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A SMART PILLOW THAT
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Oğuzlar Mah. 1374 Sok. No:2/4

Balgat - Ankara TURKEY

Tel: +90 312 342 22 45

Fax: +90312 342 22 46

bilgi@labmedya.com

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HUMMINGBIRDS MAY STRUGGLE TO EVADE CLIMATE CHANGE

New research shows that hummingbirds would struggle to cope if climate changes drives them to much higher elevations.

Any animal ascending a mountain experiences a double whammy of difficulties: the air gets thinner while it also becomes colder, which is particularly problematic for creatures striving to keep warm when less oxygen is available. For tiny animals with the highest-octane lives, such as hovering hummingbirds, the challenges of migrating to higher levels to evade climate change may be too much, but no one knew whether these incredible aviators may have more gas in the tank to keep them flying at higher altitudes.

As Anna's hummingbirds (*Calypte anna*) are comfortable up to elevations of 2,800 m (9200 feet), Austin Spence from the University of Connecticut, USA, and Morgan Tingley from the University of California, Los Angeles, USA, were curious to find out how hummingbirds that originated from close to sea level and those that live at the loftier end of the range would cope when transported well above their natural habitat to an altitude of 3,800m (12,500 feet). They published their discovery in the *Journal of Experimental Biology* that the birds struggle to hover and suffer a 37% drop in their metabolic rate at

that height – in addition to becoming torpid for most of the night to conserve energy – making it unlikely that they can relocate to higher altitudes.

To find out how the agile aeronauts fared at high altitudes, Spence first lured the animals into net traps, from sites 10m (33 feet) above sea level (Sacramento, CA) up to 2,400m (7,900 feet) (Mammoth Lakes, CA). Then he and Hannah LeWinter (Humboldt State University, USA) transported them to an aviary in western California at 1,215m (4,000 feet). Once the birds had spent a few days in their new home, the scientists set up a tiny funnel into which the birds could insert their heads as they hovered while sipping tasty syrup, and measured the birds' O₂ consumption (metabolic rate).

Spence and LeWinter also measured the hummingbird's CO₂ production (another measure of metabolic rate) overnight, as the tiny creatures allowed their metabolism to tumble when they became torpid – a form of mini hibernation – to conserve energy while they slept. Then, the duo relocated the birds to a nearby research station near the peak of Mount Barcroft, CA

(3800m/12,500 feet) where the air is thinner (39% less oxygen) and colder (5°C), and after 4 days at the new altitude, Spence and LeWinter remeasured the birds' metabolic rates as they hovered and how often and deeply the birds went into torpor as they slumbered.

Even though the hovering hummingbirds should have been working harder to remain aloft in the thin air 1000m above their natural range, the birds actually experienced a 37% drop in their metabolic rate. And when the team compared the energy used by birds that originated close to sea level and from the higher end of their range, they all struggled equally on the mountain top. "Overall, these results suggest low air pressure and oxygen availability may reduce hovering performance in hummingbirds when exposed to the acute challenge of high-elevation conditions," says Spence.

In addition to struggling to hover, the birds resorted to dropping their metabolic rate and became torpid for lengthier periods at night, spending more than 87.5% of the chilly high-altitude night in torpor. "It means that even if they're from a warm or cool spot,

they use torpor when its super-cold, which is cool," says Spence. And when the team checked the size of the animals' lungs, to find out whether the birds that originated from higher altitudes had larger lungs to compensate for their meager oxygen supply, they did not. But the birds did have larger hearts to circulate oxygen around the body.

What does this mean for the hummingbird's future as climate change forces them to find more comfortable conditions? "Our results suggest lower oxygen availability and low air pressure may be difficult challenges to overcome for hummingbirds," says Spence, meaning that the birds will likely have to shift north in search of cooler climes.

Reference: "Anna's hummingbird (*Calypte anna*) physiological response to novel thermal and hypoxic conditions at high elevations" by Austin R. Spence, Hannah LeWinter and Morgan W. Tingley, 26 May 2022, *Journal of Experimental Biology*.

