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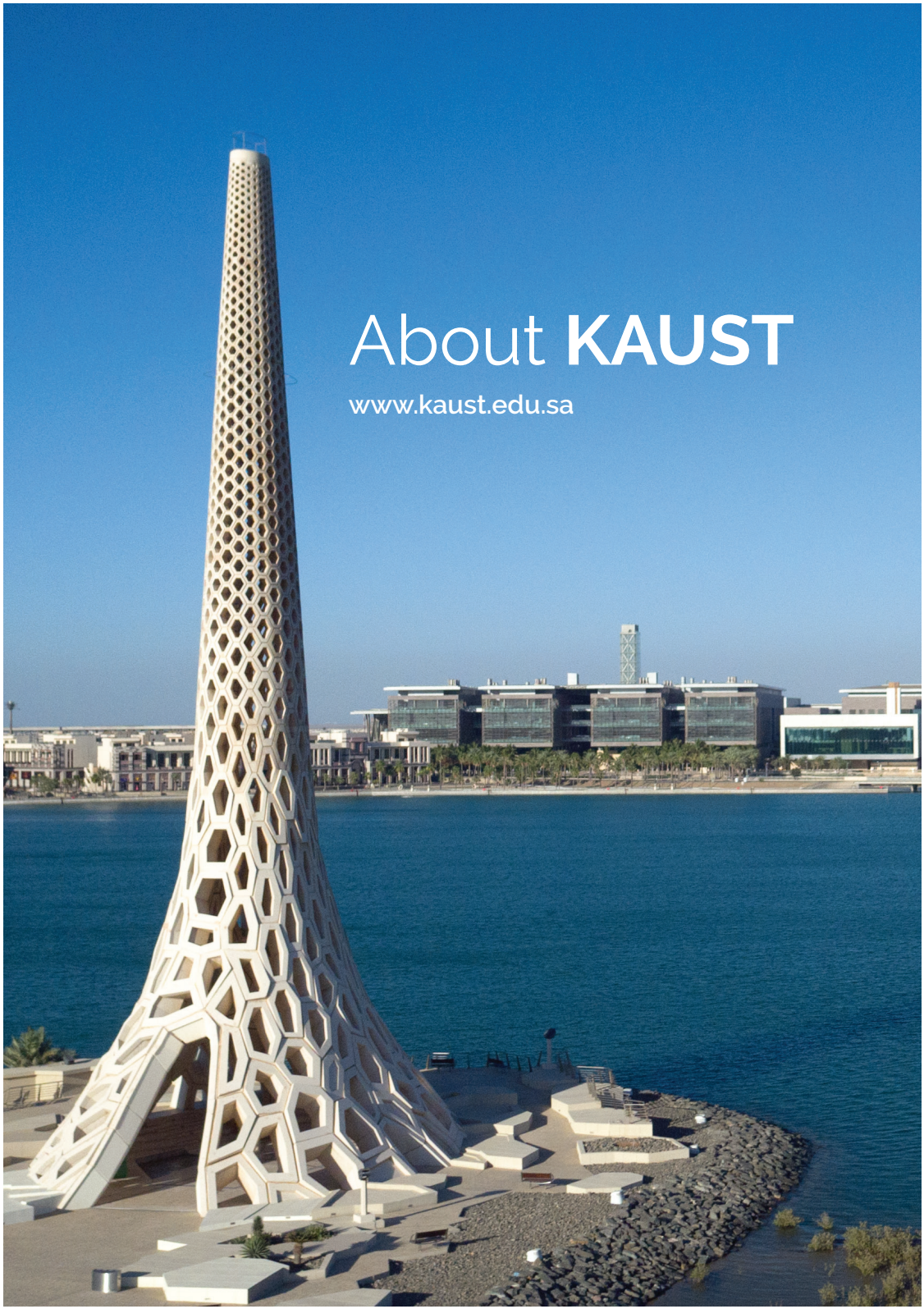
King Abdullah University of
Science and Technology

