KAUST INSIGHT

THE STORY
BEHIND THE DISCOVERY

ISSUE 02
2023

insight.kaust.edu.sa

Dear Reader,

Welcome to the second issue of *KAUST Insight*, our annual research publication that brings you the human stories behind our research discoveries. In this issue, we highlight the motivations and inspirations that drive our researchers to learn, explore and discover. *KAUST Insight* reflects the dynamism and multicultural nature of our research community, who come together to find answers to fundamental questions and push the limits of our curiosity.

In this issue's feature story, learn how a team of KAUST researchers is contributing to a once-in-a-generation revolution in healthcare in Saudi Arabia through the SmartHealth Initiative. KAUST is poised to play a crucial role in this fast-evolving cross-disciplinary field that promises to benefit citizens nationwide and beyond.

We also dedicate a section to highlight how KAUST is providing solutions to local challenges through solid and fruitful collaborations with research partners nationwide, including a cement factory in Yanbu and the flag carrier airline of Saudi Arabia, Saudia Airlines.

KAUST Insight celebrates KAUST as an international intellectual hub, attracting people from across the globe, as highlighted by our devoted "Homegrown Talent" and "Where I work" features. We hope it provides you with an awareness of the diversity of talent that KAUST nurtures and inspires in our community.

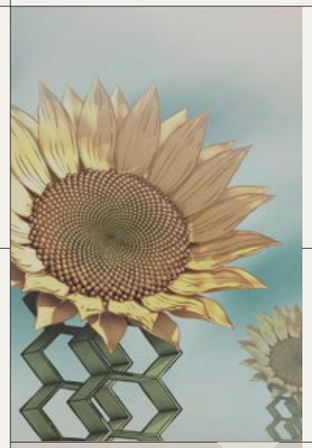
We hope you enjoy this issue of *KAUST Insight*; please share it with your colleagues, peers and family to showcase the fascinating people and human stories whose hard work and innovative spirit make this university the special place it is today.

Sincerely,
Professor Pierre Magistretti
Vice President for Research

CONTENTS

01 Future thinking

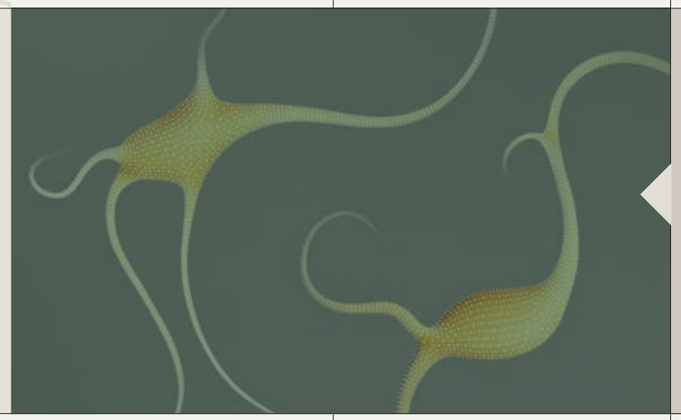
02 Making a difference



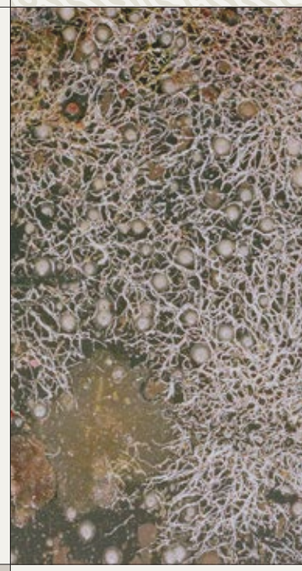
03 Partnering for local solutions

04 Social media

05 Feature on Smart healthcare



06 Working together



The cover represents AI giving society "a hand" as it enables the transition from a traditional to a precision healthcare model. The hand is signaling that with this transition, everything will be "OK." The hand is holding the smart pill of a precision model of healthcare.

COVER IMAGE BY IVAN GROMICHO

King Abdullah University of Science and Technology

KAUST INSIGHT is published with King Abdullah University of Science and Technology (KAUST) by the Partnership and Custom Media Unit of Nature Research, part of Springer Nature.

King Abdullah University of Science and Technology (KAUST) Thuwal 23955-6900 – Kingdom of Saudi Arabia.
Email: insight@kaust.edu.sa

nature research custom media

LIGHTBULB MOMENTS

Illuminating the twisting pathway to efficient wireless communications based on light.

Interior lighting has come a long way since Thomas Edison's day, says Basem Shihada, who researches advanced wireless communications systems at KAUST.

Modern LED lighting is bright, long-lived, energy-efficient and instant. Shihada and his team are using these attributes to show that LED devices could be applied beyond basic illumination. "The LED visible light infrastructure can also be used for wireless communications," he says. "We work on visible light communication, also named LiFi – like Wi-Fi, but with light."

LiFi transmits data by rapidly adjusting the brightness of the LED light source. "LEDs can be switched at very high rates for fast data transmission — so fast it can't be seen by the human eye," Shihada says. Piggybacking wireless communications onto existing lighting infrastructure could save a lot of energy.

Inside, LiFi faces a particular challenge, notes Osama Amin, a research scientist in Shihada's labs. "In a modern building where the entire façade is glass, the sunlight naturally flooding into the room can interfere with LiFi signals," Amin says.

Amin was struck by a potential solution while sitting outdoors, with bright sunlight reflecting from a nearby glass-clad building. "I wondered, could we utilize this powerful and sustainable source of light energy to transfer data?" Amin says. Rather than battle the bright sunlight that was disrupting LiFi, perhaps they could harness it by encoding data into sunlight as it spilled through a window or bounced from a building surface.

Shihada quickly warmed to Amin's idea. Shihada proposed testing the concept using existing off-the-shelf hardware: a glass shutter technology and a smartphone camera. The glass shutter could be fitted to a window to modulate passing sunlight and encode data into it and the smartphone camera could receive the data. "I thought, if I have a camera that can record the beam as a movie, it could then analyze the movie frame by frame to extract the data," Shihada says.

The team has tested the smartphone receiver and also designed a smart window system to encode data into passing sunlight. They showed that even the smart window's shutter technology could be renewably powered using a small solar panel. "Assembly of a test system of this ultimate energy-efficient mode of wireless communications is now underway," Shihada says.

Edison would be dazzled.

Paula Moraga studies spatio-temporal statistical methods to understand patterns of diseases, their relationship with risk factors and to evaluate interventions.

Better health from better data

Partnerships that deliver diverse, robust big data can underpin new ways to tackle disease.

The fast-developing science of geospatial statistics offers new insights into diverse health challenges, from cancer hotspots to problems of air pollution and the spread of COVID-19. Three new projects should yield a better understanding of what causes disease in Saudi Arabia and how to fight it. KAUST also stands to make a real contribution to the region by improving health in the Middle East and North Africa (MENA) region.

The field of geospatial statistics and health surveillance, known as GeoHealth, uses data from multiple sources to create disease maps of geographical areas. When information is presented in this way, policymakers can see where people are sick and how illness is spreading. This helps them to work out what is causing the disease and deploy resources more effectively.

Two recent developments have promoted GeoHealth. The first is digitized data from an unprecedented number of sources, including government records, satellite photographs and on-the-ground surveys, as well as internet and phone network data. The second is computers powerful enough to crunch the data.

"The basic algorithms involved are very computing intensive. A disease map that previously took two months can now be produced in five minutes," says statistician Paula Moraga, who is leading the team. "Faster computers also allow us to develop new models and methods."

Before joining KAUST in 2020, Moraga built the Australian Cancer Atlas, an interactive online map that shows the variation in the burden of the disease in high resolution across the country. To create the same cancer tool for Saudi Arabia, Moraga is working with specialists at both KAUST and King Faisal Specialist Hospital & Research Centre in Riyadh. Cancer incidence is relatively low in the country, but diagnoses are often made at a late stage, so such a tool could highlight hotspots.

Another task for Moraga is to help reduce the health impacts of air pollution. Saudi Arabia has one of the world's largest petroleum industries and an obvious way to improve health is to protect people from emissions. Moraga is installing air purifiers in selected residences to check on people's health conditions at three-month intervals. She will compare this data with control groups, such as people who work outdoors or who don't have air purifiers in their homes.

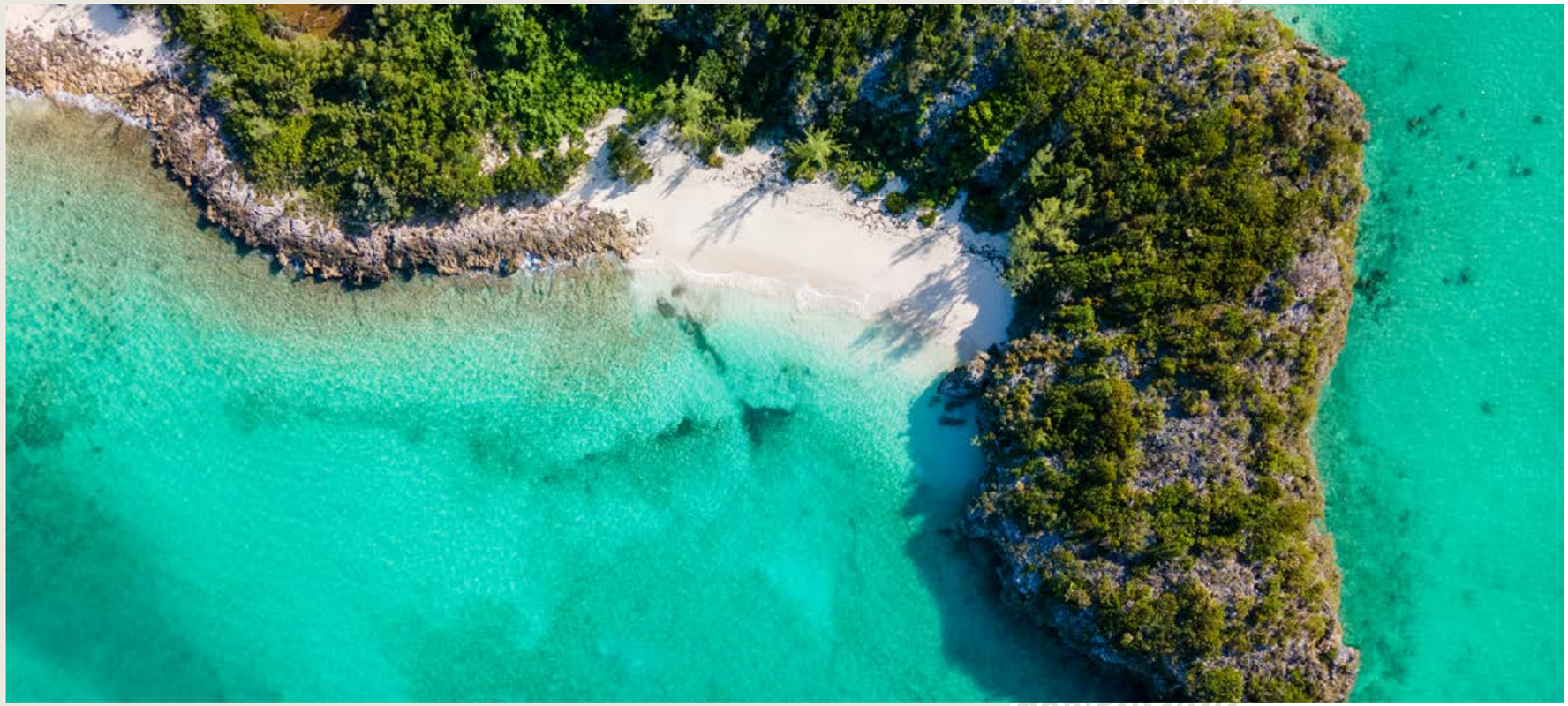
On a wider scale, Moraga is supported by global charity the Wellcome Trust to study COVID-19 in the MENA region. This project's central challenge is to establish a network to source standardized data from all countries involved. This will require training participating doctors and administrators in how to identify and gather specific information.

Collecting high-quality data is perhaps ninety percent of the effort of GeoHealth. "With data I can feed a statistical model," says Moraga. "The difficulty lies in getting the data."

The network will deliver benefits to the entire MENA region. Instead of working in partnership with Western universities, as it has done in the past, KAUST will bring an important public good to the Arabic-speaking world.

Moraga hopes her work will foster a culture of thorough record keeping. "A model is only as good as the data it relies on," she observes. "Once people see the value of such information, they will place more importance on creating it."

Soaking in the sights and sounds of seagrass meadows



A cross-disciplinary marine expedition aims to characterize an extensive seagrass ecosystem in the Bahamas.

A grass meadow with the sound of chattering fish rather than the tweeting of birds, and where you're more likely to meet a hunting shark than grazing farm animals? Welcome to seagrass meadows – ecologically complex marine environments that are as important for supporting biodiversity as coral reefs.

In November 2021, a team of researchers from KAUST, in collaboration with the US-based Beneath the Waves organization, spent a week on a boat off the coast of Great Exuma in the Bahamas. While the team is more at home in the Red Sea, this trip had an important goal: to characterize in detail the seagrass ecosystem of the Bahamas Banks for the first time. The data collected forms part of a wider project aiming to gain UNESCO World Heritage Site status for the region.

Three of the crew were KAUST Ph.D. candidates, Sofia Frappi, Michelle-Nicole Havlik and Elisa Laiolo, who are studying under the supervision of marine expert Carlos Duarte. The Bahamas trip stemmed from an earlier collaboration between Duarte and shark researcher and Beneath the Waves founder Austin Gallagher.

Shark haven

"The Bahamas hosts one of the largest shark sanctuaries in the world, making it a brilliant place to study these creatures," says Frappi. "Duarte and Gallagher had the smart idea of using sharks as interns, tagging them with cameras to observe their preferred haunts. Their data highlighted a previously unknown vast seagrass meadow off the coast of Exuma Cay, which is now the largest known seagrass meadow in the world. We plan to demonstrate just how vital these ecosystems are globally, especially for apex predators like sharks."

The cross-disciplinary team used a wide variety of methods to gather extensive data during the trip, and while each team member had a specific project, everyone supported data collection and helped solve problems.

"Extensive data is needed for characterizing an ecosystem," says Laiolo. "We needed data about everything in this ecosystem, from megafauna down to the smallest microbes and assessment of carbon stocks. Using alternative novel approaches also provides fascinating details that might otherwise be overlooked."

Listening for passing sharks

Havlik's Ph.D. involves using hydrophones to gather data on the soundscape of seagrass meadows. "Working with experienced team members was invaluable," says Havlik. "For example, the Beneath the Waves team suggested I place a hydrophone on one of their real-time receivers, which pings their mobile phones whenever a tagged shark passes it. This meant I could directly link specific sound traces with the presence of individual sharks."

"Plus, combining your expertise with different perspectives for common goals is so rewarding. Not to mention the help you get when something goes wrong," adds Havlik.

Getting to the core

A key focus of the trip was to collect sediment cores from the meadow. The seafloor sediments build up in layers that relate to specific years, with lead-210 dating used to determine exactly when each layer was deposited. These sediment cores hold far more than "just" sand and carbonate. They contain copious amounts of environmental DNA (eDNA), which is derived from the fragments of skin and other deposits from the individual creatures that live on or use the meadow over time.

"We had to hammer long cores down into the sediments underwater and then remove the material with the layers intact," says Frappi. "We collected one beautiful core but, no matter what we did, the three of us could not remove it from the tube; it was stuck fast. Eventually, someone took a circular saw to the plastic, saving our hard-earned core."

"We plan to demonstrate just how vital these ecosystems are globally, especially for apex predators like sharks."

Elisa Laiolo collects core samples from the meadow sea floor.

Using eDNA to monitor marine creatures could revolutionize understanding of different species and their relationships, including predator-prey dynamics. Frappi is collecting eDNA to map elasmobrachs' biodiversity and potentially acquire information on shark-prey interactions. She intends to use a similar approach to collect data in the Red Sea.

"Sharks are notoriously difficult to track because telemetry is costly and time consuming. eDNA provides a rapid way of monitoring sharks over time," says Frappi. "As apex predators, they are vital indicators of the health of an ecosystem."