DOI: 10.1242/jeb.243294



EATING A CERTAIN PROTEIN IS RELATED TO DEVELOPING DEPRESSION

A new study shows, in humans, mice, and flies, that elevated plasma levels and a diet rich in the amino acid proline cause a more severe state of depression.

Amino acids are monomers that are the building blocks of protein. When a person consumes food containing protein, the protein is broken down into amino acids by the digestive system. To carry out bodily functions, the body then combines the amino acids in different ways. There are 20 different amino acids, of which 9 are considered essential amino acids because they cannot be made by the body and must come from food.

Newly released research confirms the link between a certain amino acid called proline and depression. Proline is a nonessential amino acid and is found in grass-fed beef, pasture-raised chicken, gelatin, bone broth, organ meats like liver, and cage-free egg yolks. According to the study, a diet rich in proline is linked to an increased risk of depression.

Researchers from Girona Biomedical Research Institute (IDIBGI) and Pompeu Fabra University (UPF) in Barcelona, Spain, have discovered the role of an amino acid in depression in humans, mice, and flies. It is proline, an amino acid found in a broad range of foods such as gelatin, grass-fed beef, and wild-

caught fish. The findings, published in the scientific journal *Cell Metabolism*, also link a proline-rich diet to an increased risk of developing depression.

Dr. José Manuel Fernández-Real and Dr. Jordi Mayneris-Perxachs from the IDIBGI and CIBEROBN research groups on Nutrition, Eumetabolism, and Health led the study, as did Dr. Rafael Maldonado from the Pompeu Fabra University Neuropharmacology-Neurophar research group, which is affiliated with the Hospital de la Mar Medical Research Institute (IMIM).

To reach these conclusions, on the one hand, the type and amount of amino acids in the diet of the participants were analyzed. Participants also completed a questionnaire to measure their depressive mood. "We were surprised that what was most associated with depression, evaluated through this questionnaire, was the consumption of proline," says Dr. Fernández-Real, of the IDIBGI, and also head of the Endocrinology Section at Hospital Dr. Josep Trueta in Girona and director of the Department of Medical Sciences at the University of Girona. Confirming this, when

plasma metabolomics was evaluated, the concentration of proline emerged as one of the metabolites most associated with indicators of depression.

PROLINE LEVELS, DEPENDING ON THE MICROBIOTA

But not everyone who had a high intake of proline was more depressed. When studying these people's intestinal microbiota, a relationship was also observed between depression and bacteria, as well as between depression and bacterial genes associated with proline metabolism.

Thus, it was observed that circulating proline levels depended on the microbiota. "The microbiota of patients with high proline consumption but low plasma levels of proline was similar to the microbiota associated with low levels of depression and was enriched in bacterial genes involved in the transport and metabolism of proline," states Dr. Mayneris-Perxachs, a Miguel Servet researcher at the IDIBGI.

To find out if the presence of proline was a cause or a consequence of depressive mood, participants' microbiota was transplanted into mice. The rodents that

became more depressed had received the microbiota of participants with high proline, or more depressed subjects. Different genes associated with the transport of proline were also found in the brains of these mice. "The possibility of transferring the depression phenotype from humans to mice through microbiota transplantation and the demonstration that such transplantation generates alterations in proline transport reveals that this proline may be associated causally with depression," explains Dr. Maldonado, of UPF.

Another confirmatory experiment was carried out using fruit flies (*Drosophila melanogaster*), in which a more depressive mood can be induced. The researchers isolated two types of bacteria from the microbiota associated with proline consumption and added them to the flies' sterilized feed. Flies that ingested food with *Lactobacillus*, which in mice was associated with less depression, showed they were more willing to overcome difficulties they faced afterward. In contrast, those that ingested *Enterobacter*, which is associated with depression in humans, were much more depressed.