KAUST

Research Overview

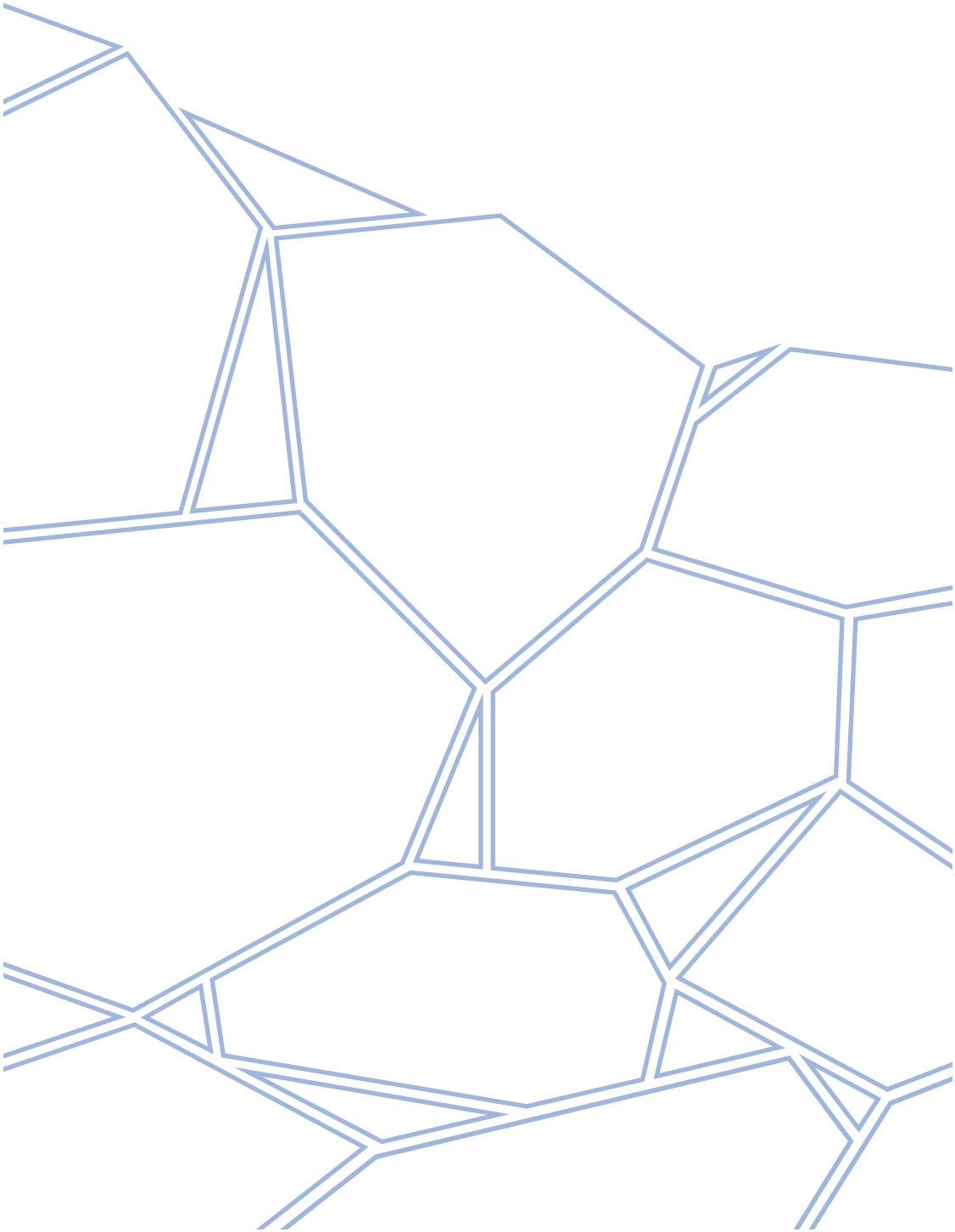


Discover a research university devoted to finding solutions to some of the world's most pressing scientific and technological challenges. KAUST is a destination where scientists collaborate across disciplines to nurture the great minds of tomorrow and promote innovation and economic development.

Explore a community where people from 120 countries live, learn, and thrive. At KAUST, people believe in doing science that matters and understand that the diversity of ideas and backgrounds enriches research and changes lives.

To address national and global needs, KAUSTs research is focused across 5 pillars; Water, Energy, Environment, Food, and AI.

We encourage you to learn more about KAUST.



Future Energy & Environment

Harvesting Lithium from Seawater

Lithium is a vital element in the batteries that power electric vehicles, but soaring lithium demand is expected to exhaust land-based reserves by 2080. KAUST researchers have now developed an economically viable system that can extract high-purity lithium from seawater.

The oceans contain about 5,000 times more lithium than land but at extremely low concentrations of about 0.2 parts per million (ppm). The KAUST team solved this problem with an electrochemical cell containing a ceramic membrane made from lithium lanthanum titanium oxide (LLTO). Its crystal structure contains holes just wide enough to let lithium ions pass through while blocking larger metal ions.

The researchers estimate that the cell would need only US$5 of electricity to extract 1 kilogram of lithium from seawater. The value of hydrogen and chlorine produced by the cell would more than offset this cost, and residual seawater could also be used in desalination plants to provide fresh water.

A Tailored Coat To Beat The Heat

Multilayered perovskite-based films, designed by KAUST researchers in the KAUST Solar Center, shield high-performance perovskite solar cells from extreme heat and moisture while also boosting their long-term stability, which is a key milestone for device commercialization.

Perovskite solar cells have emerged as the fastest growing alternative to the conventional silicon technology that dominates the photovoltaic market. Cheaper and easier to manufacture, they have shown a dramatic continual rise in performance, potentially surpassing their silicon-based equivalents. However, inherent surface defects and ion migration affect the stability of the light-responsive perovskite film, a phenomenon that becomes more pronounced at higher temperatures.

Sandwiched between charge carrier-selective materials, the three-dimensional (3D) perovskite film converts light to electricity by creating pairs of electrons and positively charged holes.

