction could therefore only take place on the ridges, with a skywalk spanning buildings high above the stream. Environmental considerations like the Skywalk, a series of pools for fish to seek refuge, and highly efficient water use earned Laboratory 2 a Leadership Energy & Environmental Design (LEED) Silver certification.

QUANTUM WAVE MICROSCOPY UNIT
The Sea Horse Project team with their prototype. They aim to build 300 large propellers that will generate 1GW of power from the Kuroshio Current near Okinawa.

Building sea horses, destroying viruses

Iconoclastic scientist meets big energy demands and exposes microscopic devils.

The last thing Professor Tsumoru Shintake wants to do is to play by the rules. As head of the Quantum Wave Microscopy Unit at OIST, he is leading two radically different projects. While building an electron microscope that he designed to produce crisp representations of the tiniest scraps of life, Shintake is also pursuing a project that first captured his interest as a teenager.

"As a 16-year-old, I constructed a wind power generator that lit up the sign of the noodle shop my parents owned," says Shintake. When he first came to OIST in September 2011 and gazed out his new office window, the turquoise East China Sea inspired him to once again develop clean energy technology—but this time, it would light up one million homes.

Shintake's Sea Horse Project aims to harness power from ocean currents, a source of renewable energy that many find daunting due to the ocean's unpredictable nature. But not Shintake. His group is already testing prototypes of an umbrella-shaped propeller with meter-long blades that sweep through the water on its two-meter body. Ideally, 300 full-size propellers, each 80 meters long, will bob and spin 100 meters beneath the surface in the Kuroshio Current near Okinawa. The farm is expected to continually generate one gigawatt, roughly the output of a nuclear reactor. Not only will this energy be clean, but it will also reduce Japan's reliance on foreign sources, which supply 80 percent of the nation's energy demands.

In early 2013, Shintake's revolutionary electron microscope project also came to fruition. Electron microscopes function similarly to light microscopes, but illuminate samples with electrons. As their wavelength is 100,000 times smaller than that of light, they reveal objects far too tiny for light microscopes.

Most contemporary electron microscopes sacrifice image contrast for detail, but Shintake argues that these methods are inadequate for viruses, some of which are nearly clear. By making a few tweaks to the voltage of the electron beam that is shot through the sample, Shintake has maximized the contrast between light and dark in an image, and is poised to uncover never-before-seen detail.

As a final feat, his design also does away with the lens. Lenses can distort images around the edges so Shintake's design uses only a detector, which records the electrons bouncing off the contours of the sample, and a computer, which assembles the data into a three-dimensional representation of the exterior and interior of the virus.

"The more we know about the structure of viruses, the better we'll be at destroying them," says Shintake. "At this point, viruses have done a very good job of keeping their exact structures secret. But I hope to debunk them with my microscope."

MARINE GENOMICS UNIT
By sequencing genomes, members of Satoh's Unit aim to reveal the relatedness of marine animals, as well as their vulnerability to climate change.

Cracking open corals and oysters

By discovering the genetic blueprints of marine life, OIST's Marine Genomics Unit is finding deep-seated clues to animal behavior and solving some of evolution's earliest puzzles.

The stony coral *Acropora digitifera* is a common reef builder along Okinawa's shores. Despite its prominence, it's sensitive to climate change, easily losing its colorful algae to increasingly warm and acidic seas. So OIST's Marine Genomics Unit leader, Noriyuki Satoh, decided to uncover more about this stony coral by sequencing its DNA.

The team found some surprises. In a 2011 *Nature* paper, they established that corals and their closest relatives, sea anemones, diverged from their common ancestor 250 million years earlier than reefs appear in the fossil record. They also found this species relies on its algal residents to supply a vital amino acid. As this dependency might affect the coral's sensitivity to climate change, the Unit has now decoded the genome of the algae to understand the complex ecology of coral reefs.

With the stony coral genome decoded, the lab looked at the relatedness of regional populations. After sequencing colonies around the Okinawa Prefecture islands, the team found that even colonies hundreds of kilometers apart have some kinship. Since the adults are fixed in place, the spreading must happen at their free-floating larval stage. A planned project with the Marine Biophysics Unit to track the strong Kuroshio Current near Okinawa could explain how the coral larvae travel, and how local corals recovered after a devastating bleaching event in 1998.

In 2012, Unit members also collaborated with the University of Tokyo and Mikimoto Company researchers to sequence the first genome of a marine mollusk: the Japanese pearl oyster. "Knowing the genome will help us understand the genetics driving pearl formation and oyster physiology and reveal how environmental changes influence bivalves." Satoh says.

Another first is the Unit's discovery of genomic evidence for the Precambrian ancestor that links vertebrates—animals with backbones, from fish to frogs to humans—to the spineless sea stars and urchins.

In essence, the Marine Genomics' studies of life's tiniest building blocks are helping to elucidate its biggest evolutionary mysteries.