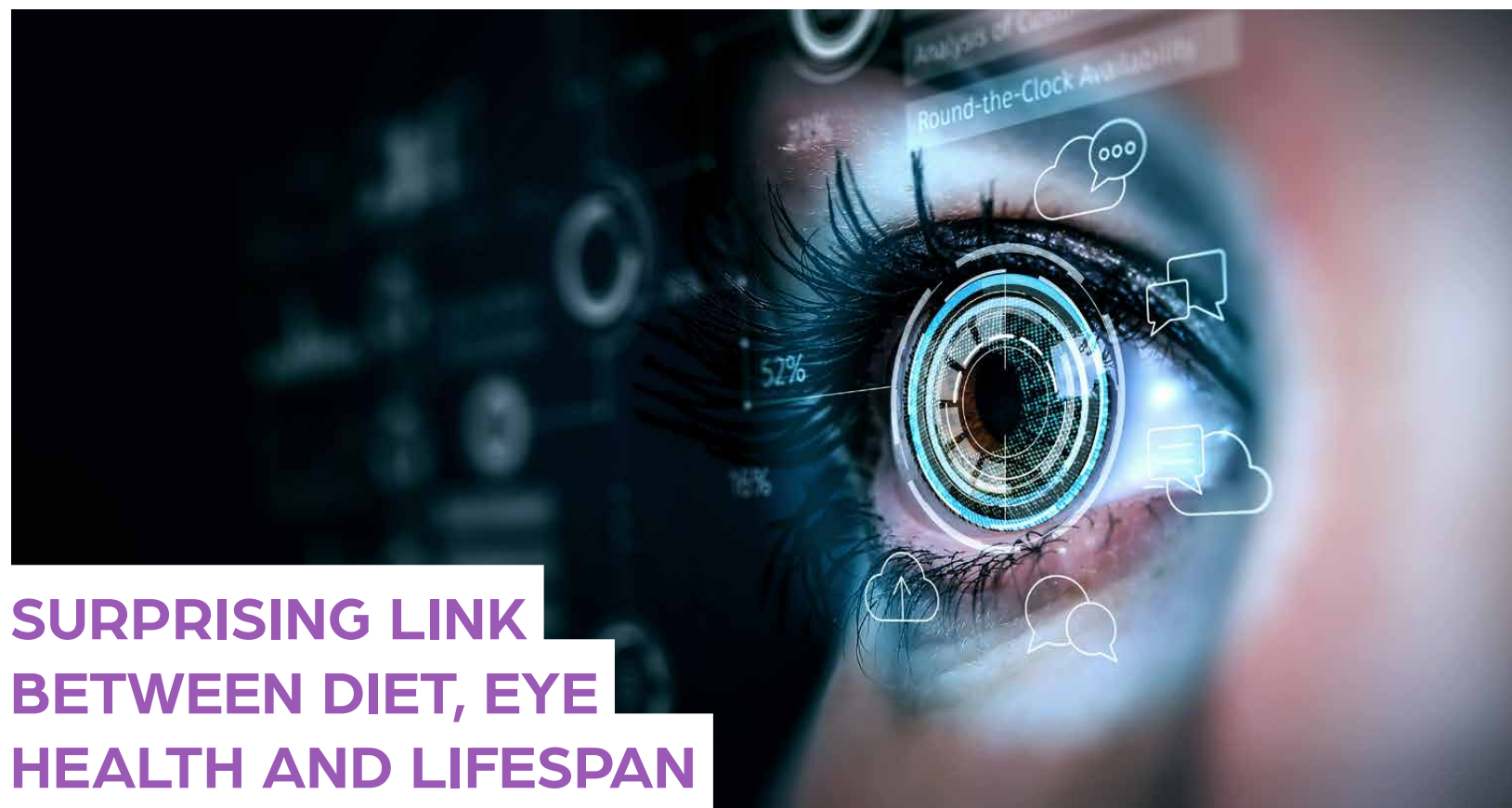
Finally, the same experiment was performed on genetically modified flies to eliminate the channels that carry proline to the brain. In this case, the proline was unable to reach the brain, and the flies proved to be highly resilient to depression.