Two-dimensional (2D) perovskites are more resilient than their 3D counterparts under thermal stress and external conditions such as varying moisture and oxygen. Growing a 2D perovskite layer on top of a 3D perovskite film produces a heterojunction that blocks ion migration as well as moisture and oxygen. These 2D perovskite capping layers also considerably improve the resistance of unsealed devices against extreme outdoor-like moisture and thermal stress.

"The team is now designing new molecules for 2D perovskites to develop ultrastable inverted perovskite solar cells with efficiencies close to those of regular devices that exceed 25 percent," lead researcher Dr Randi Azmi says.

Dr Randi Azmi
Photovoltaics Laboratory

Physical Science and
Engineering Division

Professor Ibrahim Hoteit
Earth Science and Engineering

Physical Science and
Engineering Division

Dr Sabique Langodan
Earth Science and Engineering

Physical Science and
Engineering Division

Reconstructing Sea-level Rise in The Red Sea

A study of the relative contributions of surface winds and atmospheric pressure on sea-level rises in the Red Sea has shown that wind variations are the main drivers of basin-wide sea-level extremes. These meteorological surges, or storm surges, lead to coastal flooding and erosion and are considered one of the greatest threats to coastal environments and communities.

This problem led Ibrahim Hoteit, Sabique Langodan, and colleagues from KAUST's Red Sea Modeling and Prediction Group to study the meteorological origin of sea-level extremes in the Red Sea basin.

"Understanding sea-level extremes requires high temporal (hourly or less) data from tidal gauges distributed along the coastline and over long periods, ideally decades," explained Langodan. "Unfortunately, long-term tidal observations are very scarce for the Red Sea."

To overcome this, the researchers resorted to advanced computer simulations of storm surges to generate high-spatial-resolution, long-term datasets of sea-level variations in the Red Sea. They first validated the datasets with hourly sea-level observations for three years (2013-2015) from six tidal gauges along the Saudi coast of the Red Sea.

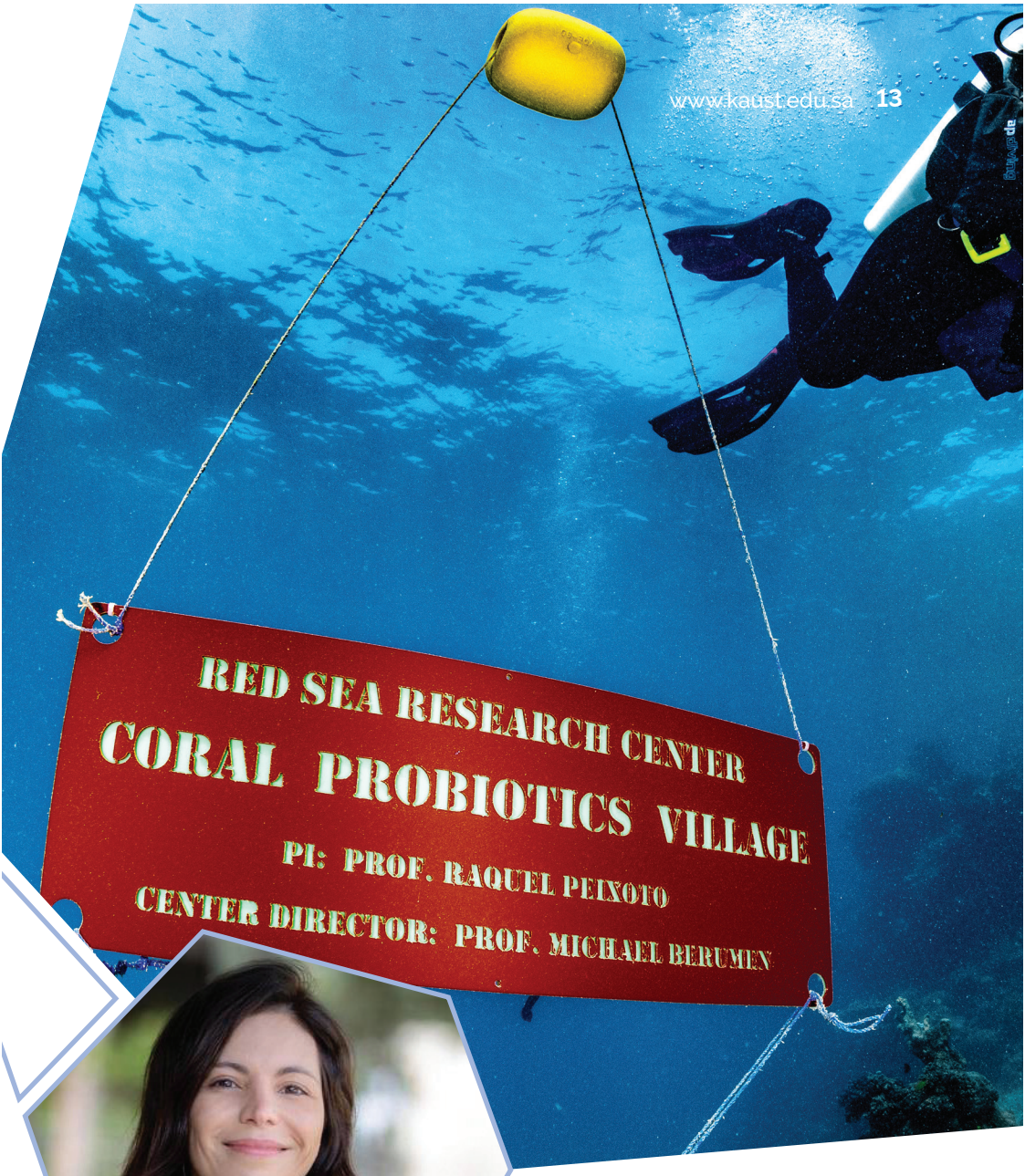
This work has important implications for managing and developing the Red Sea coastline, including the megacity projects and the rapid expansion of tourism along the coast. It will also support strategies to mitigate their impact on the Red Sea's unique marine environment and coral reefs.