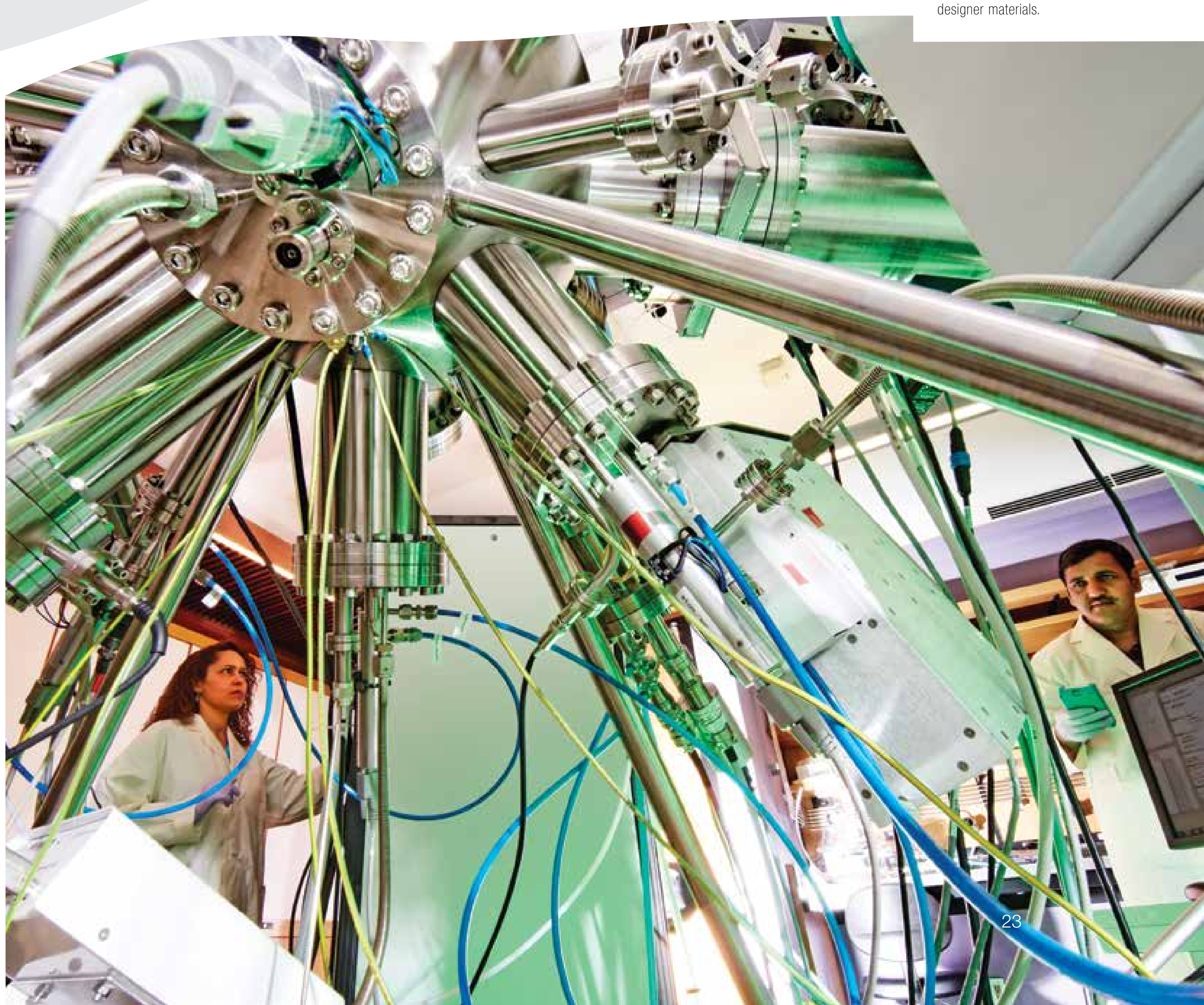
Creating good things in small packages

Mukhles Sowwan studies the unusual properties of nanomaterials, and helps other researchers along the way.

In the nanoworld, materials behave differently than at the human scale. Physical and chemical properties transform as the material shrinks: gold nanoparticles, for example, can be red, purple, or blue depending on their size and distance apart.

OIST researchers rely on Mukhles Sowwan's Nanoparticles by Design Unit in their projects that require fine-tuned magnetic, structural, electronic, chemical, or other properties that shift in the ultra-small world. The Unit's deposition system streams up to three different elements, forming clusters that are filtered between 2 and 20nm—comprising a few tens to millions of atoms each—then deposited onto a surface or gathered for a specific use. Custom-built nanoparticles can be used in sensors, drug delivery devices, and clean energy development, such as in structures for the microbial fuel cells currently being studied in the Biological Systems Unit.

NANOPARTICLES BY DESIGN UNIT
The Unit harnesses atoms' nano-scale properties to build designer materials.



Fluid alliance reduces friction in the world

Exploring the physics of turbulent flows reveals how theoretical details can have big consequences in everyday life and technology.

FLUID MECHANICS UNIT
Studies of soap film reveal previously unknown aspects of turbulence in two dimensions.