THE IMPORTANCE OF PROLINE IN FUTURE TREATMENTS

"These results demonstrate the importance of proline and its influence on people's depressive mood, which so far had not been taken into account," highlights Dr. Fernández-Real. The study also opens the way for new studies to find possible diet-based treatments for depression.

This study has also enjoyed the collaboration of researchers from the FISA-BIO Foundation, the Lleida Biomedical Research Institute (IRBLleida), and the Institute for Integrative Systems Biology (I2SysBio) of the University of Valencia and the CSIC.

Reference: "Microbiota alterations in proline metabolism impact depression" by Jordi Mayneris-Perxachs, DOI: 10.1016/j.cmet.2022.04.001



SURPRISING LINK BETWEEN DIET, EYE HEALTH AND LIFESPAN DISCOVERED



In an experiment on flies, scientists discovered that the aging process is driven by processes in the eye.

Scientists have demonstrated for the first time a link between diet, circadian rhythms, eye health, and lifespan in *Drosophila*. Publishing in the June 7, 2022 issue of the journal *Nature Communications*, the researchers from the Buck Institute additionally and unexpectedly found that processes in the fly eye are actually driving the aging process.

Previous studies have shown in humans that there is an association between eye disorders and poor health. "Our study argues that it is more than correlation: dysfunction of the eye can actually drive problems in other tissues," said senior author and

Buck Institute Professor Pankaj Kapahi, PhD, whose lab has demonstrated for years that fasting and caloric restriction can improve many functions of the body. "We are now showing that not only does fasting improve eyesight, but the eye actually plays a role in influencing lifespan."

"The finding that the eye itself, at least in the fruit fly, can directly regulate lifespan was a surprise to us," said lead author, Brian Hodge, PhD, who did his postdoctoral studies in Kapahi's lab.

The explanation for this connection, Hodge said, lies in circadian "clocks," the molecular machinery

within every cell of every organism, which have evolved to adapt to daily stresses, such as changes in light and temperature caused by the rising and setting of the sun. These 24-hour oscillations — circadian rhythms — affect complex animal behaviors, such as predator-prey interactions and sleep/wake cycles, down to fine-tuning the temporal regulation of molecular functions of gene transcription and protein translation.

In 2016 Kapahi's lab published a study in *Cell Metabolism* showing that fruit flies on a restricted diet had significant changes in their circadian rhythms in addition to

extending lifespan. When Hodge joined the lab later that year, he wanted to dig deeper to figure out which processes that enhance circadian functions were altered by the diet change, and whether circadian processes were required for the longer lifespan seen with dietary restriction.

"The fruit fly has such a short lifespan, making it a really beautiful model that allows us to screen a lot of things at once," said Hodge, who is currently a scientist at Fountain Therapeutics in South San Francisco. The study began with a broad survey to see what genes oscillate in a circadian fashion when flies on an unrestricted diet

were compared with those fed just 10 percent of the protein of the unrestricted diet.

Immediately, Hodge noticed numerous genes that were both diet-responsive and also exhibiting ups and downs at different time points, or "rhythmic." He then discovered that the rhythmic genes that were activated the most with dietary restriction all seemed to be coming from the eye, specifically from photoreceptors, the specialized neurons in the retina of the eye that respond to light.

This finding led to a series of experiments designed to understand how eye function fit into the story of how

dietary restriction can extend lifespan. For example, they set up experiments showing that keeping flies in constant darkness extended their lifespan. "That seemed very strange to us," said Hodge. "We had thought flies needed the lighting cues to be rhythmic, or circadian."

They then used bioinformatics to ask: Do the genes in the eye that are also rhythmic and responsive to dietary restriction influence lifespan? The answer was "yes, they do."

"We always think of the eye as something that serves us, to provide vision. We don't think of it as something that must be protected to protect the whole organism," said Kapahi, who is also an associate adjunct professor of urology at UCSF.

Since the eyes are exposed to the outside world, he explained, the immune defenses there are critically active, which can lead to inflammation, which, when present for long periods of time, can cause or worsen a variety of common chronic diseases. Additionally, light in itself can cause photoreceptor degeneration which can cause inflammation.