Blue carbon potential

The root system of the Bahamas seagrass meadow is extensive and home to thousands of microbial communities. Seagrass meadows are blue carbon habitats, capable of sequestering far more carbon for far longer than scientists initially thought, but the mechanisms inherent in these ecosystems are unclear.

"This is where my Ph.D. project comes in," says Laiolo. "I'm focusing on microbial communities, and I'm particularly interested in blue carbon habitats. Using a metagenomic approach, I study the functional traits of microbes and how these complex communities can contribute to biogeochemical cycles and processes, like carbon sequestration."

The researchers hope to find evidence of the influence of human activity on the Bahamas seagrass ecosystem. Not just in terms of disturbance by boats and fishing, but also to discover if the seagrass meadow has revitalized since the area was designated a shark sanctuary in 2011, which built on the area's long history of being a marine protected area. If the ecosystem's health is shown to have improved, it will boost the chances of securing further protection for this and other regions.

"Visiting the Bahamas and witnessing the good status of the ecosystems under protective measures really motivates us to demonstrate that such policies are worth pursuing," says Laiolo.

"We must have hope and continue to push forward with finding new knowledge and new ways to collect data while suggesting ways to help protect all marine habitats," says Havlik.

"Otherwise, no policies will change, no one will act," adds Frappi. "We have to fully protect at least 30 percent of our oceans by 2030 so that marine life can begin to recover worldwide. We're so proud that our work contributes to this wider goal."

GIVING GLOBAL POLLUTANTS THE COLD SHOULDER

A collaboration with KAUST researchers helps a multinational company rethink ways to reduce nitrogen oxide emissions using catalysts.

For Umicore, one of the world's largest materials technology companies, a collaboration with Javier Ruiz-Martínez is helping them rethink how to use catalysts to reduce emissions of the pollutant nitrogen oxide. Nitrogen oxide (NOx) gases are highly toxic for plants, potentially reducing some crop yields by as much as twenty-five percent.

Most NOx emissions come from fuel in diesel engines, but this can be reduced if Ruiz-Martínez and his team can find the right catalyst. A silver lining of the COVID-19 shutdown of their lab was that it gave the team time to think extensively about different catalysts and their correlations.

Wired for sustainability

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Through artificial intelligence, KAUST scientists shift the paradigm from wet lab to wired lab for a more sustainable manufacturing industry.

Two startling statistics drive chemical engineer Gyorgy Szekely's sustainable manufacturing research.

The first is that less than fifty percent of the energy consumed by the chemicals-based manufacturing industry is actually used to make their products. Whether a commodity chemical, a polymer for a mobile phone component or a finely crafted pharmaceutical, most energy expenditure occurs in purifying or isolating the desired molecule from the complex mixture that it was produced in. Traditional industrial separation techniques, such as distillation, are heat-driven processes that can consume vast amounts of energy when conducted on an industrial scale.

Szekely's research is focused on a technology that could slash that energy consumption by ninety percent. Replacing high-temperature separations with selective porous membranes – to simply filter out the desired product at ambient temperature – can bring dramatic efficiency gains. "Membrane processes use a fraction of the energy of conventional separation technologies," Szekely says.

Converting industry's energy-hungry heat-driven product separations into highly efficient membrane-based processes is a challenge Szekely first faced as a chemical engineering Ph.D. student specializing in pharmaceutical separations. "I was part of a European program that brought together industrial and academic partners to try to deal with the product separation problems the industry was facing." His work has remained focused on industry problems, and some of his membrane separation projects are now in commercial use.

But it is a slow process. Optimizing separation materials for a particular application involves simultaneously fine-tuning multiple material parameters; traditionally this has meant months of experiments in the lab. The cost of that approach is not just measured in time but in resource consumption and waste generation. "Developing new separation materials potentially creates more sustainability issues than it solves," Szekely says.

"What the field has struggled with for decades is a lack of organized and accessible data," Szekely explains. The fragmented information generated for each project rarely allows generalized patterns to be discerned; yet these are needed to make accurate predictions for the next separation problem. "Limitations with the data prevent us from taking the next step and running more efficient separations."

"Membrane processes use a fraction of the energy of conventional separation technologies."

Where data challenges have previously proven intractable to the human eye, now, new tools are available to look afresh and pick out patterns we cannot see. "Artificial Intelligence is a new approach to tackling data problems," Szekely says. "In the past, AI needed large datasets — which we did not have," he adds. "Now, recent advances in computer science mean we can apply AI to smaller experimental datasets, which we are already doing."

From a few select experiments conducted in the lab, or from small preexisting datasets, machine learning can be applied to help connect the dots to develop or identify the ideal separation material and conditions for the task. "For us to go to the lab and optimize manually would take ages, but if it is computer-based, we can do it in minutes or hours."

For the membrane separations subfield of organic solvent nanofiltration, the Szekely group recently created an open-access database that anybody can use to help them with a separation problem. "It is not only a database, we also provide a prediction tool based on machine learning algorithms," he adds. "People can go online, draw in their molecules and then use the database and the AI to get the solution for their separation problem."

To put the new computational tool to the test, Szekely sought out a collaboration across the campus. "I realized that we are not the only group at KAUST with the word 'sustainability' in the name," Szekely says. "Kyle Lauersen also works with sustainable technologies, so I contacted him to chat about what each of us was doing and how we could work together."

It turned out that Lauersen and his team had engineered algae for the sustainable bioproduction of a pharmaceutical product, patchoulol, but had issues with isolating it. To develop a membrane-based process, the team plugged the problem into the Szekely group's online tool. "The computer predicted that a membrane would retain one-hundred percent of the patchoulol, and when we tested that membrane, we measured one-hundred percent patchoulol recovery," Szekely says. "The AI was one-hundred percent accurate in a real-world problem."

Based on that result, Szekely now has a third compelling statistic to drive his sustainable manufacturing research forward.

A shape shifting approach to industrial design

Design and computer modeling play a key role in developing chemical reactors and new separation processes for this multi-disciplinary team.

Concepts of time and shape are bringing new thinking to the production of next-generation equipment and materials for chemical and pharmaceutical industries.

Carlos Grande and his team are seeking novel ways to develop chemical reactors and separation processes from a mathematical design perspective.

"Time and shape ultimately define the viability of a given process, such as a chemical reactor," Grande explains. Working with other groups that make materials and catalysts, Grande's team uses concepts of time and shape to create the best environment to enhance their properties.

"We want to manufacture bespoke reactors and separation processes. If the shape can improve the transport properties, the chemistry will control the final operation."

He likens it to a shirt that does not quite fit. "But a tailored shirt is cut to fit perfectly. If we cut the right shape from the beginning, we avoid wasting fabric, making the process more sustainable," he explains. "We can create customized shapes that are very complex but use less material to reduce energy and material consumption even at the construction phase."

Computer simulations have advanced the field of industrial design but, according to Grande, the real revolution involves aligning design, modeling and 3D printing.

Customization of new shapes that can be 3D printed is one of the group's main research topics. The entire process is digital – they design and model each piece of equipment and then only produce something once they are satisfied with the simulated results.

The team is also interested in the internal elements used in reactors and separator units, whose main role is to enhance the area of contact, either to improve mass transfer or heat transfer.

"The design of these elements is complex; a large increase in surface area can be associated with a higher pressure drop so the process can be shorter but still consume more energy," says Grande.

They are trying to find novel designs that enhance mass/energy transfer and keep pressure drop low.

"Our simulations show we can design new internals with an increase of heat transfer properties of fifteen to twenty percent and a thirty percent lower pressure drop. The new designs are twice as efficient," says Grande.

Grande says there is a lack of training to help engineers design the next generation of reactors. "This prevents methods like 3D printing becoming more widely used in industry." He believes KAUST has a niche opportunity to lead in this sector.

Students from diverse backgrounds pool their expertise to develop a sun-tracking technology for solar cells.

SALUTE TO THE SUN

Solar panels that bow toward the rising sun and readjust their position throughout the day to track its movement have been developed by a multidisciplinary team of interns and their advisor, electrical engineer Nazek El-Atab. The solar-tracking technology does not consume electrical energy but significantly increases the energy output of the solar cells it attaches to.

"We always look for projects that address real challenges faced in the region and the world," says El-Atab. "Solar is the most viable renewable energy source to enable the transition away from conventional carbon energy," she adds.

A lot of research is focused on improving the efficiency of solar panels. However, this does overcome the problem that when the sun is low in the sky and its rays strike the panel at an angle, only a fraction of the energy is produced compared to when sunlight strikes the panel from directly overhead.

Solar cells have been mounted on tracking systems that follow the sun, but these generally are bulky mechanical systems incorporating light sensors, microprocessors and motors. "These big heavy systems are costly, consume energy and require maintenance," El-Atab says. "They have limited application."

El-Atab had a considerably simpler concept in mind. "One of the main fields my group focuses on is 4D printing," El-Atab says. "Similar to 3D printing, 4D printing uses smart materials that can interact with the environment and change their shape." The printed object shape shifts in a predetermined manner in response to a specific stimulus, such as heat, humidity or light.

"Our idea is to 3D print legs for solar cells using materials that interact with the sunlight," El-Atab says. "When light hits this material, it contracts." Sunlight hitting the panel from one side would cause the sun-exposed leg to shorten, tilting the panel toward the sun and increasing its power output.

To develop the concept, El-Atab assembled a team of interns with the necessary spread of skills. "The project required some physics, some electrical engineering and some mechanical engineering, so we found students with these three backgrounds," she says.

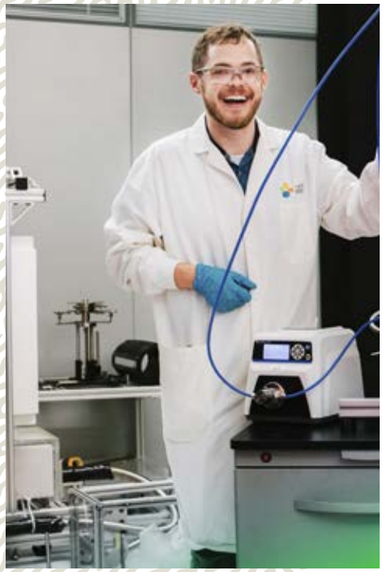
"We always look for projects that address real challenges faced in the region and the world."

Physics student Serhii Tytov from Ukraine, Saudi mechanical engineering student Fhad Al-Modaf and electrical engineering student Shicheng Su from China collaborated on the project. Their leg design is based on a stack of hollow cylinders. When exposed to sunlight, each cylinder's shape changes from a circular to an elliptical profile, shortening the leg.

The latest design revision came with the help of Tytov's permanent marker pen. "The material is white, and he got this idea of coloring it black," El-Atab says. The pen offered a quick way to test the idea, and the hunch paid off. When exposed to light, the darkened material changed shape almost twice as quickly as the white original. "We are now working on adding black coloring to the material as we print it," El-Atab says.

In testing, solar panels fitted with the 4D printed legs faithfully tracked the sun. "We showed that if the sun tilts by around 30 degrees, a fixed solar cell would lose around thirty percent of the power output, compared to only six percent with our solar tracker," El-Atab says. "The six percent loss means there is still room for improvement!" she adds.

With all three project interns soon to join KAUST as full-time master's or Ph.D. students in El-Atab's lab, the project's future looks bright.



When cool ideas come raining down

A rain oil lamp provides a breakthrough moment for optimizing the carbon dioxide freezing process in low-temperature carbon-capture technology.

Capturing carbon dioxide (CO_2) from flue gases by freezing it to a solid is potentially more cost effective and efficient than absorption/desorption methods.

"At the heart of our low-temperature carbon-capture technology is a spray tower, where very cold liquid is sprayed onto incoming flue gas," says Christopher Wagstaff, a Ph.D. candidate in combustion science. "The CO_2 in the gas instantly freezes on contact with the liquid, which enables it to be collected. However, to optimize the process, the spray of cold liquid droplets needs to be uniform, consistent and densely but evenly distributed. Current designs do not achieve this."

Wagstaff is working on this challenge under the supervision of mechanical engineer William Roberts. After exploring various concepts with colleagues, Wagstaff came to believe that slight changes to the nozzles or spray patterns would not make much improvement.

Then, scrolling through social media one day, Wagstaff came across a group called Weird Secondhand Finds. Someone had shared an image of a rain oil lamp, which Wagstaff instantly recognized from his childhood.

"Family friends had a rain oil lamp, and as a kid, I would gaze at the droplets gliding along the oil-wetted wires while the adults were having a boring conversation," says Wagstaff. "The way the droplets glide is really eye-catching: they move 'mostly' predictably, like water over a waterfall."

Wagstaff realized that this wetted-wires design could improve the spray tower. "Having the droplets slide on wires would make them more uniform in size and evenly and tightly distributed, and they would 'fall' much more slowly than droplets in freefall," he says. By engineering the wires to precisely control the droplets, the team could feasibly harvest more CO_2 from flue gas.

"Finding inspiration from seemingly unrelated fields to tackle challenging problems takes a sense of wonder and excitement; Chris has both in spades," says Roberts.

Wagstaff conducted extensive experiments to determine the most compact wire spacing and best orientation to avoid droplets merging; he also examined the surface tension under the input gas counterflow. Initial trials with the wetted wires are showing great promise.

"It is a tricky problem, but if the wetted wire phenomena can be engineered into a practical solution, then it will transform the efficiency and scalability of this system," says Roberts.

"We're working with Saudi companies to demonstrate low-temperature carbon capture," adds Wagstaff. "Actually, wetted wires could have many applications, for instance, distillation and refining processes could benefit from this idea."

"To tackle challenging problems takes a sense of wonder and excitement; Chris has both in spades."

©KAUST 2022; ANASTASIA SERIN

WHERE I WORK: VANESSA MELINO

An interest in gardening sparked a career in developing salt-tolerant crops to support food security.

> "Salicornia is so salt tolerant that it can grow in full seawater"
>
> VANESSA

Few plants have a taste for salt like Salicornia, the plant I'm holding in this photograph. Salicornia is so salt tolerant that it can grow in full seawater. If it has only fresh water, it will die.

Salt tolerance is a critical consideration for the future of agriculture. Farming in regions with low rainfall relies on deep wells for irrigation. But in many places, we extract groundwater much faster than it is renewed, and the remaining water becomes increasingly salty. In some arid areas, groundwater depletion and accumulation of salt in the soil mean that even our most salt-tolerant crops will no longer grow there.

I work as a plant physiologist in Mark Tester's lab, developing new crops with extreme salt tolerance. One plant we look at is quinoa, a semidomesticated pseudo-cereal crop from South America. We have a program to improve the heat tolerance and agronomic traits of this already salt-tolerant species.

The other plant is Salicornia, also sometimes known as sea asparagus, sea beans or samphire. I am leading a project targeting the oily seed, which is rich in nutritionally beneficial fatty acids. Today's main oil crops, canola and soybean, require fresh water. To preserve this nonrenewable resource, we hope to develop Salicornia as an alternate crop.

The plants in the photo were collected from a great inland salt lake in Al Qassim, northwest of Riyadh. Once a small lake surrounded by farms, now there is nothing but salt and Salicornia. In other places, Salicornia grows in tidal areas and gets some respite from salt at low tide. Given their constant exposure to high salinity and temperature, there is potentially something remarkable about this Saudi Salicornia species.

My mum is an avid gardener, and I think that time spent in the garden with her helped set me on this career path. Here at KAUST, I garden with my kids and we grow tomatoes, bananas and okra. They are learning just how much watering is needed to mitigate the heat stress. My husband works in NEOM, one of the new smart cities being planned in Saudi Arabia, developing the water policy. It is a good family life here, and I feel like we are both having an impact in our respective areas of work.

Concrete solutions for sea turtle survival

An environmental foundation and a cement factory are supporting ongoing efforts and research to help safeguard the future of Red Sea turtles.

©KAUST 2022; MORGAN BENNETT SMITH

One of the largest sea turtle nesting grounds on the Red Sea could become a conservation area due to an unusual alliance. A cement company that once undermined the survival of green turtles on Saudi Arabia's Ras Baridi beach is now supporting KAUST's research efforts to protect this endangered species.