From typhoons and rivers to pipelines, a range of natural and engineered marvels interest OIST physicist Pinaki Chakraborty. Their common quality is motion: all have air, liquid, or solid particles that stream and swirl. As the head of OIST's Fluid Mechanics Unit, Chakraborty studies the turmoil, or turbulence, within these flowing substances.

"Turbulence is among the most fascinating, and common, phenomena in the world," says Chakraborty. When gradually turning on a faucet, water streams in a smooth column, he explains. But crank it open and the stream starts to wiggle. The flow has turned turbulent. Winds, ocean currents, typhoons, even avalanches behave this way.

Turbulence is easy to measure, but hard to predict. This problem drives physicists to better understand some of its properties, such as the "frictional drag" that quantifies the energy lost to friction within a flow. The loss of energy can have enormous consequences. It increases the cost of pumping oil through hundreds of miles of pipeline, adding to the price of gasoline. It also regulates a typhoon's intensity, both slowing the swirling winds and speeding the main updraft.

Chakraborty's main goal is to explain why turbulence increases this drag. The answers could lessen pumping costs by finding drag reducers and keep local weather damage to a minimum by enhancing models that predict Ryukyu Archipelago's annual typhoons.

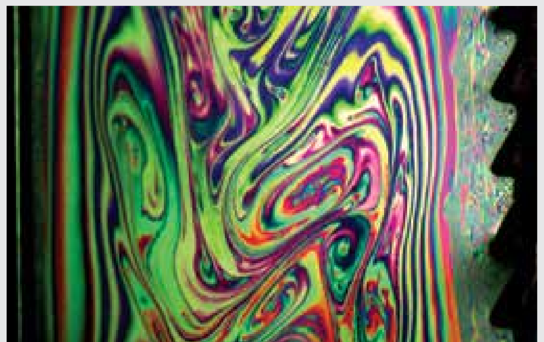
Equally dedicated to this goal is Professor Gustavo Gioia, head of the Continuum Physics Unit. Gioia has carried out much research trying to understand the behavior of granular materials. How powder, for instance, can be compacted into a solid-like aspirin tablet, or how layers of motionless grains of snow will abruptly flow in an avalanche. These materials can take on a "double personality," acting like both solids and liquids. This connection developed Gioia's interest in fluids.

The two researchers have worked together for more than a decade and enjoy OIST's emphasis on collaboration. "At OIST, our research is so intertwined that I don't even know if a post-doc is in my Unit or in Pinaki's," says Gioia.

Together they developed a theory that links the frictional drag of turbulent flows to the whirlpools or "eddies" within them. A mathematical model of eddies had been known, but no one had used it to predict a flow's drag.

They tested their theory in two dimensions in labs at the University of Bordeaux and the University of Pittsburgh, with another collaborator from the University of Illinois. In each lab, researchers projected a sheet of laser light onto soap films and measured variations in flows and eddies as gravity slowly tugged the colorful whorls earthward. Now the team will add the third dimension by measuring substances as they flow through a pipeline they've constructed at OIST.

"Our theory tells us there's something fundamental hidden here that we might be able to crack," says Chakraborty.



DEVELOPMENTAL NEUROBIOLOGY UNIT
Scientists within Masai's zebrafish project discover clues to how the retina develops in animals, in turn increasing our understanding of causes of related eye diseases.

Zebrafish earn their stripes

Ichiro Masai is uncovering secrets to healthy vision in schools—of fish.

"When an embryo is developing, the retina develops as an extension of the growing brain, so it is actually made of brain tissue," explains Ichiro Masai, head of the Developmental Neurobiology Unit at OIST. "Since the fundamental structure of the retina is similar in all animals from fish to humans, we use zebrafish to study its development."

By observing and breeding thousands of zebrafish strains and carefully tracking each fish's genetic information and health condition, researchers pinpoint mutations in the fishes' genes that harm the retina. And by knowing what can go wrong, they simultaneously uncover the genes responsible for the healthy development and maintenance of the retina.

So far, the Unit has identified more than 300 mutations that damage the retina. The Unit currently focuses on finding the mutations that lead to retinitis pigmentosa, a disease that afflicts both humans and zebrafish alike by impairing photoreceptor cells to the point of blindness. Their fundamental research will aid in finding a treatment that can slow, and potentially halt, the onset of this hereditary blindness in humans.

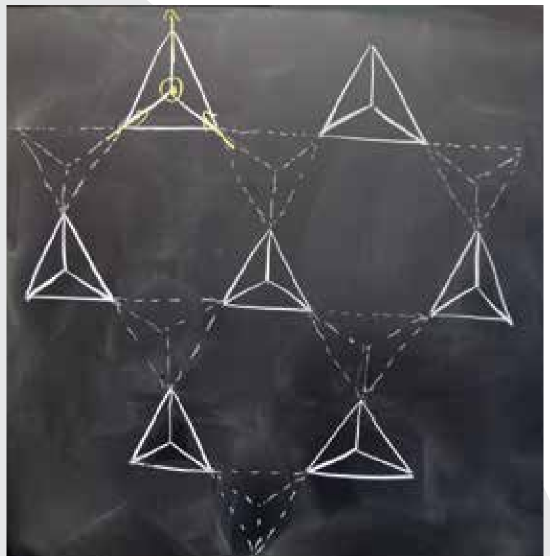
"The zebrafish at OIST must be some of the most carefully nurtured fish in the world, but they deserve the best care," says Masai. "Though they may not know it, these little fish are doing a huge service to humanity."