"Staring at computer and phone screens, and being exposed to light pollution well into the night are conditions very disturbing for circadian clocks," Kapahi said. "It messes up protection for the eye and that could have consequences beyond just the vision, damaging the rest of the body and the brain."

There is much to be understood about the role the eye plays in the overall



health and lifespan of an organism, including: how does the eye regulate lifespan, and does the same effect apply to other organisms?

The biggest question raised by this work as it might apply to humans is, simply, do photoreceptors in mammals affect longevity? Probably not as much as in fruit flies, said Hodge, noting that the majority of energy in a fruit fly is devoted to the eye. But

since photoreceptors are just specialized neurons, he said, "the stronger link I would argue is the role that circadian function plays in neurons in general, especially with dietary restrictions, and how these can be harnessed to maintain neuronal function throughout aging."

Once researchers understand how these processes are working, they can begin to target the molecular clock to decelerate aging,

said Hodge, adding that it may be that humans could help maintain vision by activating the clocks within our eyes. "It might be through diet, drugs, lifestyle changes... A lot of really interesting research lies ahead," he said.

Reference: "Dietary restriction and the transcription factor clock delay eye aging to extend lifespan in *Drosophila*" 7 June 2022, Nature Communications.

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NEW TYPE OF MAGNETIC WAVE DISCOVERED ACROSS EARTH'S OUTER CORE

Scientists have discovered a completely new type of magnetic wave that sweeps across the outermost part of Earth's outer core every seven years.



While volcanic eruptions and earthquakes serve as immediate reminders that Earth's interior is anything but peaceful, there are also other, more elusive, dynamic processes taking place deep down below our feet. Using information from ESA's Swarm satellite mission, scientists have discovered a completely new type of magnetic wave that sweeps across the outermost part of Earth's outer core every seven years. This fascinating finding, presented today at ESA's Living Planet Symposium, opens a new window into a world we can never see.

Earth's magnetic field is like a huge bubble protecting us from the onslaught of cosmic radiation and charged particles carried by powerful winds that escape the Sun's gravitational pull and stream across the Solar System. Without our magnetic field, life as we know it could not exist.

Understanding exactly how and where our magnetic field is generated, why it fluctuates constantly, how it interacts with solar wind, and, indeed, why it is currently weakening, is not only of academic interest but also of benefit to society. For example,

solar storms can damage communication networks and navigation systems and satellites, so while we can't do anything about changes in the magnetic field, understanding this invisible force helps us to be prepared.

Most of the field is generated by an ocean of superheated, swirling liquid iron that makes up Earth's outer core 3000 km (1900 miles) under our feet. Acting like the spinning conductor in a bicycle dynamo, it generates electrical currents and the continuously changing electromagnetic field.

ESA's Swarm mission, which comprises three identical satellites, measures these magnetic signals that stem from Earth's core, as well as other signals that come from the crust, oceans, ionosphere, and magnetosphere.

Since the trio of Swarm satellites was launched in 2013, scientists have been analyzing their data to gain new insight into many of Earth's natural processes, from space weather to the physics and dynamics of Earth's stormy heart.

Measuring our magnetic field from space is the

only real way of probing deep down to Earth's core. Seismology and mineral physics provide information about the material properties of the core, but they do not shed any light on the dynamo-generating motion of the liquid outer core.

But now, using data from the Swarm mission, scientists have unearthed a hidden secret.

A paper, published in the journal *Proceedings of the National Academy of Sciences*, describes how a team of scientists detected a new type of magnetic wave that sweeps across the 'surface' of Earth's outer core – so where the core meets the mantle. This mysterious wave oscillates every seven years and propagates westward at up to 1500 kilometers (900 miles) a year.

Nicolas Gillet, from the University of Grenoble Alpes and lead author of the paper, said, "Geophysicists have long theorized over the existence of such waves, but they were thought to take place over much longer time scales than our research has shown.