Every year, more than 300 green turtles (*Chelonia mydas*) come to lay eggs at Ras Baridi, just north of Yanbu in Saudi Arabia. In 1999, wildlife researcher Nicolas Pilcher published a study on the impacts of a local cement factory on these nests. Cement dust settling on the beach was mixing with seawater to form a solid crust that prevented turtle hatchlings from digging themselves out of the nest to the surface.

After learning this, the Yanbu Cement Company drastically cut its dust emissions and is now a key stakeholder in conservation efforts led by the Ba'a Foundation, a not-for-profit entity with a focus on ecological and cultural initiatives and funded by Extreme E, the Ruia Family and Stamina Productions.

Sea turtles are vulnerable from the moment they are laid in a nest dug by their mothers. Even before they hatch, the eggs can be crushed by careless drivers on the beach, drowned by rising tides or dug up and eaten by humans and other wildlife.

Another looming threat to the future of sea turtles is climate change. Adult turtles are well adapted to warm waters, but their eggs are highly heat sensitive. The temperature in the nest determines the sex of the hatchlings, with a sweet spot of around 29.2 degrees Celsius producing an equal ratio of males to females. If temperatures go higher, hatchlings will be mostly female. If temperatures rise further to around 33-35 degrees Celsius, all eggs perish.

"Mean temperatures in Saudi Arabia are about 30 degrees Celsius during the nesting season and Ras Baridi is a dark sand beach, which retains more heat," says Kirsty Scott, a Ph.D. student under the supervision of marine scientist Michael Berumen. "Previous studies have found nest temperatures up to 34 degrees Celsius, so we'd expect to find a larger proportion of females here."

Despite this, turtle numbers in the area suggest that the population is healthy. "These local populations seem to have adapted to the conditions here, and we are currently investigating that," says Hector Barrios-Garrido, a sea turtle expert at KAUST and project manager of the Ras Baridi conservation program. "But we don't know what will happen with global warming. The Red Sea is already much hotter than other oceans, so we can use it as a living laboratory to study what might happen in other parts of the world as it warms," he adds.

Scott's team will head to Ras Baridi in August, where their work will start once the mothers begin emerging from the sea to dig their nests. Once each mother has buried her eggs and returned to sea, Scott will insert a probe into the nest to record its temperature throughout the incubation period — about 50 to 60 days. The team will assess whether a simple adaptation, such as shading techniques, could cool nests enough to rebalance turtle sex ratios as global temperatures rise. They will cover half of the nests with either palm leaves or white sand, which they will remove shortly before the eggs hatch.

Male and female turtle hatchlings look the same and so determining their sex typically requires invasive methods. However, recent research has succeeded by using hormonal markers in the blood. When the hatchlings emerge, Scott's team will scoop up 10 turtles from each of the 40 nests to extract minuscule blood samples for screening. "It's a relatively inexpensive and simple method, although taking blood from 400 turtles could take a while," says Scott. "Most importantly, it doesn't harm the hatchlings."

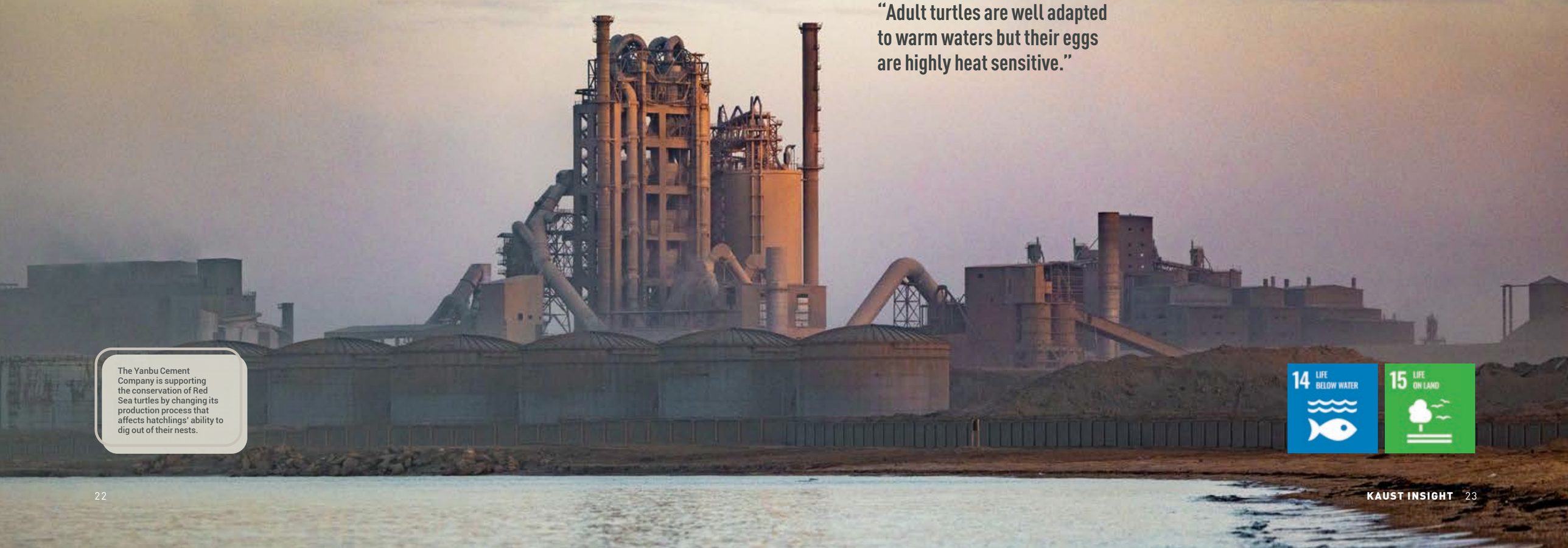
This data will be used to model changes in turtle sex ratios at Ras Baridi with global warming and will show how conservation efforts can help protect global turtle populations.

"Turtles in the Red Sea face a variety of pressures, ranging from coastal developments to climate change," says Berumen. "It is encouraging to see Saudi Arabia recognizing the value of these animals and key stakeholders making strong commitments toward protecting these species."

The cement factory is also helping out with logistics. For previous projects, Scott explains that she had to travel for several hours at night to visit remote nesting sites. "Sometimes we'd finish at 4 am, and you really don't want to drive at this time," she says. "At Ras Baridi Foundation, we'll stay onsite in a house provided by the cement factory, using a spare room as our lab and we have a permit to drive through the factory grounds."

"The KAUST-led team is implementing a five-year project, supported by Ba'a foundation and its key partners, to establish a marine turtle conservation area in Ras Baridi. This initiative entails monitoring the turtle nesting activity and stress factors, as well as developing an environmental awareness and educational program to raise awareness for marine turtle conservation, especially the uniqueness and conservation value of the Ras Baridi breeding grounds," says project director Ricardo O. Ramalho. "I want to ensure that my daughter and future generations can see turtles too," says Barrios-Garrido.

"Adult turtles are well adapted to warm waters but their eggs are highly heat sensitive."



The Yanbu Cement Company is supporting the conservation of Red Sea turtles by changing its production process that affects hatchlings' ability to dig out of their nests.

Helping Saudi solar shine, no matter the weather

Real-world testing enables local industry to profit from the unique climate of the Middle East.

Booming investment in Saudi Arabia's renewable energy sector is set to drastically reduce the country's carbon emissions by 2030 and spur employment opportunities. The region's plentiful sunshine positions it as a possible exporter of solar energy; however, practical issues related to desert climates still need to be solved.

"The problem is the combination of extreme heat with all the other environmental factors – humidity, a lot of wind and soiling," says Michael Salvador, technology lead at the KAUST Solar Center. "There's no certified way to test photovoltaic modules for all these conditions at the same time."

Salvador and his colleagues are emerging as a critical resource for local solar companies looking to improve their balance sheets. Thanks to the Center's expertise in testing photovoltaic panels in harsh conditions, industrial partners are now finding it easier to fund expansion plans.

"If these companies could provide data to the banks about testing their modules and systems in our climate, it may enable them to negotiate better financing conditions," says Salvador. "It's good because the information flow between KAUST and these companies allows us to increase our knowledge about these issues as well."

Haala Energy, a Jeddah-based engineering and construction firm, turned to the Center to help solve a practical issue related to rooftop installations of solar panels. Following complaints of unexpected power failures, the company found that the panels were exposed to higher temperatures than predicted, with the likely culprit being trapped air underneath the panel's sheet metal mounting frame. Ongoing work at the outdoor testing field in KAUST is helping the company explore different mounting setups that provide relief from the desert heat.

"The trapped heat accumulates and it warms up the panel even more than in an open field," explains Salvador. "Haala Energy knew about the problem but didn't have the means to investigate it. That's where we came in. Our contribution should have practical benefits for installing photovoltaic systems across the country."

As a leading global developer of seawater desalination plants and utility scale solar power plants, Acwa Power makes extensive use of photovoltaics to reduce energy input costs. Recently, they teamed up with Salvador to examine a technology uniquely suited for the reflective nature of desert sands: solar panels capable of capturing energy on both sides of their mirror-like surfaces, so-called bifacial solar panels.

These are teamed with "trackers" – installations that adjust their angle of orientation throughout the day to track the movement of the sun. Collaborative experiments at the Center ensure that these bifacial modules on trackers match the requirements of the solar panels before they are deployed into massive solar farms.

"There are different ways of tracking: the panel can be centered around a single axis, or you can have the axis between two panels to reduce shading from the back," notes Salvador. "There are strong economic benefits to bifacial solar panels, but current tracker designs do not fully exploit its potential, even if there is a lot of light outside."

The Center is also collaborating with Desert Technology, a Jeddah-based manufacturer of photovoltaic products. Together, the partnership is developing vehicle-mounted systems that can test the performance of solar technology in specific microclimates.

"It's really hard to simulate the effect of wind, soiling and humidity on these systems, so most companies don't even try," says Salvador. "But our system is fully autonomous – you put it on a boom truck and drive to where you need it to be."

Salvador, who is a founder of a startup that develops lightweight solar panels for building integration, remarks that the companies appreciate having a local hub for information and cooperation. "My contact at Acwa Power received his Ph.D. from the KAUST Solar Center. They hired local, which was a wise decision as it greatly facilitated the collaboration," he says.

"Our contribution should have practical benefits for installing photovoltaic systems across the country."

Stefaan De Wolf, also from the Center and with expertise in the science and technology of photovoltaics, explains that "building up expertise around the interaction between hot and sunny climates and photovoltaic modules through local collaborations is of tremendous importance to develop long-lasting, reliable and renewable energy solutions for Saudi Arabia."

7 AFFORDABLE AND CLEAN ENERGY

New partnership delivers high-flying salad

11 SUSTAINABLE CITIES AND COMMUNITIES

A new collaboration between the Saudi agricultural technology company Red Sea Farms and the national carrier SAUDIA is putting sustainably produced food on the plates of the airline's passengers.

Ryan Lefers, Mark Tester and Derya Baran founded Red Sea Farms in 2018 to grow produce in harsh climates using technology they developed at KAUST to reduce water and energy use. These innovations include solar technology in fan systems and for night-chilling crops, salt water for evaporative cooling in greenhouses and salt-tolerant crops.

Red Sea Farms CEO, Ryan Lefers, says they were all motivated to do something about the huge amount of fresh water and energy that is required to grow food in hot environments like Saudi Arabia.

"We wanted to break the food-water-energy nexus and enable long-term sustainability to help feed the world. We want to create real and lasting impact on feeding people and protecting the planet," he says.

This goal struck a chord with SAUDIA, which has a commitment to continually improve its environmental performance and become an industry leader in sustainability.

Saudi Arabia, through Vision 2030, has an ambitious tourism strategy that aims for tourism to contribute 10 percent of the country's GDP by 2030, while ensuring that tourism meets the Vision's sustainability goals.

The new partnership will lower food miles by replacing imports of snack tomatoes, cucumbers and peppers.

"We are very excited about the

"We are very excited about the partnership with SAUDIA, a company which shares our sustainability goals."

partnership with SAUDIA, a company that shares our sustainability goals," says Lefers.

Currently, Red Sea Farms sells its snack tomatoes, cucumbers and peppers in more than 100 retail outlets across Saudi Arabia with numbers expected to increase in 2023.

"Outside of Saudi Arabia, other growers are using our technology to grow tomatoes and strawberries, with many more crops expected in 2023," says Lefers.

Blending precision climate control, plant science and AI-enabled systems, the company's methods save 300 liters of fresh water for every kilogram of produce grown compared with conventional outdoor crop production in Saudi Arabia.

Red Sea Farms long-term goal is to become a world leader in providing sustainable agricultural technologies for harsh environments. A vital first step is to become one of the most sustainable food businesses in Saudi Arabia, where more than 80 percent of fresh food is imported.

The partnership with SAUDIA marks another step in the company's rapid development since January 2022, including expansion into the United States, completion of a new commercial-scale six hectare site near Riyadh and an R&D facility at KAUST.

"Red Sea Farms long-term goal is to become a world leader in providing sustainable technologies for harsh environments."

SPARKING CONVERSATIONS

Research shows that, in 20 days of social media use, our thumbs scroll the equivalent distance of climbing Mount Everest. With mountains of content to read, which **#KAUSTResearch** story will stop your scroll?

In this story, we share some previous social media scroll stoppers. Publishing methods to extract clean energy from seawater, celebrating Earth Day, presenting posters at conferences — this year in social has been made up of memorable moments. Too numerous to mention, we invite you to follow KAUST Research channels for a daily top up of research stories.

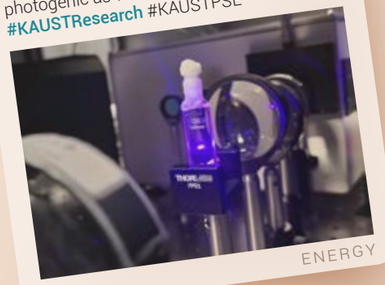
@ddcorzo

It's Earth day! and I would like to share this pic of the printed solar cells we make @KAUST_OMEGALab . #sustainability and #Renewable #energy is what attracted me to **#kaustresearch** and I love being a part of the transformation. #earthday2022

ENERGY

@PatyFromPuebla

Our "slow" dynamics lab can be quite photogenic as well :) #UFDpeople **#KAUSTResearch** #KAUSTPSE



ENERGY

@TihanaPensa

I am so lucky to be a #geologist and have my birthday on #EarthDay #EarthDay2022 **#kaustresearch** #kaustsustainability

EARTH

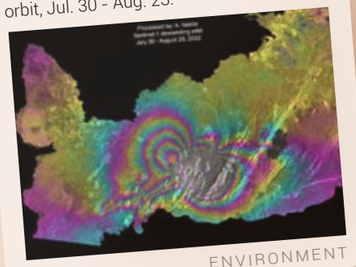
@LauraParisi_Sci

A #Saudi beauty for #EarthDay2022 #NOFILTER **#KAUSTResearch** @Matrau5

EARTH

@j_p_joule

Another amazing butterfly for my collection. This is the total dike-induced displacement associated to the Meradalir eruption (SW Iceland - Reykjanes peninsula). Sentinel-1A images (each fringe ~3 cm), descending orbit, Jul. 30 - Aug. 23.



ENVIRONMENT

Which news story or image stopped your scroll in its tracks this year? Let us know via our social media channels!