Coral Probiotics Village

Despite the ecological and economic importance of coral reefs, the combination of negative impacts in the Anthropocene may have challenged corals, the foundational species of these ecosystems, beyond their threshold. Most coral reefs are currently endangered and some may go extinct within the next decades.

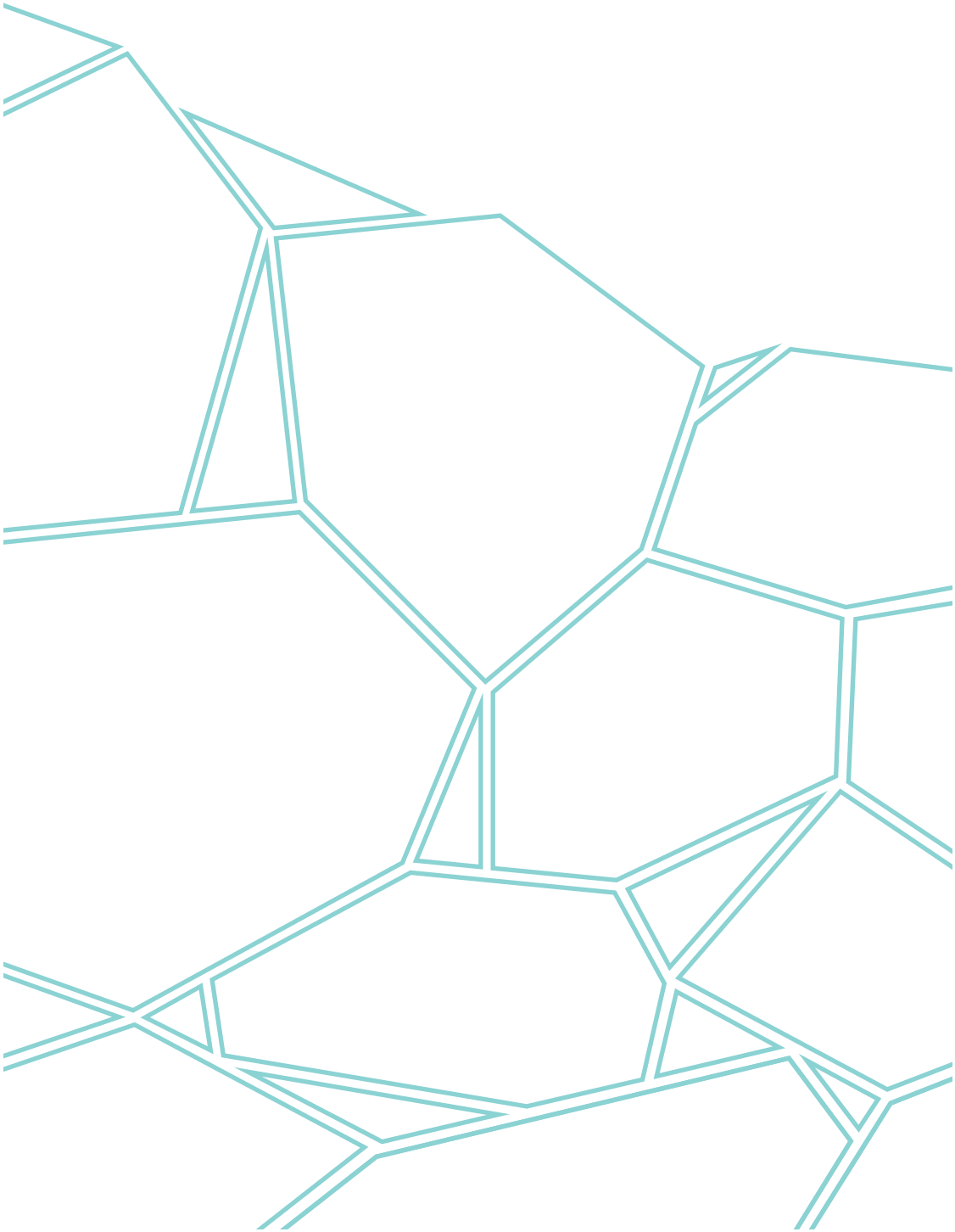
Following one of the three pillars suggested by the International Coral Reefs Society's (ICRS) plan to save corals reefs, KAUST scientists have been focused on the development of innovative tools for the active restoration and rehabilitation of these organisms and ecosystems, with special focus on coral probiotics.