"Measurements of the

magnetic field from instruments based on the surface of Earth suggested that there was some kind of wave action, but we needed the global coverage offered by measurements from space to reveal what is actually going on.

"We combined satellite measurements from Swarm, and also from the earlier German Champ mission and Danish Ørsted mission, with a computer model of the geodynamo to explain what the ground-based data had thrown up – and this led to our discovery."

Owing to Earth's rotation, these waves align in columns along the axis of rotation. The motion and magnetic field changes associated with these waves are strongest near the equatorial region of the core.

While the research exhibits magneto-Coriolis waves near seven-year period, the question of the existence of such waves that would oscillate at different periods, however, remains.

Dr. Gillet added, "Magneto-Coriolis waves are likely to be triggered by disturbances deep within the Earth's fluid core, possibly related

to buoyancy plumes. Each wave is specified by its period and typical length-scale, and the period depends on characteristics of the forces at play. For magneto-Coriolis waves, the period is indicative of the intensity of the magnetic field within the core.

"Our research suggests that other such waves are likely to exist, probably with longer periods – but their discovery relies on more research."

ESA's Swarm mission scientist, Ilias Daras, noted, "This current research is certainly going to improve the scientific model of the magnetic field within Earth's outer core. It may also give us new insight into the electrical conductivity of the lowermost part of the mantle and also of Earth's thermal history."

Reference: "Satellite magnetic data reveal interannual waves in Earth's core" by Nicolas Gillet, Felix Gerick, Dominique Jault, Tobias Schwaiger, Julien Aubert and Mathieu Ista, 21 March 2022, *Proceedings of the National Academy of Sciences*.

DOI: 10.1073/pnas.2115258119

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CONSEQUENCES OF CLIMATE CHANGE IN THE ALPS

Global warming has a particularly pronounced impact on the Alpine region. Like the Arctic, this European mountain range is becoming greener.



Scientists from the University of Lausanne and the University of Basel, writing in the journal *Science*, have now used satellite data to show that vegetation above the tree line has increased in nearly 80% of the Alps. Snow cover is also decreasing, albeit so far only slightly.

As the highest and most extensive mountain range system that lies entirely in Europe, the Alps are known for their majestic beauty. Many think of it as a pristine area that would be mostly free from the effects of human civilization. After all, Mont Blanc, the highest mountain in the Alps, reaches to a height of 4,809 m (15,778 ft) and 128 peaks are higher than 4,000 m (13,000 ft). Yet like the Arctic, the Alpine region is acutely feeling the impact of climate change.

It isn't just a matter of melting glaciers either. Satellite data shows that vegetation above the tree line has increased in nearly 80% of the Alps and snow cover is decreasing.

Melting glaciers have become a symbol of climate change in the Alps. Now, the reduction in snow cover

is already visible from space but this is by no means the biggest change. This is the conclusion of a research team led by Professor Sabine Rumpf from the University of Basel and Professor Grégoire Mariéthoz and Professor Antoine Guisan from the University of Lausanne.

Working with colleagues in the Netherlands and Finland, the researchers investigated the change in snow cover and vegetation using high-resolution satellite data from 1984 to 2021. Over this period, plant biomass above the tree line increased in more than 77% of the observed area. This phenomenon of "greening" due to climate change is already well documented in the Arctic and starts also to be detected in mountains.

The Alps stretch about 1,210 km (750 miles) across France, Switzerland, Monaco, Italy, Liechtenstein, Austria, Germany, and Slovenia. Greater plant biomass in three-quarters of the Alps

"The scale of the change has turned out to be absolutely massive in the Alps," says Sabine Rumpf, lead

author of the study and, since February, assistant professor at the University of Basel. The Alps are becoming greener because plants are colonizing new areas and the vegetation is generally becoming denser and taller.

Previous studies have primarily focused on the influence of global warming on Alpine biodiversity and changes in the distribution of plant species. Until now, however, no one had conducted such a comprehensive analysis of the changes in vegetation productivity in the Alps. The authors show that the increase of plant biomass is primarily due to changes in precipitation and longer vegetation periods as a result of rising temperatures.