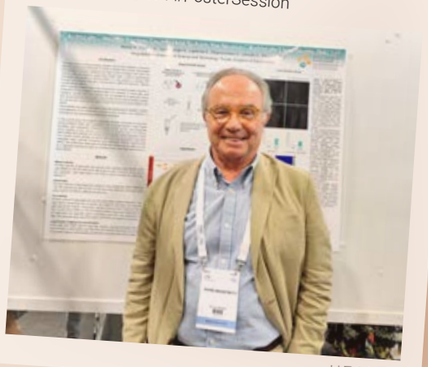
@KAUST_ECRC

Accelerating the pseudo inverse computation on the @SubaruTel_Eng telescope by @KAUST_CEMSE PhD student @Dalalsukkari : twinkle twinkle little star! :-) @KAUST_News @KAUST_HPC

DIGITAL

@mariferveloz_

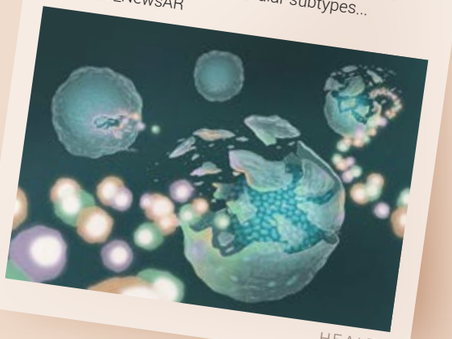
Back to the roots! Prof. Pierre Magistretti at poster 218 presenting his latest **#KAUSTResearch** on brain energy metabolism at FENS2022. Stop by and solve all your doubts about it! #FENSAmbassador #neuroscience #PI #PosterSession



HEALTH

@RNASeqBlog

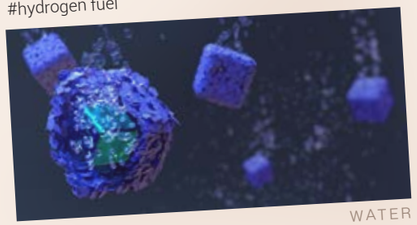
By integrating #singlecell #geneexpression data (single-cell #RNAsequencing) for each of these #celltypes, researchers from **@KaustResearch** were able to unravel the heterogeneity of these niche cells, identifying multiple cellular subtypes... @KAUST_NewsAR



HEALTH

@GlobalGreenGame

Tapping into seawater's energetic potential via **@KAUSTResearch** @KAUST_News #KAUST-led team has developed #WaterSplitting #catalysts to tap into seawater's energetic potential. Seawater key in #sustainable production of clean #hydrogen fuel



WATER

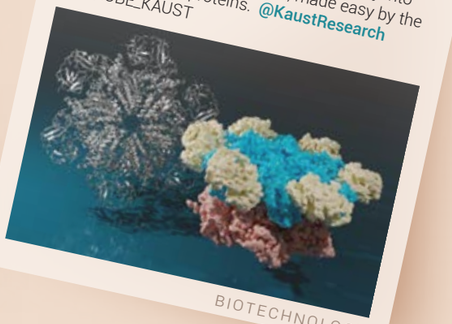
@GlobalPlantGPC

AI system facilitates plant imaging from germination to root development https://buff.ly/3PCtDF1 via **@KAUSTResearch** #plantscience

FOOD

@CryoHuntington

Incredibly honored to have our research showcased by @KAUST_SHI !! Many thanks to everyone on the project. Also, my first foray into #scicomm using Blender #b3d, made easy by the natural beauty of proteins. **@KaustResearch** @STRUBE_KAUST



BIOTECHNOLOGY

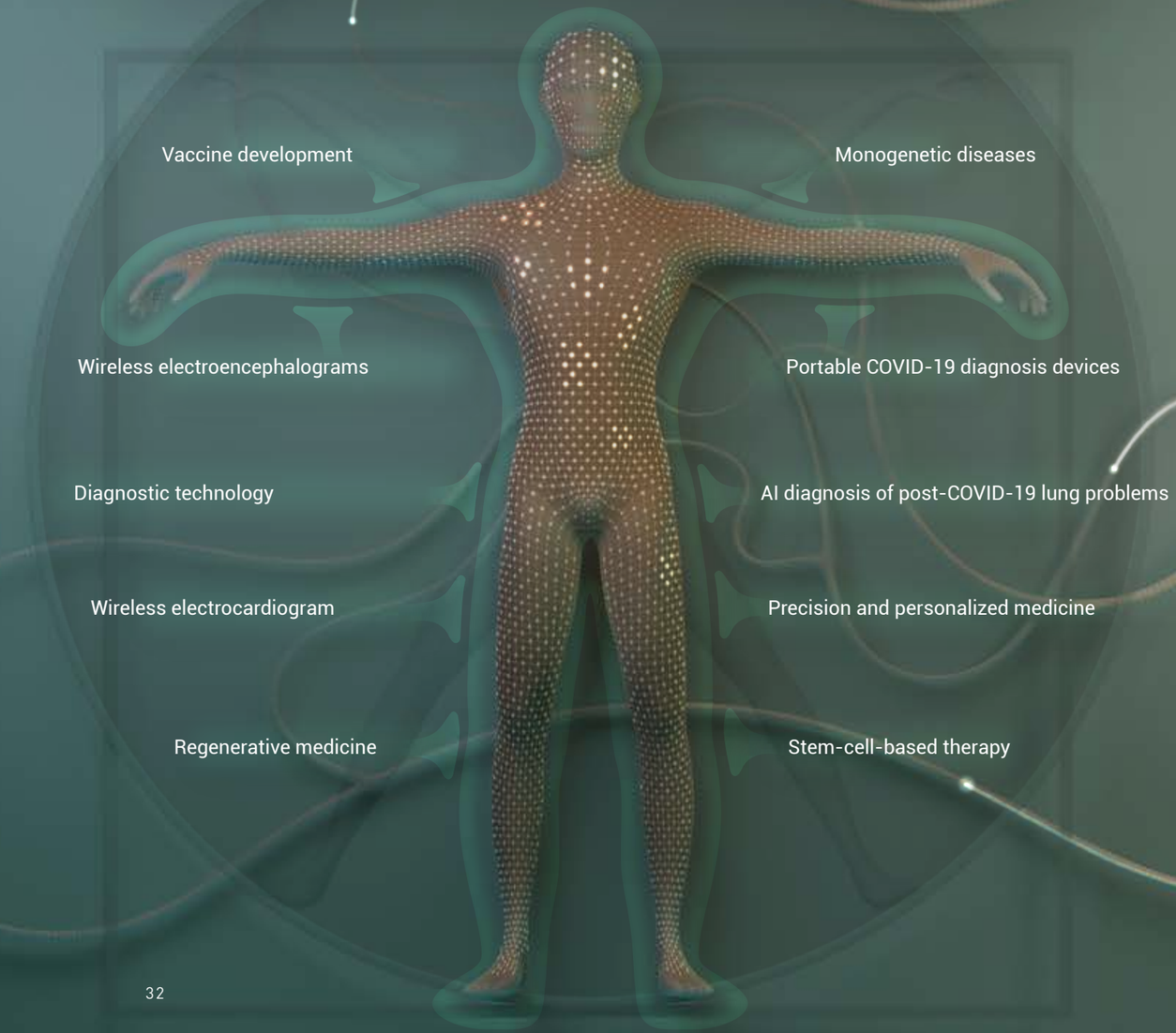
Programming ideal healthcare

The KAUST Smart-Health Initiative brings together biomedical researchers and clinicians in Saudi Arabia's medical centers to improve the quality of healthcare nationwide, under the umbrella of personalized medicine.

The Initiative applies KAUST's capability in basic scientific research to solve disease-related questions. Using smart tools like artificial intelligence (AI), machine learning and a suite of digital tools, the initiative will help the country's healthcare system transition from traditional (one size fits all) medicine to precision (personalized) medicine.

In a personalized healthcare system, clinicians use smart technologies, such as AI, to better understand disease mechanisms for improved diagnosis and for treatment and prevention.

As well as world-class facilities and programs to drive collaboration with national and international institutions, the Initiative provides exceptional training to the next generation of Saudi medical practitioners and scientists.



Bioinnovation

The Initiative is a springboard for new startup businesses, such as biobanks for specific applications and capability building. One facility will produce vaccines and other therapies in collaboration with Merck, while another will function as a training center for biotechnologists. Also on offer are professional M.Sc. and Ph.D. degrees in bioinnovation and biomanufacturing.

Education

Faculty, students and education programs are built around the themes of genomics, metabolic disease, host-pathogen interaction and digital health. An M.Sc.-Ph.D. program with Alfaisal University is helping to train new clinicians to use smart tools in precision medicine, while a clinician-scientist program will enable doctors and nurses to spend time in KAUST's labs.

Research

KAUST researchers aim to develop the next generation of smart-health technologies. Seed grants are enabling collaborative teams to test their novel ideas. "Bench to bedside" funding will help ideas move to the next step. Funding will be available to take successful projects to clinical trials.

Partnerships

Collaborations with national medical centers will help bridge the "bench to bedside" gap, bringing together clinicians and scientists. KAUST is also building partnerships with other national and international universities.

ART AND DESIGN: IVAN GROMICHO, RESEARCH COMMUNICATION, KAUST.
SOURCE: IMED GALLOUZI, KAUST SMART-HEALTH INITIATIVE.

THE HEARTS AND MINDS OF SMART HEALTH

The Smart-Health Initiative at KAUST brings together researchers from different disciplinary backgrounds to address health-related questions about genetic and metabolic diseases, infectious diseases, digitalization and artificial intelligence.

Some of the researchers in this initiative discuss their work, teamwork and motivations, as well as how their research will help deliver on the health goals of Saudi Arabia's Vision 2030 strategy.

Constructive collaboration

- "Being a part of the Initiative gives me the opportunity to collaborate with colleagues across a wide range of disciplines to come together to address a grand challenge."
  — Ahmed Eltawil
- "Clinicians are at the heart of these collaborations and their knowledge and insight dealing with patients help us to pave new roads to drive our research toward improving disease diagnosis and prognosis in a more strategic manner."
  — Jasmeen Merzaban.
- "There is an important synergy that occurs when we cooperate by coupling the expertise of clinicians with the expertise of researchers."
  — Antonio Adamo
- "The most important aspect for working together is the natural curiosity about the truth, sharing our ideas and thoughts 24/7. You never know when a good idea will pop up, and being surrounded by colleagues who are on the same page is very valuable for combining work and planning next steps."
  — Łukasz Jaremko

> **"In my career, nothing has been more rewarding than mentoring students and seeing them mentor others."**
>
> JASMEEN MERZABAN

JASMEEN MERZABAN

Bioscience

Our research seeks to understand the mechanism by which cells (immune cells, cancer cells and stem cells) exit blood circulation to migrate to specific sites within the body. Our ultimate goal is to gain a holistic understanding of how these cell types can be manipulated/directed to control disease processes as they pertain to stem cell transplantation and tissue regeneration, inflammation and cancer growth and metastasis.

BASEM SHIHADA

Computer Science

Our work on smart health focuses on users' expectations and the e-health application model through three goals. The system needs to be: intelligent to assist with decisions made by medical professional and patients; respond quickly to abnormal changes in vital signs, keeping data current; and secure so that the user's sensitive data is protected.

Delivering on Saudi Arabia's Vision 2030

A cornerstone of Saudi Arabia's Vision 2030 strategy is "to expand the provision of e-health services and digital solutions, as well as improving the quality of health services."

The Smart-Health Initiative is well positioned to help the nation deliver on this vision.

Preventive medicine can be supported by internet-of-body sensors

- "Reliable medical-grade remote monitoring empowers patients to take a leading role in the management of their own health. Simultaneously, it can aid medical practitioners to better organize healthcare delivery to improve the quality and outcomes with access for all."
  — Ahmed Eltawil

Technology both empowers and challenges the healthcare industry.

- "Users expect smart health applications to be responsive, intelligent and secure. By focusing on three facets — analyze, acquire and authenticate — our project underpins a framework that addresses those expectations, along with concrete examples of smart health applications across a lifetime."
  — Basem Shihada

Improving clinical outcomes for the Saudi population

- "We are developing Saudi patient-specific protocols to treat cancers that are most common in the Saudi population, such as colorectal cancer and leukemia. Our work also has promising applications in 3D organoids, which can be delivered to the newly established Saudi biobank."
  — Charlotte Hauser
- "Through collaborating with clinicians, we can use patient samples to test our models to ensure they are working efficiently and effectively. Our long-term goal is to develop an assay or kit that could be used in a clinical setting to identify tumor tissue, breast cancer subtypes, cancer types and tissue types. Our assay is also useful for predicting survival and monitoring cancer treatment."
  — Jasmeen Merzaban
- "Our goal is to identify and optimize small molecule inhibitors and the therapeutics of these biomolecules that will lead to new drug candidates. Our work is crucial to support the development of new medications."
  — Łukasz Jaremko

Building local capacity

- "Many of our M.Sc. and Ph.D. scholars are recruited from among Saudi Arabia's best students, ensuring that the nation's brightest young minds will be trained to the highest level of scientific endeavor. But the learning goes both ways: each time I talk to my students and postdocs, I am inspired by their enthusiasm and determination to answer new and exciting questions."
  — Łukasz Jaremko

Success is its own reward

KAUST researchers are passionate about their work and its potential to support better health for patients in Saudi Arabia. They aim to facilitate equitable access

ANTONIO ADAMO

Bioscience

We work with induced pluripotent stem cells, which are cells derived from the skin of living patients. We engineer these cells and then bring them back to their embryonic state. This helps us to model the onset and the progression of a specific disease on the real cells of a real patient.

CHARLOTTE HAUSER

Computational Bioscience

Our research activities include tissue engineering, 3D bioprinting and regenerative medicine, specifically developing personalized 3D disease models and organoids using biofunctionalized 3D matrices to study cancer (colorectal cancer, leukemia) and neurodegenerative diseases (Parkinson's, Alzheimer's). We also develop healthy 3D tissue and bone models to replace diseased or missing human tissue.

to quality healthcare and to build improved health research capacity within the country.

- "I would be extremely satisfied to know that my research is improving the life of chronically sick patients and will be able to offer regenerative tissue replacement therapies."
  — Charlotte Hauser
- "The most rewarding aspect of my work is making a difference for the Saudi population. It is also satisfying to advance knowledge through better understanding of the genetic background of Saudi citizens, which is highly conserved due to a high consanguinity rate. The Saudi population, therefore, represents a unique genetic model for the study of the genetic origin of diseases."
  — Antonio Adamo
- "We are exploring how we can apply our expertise to all smart health applications. However, independent of the application, we are evaluating how we can integrate intelligence with rapid response in a secure way."
  — Basem Shihada
- "COVID-19 has shown us that there is worldwide inequality in healthcare access, which can lead to disastrous consequences. If we can contribute even a small percentage toward achieving universal affordable healthcare, then that is a reward in itself."
  — Ahmed Eltawil
- "In my career, nothing has been more rewarding than mentoring students and seeing them mentor others."
  — Jasmeen Merzaban
- "The reward is that the research never ends because any answer gained today may become an even stronger research challenge tomorrow."
  — Łukasz Jaremko

> **"Being a part of the Initiatives gives me the opportunity to collaborate with colleagues across a wide range of disciplines to come together to address a grand challenge."**
>
> AHMED ELTAWIL

AHMED M ELTAWIL

Communications Technology

We develop internet-of-body sensors, including designing seamless wearable sensors that enable an individual to better monitor their own health and health metrics.

ŁUKASZ JAREMKO

Bioscience

Our research considers the causes of underlying diseases, such as neurodegenerative conditions or cancer, at the bimolecular level. We identify candidate molecules, and then we use a range of advanced interdisciplinary methods to study their structure and dynamics, biophysical properties and biological turnover. Ultimately, we aim to identify and optimize small-molecule inhibitors and therapeutics of these biomolecules, which will lead to new drug candidates.

GENE DETECTIVES SOLVE DISEASE MYSTERIES

Researchers are diagnosing many rare genetic conditions by applying the latest AI methods combined with machine learning.

Since 2016, when he began collaborating with Saudi clinicians, Stefan Arold and his team have analyzed more than 100 rare genetic diseases. This work, he says, can provide answers to people who have been searching, often for many years, for the cause of an illness or unexplained condition.

Arold and his team use 3D protein structure mapping powered by the latest AI methods and other bioinformatic and computational tools to contribute to diagnosis of genetic disease in Saudi Arabia.

"Usually, the doctors identify patients with a genetic disease, meaning that the phenotype is caused by one or more

mutations in their genome," Arold explains.

"The clinician sends us the genetic alteration they think caused the disease, and we use our expertise in structural biology to map this mutation onto the three dimensional atomic structure of the affected proteins."

By putting the mutation into the context of the protein it affects, Arold's team can often identify a molecular cause for the disease or can help the clinician identify or confirm which mutation is the most likely cause.