To support this development, as well as the implementation of other innovative tools, the "RSRC Coral Probiotics Village" (CPV) was created as a permanent natural laboratory established and closely monitored for the development of coral-reef related research. The CPV is one of the results of a project funded by KAUST's VPR office, through the Red Sea Research Center Competitive Funding (CCF) for coral probiotics lead by Raquel Peixoto (PI) in collaboration with several KAUST PIs and researchers.



Raquel Peixoto
Associate Professor, Marine Science

Biological and Environmental Science and Engineering Division



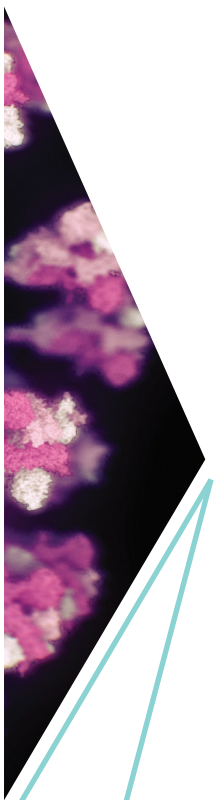
Health & Food Security

Dr Ondřej Strnad

Computer Science

Computer, Electrical and Mathematical Sciences and Engineering Division

Peering under the "hood" of SARS-CoV- 2



Information from electron microscope images and protein databases has been used to develop a detailed 3D model of SARS-CoV-2. The modeling tool has potential for visualizing components in other biological organisms, ranging from 10 to 100 nanometers in size.

"Our 3D model demonstrates the current state-of-the-art structure of SARS-CoV-2 at the atomistic level and reveals details of the virus that were previously impossible to see, like how we think nucleocapsid proteins form a rope-like structure inside it," says KAUST research scientist Ondřej Strnad. "The approach we used to develop the model could steer biological research into promising new directions for fighting the spread of COVID-19, because it could help scientists rapidly incorporate newly discovered information into the model and thus provide an up-to-date structure of the virus," he says.

The modeling system is intuitive and easy to use. It takes information from readily discernible structures in a small number of electron microscope images of an organism. For SARS-CoV-2, this involved information on the shape and size of the virus's membrane and on the protein structures attached to it.

The team hopes their SARS-CoV-2 model will help reveal aspects of the virus and its structure that could hasten drug discovery for treating COVID-19.

A Next-Generation Sensor Combining Speed and Precision

The COVID pandemic has demonstrated that sensor technology is critical for containing the spread of the virus and for making informed policy decisions. However, the pandemic has also revealed that we still lack sensor technology that is sufficiently fast, precise, and portable to allow confident on-the-fly testing of persons, for example before they enter a plane or their workplace.

KAUST Professors Sahika Inal and Stefan Arold noticed that a combination of technologies developed in their teams may effectively solve this problem. Prof. Inal's team designs organic electrochemical transistors that translate protein–protein interactions into electrical currents that can be amplified millions of times. Dr. Raik Grünberg, a research scientist in the Arold lab, developed a self-catalysing protein system that anchors a so-called nanobody (the "business end" of single-chain antibodies) at a high density to a surface. The combination of both technologies produced a device that can detect the presence of the SARS-CoV-2 virus in minutes from saliva with the same precision as PCR tests.

Importantly, by simply changing the nanobody, the sensor can detect different biomarkers. The team is now working closely with in-kingdom clinicians to adapt their device to detect other diseases of national and international relevance. By combining speed and precision, this sensor technology could compliment or supplant a wide range of methods for clinical or industrial applications.

Stefan T. Arold
Professor, Bioscience
Associate Dean, Biological and

Environmental Science and
Engineering Division

Sahika Inal
Professor, Bioengineering

Biological and Environmental Science
and Engineering Division

Jasmeen Merzaban
Associate Professor, Bioscience

Biological and Environmental
Science and Engineering Division

Enhancing the Efficiency of Stem Cells

One of the primary focuses of KAUST Associate Professor Jasmeen Merzaban is to understand and visualize cell adhesion systems on stem cells. This understanding assists in the discovery of how these cell types can be manipulated to facilitate transplantation of therapeutic stem cells in disease, such as blood stem cells (HSCs) for the treatment of leukemia.

Recently, PhD student Asma Al-Amoodi and post-doc Dr. Yanyan Li, established an in vivo system to study and visualize rare HSC populations isolated from human umbilical cord blood and mouse bone marrow that are responsible for short-term and long-term establishment of all blood cells. Using a variety of assays including an analysis of single cell RNA sequencing data and the tracking of these HSCs using in vivo xenotransplantation models, they discovered that the unique and distinct expression patterns of adhesion receptors on each population helps to explain why their therapeutic use could be limiting their efficiency in bone marrow transplantation clinically.