"Alpine plants are adapted to harsh conditions, but they're not very competitive," says Rumpf. As environmental conditions change, she says, these specialized species lose their advantage and are outcompeted: "The unique biodiversity of the Alps is therefore under considerable pressure."

Already a slight reduction in snow cover

In contrast to vegetation, the extent of snow cover above the tree line has only changed slightly since 1984. For their analysis, the researchers excluded regions below 1,700 meters, glaciers, and forests. In the remaining regions, they found that snow cover had decreased significantly in almost 10% of the area. This may not sound like a lot, but the researchers are keen to highlight that it is nevertheless a worrying trend.

"Previous analyses of satellite data hadn't identified any such trend," explains Antoine Guisan, one of the two senior authors of the study. "This may be because the resolution of the satellite images was insufficient or because the periods considered were too short."

"For years, local ground-based measurements have shown a decrease in snow depth at low elevations," adds Grégoire Mariéthoz. "This decrease has already caused some areas to become largely snow-free." Based on the satellite data, it's possible to distinguish whether a specific area is covered with snow or not, but doesn't allow to draw

conclusions about snow depth.

As global warming continues, the Alps will turn more and more from white to green, creating a vicious circle: "Greener mountains reflect less sunlight and therefore lead to further warming – and, in turn, to further shrinkage of reflective snow cover," says Rumpf. Warming also causes further melting of glaciers and the thawing of permafrost, which may lead to more landslides, rockfalls, and mudflows. Furthermore, Rumpf emphasizes the important role of snow and ice from the Alps in the supply of drinking water and, not least, for recreation and tourism.

Reference: "From white to green: Snow cover loss and increased vegetation productivity in the European Alps" by Sabine B. Rumpf, Mathieu Gravey, Olivier Brönnimann, Miska Luoto, Carmen Cianfrani, Grégoire Mariéthoz and Antoine Guisan, 2 June 2022, *Science*.

DOI: 10.1126/science.abn6697



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A POTENTIAL CURE FOR AUTISM: GENE THERAPY COULD TREAT PITT-HOPKINS SYNDROME

A new study has shown that gene therapy may be able to prevent or reverse many deleterious effects of Pitt-Hopkins syndrome.



New research from the UNC Neuroscience Center lab of Ben Philpot, Ph.D., finds restoring lost gene activity prevents many disease signs in an animal model of Pitt-Hopkins syndrome, a rare, single-gene neurodevelopmental condition.

Pitt-Hopkins syndrome is a rare genetic condition caused by a mutation in the TCF4 gene on chromosome 18. Pitt-Hopkins syndrome is characterized by developmental delay, potential respiratory concerns such as episodic hyperventilation and/or breath-holding while awake, recurrent seizures/epilepsy, gastrointestinal difficulties, a lack of speech, and distinctive facial features. Children diagnosed with Pitt-Hopkins syndrome often have a happy and lively attitude with frequent smiling and laughing.

The prevalence of Pitt-Hopkins syndrome in the general population is unclear. However, some estimates place the frequency of Pitt-Hopkins syndrome between 1 in

34,000 and 1 in 41,000. The disorder affects both men and women and is not restricted to a single ethnic group.

Pitt Hopkins syndrome is classified as an Autism Spectrum Disorder, and some people who have it have been diagnosed with Autism, 'atypical' autistic characteristics, and/or Sensory Integration Dysfunction. Many researchers believe that treating Pitt Hopkins syndrome will lead to treatments for similar disorders because of its genetic link to autism and other conditions.

For the first time, researchers at the University of North Carolina School of Medicine have shown that postnatal gene therapy may be able to prevent or reverse many of the negative effects of Pitt-Hopkins syndrome, a rare genetic disorder. Severe developmental delay, intellectual disability, respiratory and movement abnormalities, anxiety, epilepsy, and moderate but distinctive facial abnormalities are all symptoms of this autism spectrum disorder.