"Understanding how a particular mutation causes a patient's symptoms can help the doctor to tailor treatment and therapy," he says. "Also, if a parent is a recessive carrier for the protein variant (meaning they don't show symptoms), then knowing the cause of their child's disease will allow them to have healthy children through genetic screening."

Knowing the problem can end what Arold describes as "a long and draining diagnostic odyssey" during which ill children often endure many, sometimes invasive, tests in efforts to find a cause for their condition.

Even though genetic diseases are relatively common in Saudi, each disease itself is "rare" and requires personalized healthcare.

Arold's colleague Xin Gao uses innovative machine learning methods for genetic detective work. Gao and his team developed the world's first end-to-end pipeline for nanopore sequencing (a method of sequencing DNA) data analysis and applications. This approach allows them to produce the high-confidence long-gene sequences that enable identification of otherwise hidden genetic alterations in patients.

They have used the method to diagnose genetic diseases, such as microcephaly and congenital heart and eye malformations, in collaboration with King Faisal Specialist Hospital and Research Center.

"Our method has made a huge difference to families who have been searching for answers for years after even whole exome sequencing has failed to identify their mutation," says Gao.

"Our method has made a huge difference to families who have been searching for answers for years after even whole exome sequencing has failed to identify their mutation."

Following the success of his method, Gao has co-founded a startup called Peregrine Genomics, which was a winner of 2019 Taqadam startup competition and a finalist in the GITEX supernova startup competition.

Arold and Gao presented their research at two high-profile conferences in Riyadh in November 2022: the International Conference on Genomic Medicine and the HIMSS22 Middle East Health Conference & Exhibition. Both researchers underline the importance of such events for discussions with clinicians, healthcare providers and policy makers to help connect their research with the healthcare needs of the country.

A WINNING TEAM EFFORT

A winning machine learning model for a prestigious international competition has implications for understanding how single cells differ despite their common genetic blueprint.

Over a period of six weeks in 2021, a multidisciplinary team of KAUST students, researchers and collaborators worked together to solve complex machine learning tasks. The tasks aimed to develop computer codes and algorithms that can sift through enormous amounts of cellular data, filter superfluous information, improve its resolution and predict one type of data from another.

The work led to two first-prize awards in one of the world's most prestigious machine learning conferences: the Conference and Workshop on Neural Information Processing Systems (NeurIPS). Bioscientist Jesper Tegnér, who supervised the winning team, says that "It's quite remarkable to come from outside the field of biology and to lead the two tasks to the extent that we win them."

Working with Tegnér was postdoc Sumeer Khan and Aidyn Ubingazhibov, then an undergraduate intern. Khan and Ubingazhibov both specialize in machine learning, and their tasks for the NeurIPS competition were to develop algorithms to solve problems in multimodal single-cell data integration.

This is a very recent field of biology that has developed out of technological advances that allow scientists to measure huge amounts of DNA, RNA and protein data at the single-cell level. Analyses of these data will help explain how our common genetic blueprint gives rise to distinct cell types, organs and organisms, which is key to unlocking disease mechanisms. Scientists hope that the artificial intelligence revolution will expedite these complex analyses.

Art at the cutting edge of coral reef research

From lens to lab, artists and scientists have been capturing the critters hidden in coral reefs.

Underwater apartment blocks: artists bring a new perspective to an old research tool.

Innovative science is often a source of inspiration for artists. When photographers Nico Krebs and Taiyo Onorato encountered autonomous reef monitoring structures (ARMS) at KAUST's Red Sea Research Center, they did not just see scientific instruments for measuring marine biodiversity, they saw underwater apartment blocks where creatures move in, compete, cooperate and move out.

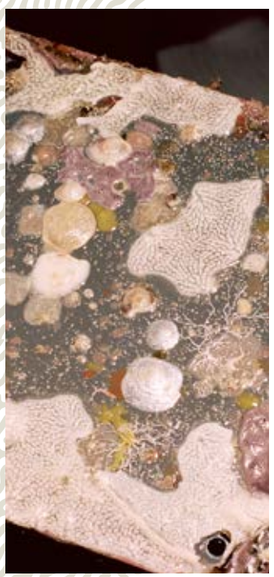
The pair met graduate student João Rosado while participating in a residency through the Artists in Labs program. The Zurich-based program, which KAUST joined in 2016, enables artists to get close to scientific research and get creative at the cutting edge. It also exposes scientists to diverse perspectives that can help them to see their work in a new light.

"So much life is concealed in the cracks of rocks and corals."

ARMS are stacks of tiles designed to mimic the complex structure of coral reefs. Each stack consists of nine plates separated by a gap containing intertwined plastic shapes to create areas of higher flow and lower flow, like within a reef. Placed on the seabed, they are left to be colonized by marine species, then collected and taken apart in the lab to see what has moved in.

"We were absolutely stunned by the concept of these units," says Krebs, "and fascinated by the visual manifestation of an extremely diverse range of creatures colonizing the same structure." During their stay, Krebs and Onorato learned to scuba dive and, guided by underwater photography specialist Morgan Bennett-Smith and reef ecologist Song He, built up a huge collection of images and videos of ARMS in the sea and in the lab.

But for Rosado, who is studying reef biodiversity on a near-shore reef, ARMS were simply the best tool for the job. "They are the best way to truly and reliably capture cryptobenthic biodiversity," he says. "You will never see anything close to the full biodiversity of the reefs while diving because so much life is concealed in the cracks of rocks and corals." These hidden organisms, sometimes referred to as the cryptobiome, can represent up to 70 percent of a reef's biodiversity, yet remain largely



understudied. ARMS are typically used to compare biodiversity between reefs in different locations. Still, Rosado is interested in how cryptobenthic communities differ from the established cryptobiome across different habitats within reefs.

In August 2021, Rosado and a team of scientists led by marine scientists Michael Berumen and Susana Carvalho placed 32 ARMS on the Tahla reef off the coast near KAUST, dividing them evenly between four distinct reef habitats: branching corals, plating corals, algae pavement and coral rubble. In his M.Sc. project, Rosado is investigating how pioneer (early settlers) and mature (two years post immersion) communities differ across those habitats.

"It usually takes two years for ARMS to be fully colonized, but this depends on the region," he says. "Nature moves at its own pace." In March 2022, Rosado collected four ARMS from each habitat. "It's a very intricate process because each structure must be sealed in a container to ensure nothing escapes — such as mobile organisms like fish and crabs — and then incubated in the dark to evaluate the biochemical cycles that take place on it," he says. "It took one day to deploy all 32 units, but two weeks to retrieve 16."

Back in the lab, Rosado blended the organisms on each plate and used DNA metabarcoding to identify and assess this previously hidden biodiversity. "The cryptobenthic communities differ among habitats at each site and are mostly distinct even though these habitats are not so distant from each other," says Rosado. "There is some crossover, but most species are unique to one habitat." For example, 28 percent of the diversity on the algae pavement appeared nowhere else. "I'm very interested to see whether these communities become more similar or different over time," he adds.

Through the artists' eyes, these communities almost resembled human societies. "It's fascinating thinking about how they divide space, enter benevolent or hostile relationships and claim, gentrify and abandon habitats," says Krebs. "Seeing all this happen in a structure that resembles an apartment building is very thought-provoking, but it also makes us question our inherent anthropocentric perspective." He and Onorato hope their work will encourage people to question what they see. "It would be great if we can inspire more curiosity about the nonhuman world, albeit a noninvasive, compassionate curiosity," he adds.

"Art is vital in communicating science," agrees Rosado. "It reminds us that we can reach out to people. We as scientists can be very focused in academia and in writing papers sometimes, but we can't achieve much if we only talk amongst ourselves," he adds. In this, the artists and scientists found common ground. "I was amazed at how obsessive scientists are," says Krebs. "I thought only artists could get like that."

Marine scientists are currently on a global mission to preserve underwater environments that have been degraded by human activities, especially in light of climate change and local anthropogenic impacts. "Coral reefs are declining, and some reports show that 99 percent of corals might die by 2050 because of global warming," says Rosado. "We need to reach as many people as we can, and art can deliver a strong message in a way that everyone can understand and interpret."

"With the pressures that marine systems currently face, there has never been a more important time for outreach and awareness. The Artists in Labs collaborations bring direct benefits to both the scientists and the artists, but there is also an immeasurable increase in the impact that the work has on a broader audience," says Berumen.

"Art can deliver a strong message in a way that everyone can understand and interpret."

Husam Alshareef and some members of his MXenes team.

Doubling down on new ideas for 2D nanomaterials

The numerous potential applications of MXenes spark a diverse range of research across KAUST and farther afield.

Atomically thin MXenes boast a combination of electrical, optical and chemical properties that can be exploited for a large number of applications, says Husam Alshareef, a pioneer of MXene science and technology at KAUST.

A class of two-dimensional inorganic compounds, "MXenes are similar to graphene, except that we are able to manipulate their composition and surface chemistry over a wide range," Alshareef says. To date, more than 30 MXenes have been experimentally synthesized, but hundreds more actually exist.

Alshareef, together with colleagues from KAUST and beyond, is putting MXene properties to the test. MXenes produced in the Alshareef lab are being assessed in devices ranging from solar cells to implantable batteries. Alshareef's collaborative MXene research now extends to projects with 16 professors across various fields within KAUST alone.

The technical achievements powered by the lab's diverse range of collaborations are many and range from nanoelectronics to batteries, catalysis and biosensors. These snapshots of MXene collaborative research illustrate just some of the uses being explored for these exciting two-dimensional materials.

Implantable batteries recharged by ultrasound

MXenes typically are formed of a titanium and carbon atom core sandwiched by a metal oxide or hydroxide. This conductive core and chemically active surface are key to many potential MXene applications, including batteries that are implantable and wirelessly rechargeable that could power pacemakers, medical sensors or implanted drug delivery devices.

In collaboration with Abdulkader Alkenawi, a physician at the King Saud bin Abdulaziz University for Health Sciences in Jeddah, Alshareef's team is exploring MXene-based biocompatible hydrogels.

When exposed to medical ultrasound, the interaction between the negatively charged outer MXene surface and positively charged protons in the hydrogel generates a current in the MXene that could be used to charge and power implanted electronic devices.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Saltwater energy harvester

MXene membranes could enable electricity generation simply by exploiting the salinity difference between two containers of water, shows research conducted in collaboration with environmental scientist Peng Wang.

The team's membrane consists of multiple MXene sheets. Nanoscopic channels between the sheets allow water and ions to flow. "If you place this membrane between two water tanks of different salinity, the MXenes' negative surface charge will accelerate the movement of the cations between the tanks, which produces a current in an external circuit," Alshareef says.

"The team won seed funding to develop a large-scale device that could use seawater to charge a battery overnight and is now seeking industrial collaborations."

Cutting the cost of solar

Silicon solar cells rely on indium tin oxide (ITO), an optically transparent and electrically conductive material, to generate an electronic current from sunlight. To boost ITO's conductivity, a coating of silver is usually applied. "Silver is the best conductor we know, but it is expensive," Alshareef says. "MXenes would be cheaper once they are scaled up."

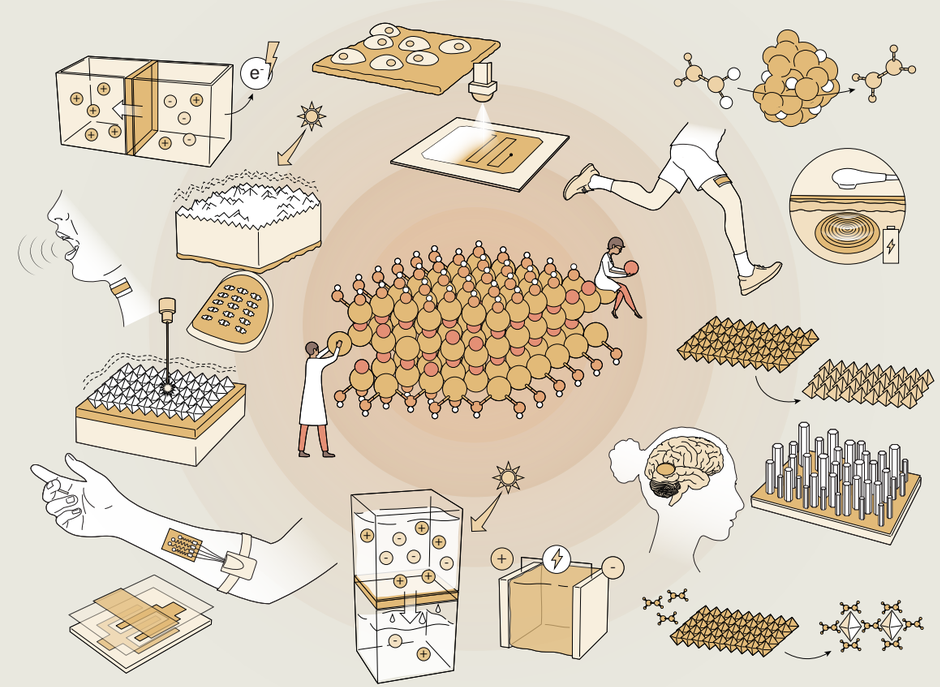
With materials scientist Stefaan De Wolf, the team developed a process to coat MXenes onto commercial 6-inch silicon solar cells. "We tested MXene and silver solar cells side by side and got exactly the same efficiency of 20 percent," Alshareef says. The team is now working to repeat the feat with tandem silicon-perovskite solar cells.

Seeing the light

Photodetector materials, which convert incoming light into an electrical signal, are used in many sensing and imaging applications. MXenes have great potential for photodetector devices, suggests research by collegues Alshareef and Omar Mohammed.

"Conventional photodetectors use a semiconductor for light detection, but MXene photodetectors work a little differently," Alshareef explains. "Light absorption in MXenes happens by exciting electron oscillations called surface plasmons," he says. "Surface plasmons can excite electron-hole pairs in the material, which are swept across the device and collected as photocurrent."

A molybdenum based MXene proved particularly effective for photodetection, the team showed. "Some MXenes absorb in the infrared, a wavelength of light that passes through the skin, so it may have biomedical imaging applications," Alshareef says.



CODE OF COLLABORATION

A cross-disciplinary project has resulted in improved efficiency for seismic processing, with promising applications for the energy industry.

"Conversations that go beyond the boundaries of departmental meetings or thesis committees are where brilliant ideas are planted!" says KAUST's expert in high-performance computing David Keyes.

Before geoscientist Matteo Ravasi arrived at KAUST, he was checking out work by various groups and came across a matrix algorithm originally developed by Keyes's group for computational astronomy. He quickly recognized its potential for similar large datasets that are used in seismic imaging.

A major challenge facing the energy sector is finding efficient and precise ways to image and characterize the subsurface, such as the information required for extraction of oil and gas, but also for identifying optimal locations for green energy initiatives including offshore wind farms.

"The size and complexity of seismic datasets mean that imaging the subsurface is very computationally expensive, which has limited algorithmic developments," says Ravasi.

The researchers along with Ph.D. student Yuxi Hong, have now reworked Keyes's original code into a larger algorithm designed specifically for seismic processing. The algorithm can directly utilize data in their compressed form, improving efficiency while yielding high-quality subsurface products.

Collaboration is key to innovation, note the researchers. "You are twice as effective and twice as competent in a team," says Ravasi. "The campus is set up so that you can talk easily to one another; living and working together also helps."

There is now considerable interest in the team's work from the energy industry in Saudi Arabia. "We're all enjoying riding this particular wave, and hopefully we'll find more to collaborate on in future," says Ravasi.

WHERE I WORK: MUATH ALAMRI

From a childhood love of working with his hands to creating scientific tools that meet a very precise brief.

> My favorite part of the job is working in an environment of multiple cultures and different backgrounds.
>
> MUATH

I work as a computer numerical control (CNC) machinist at the Prototyping & Product Development Core Lab, where we support the KAUST research community by providing product design and fabrication solutions. We make the bespoke tools or components that researchers need to run their experiments. Almost every project is special or unusual in some way.

CNC machining uses computer-controlled machine tools to remove layers of material from a stock "workpiece" to produce a custom-designed part. It is the latest technology in manufacturing – faster and more accurate than conventional machining. CNC machining makes it possible to manufacture complicated designs and shapes in a wide range of materials, including metals, plastics, wood, glass, foam and composites.