THEORY OF QUANTUM MATTER UNIT
Informal presentation in the Theory of Quantum Matter Unit.

Eavesdropping on electrons

Understanding how electrons behave in a group could change electronics forever.

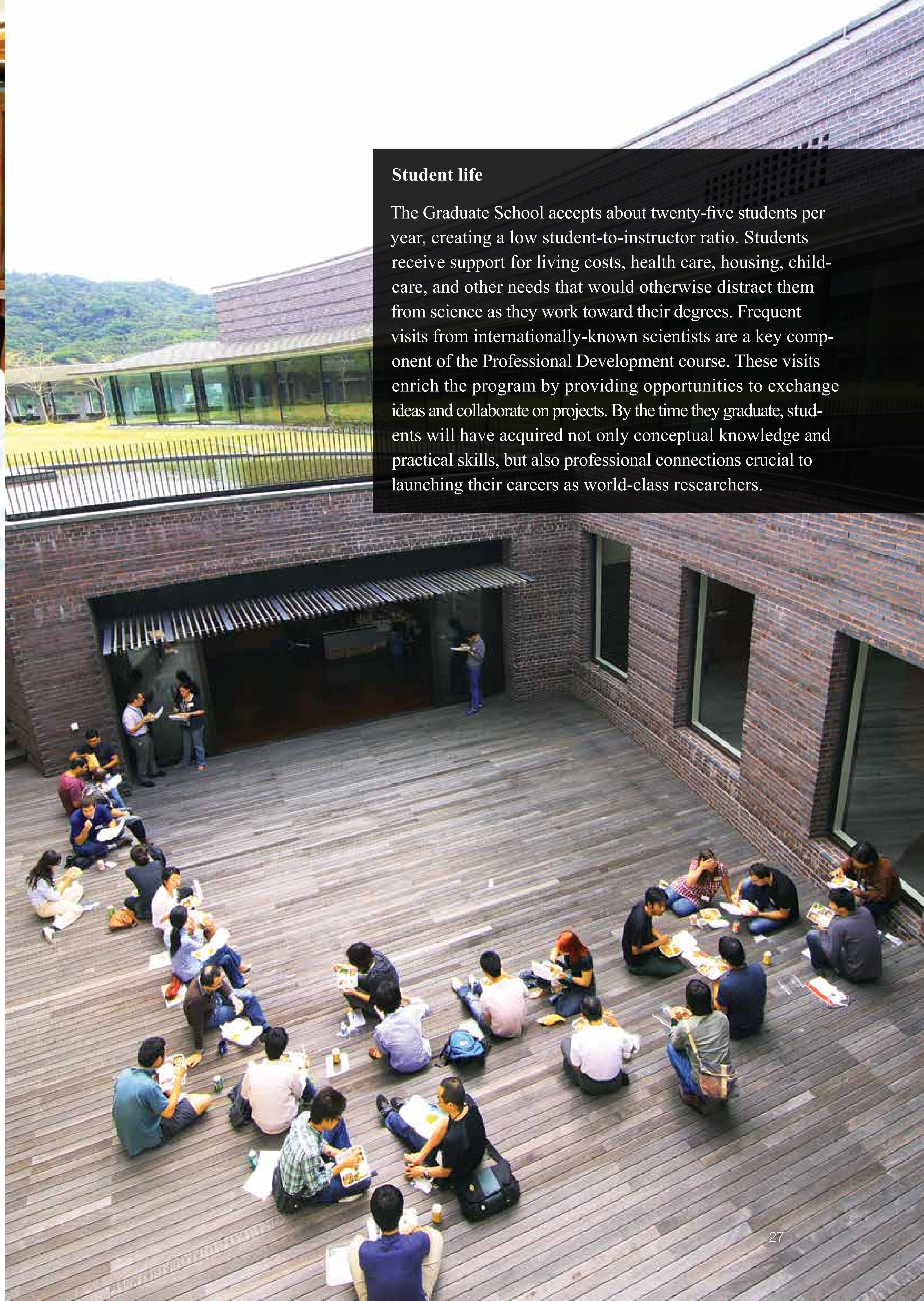
"Every time there's been a major breakthrough in our understanding of electrons, it has kick-started a revolution in technology," points out Nic Shannon, head of OIST's Theory of Quantum Matter Unit. When physicists discovered the laws that govern electrons in a vacuum, it led to the vacuum tube, which then made radar, television, and the first computers possible. Similarly, a breakthrough in understanding electron behavior in crystals led to transistors, silicon chips, and the explosion of information technology.