By recognizing what is "missing" on these populations, they created a non-genetic engineering toolbox to aid in transforming cell surface adhesion and thus boosting their transplantation potential to promote production of all the cellular components of the blood. In one example, they expressed and purified active recombinant human enzymes, glycosyltransferases, using eukaryotic expression systems and through treatment of these HSC populations, enhanced blood cell recovery was achieved. This work has generated two international patents in addition to several publications and more to come.

Tech Startup Edama Organic Solutions

Following the success of their composting pilot facility, Edama has received seed investment of $780,000 USD from the KAUST Innovation Fund. The University has also signed a contract to build a commercial-scale composting facility for the startup on its Thuwal campus. The facility started operations in 2021 and has a recycling capacity of 5,500 tons to help KAUST achieve its zero-waste target of recycling over 80% of the total waste that University generates.

KAUST has committed to supporting the visionary waste management startup, as a way to lead change in the Kingdom and achieve the University's zero-waste sustainability goals. Together, Edama and KAUST are working to change attitudes and approaches to waste management and help Saudi Arabia move toward smarter, more sustainable businesses and lower impact living.

"Here at KAUST, we produce a lot of horticulture and food waste. The Edama composting facility allows us to reach 96% of our organic waste-management goal, so we can divert waste away from landfill and focus on recycling," Matthew Early, vice president of facilities management at KAUST, explained.

With no other large-scale composting companies in operation specialized in desert composting, KAUST and Edama believe their collaboration is a pilot for others in the Kingdom to follow.

Find out more about Edama at **edamasolutions.com**

AI & Extreme Computing

Mani Teja Vijjapu
PhD Student, Electrical and Computer Engineering

Computer, Electrical and Mathematical Sciences and Engineering Division

Khaled Nabil Salama
Professor, Electrical and Computer Engineering

Associate Dean, Computer, Electrical and Mathematical Science and Engineering

Now You See It: Artificial Retina Reads Handwritten Numbers

An artificial electronic retina that can "see" in a similar way to the human vision system and can recognize handwritten digits has been built by KAUST researchers as they seek to develop better options for computer vision applications.

"The ultimate goal of our research in this area is to develop efficient neuromorphic vision sensors to build efficient cameras for computer vision applications," explained Professor Khaled Salama. "Existing systems use photodetectors that require power for their operation and thus consume a lot of energy, even on standby. In contrast, our proposed photoreceptors are capacitive devices that don't consume static power for their operation."

Mani Teja Vijjapu, an electrical engineering Ph.D. student, Khaled Nabil Salama and coworkers have designed and fabricated an array of photoreceptors that detect the intensity of visible light via a change in electrical capacitance, mimicking the behavior of the eye's rod retina cells. When the array was connected to an electronic CMOS-sensing circuit and a spiking neural network (a single-layer network with 100 output neurons), it was able to recognize handwritten numbers with an accuracy of around 70 percent.

Future plans for the team include building larger arrays of photoreceptors, optimizing the interface circuit design and employing a multilayered neural network to improve the accuracy of the recognition functionality.

Manipulating Air Flow

When McLaren Racing teammates Daniel Ricciardo and Lando Norris finished first and second in the 2021 Italian Grand Prix, the gap between them was just 1.747 seconds.

If either had run just a few seconds slower at Monza, Formula 1's fastest track, they would have tumbled off the winner's podium and into the middle of the pack.

That is why F1 teams has embraced computational fluid dynamics, which harnesses supercomputing-level processing power to massively simulate and optimize airflow over surfaces.

Matteo Parsani, associate professor of applied mathematics and computational science at KAUST, said: "Why is an F1 car faster around the track than a Grand Prix motorcycle, which can also achieve speeds of 300 km/h? Aerodynamics. The manipulation of air around the vehicle is the single biggest differentiator in F1."

In 2018, the McLaren team signed a five-year research partnership deal with KAUST – to treat its vehicles as living laboratories. In exchange, KAUST's students and faculty would bring their expertise in software, sensors, and chemistry to bear on a unique challenge: Navigating the corners and straightaways of Jeddah's corniche a few seconds faster than everyone else.

No one could ask for a better classroom than a F1 track.

Matteo Parsani
Assistant Professor, Applied Mathematics and Computational Science

Computer, Electrical and Mathematical Science and Engineering Division

Mo Li
Assistant Professor, Bioscience

Biological and Environmental Science and Engineering Division

Tech Startup Peregrine Genomics

Precision medicine is the most promising frontier of modern medicine that leverages big data and artificial intelligence, to deliver accurate and effective healthcare to society on a personalized basis. There is a great need for accurate and accessible genetic diagnosis.

New technologies developed at KAUST work with routine clinical samples (e.g., a simple blood draw) and provides ultra-long DNA reads that can resolve any type of genetic variants. The targeted sequencing workflow can run on the pocket-sized Nanopore MinION sequencer connected to a laptop. Sequencing data are analyzed in real-time by a set of novel algorithms based on machine learning and generate the genetic variants information on the spot. The entire sequencing setup can be brought in a briefcase to remote locations and run by any clinical technician without specialized training.