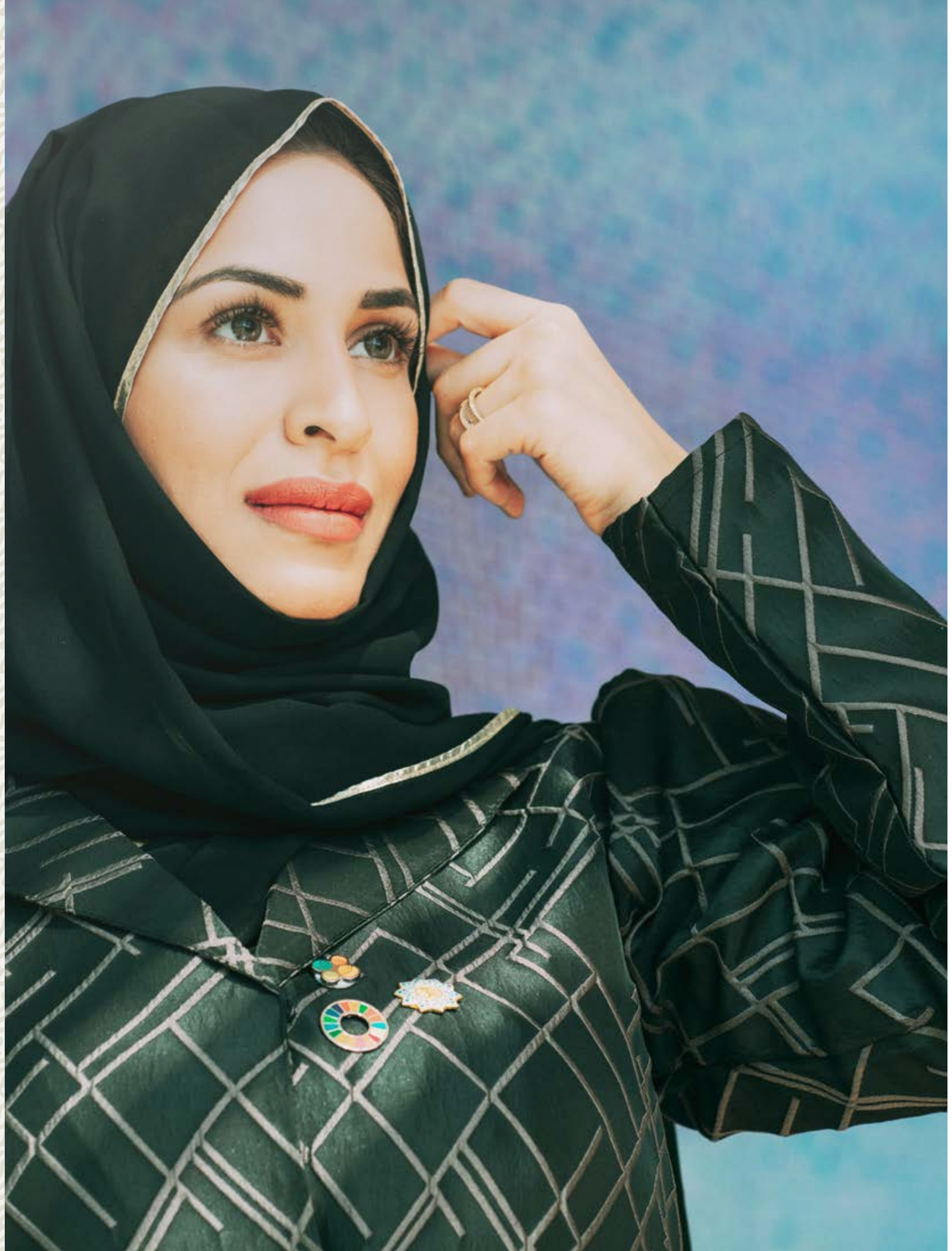
In this photo, taken at the Central Fabrication Lab where I mostly work, I am holding a stainless steel CNC-machined block called an optical window holder. This object, made for the Clean Combustion Research Center, is used to study processes inside internal combustion engines by allowing researchers to shoot a laser right into the combustion chamber.

This optical window holder was a very detailed design to manufacture. Its complicated shape required many machining steps and is a great example of what CNC machining technology is capable of. Conventional machining can't make such a design.

Growing up, I always loved making things, which led me to study manufacturing engineering technology. I then joined the Machinist Development Apprenticeship Program at KAUST. After an 18-month apprenticeship, I became a CNC machinist. If you like to work with your hands and manufacture things, this is a field with almost no limitations. You can make anything from a screw to a rocket!

Since most of my work is for research and development applications, every project has its own new or custom design to fabricate, so I have to switch gears quite often. My favorite part of the job is working in an environment of multiple cultures and different backgrounds.

Since I work with researchers, when they succeed, I succeed. It's a great feeling to know that I was able to contribute to that success.



13 CLIMATE ACTION

A predictive eye on the prize

Climate prediction models have had a mathematical makeover that has won attention from a computer science award.

A global weather prediction model built by KAUST researchers was nominated for the Gordon Bell Prize for outstanding achievements in high-performance computing.

The award honors innovative computing in science, engineering and large-scale data analytics, which is used in environmental modeling. "Climate prediction models require the fastest computers in the world," says Rabab Alomairy, a specialist in optimizing computer models for scientific applications. As part of her Ph.D., she joined a multidisciplinary team led by David Keyes that has built ExoGeoStat, a global weather prediction model powered by the world's second fastest supercomputer, Fugaku, at RIKEN in Japan.

Before moving into environmental prediction models, Alomairy had worked in acoustic scattering, fluid dynamics and bioinformatics. Her role in this project was to scale up the underlying mathematical models of existing geostatistical models to make them compatible with both current and future supercomputers. Keyes provided invaluable support throughout. "He is an expert in applied mathematics who understands the needs of climate scientists," says Alomairy. "He connected me with the right people, such as Hatem Ltaief – a specialist in high-performance algorithms who helped me build the linear algebra models – and Sameh Abdullah who built the statistical models."

Alomairy was one of the few team members entrusted to run their code in Fugaku. "Each run on a supercomputer can cost tens of thousands of dollars in operational costs, facility staff time and electricity bills," says Keyes, "so each run must be painstakingly prepared and monitored to avoid wasting a precious resource on a failed or irrelevant run." The latest version of ExoGeoStat can process weather data from 10 million locations in 90 minutes, compared with 18 hours for previous models, and uses it to predict phenomena such as wind, temperature and rainfall.

For Alomairy, submitting the work to the Gordon Bell Prize was an achievement in itself. "Participating in the awards was originally just a dream, but KAUST is a highly motivational place, and people encouraged me to enter," she says. "It felt like breaking the first barrier of something I thought was impossible, and when I heard we were finalists, I felt like I could challenge myself even further."

It is the first time in 35 years of the prize that a spatial statistics model made it to the final six, and Alomairy is determined to keep on improving the model. "This has proved that I can make it if I try, and winning does not seem impossible anymore," she adds.

Keyes and Alomairy hope that the nomination will attract even more experts to help develop the model. "KAUST is recognized internationally as a leading university for computational science and engineering," says Keyes. "Simulation and big data analytics are major sources of employment in countries prioritizing sustainability, and we hope that supercomputing apprenticeships like ours will be replicated worldwide."

Awards aside, the team hope that ExoGeoStat can be used to identify suitable sites for renewable energy and smart agriculture systems, such as wind farms, solar farms and greenhouses, which will help Saudi Arabia address climate, energy and food challenges to meet Saudi Arabia's Vision 2030 and its goal to achieve net zero by 2060.

"It feels like all of my hard work has been recognized by this nomination. I am finishing my Ph.D. on a very high note," concludes Alomairy.

Design school powers engineers in photovoltaic skills

A highly skilled workforce will be necessary to achieve Saudi Arabia's net zero goals.

A new short course for engineers in Saudi Arabia is helping to develop the expertise in photovoltaic solar design to achieve Vision 2030 sustainability goals.

An accredited photovoltaic design school has been developed through a partnership between the KAUST Solar Center and Saudi Electric Services Polytechnic, with support from the team at KAUST Innovation.

Saudi Arabia's Vision 2030 presents a pathway toward a sustainable future for the country, with a plan to reach net zero by 2060. This also fits with the UN Sustainable Development Goal for affordable and clean energy.

While solar radiation is in plentiful supply in Saudi Arabia, much interdisciplinary research, training and innovation are still needed for its large-scale implementation. A highly skilled and trained workforce will also be key to developing the necessary techno-economic environment.

As a way to achieve this objective, the Solar Center is collaborating with Saudi Electric Services Polytechnic — a leading vocational and professional training body — to establish a new accredited photovoltaic design school at KAUST.

"Vision 2030 promotes green and renewable energy and diversification of the Saudi economy from oil. What better way to participate in this collective effort than by providing young professionals working in the country with the right skillsets?" says Marios Neophytou, partnership specialist at the Center, who helps organize the photovoltaic design schools.

The goal of the design school is to train early-career engineers employed across industry and government to qualify them to work as photovoltaic designers in the country's industrial photovoltaic sector. "We need people who can understand the modeling, design and optimization and who also can analyze the performance of solar-based power plants based on new photovoltaic technologies," says Neophytou.

The combination of Saudi Electric Services Polytechnic's training expertise with the cutting-edge research and technology of the Solar Center is proving to be hugely popular. The design school is now being run several times a year to equip more Saudi engineers to work on designing photovoltaic systems.

The five-day course, first delivered in October 2021, includes classroom lectures combined with hands-on training, site visits and lab tours. So far, six sessions have been run with more than 100 engineers trained.

The initiative has brought together individuals from diverse professional backgrounds, including those trained in electrical, computer, chemical and civil engineering, material scientists, physicists and petroleum engineers from diverse companies and government bodies across the country.

The design school focuses primarily on grid-direct photovoltaic systems, the largest and fastest growing segment of the market, and also includes material critical to understanding local standards and regulations.

The course was designed to create a fundamental understanding of concepts such as system components, wiring, site analysis and mounting solutions, as well as safety and commissioning according to Saudi regulations.

Students are trained in activities like performing power and energy calculations and load analysis for grid-direct systems. They obtain hands-on experience in wiring and connecting solar panels or checking for defects and deteriorating performance and how to mount and design a solar park to avoid shadowing effects. Assessment is provided through daily practical exercises.

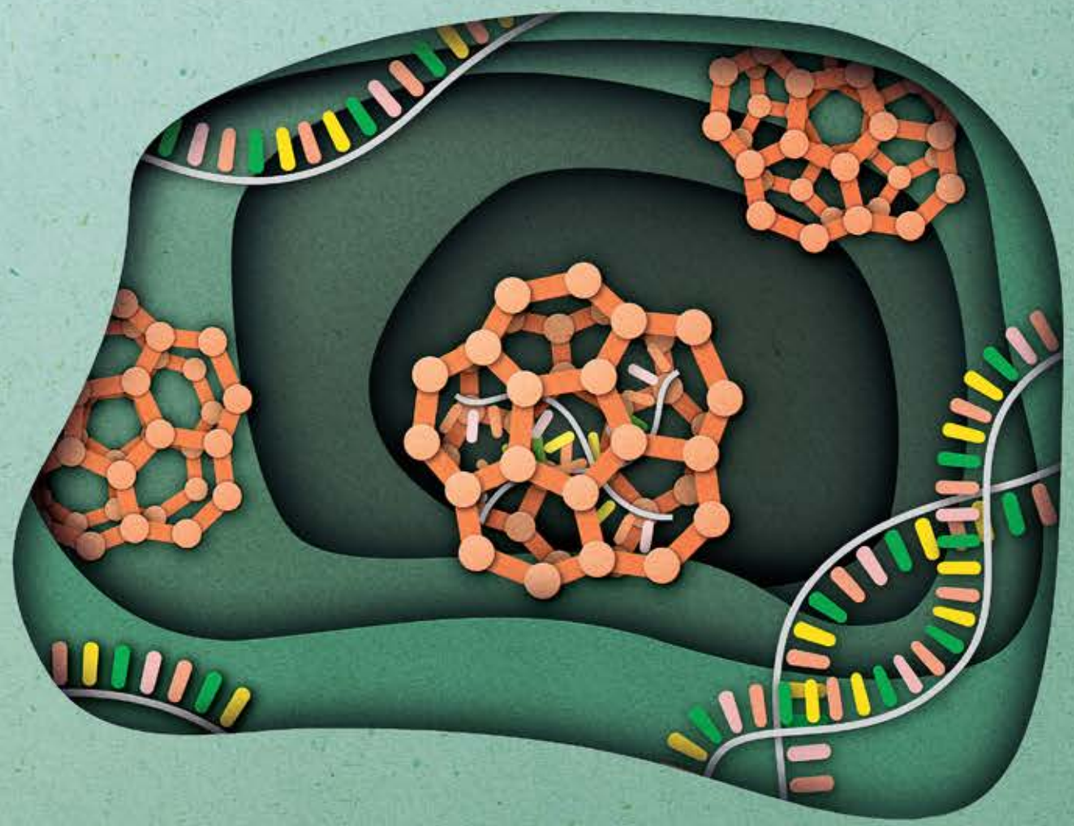
The theory and practical sessions are interspersed with on-site and lab visits — including to the Solar Center's lab facilities and KAUST central laboratories and Innovation Hub — where trainees observe and operate state-of-the-art equipment. They also visit KAUST's New Energy Oasis, where researchers are testing various photovoltaic technologies in real-world outdoor conditions.

Feedback from trainees after the course included the following:

- "Excellent training…and a very interactive learning experience. I have now obtained my certificate and am starting my own company…"
- "The course was excellent for its structure encompassing the practical aspects of photovoltaic design… The classroom combined with practical visits brought clarity to the topics discussed. Even for advanced learners, the course highlighted the real-world challenges in the field."
- "…helped me realize and close the knowledge gap from lab to real-world applications of photovoltaics."

"Through the already established photovoltaic design school, and the soon-to-be-launched photovoltaic installation training, the Center is playing a significant role in helping to develop the multidisciplinary workforce needed to achieve the sustainability aspirations of Vision 2030," says Interim Director of the Center, Frédéric Laquai.

4 QUALITY EDUCATION



Animated art takes small steps to communicate big concepts

A team uses stop motion art to break down the results of metal-organic framework research.

What is a metal-organic framework and why should the general public want to know? Even the best science communicators can struggle to simplify complex scientific concepts like this, especially ones that people may not interact with very often.

That is precisely what Weronika Bednarska does in her role as communications coordinator for KAUST's designated center for research on membranes and porous materials. When Niveen Khashab's lab published a study titled "DNA-mimicking metal-organic frameworks with accessible adenine faces for complementary base pairing," Bednarska knew she needed an innovative approach to explain this significant achievement to a broader audience.

"Bednarska knew she needed an innovative approach to explain this significant achievement to a broader audience."

She had an idea. Bednarska follows Polish biologist and science communicator Kasia Gandor on YouTube. "She uses different methods to explain complex concepts, including stop motion animation using cutouts from paper and simple drawings," explains Bednarska. "So, when I saw the study with DNA in its title, I made an immediate connection."

Stop motion is an animation technique that involves physically manipulating objects in small increments in individual video frames.

With support from Khashab, Bednarska worked with Ph.D. student Walaa Baslyman, who was involved in the study, to put together a script. "Walaa did a great job of breaking down the science into more simple concepts," says Bednarska. "This is a crucial step for me before starting any work: I need to understand the research I want to communicate."

She then went about making a video. "I had no clue how to do stop motion, but with help from Google, I tried. It was a bit frustrating, but I am happy with the results."