The new frontier is quantum materials, atomic structures that exhibit superconductivity, magnetism, or other phenomena driven by interactions between electrons. Electrons in copper pipes and iron nails largely ignore one another, but in quantum materials they have a social life.

"Just like people, electrons behave differently in groups," Shannon says. The Unit's main goal is to uncover the new laws of physics which emerge from these interactions. Their recent work has concentrated on 'frustrated magnets,' systems where competing interactions rule out conventional forms of magnetic order.

The Japanese government has invested heavily in developing new quantum materials, which made OIST particularly appealing for Shannon. "Japan is the undisputed world leader in this area, and it's very exciting to be close to the new developments. Having a lab here means that we are ideally placed to participate in the discovery of new quantum phases."



Student life

The Graduate School accepts about twenty-five students per year, creating a low student-to-instructor ratio. Students receive support for living costs, health care, housing, childcare, and other needs that would otherwise distract them from science as they work toward their degrees. Frequent visits from internationally-known scientists are a key component of the Professional Development course. These visits enrich the program by providing opportunities to exchange ideas and collaborate on projects. By the time they graduate, students will have acquired not only conceptual knowledge and practical skills, but also professional connections crucial to launching their careers as world-class researchers.

Research activities

The OIST research program aims to be at the leading edge of science and technology, encompassing the life sciences, the physical sciences, the environmental sciences, and mathematics. OIST's mandate of collaborative, boundary-free research is built into every element of the campus design and layout. Flexible workspaces and shared equipment keep disciplines from clustering, while grouping major research instruments helps maintain equal access.

G0 CELL UNIT

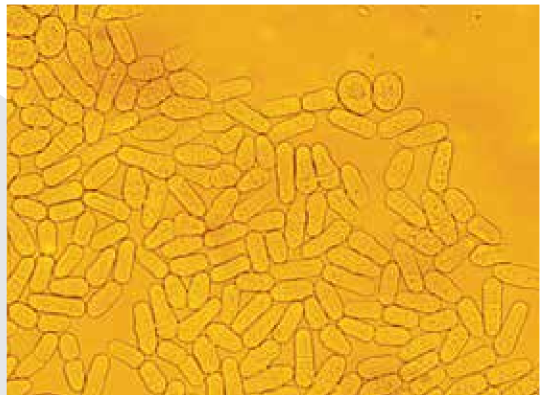
Manipulating populations of yeast helps scientists in the Yanagida lab find molecular switches crucial to longevity.

Studying longevity in cultures, from single cells to social customs

Mitsuhiro Yanagida examines fundamental cell processes and Okinawans' habits to understand how humans can lead longer, healthier lives.

"Longevity has not been a serious target of medical research because aging is not considered a disease," says Yanagida. "But Okinawans' lengthy lifespans suggest that healthy aging could be a global experience."

To learn what makes humans tick past their hundredth birthday, Yanagida's lab looks at how we rest — or rather, how our cells do. When not dividing, cells are suspended in what's known as the G0 phase. The phase is so important to life that Yanagida's lab, the G0 Cell Unit, is devoted entirely to it. Cells may be stressed into this phase or may simply settle into it on maturing (our neurons and heart muscle cells carry about their business in G0, for example). By starving and feeding populations of yeast, a single-celled organism, the Unit is identifying the molecular switches that control the phase.



The quest to find these switches is greatly helped by analyzing the full set of small molecules a cell can create, collectively called a metabolome. Lab member Tomáš Pluskal led a G0 Cell Unit project that uncovered a fission yeast metabolome in 2010. This pioneering work offers data and techniques to study how cells respond to stresses and mutations. This information could improve regenerative medicines that stimulate cell growth and targeted cancer therapies that suppress it. Lab members are now applying the metabolome method to Okinawan plants, among them a local variety of turmeric and the citrus fruit tankan, in their search for molecules to treat diseases and enrich diets.

Recently, the G0 Cell Unit has teamed with researchers at the University of the Ryukyus, Kyoto University, and two local private companies, in a project to boost both global health and Okinawa's economic development.

"Okinawan ingredients could be used in biotechnological ventures that have worldwide appeal," says Yanagida. "This is the prime time and place for the life sciences and industry to connect."

Epigenetics: detecting the master switches of life

Saze's indoor jungle provides a genetic playground to help researchers identify which genes control plant growth.

For OIST's plant biologist, Okinawa's jungle setting is an inspirational backdrop. On the Institute's second floor, tiny rice plants and mustard plants sprout in orderly rows, in contrast to the wilderness beyond the windows. Here, Hidetoshi Saze and his Plant Epigenetics Unit find which genes trigger sudden stunted growth or deformed leaves.

Every cell of an organism contains the same set of genes, so how does a plant cell develop into a leaf or a stem or a flower? The answer lies in epigenetics: chemical changes to DNA that do not alter the genetic code but can keep genes from being used by the cell. Epigenetic changes help organisms adapt by using genes only when needed. But those modifications can go awry, such as when a cell locks up a set of genes vital to healthy growth. By attaching specific molecules to genes' starting points, which switches them on or off, epigenetics sets the cell's destiny.