A startup, Peregrine Genomics, based on these technologies won the Taqadam Startup Accelerator Program of Saudi Arabia, the Saudi Final of Entrepreneurship World Cup (EWC) 2020, and the Top 25 startups in EWC global final. We showed that our technology provides a fast and cost-effective solution to diagnose genetic diseases, including sickle cell disease and Batter syndrome.

Our vision is to conquer the technical hurdles in genetic diagnostics and provide enabling technologies to healthcare providers to improve human health.

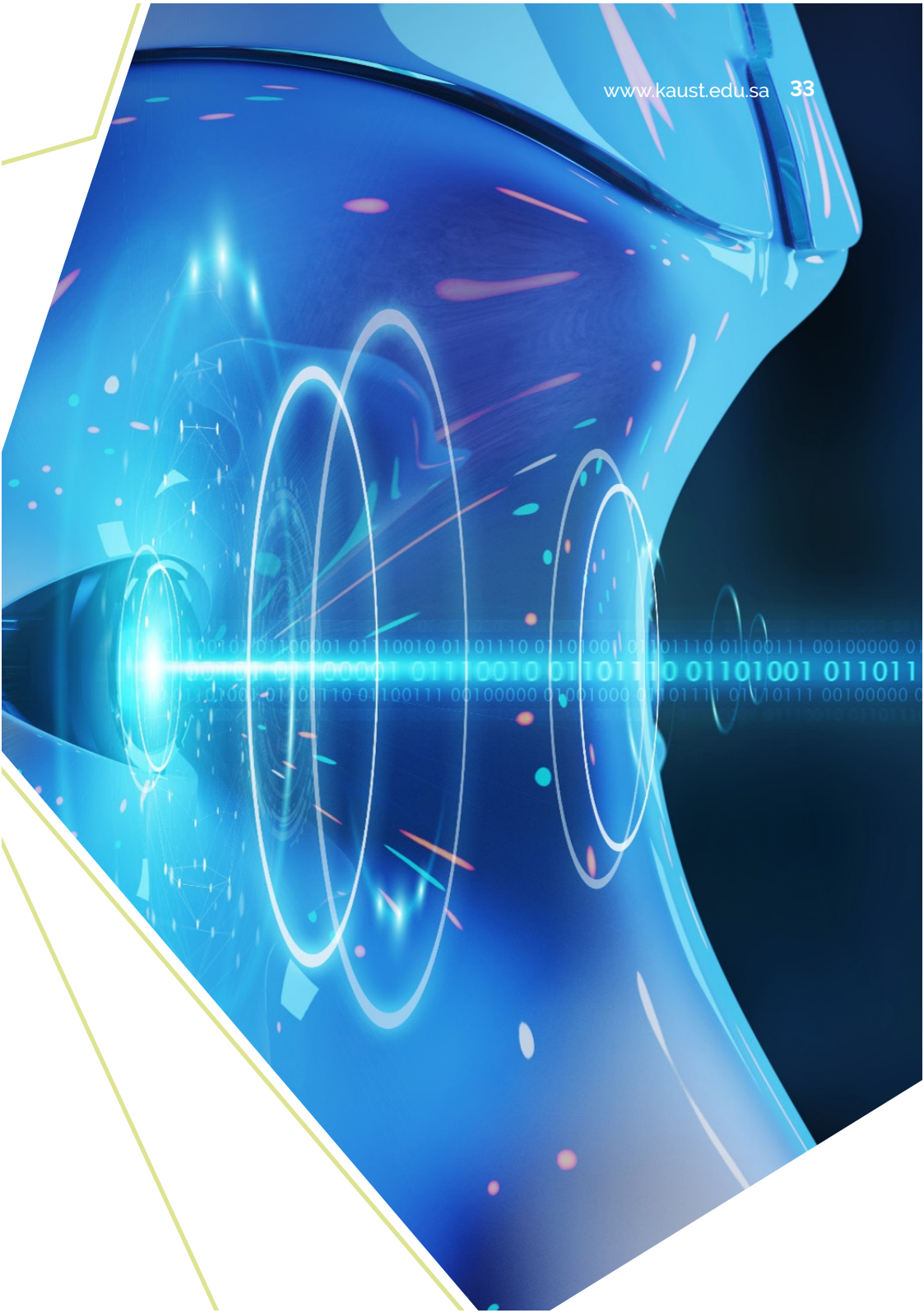
Tech Startup Quantum Solutions

Quantum Solutions develops technology for wide range image sensors. Since the company was established in 2017, they have supplied products and built partnerships with hundreds of companies and universities around the world.

Their mission is to provide a quantum dot platform to enable wide range image sensors. They do this by providing integrated quantum dot (QDot™) platforms that enable silicon sensor technologies to detect the light beyond the visible spectrum. These wide range image sensors enable "superhuman" vision and capture images that would be invisible to the naked eye: lower energy infrared (IR) lights or higher energy UV and X-ray lights.