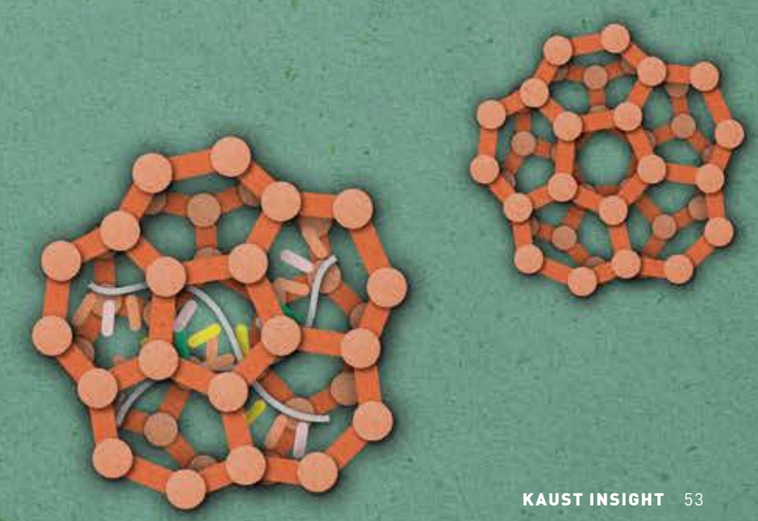
Baslyman then found herself responsible for narrating the video. "It was nice to do something different and still within the realm of my research," she says.

The short two-minute production uses colorful cutouts to explain the biologically inspired porous materials developed in Khashab's group to safely deliver single-stranded DNA into cell nuclei. These metal-organic frameworks are very promising for targeted gene delivery.

The video received more than 4,000 impressions during the first month following its launch on social media and generated lots of positive feedback.

Baslyman has often struggled to explain her research to her computer engineer sister and 16-year-old cousin, she says. "I probably get into too much chemistry, so I always lose them. But with this video, they both understood it very well. And now my cousin is even becoming interested in chemistry and material design."

Khashab encourages other labs to follow in her team's footsteps. "It is important that we make science accessible to everyone all the time, especially younger generations who might be intrigued by these scientific concepts."



Tech tackles a familiar pain in the neck

A tiny clip-on device that detects bad posture could help tackle "tech neck" and reduce back pain among office workers.

Smart headwear that monitors posture could help reduce neck and back pain caused by long periods of sitting at computers and using smartphones.

Studies indicate that people crane their neck at a 45-degree angle when texting on their phone, placing an enormous amount of strain on the spinal ligaments and other muscles. For many office workers, the gradual onset of neck or back pain eventually reminds them to readjust and stretch.

"The app alerts the wearer and provides relevant exercises to help alleviate pain and reduce the risk of future injuries."

When Ali Muqaibel from King Fahd University of Petroleum & Minerals visited KAUST in 2018, he got chatting with Faculty Tareq Al-Naffouri about a potential solution – a wearable device for monitoring posture. "The position of the head reveals a lot about a person's posture," says Al-Naffouri, "so we started exploring a device that can attach to oqals, the traditional headpieces worn by many Saudi men."

To advance the idea, Muqaibel and Al-Naffouri were joined by Ahmed Bader, a KAUST research fellow with a track record in commercializing new technologies, as well as some young talents from King Abdulaziz University in nearby Jeddah who had come to KAUST for an internship.

"When you work in a small team, each new member is a huge investment," says Bader, who acted as an advisor and mentor. "The three Jeddah graduates showed passion, tenacity and the ability to learn, so they were a great fit for the project."

The project was awarded KAUST's Impact Acceleration Grant to get things started. Guided by Bader's business experience and Al-Naffouri's electronics expertise, the team transformed what was a large and unattractive device designed only for Saudi men into a tiny tag that can be clipped

discreetly on any headwear, such as scarves, glasses or headphones.

"The team were quite attached to their original design, but it was too costly and bulky to take to market," says Bader. "They had to do a lot of hardcore electronics to shrink it."

The device has a sensor that monitors the angle and duration of head tilt and sends this data to a mobile app, which uses AI to assess the user's posture. If it is unhealthy, the app alerts the wearer and provides relevant exercises to help alleviate pain and reduce risk of future injuries.

"The team were quite attached to their original design, but it was too costly and bulky to take to market."

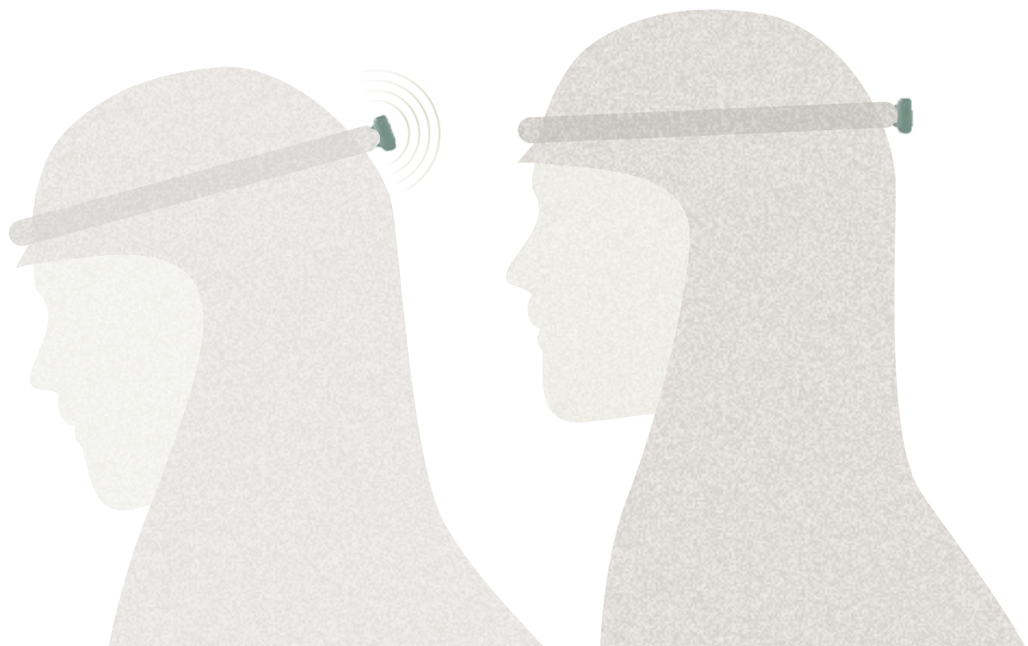
One of the graduates, Mohammed Shukri, who became the team's technical consultant after his internship in 2020, worked on the posture detection algorithm and the mobile app while learning the details of commercializing a tech product. "As well as helping me tackle the engineering challenges, KAUST's start-up environment taught me how to navigate funding and reach out to new business prospects," he says.

For Marya Bamkhramah, another of the graduates, being involved in product development from an early stage was a valuable and unique experience. "Working at KAUST allowed me to leave my comfort zone," she says. "We faced many technical issues in setting up the sensor, but together we've always found a solution." Getting the right components at an affordable price posed further challenges. "KAUST's support was essential here," says the third graduate Safwan Ibrahim, "as the team could access funds and resources that would otherwise have been unavailable."

Within two years, the young trio were leading the project, and in 2021 they launched a start-up called Qawam – an Arabic word signifying a healthy composure – to commercialize their product. The device, designed for office workers, is now in the hands of about 20 "friendly" users who are testing the product and providing feedback.

This is not the end of Qawam's journey because there are several other potential markets to explore, such as gamers, drivers and young children who often sit transfixed to a small screen. "We could also venture into rehabilitation and physiotherapy, as well as personalized coaching software," says Bader, adding "It's great to see technology being put to good use."

Despite their input, Bader and Al-Naffouri are not stakeholders in the project. Their return on investment is pride in what these young engineers have achieved so far and what they are poised to accomplish in the future. "This is not just another app," says Al-Naffouri. "It's an app with an accessory, and the effort involved in creating a physical product is tremendous."



©KAUST 2022; ANASTASIA SERIN

WHERE I WORK: VISWASANTHI CHANDRA

How studying ancient rocks may help to guide us toward a low-carbon-energy future.

Looking through a microscope at samples of Jurassic carbonate rock, millions of years old, you wouldn't believe the fascinating things I see there. Carbonate rocks are special, not only in the enigmatic way that they form, but in their beautiful complexity. Studying them up close is one of my favorite parts of my job.

The essence of my work at the Al-Naimi Petroleum Engineering Research Center is characterizing geomaterials for subsurface applications. Traditionally, the main application of this work is for analyzing fossil fuel reservoirs. We would assess how much hydrocarbon energy is in a reservoir, and where, and then determine the best way to extract it safely and economically.

As the world moves to renewable energy sources, I am eager to transition into sustainable-energy research. Today, in the context of KAUST's Circular Carbon Initiative, I apply my skills and knowledge toward a low-carbon-energy future. Applications of my work include carbon capture, utilization and storage, and geological storage of alternative fuels, such as hydrogen.

Visiting KAUST for the first time, it was clear to me that this university could provide an opportunity like no other to carry out this work. I am grateful to have access to the broad range of equipment we have at the Research Center and KAUST's central laboratories. The types of tools we use range from x-ray CT scanners, where we can visualize fluid flow through porous media, to high-resolution scanning and transmission electron microscopes. In the photo, you can see on the computer screen how we combine data from different tools to study our samples.

I am grateful to have access to the broad range of equipment we have at the Research Center and KAUST's central laboratories.

VISWASANTHI

As well as the ancient subsurface carbonates, more recently I have studied modern carbonates from the Red Sea and Arabian Gulf. In these modern carbonates, we see how microbes can impact the grains as they bore through, changing them chemically and mechanically.

Looking forward, I think that a big part of the next phase of my work will be carbon capture, utilization and storage, and sustainable-energy research. It will be a beautiful combination of the knowledge we gained from pore-scale studies of rocks and our work on the role of microbes in modern carbonates. I am looking forward to applying everything we have learned so far to these projects.

SPARKS OF INSPIRATION

Curiosity and perseverance combine to unmask the mystery metal at the heart of a green-fuel-forming reaction.

In the kitchen, microwaves and metals do not mix. But with careful handling in the lab, the results can be spectacular. Research scientist Jeremy Bau has used an under-appreciated microwave-based method, electron paramagnetic resonance spectroscopy, to capture an elusive molybdenum-hydrogen bond.

The finding settles a nearly two-decade-long debate on molybdenum's role in an electrocatalyst that splits water molecules to produce clean hydrogen fuel. "The goal is to provide a strong rationale for why we can replace expensive platinum catalysts with molybdenum, a relatively common industrial metal," says Bau. "Economically and environmentally this would be a huge upgrade."

Molybdenum's role in the reaction had remained an enigma, limiting efforts to design improved catalysts. One possibility was that molybdenum +3 ion was the catalytically active species. "I thought it was an interesting idea, and Jeremy's combination of skills and enthusiasm were ideal for the project," says catalyst researcher Magnus Rueping.

The initial challenge was to get an electrochemical cell inside an electron paramagnetic resonance machine to check for the target ion. "This machine uses microwaves to probe a sample, so putting electrically conductive things in there is a little like when your younger brother puts aluminum foil in the microwave," Bau says.

Working with scientist Abdul-Hamid Emwas, Bau built an electrochemical cell to go inside the machine. The breakthrough came with use of the catalyst material, molybdenum sulfide. "It was one of those chance discoveries where you know you have found something big, even though you don't yet understand the full implication."

The team showed that the broadened peak was due to the molybdenum-hydrogen bond, confirming the metal's direct role in the reaction.

Investigations into the applications of the discovery are continuing. "Electron paramagnetic resonance is a little complicated, but for studying electrochemistry mechanisms it can be helpful," concludes Bau. Rueping adds, "I like to support my students and postdocs when they come up with new ideas, and this is an example where it has turned out wonderfully."

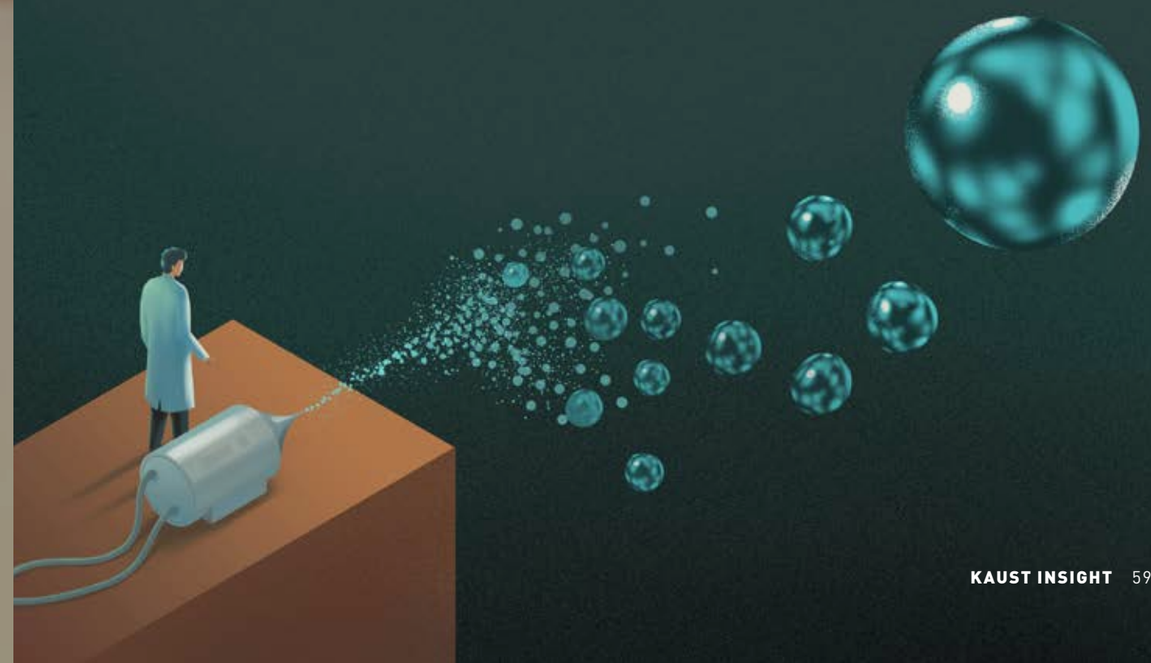
Perseverance douses debate

After a year-long effort, researchers settle controversial claims about water microdroplets.

"Think about drops of water in their natural context, which is in the clouds," says Himanshu Mishra, an expert in water interfaces. "If you do a rough calculation, the surface area of all those droplets is close to 50 times that of the planet itself. Any chemical reaction involving water surfaces can become quite significant on these droplets, much more than on the ocean surface, for example."

In 2019, Mishra became aware of a new study that could upend conventional understanding of water surfaces. A team from Stanford University reported that fine sprays of water, containing droplets no more than 20 micrometers wide, could spontaneously generate hydrogen peroxide — an energetically unfavorable chemical reaction that normally requires catalysts to be successful.

> "If you do a rough calculation, the surface area of all water droplets is close to 50 times that of the planet itself."



The Stanford team postulated that ultrahigh electric fields at the microdroplet interface could pry electrons away from water molecules, leading to peroxide formation. But to Mishra, this explanation failed to add up.

"Why would the surface of water do that?" asks Mishra. "If it has something to do with the polarity of the oxygen-hydrogen bond, then you would imagine the same features should appear in methanol and other alcohols."