"This basic mechanism occurs for most life," notes Saze. "Plants are just easier to handle, since all they need are some light and water." By comparing genomes of regular and mutated mustard plants, Saze finds the genes responsible for the changes and those that regulate epigenetic controls.

He also looks for controls that rouse or quell lengthy genetic sequences that jump around in the genome. This "transposable DNA" makes up nearly half the human genome, affecting our evolution and mutations. Exploring its behavior could lead to far greater understanding of human growth and developmental diseases. Recently, Saze discovered a gene that silences transposable DNA in mustard plants and one that switches on many others at once.

The Unit also contributes to an Okinawan health project. Saze linked up with researchers from Mizuho-shuzo, Osaka Prefecture University and the University of the Ryukyus to combine a high-fiber rice strain from western Japan with a local strain. By using OIST's fast DNA sequencers, the team can find and cross-breed the high-fiber trait with the local strain to make a useful new variety that suits Okinawa's agricultural space and subtropical growing conditions. This rice will be ground into powder to add to bread—Japan's popular dietary newcomer—among other foods. The team is also investigating the rice's potential in preventing diabetes.

PLANT EPIGENETICS UNIT
As part of Saze's Unit, scientists study how epigenetic changes come about, a concept with wide-ranging implications for plants and animals alike.

BIODIVERSITY AND BIOCOMPLEXITY UNIT
Ant biology and behavior help understand forces shaping evolution across all life.

Tracing evolution's pathways

Biologist Evan Economo channels diverse disciplines to track biodiversity around the world.

All life on Earth is shaped by evolutionary forces. At OIST, Evan Economo's Biodiversity and Biocomplexity Unit investigates how those forces create the vast diversity of genes, species, and ecosystems on our planet.

Economo has a background in developing mathematical models of biodiversity dynamics, which apply to any organism. But he and his unit have a particular interest in ants. "Ants are extremely ecologically important," notes Economo. They aerate soil, move nutrients around, and pollinate flowers. Their combined mass on earth is nearly that of humans, and parallels exist between their highly-evolved, complex societies and our own. "But more generally, we use them as a model system to address fundamental questions in ecology and evolutionary biology—namely: how species evolve, spread, and adapt to their environments."

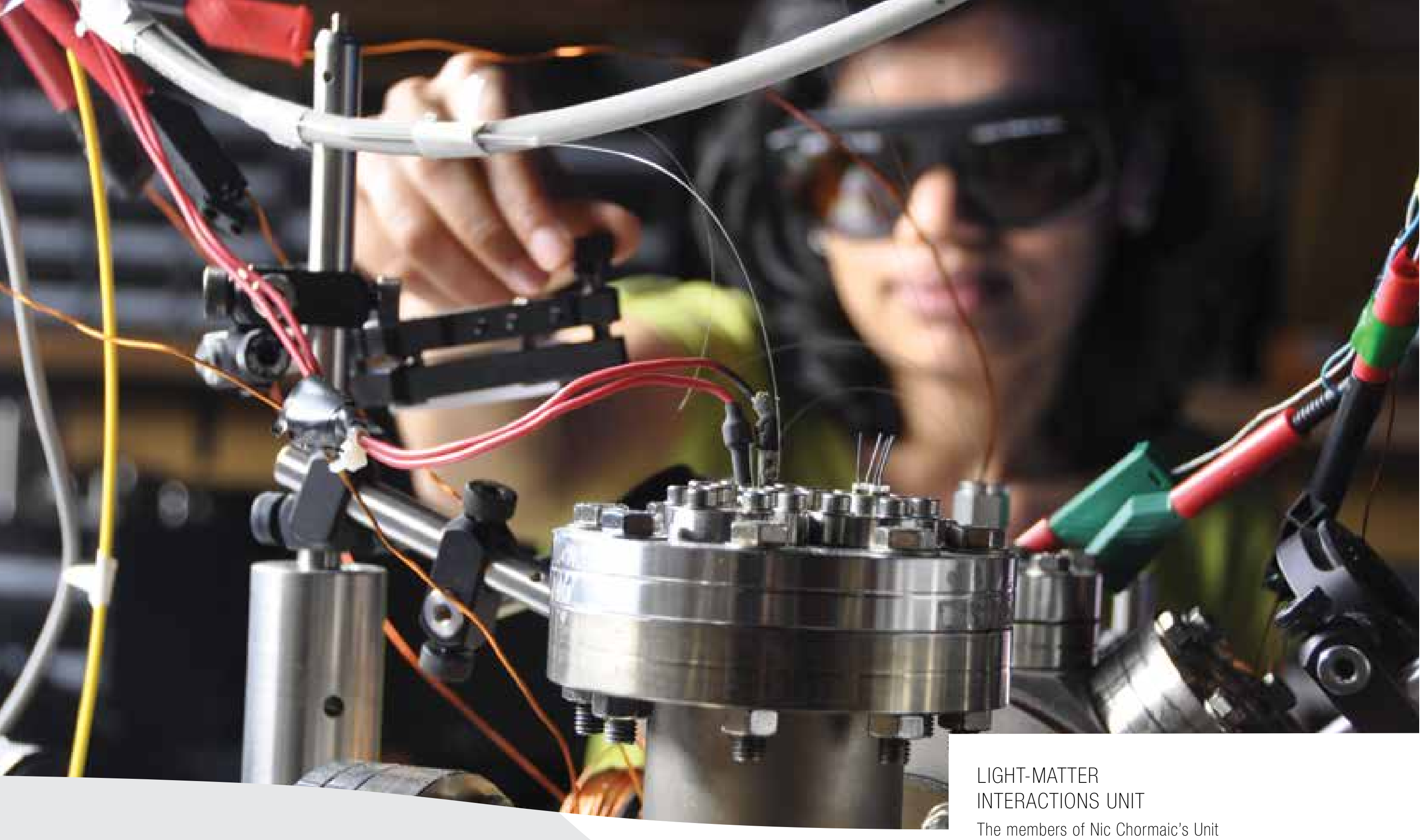
The Unit approaches these big questions from several directions: combining mathematical and statistical modeling, analyzing big datasets in addition to detailed specimen and taxonomic work. "The goal is to integrate different approaches across levels of biological organization in order to understand biodiversity," says Economo.