Cameras enhanced with these quantum dot platforms are finding applications in many fields: machine vision (quality inspections and control, food security, pharmaceuticals), the automotive industry, security, consumer electronics (smartphones and AR/VR headsets). They have a vision of a future where these cameras, with their augmented vision, will be the norm in our world.

Find out more at **quantum-solutions.com**



KAUST in **numbers**

120
Nationalities

2400+
Alumni

1400+
Students

183
Faculty

477
Postdocs

398
Research Scientists & Staff

77%
Students are Ph.D.

64%
Students are international

37%
Students are woman

8:1
Faculty ratio

International University Rankings

#1 Most Cited Per Faculty
QS University Rankings (2016-2021)

#1 Top 20 under 20
a3 Academic Rankings 2018

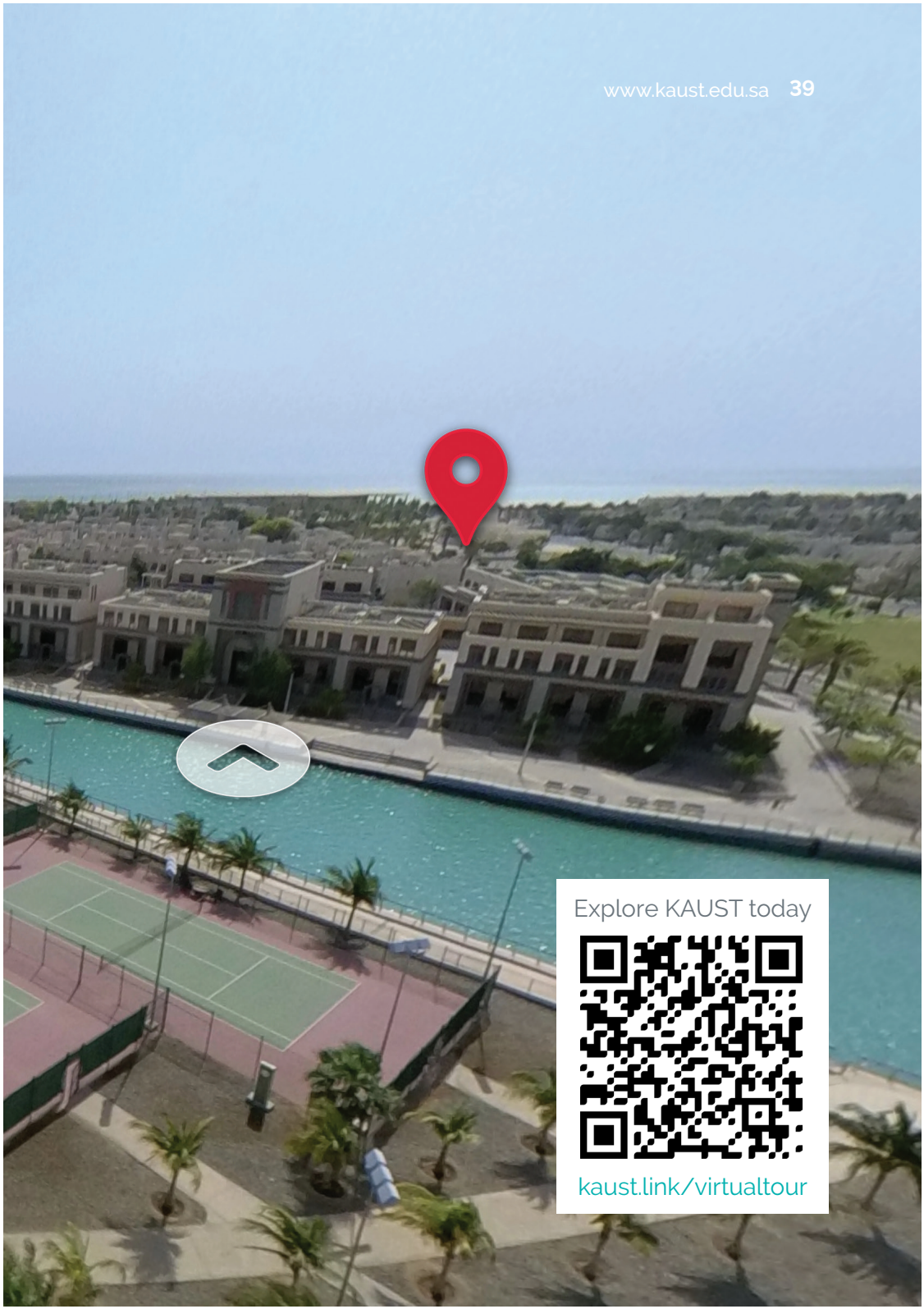
#2 Under 20 years of age
Nature Index Young Universities 2021

#10 Percentage of total publications that are among the 10% most cited
US News Best Global Universities 2022

15 Highly Cited Researchers
8% of faculty at KAUST

KAUST Virtual Tour

Explore our purpose-built, state-of-the-art environment where the best come together to research without distraction. The KAUST Virtual Tour features 60 locations across our incredible campus, facilities, and community and is accessible from any device, anywhere in the world.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