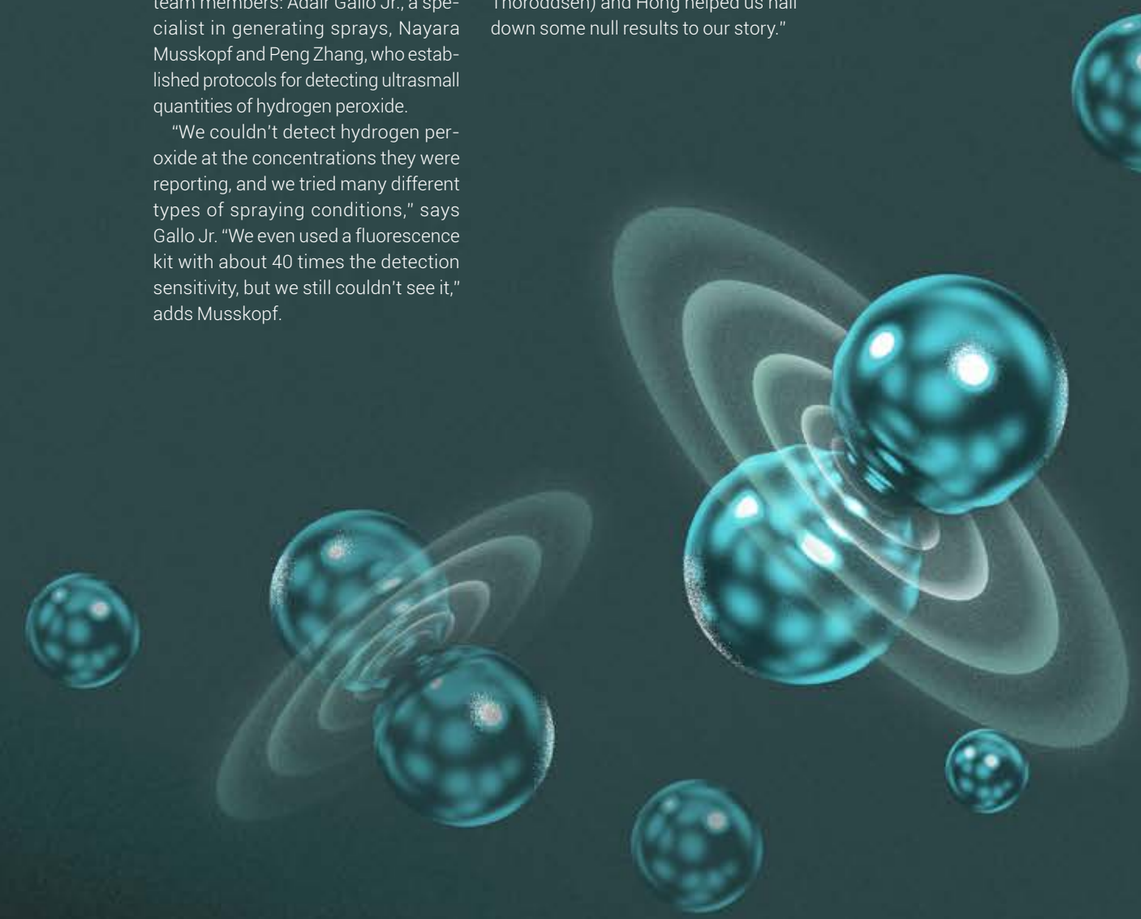
From previous experience studying water sprays, Mishra knew that such microdroplets needed to be characterized with a combination of techniques to eliminate the possibility of artifacts influencing the experimental results. For this task, he enlisted three of his team members: Adair Gallo Jr., a specialist in generating sprays, Nayara Musskopf and Peng Zhang, who established protocols for detecting ultrasmall quantities of hydrogen peroxide.

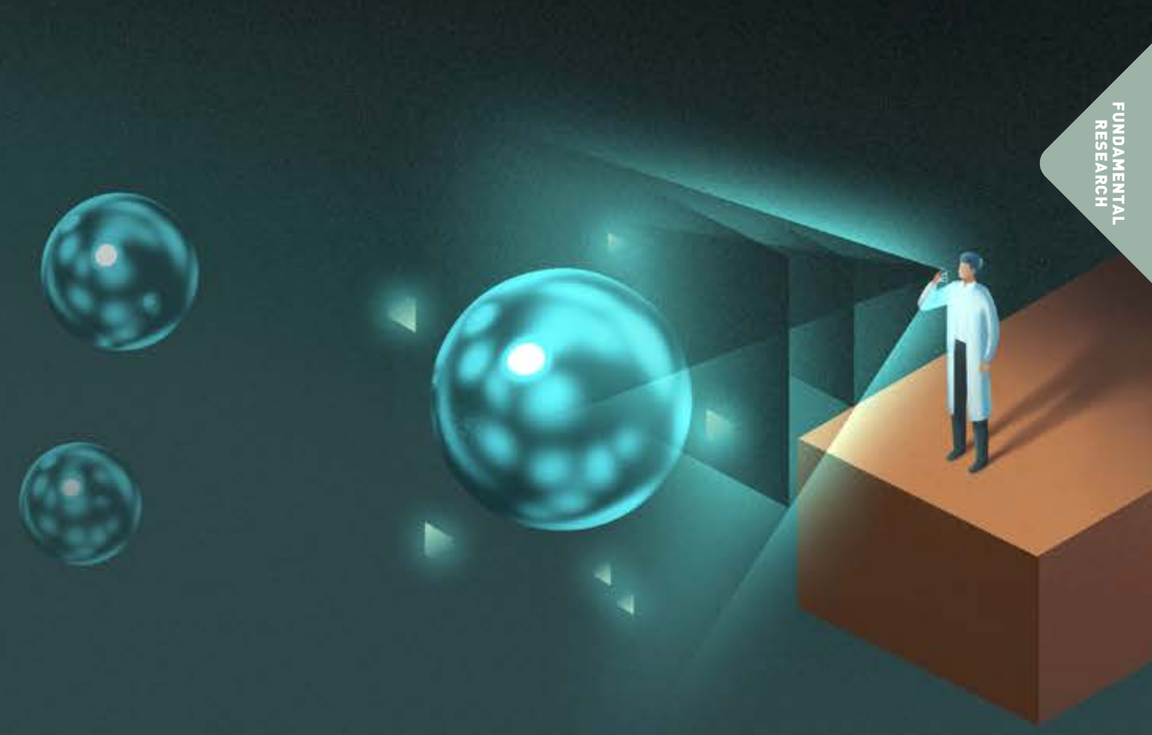
"We couldn't detect hydrogen peroxide at the concentrations they were reporting, and we tried many different types of spraying conditions," says Gallo Jr. "We even used a fluorescence kit with about 40 times the detection sensitivity, but we still couldn't see it," adds Musskopf.

Next, the team turned to their colleagues to help sort out the peroxide puzzle. "We thought that it might have something to do with the shockwaves generated by the sprays," recalls Mishra. "We requested mechanical engineer Hong Im and his team to carry out simulations of the problem and, with fellow mechanical engineer Sigurdur Thoroddsen and his team, we tried to examine the microdroplets with high-speed imaging."

Even with the extra brainpower on the case, the researchers could not find evidence of hydrogen peroxide. "There were some shockwaves," says Mishra, "but those conditions were pretty mild and not strong enough to drive spontaneous chemistry. Siggy (Sigurdur Thoroddsen) and Hong helped us nail down some null results to our story."

"We thought that it might have something to do with the shockwaves generated by the sprays."





"When you're claiming something about water that's almost like alchemy, you really have to drill down and check with multiple techniques before changing the chemistry textbooks."

After a year of experiments that seemed to go nowhere, even the most dedicated researchers would begin to have doubts. "I think I resigned from the project at least twice," admits Gallo Jr. "We really didn't want to face this anymore."

Eventually, serendipity came in the form of a 40-year-old article about atmospheric chemistry. While studying the paper, Mishra came across a paragraph mentioning artifacts that can influence peroxide studies — one of them being ozone molecules.

"When I read this, I just jumped and ran to my lab to tell Adair. We have an ozone generator, we turned it on with the water microdroplets, and for the first time, our peroxide detection strip changed color," recalls Mishra. "We deduced that there is just more ozone in the Stanford lab, and in the air in California generally, because of pollution."

Recently, the Stanford researchers admitted that ozone may be behind the anomalous generation of hydrogen peroxide signals and are now taking great care to eliminate the molecule from microdroplet experiments.

"When you're claiming something about water that's almost like alchemy, you really have to drill down and check with multiple techniques before changing the chemistry textbooks," says Mishra.

Creating an algal innovation bloom

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

KAUST provides crucial support to scientists using algae to produce a range of valuable chemicals.

Algae, although just single-celled aquatic organisms, are tricky to grow under laboratory conditions. Because these small oxygen-producing powerhouses have such diverse potential, KAUST researchers and craftsmen have developed a bespoke laboratory setup to reproduce the conditions needed by algal species for optimal growth.

Biotechnologist Kyle Lauersen leads a specialized lab that applies algal biotechnology implementation for the Arabian Peninsula. The research team uses synthetic biology and engineering to pursue their work in bioprospecting new algal species, developing cultivation infrastructure and generating useful products from algae.

"Our lab is focused on innovation at all levels of the algal biotechnology space," says Lauersen, which enables them to generate a diverse portfolio of products from microalgae. "With the help of KAUST's central laboratories, we developed and maintained the specialized laboratory infrastructure that we needed to cultivate these light-driven organisms."

The difficult part of culturing algae in the lab is providing them with enough light to grow well. Algae need bright, consistent light for photosynthesis. The electrical and fabrication teams built customized illuminated shelving and storage for Lauersen's lab using LED lighting tubes to create a spectrum that emulates sunlight.

Algae are healthiest grown under specific concentrations of air and carbon dioxide. This requires precise control over air and carbon dioxide input flow rates using pairs of gas mixers that were mounted and installed by the central and electrical workshop teams.

"We work at a very specific interface that requires appropriate light and gassing brought to the cultures," says Lauersen. "We also rely on specialized transparent glass vessels to grow algae, and so we're delighted that KAUST has its own glassblowing workshop and training program."

Some algae are extremophiles that thrive at the edges of acidic hot springs. The team developed double-layered glass tubes, where the outer chamber of each tube contains water that is kept at precisely 42 degrees Celsius to ensure that the algae growing in the inner chamber stay healthy.

"These particular algae are fascinating. They are red algae in terms of their genetic lineage, but they are colored green, and if you break them open, they give off a blue pigment into the water; they're pretty fun!" says Lauersen.

"Our lab is focused on innovation at all levels of the algal biotechnology space."

"We have a brilliant glassblowing team with master glassblowers in residence and several apprentices – they can make anything," says Lauersen. "I asked master glassblower Emilio Harina to copy these tubes and make us some new ones; he only took a week to make them all. It was incredible, and it saved us considerable time and resources."

©KAUST 2022; ANASTASIA SERIN

WHERE I WORK: THOMAS ALLEN

An inspirational science teacher sparked a career in solar energy.

> **"I still find it amazing that you can stick a thin sliver of silicon out in the sun and generate electricity: it's extraordinary."**
>
> THOMAS

Solar cells first caught my interest as a high school student, growing up in a small town in the snowy mountains of Australia. My physics teacher was really into solar energy and had installed a solar battery system; I just had an affinity for it. I still find it amazing that you can stick a thin sliver of silicon out in the sun and generate electricity — it's extraordinary.

Even when I went to university to study, solar cell technology was quite fringe. People didn't really know about it. Today, it is a multibillion-dollar industry, the fastest growing deployed electricity generation technology in the world and still growing at an incredible rate. I remember when solar was the most expensive way to generate electricity. Now, it is the cheapest, and the technology is still improving.

As a research scientist in Stefaan De Wolf's lab, my work is focused on an emerging technology called a tandem solar cell. We essentially make a silicon solar cell and then add another solar cell made of a semiconductor called perovskite on top of it. The perovskite absorbs blue light best, whereas the silicon absorbs red light best. Combined, they can capture more of the energy in the sunlight than either cell can by working alone.

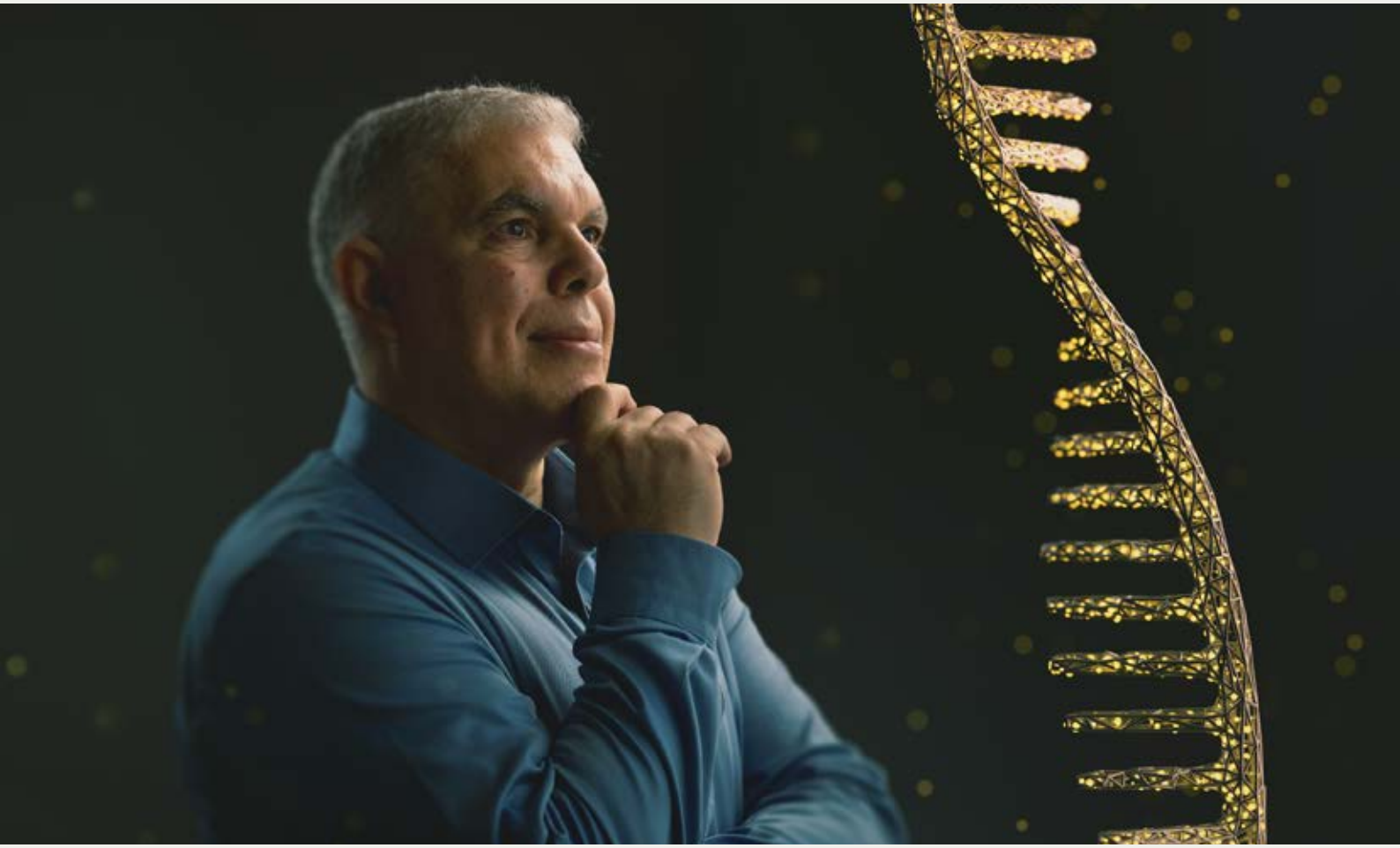
A tandem cell needs a physical electrical connection between the two solar materials. I develop and test materials that can form that connecting layer, aiming to identify materials that maximize the efficiency and working lifetime of the tandem device. In the photo, I am holding a thin film of nanocrystalline silicon that is ready to be tested as the connecting layer.

When I first joined Stefaan's group five years ago, he was just establishing his labs at KAUST. It was great to be a part of it — on the ground floor — as Stefaan was setting up the lab and all that entails in terms of navigating a research direction. Stefaan is very open and collaborative, the kind of guy who considers your opinion and appreciates it. We started out making silicon cells that converted solar energy into electricity with less than 20 percent efficiency. Today, we are making tandem solar cells reaching up to around 30 percent efficiency.

Silicon perovskite tandem technology is starting to get a lot of interest in the solar-cell-manufacturing community. I'd like to stay at KAUST for at least another year or two, and from there maybe get a job in industry. That would be a great next step for me.

KAUST INSIGHT
THE STORY BEHIND THE DISCOVERY

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology



"In 5-10 years, I hope to find myself in a place where people are trained to use smart technologies to solve clinical problems that are important for the country. We endeavor to be a catalyst that will support the country's transition from traditional medicine to precision and personalized medicine."

Imed Gallouzi

#KAUSTResearch

Show **Tell** Share

Go to insight.kaust.edu.sa and follow us on these channels to learn more:

KAUST Research @KaustResearch kaust_research

insight.kaust.edu.sa