One project explores the global variety of *Pheidole*, the most diverse ant genus, with over 1,200 species. *Pheidole* thrives on six continents and develops new species extremely rapidly. "Each species needs to solve the problem of survival—whether it's in a canopy or underground, in the desert or jungle—and how they do that tells us a lot about the evolutionary process, which applies from bacteria to humans," Economo explains.

Starting with thousands of X-rays of ants, his team builds 3D computer models to scrutinize jaw muscles, brain shape, leg length ratio, and other physical details. They combine this with details of ecology and behavior to find patterns in adaptation and to test theories on how the genus diversified and spread across the globe.

Another project focuses on the Fijian archipelago, which is a hotspot of ant evolution with many localized radiations. Working with OIST's Ecology and Evolution Unit, Economo's team is using genetic sequencing to explore the population genetics of every species in the community at once, to determine which populations are expanding and shrinking, and to reconstruct how the community has changed over time.

Some of the ant species were brought accidentally by humans and have damaged public health, agriculture, and native biodiversity. Considering such invasive ants cost economies billions of dollars every year, pinpointing why some species become invasive is a key question both for applied and basic biologists.



LIGHT-MATTER INTERACTIONS UNIT

The members of Nic Chormaic's Unit study interactions between light and matter to better understand photons and electrons, and to harness them for new delicate technologies.

Manipulating light, maneuvering matter

Using optics to probe the nanoworld advances both science and technology.

"Light and matter are constantly interacting, from the lenses in our eyes to photosynthesis," points out Síle Nic Chormaic, head of the Light-Matter Interactions Unit. The northern lights, rainbows, solar cells, and laser surgery owe their existence to this delicate interplay. "By harnessing light, we can investigate and manipulate nanoscale systems."

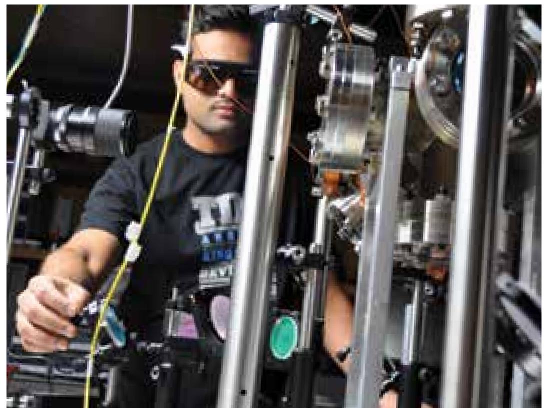
To do so, Unit members make investigative tools by stretching optical fibers so thinly that a hundred could hide side-by-side behind a human hair. In the lab's various experiments, these nanofibers channel light, probe atoms, sense trace chemicals, and tether cell-sized particles.

In one project, lab members use laser beams to slow rubidium atoms, cooling a cloud of them to nearly absolute zero—which makes the Nic Chormaic lab the coldest place in Okinawa. A nanofiber acts as a probe in the middle of the cloud, sensing individual light-matter interactions with as few as six atoms as they pass the surface of the fiber and the photons emitted from the atoms enter the fiber.

In another project, Unit members propagate laser light down a nanofiber immersed in water to produce a tiny conveyor belt made of light. As light strikes the fiber's edge internally, some of it leaks out, creating an 'evanescent field' that attracts and then propels plastic beads the size of red blood cells alongside the fiber. Using light to trap and move matter offers new directions in optical tweezers, for biological fields requiring high-precision manipulation.

A third lab project sends the light from evanescent fields into glass microbubbles. When light hits the wall of a bubble at a certain angle it reflects thousands of times inside the sphere in a way similar to how a whispering gallery bounces sounds at specific points. This creates a cavity that resonates with light. These gently illuminated bubbles respond to slight disturbances, making them excellent at detecting trace amounts of gases or even viruses.

"It's exciting to explore the versatility of light by pushing the edge of optics research and nanotechnology," says a PhD student in the Unit.



Candid portraits reveal the everyday life of cells

Ulf Skoglund's new 3D imaging is shattering decades-old assumptions about how proteins work and opening a new door to personalized medicine.

We used to think that each protein floats about its cell in its relaxed shape until a signalling molecule latches onto it, snapping it into its active shape. But OIST's Structural Cellular Biology Unit has found they are far more active. Using a technique called Molecular Electron Tomography (MET), the Unit freezes biological molecules in their natural state and takes pictures at hundreds of angles to generate 3D images of their many forms. They have shown that every protein in our bodies—and we have tens of thousands of kinds—constantly jostles into many forms thousands of times a second. And they look far different from what we thought.

"When researchers finally get to see in 3D the proteins they've been studying for years, the first thing they say is, 'What?!' " says Ulf Skoglund, the Unit's head.

One project that illustrates the power of shape is Skoglund's collaboration with a project in Brisbane, Australia. There researcher Robert Parton studies flexible cell surface pits called caveolae found in many animal cells and formed by proteins called caveolins.

Intrigued by caveolins' abundance, Parton asked the Unit to help him take a closer look, and discovered that caveolins had a specific shape, similar to a 20-sided die. In short, they are robust. And since they are made and used by the thousands every day in every cell in the human body, they can pass freely through our system.

Their potential for drug delivery is astounding. Current practices have some stark limits: irradiating a person to kill a cancerous tumor severely weakens the patient; some tumors are inoperable; and the microscopic packaging of the active ingredient within prescribed pills can rupture too early, flooding the system and shocking the patient's liver. In contrast, highly specific drug delivery in durable nano-packaging would release their chemicals only at the offending site.

With the momentum of these successes, Skoglund is creating a spin off company in Okinawa under a grant from the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). Its mission is to use these protein-viewing techniques to help the pharmaceutical industry make cheaper, more efficient drugs, and advance toward personalized medicine.

STRUCTURAL CELLULAR BIOLOGY UNIT

New means of examining biological molecules are changing our understanding of their shapes and behaviors.

The graduate experience

The students' perspective: What makes OIST different?

In September 2012, OIST began its Graduate School program with 34 students from 18 countries and regions. The program lasts up to five years, accommodating bachelor's and master's degree students, with all graduates earning a PhD. Courses are often punctuated with lectures from world-famous scientists, visiting for research collaboration. Before choosing a doctoral focus, students spend each of three terms in a different lab pursuing a research project.

"Being in OIST made all the difference," says Lashmi Piriya Ananda Babu, a student from India. She first came to OIST as an intern and was struck by the variety of learning opportunities and how much the faculty cared about her research interests. Of all the places she was accepted for graduate studies, "I thought I would fit in more at OIST."

With her training in biotechnology, Ananda Babu found her out-of-field rotation in Fluid Mechanics challenging, but worthy. "My whole view of learning changed," she explains. "I discovered entirely new ways to reframe questions." The experience has helped her redefine her scientific interests, and she now intends to study in an environment that promotes interactions.

"We are given a lot of power to bring new ideas," says Will Powell, a student from England with a degree in mathematics. He finds the flexibility refreshing. "It gives you confidence knowing you're given the responsibility to pursue your own research questions."

Mohamed Abdelhack, a student from Egypt with a degree in electrical engineering, knew he wanted to go into neuroscience. OIST appealed to him because it encouraged him to move into his region of interest and combine his own experimental biology with modeling nervous systems.

"I get to conduct research and at the same time meet great people from all over the world," says Abdelhack, noting that Okinawa's proximity to many other countries lets him expand his horizons by immersing himself in different cultures a short flight away. "What else can I ask for? I'm improving myself as a scientist and as a person."

Okinawa

Okinawa is a beautiful subtropical island located in the center of Asia, a region of rapid economic growth. This idyllic location offers a rich research environment for a world-class graduate university and the potential for future development. With its highly imaginative academic minds and sophisticated research infrastructure, OIST will make scientific discoveries that will drive technological development in Okinawa. The campus technology-transfer program aims to enhance cooperation with industry through joint research and collaboration with corporations, commercialization of research for future development, and helping launch start-up companies based on OIST's intellectual property.

As one of OIST's regular exhibits of local artists, this installation displays Okinawan ceramics by Shinman Yamada.

Join us...

Please join us in Okinawa for a visit to the OIST Campus. You'll be in good company: we have hosted the Imperial couple, the Prime Minister of Japan, Nobel Laureates, and many scientists and luminaries from around the world. Explore our rich coral reefs and hilly jungles. Experience our culture. Speak with our scientists. And discover the future of research and education.

沖縄科学技術大学院大学

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