The scientists, who published their findings in the journal eLife, created an experimental, gene-therapy-like technique to restore the normal function of the gene-deficient in people with Pitt-Hopkins syndrome. The medication prevented the onset of disease indicators such as anxiety-like behavior, memory impairments, and abnormal gene expression patterns in afflicted brain cells in newborn mice that would otherwise model the syndrome.

"This first, proof-of-principle demonstration suggests that restoring normal levels of the Pitt-Hopkins syndrome gene is a viable therapy for Pitt-Hopkins syndrome, which otherwise has no specific treatment," said senior author Ben Philpot, Ph.D., Kenan Distinguished Professor of Cell Biology and Physiology at the UNC School of Medicine and associate director of the University of North Carolina (UNC) Neuroscience Center.

Most genes are inherited in pairs, one copy from the mother and one from

the father. Pitt-Hopkins syndrome arises in a child when one copy of the gene TCF4 is missing or mutated, resulting in an insufficient level of TCF4 protein. Typically, this deletion or mutation occurs spontaneously in the parental egg or sperm cell prior to conception, or in the earliest stages of embryonic life following conception.

Only about 500 cases of the syndrome have been reported worldwide since it was first described by Australian researchers in 1978. But no one knows the syndrome's true prevalence; some estimates suggest that there could be more than 10,000 cases in the United States alone.

Since TCF4 is a "transcription factor" gene, a master switch that controls the activities of at least hundreds of other genes, its disruption from the start of development leads to numerous developmental abnormalities. In principle, preventing those abnormalities by restoring normal TCF4 expression as early as possible is the best treatment strategy

— but it hasn't yet been tested.

Philpot's team, led by first author Hyojin (Sally) Kim, Ph.D., a graduate student in the Philpot lab during the study, developed a mouse model of Pitt-Hopkins syndrome in which the level of the mouse version of TCF4 could be reliably halved. This mouse model showed many typical signs of the disorder. Restoring the full activity of the gene from the start of embryonic life fully prevented these signs. The researchers also found evidence in these initial experiments that gene activity needed to be restored in essentially all types of neurons to prevent the emergence of Pitt-Hopkins signs.

Next, the researchers set up a proof-of-concept experiment modeling a real-world gene therapy strategy. In engineered mice in which roughly half the expression of the mouse version of Tcf4 was switched off, the researchers used a virus-delivered enzyme to switch the missing expression back on again in neurons, just



diagnosis and treatment in utero," Kim said.

Philpot and his lab now plan to explore the effectiveness of their strategy when applied to Pitt-Hopkins mice at later stages of life. They also plan to develop an experimental gene therapy in which the human TCF4 gene itself will be delivered by a virus into a Pitt-Hopkins mouse model – a therapy that ultimately could be tested in children with Pitt-Hopkins syndrome.

"We'll be working on a gene therapy, but our results here suggest that there are other TCF4-restoring approaches that could work, including treatments that boost the activity of the remaining, good TCF4 copy," Philpot said.

The research was supported by the Ann D. Bornstein Grant from the Pitt-Hopkins Research Foundation, the National Institute of Neurological Disorders and Stroke (R01NS114086), the Estonian Research Council, and the Orphan Disease Center at the Perelman School of Medicine at the University of Pennsylvania (MDBR-21-105-Pitt Hopkins).

Reference: "Rescue of behavioral and electrophysiological phenotypes in a Pitt-Hopkins syndrome mouse model by genetic restoration of Tcf4 expression" by Hyojin Kim, Eric B Gao, Adam Draper, Noah C Berens, Hanna Vihma, Xinyuan Zhang, Alexandra Higashi-Howard, Kimberly D Ritola, Jeremy M Simon, Andrew J Kennedy and Benjamin D Philpot, 10 May 2022, eLife.

DOI: 10.7554/eLife.72290

after the mice were born. Analyses of the brains showed this restoration of activity over the next several weeks.

Even though the treated mice had moderately smaller brains and bodies compared to normal mice, they did not develop many of the abnormal behaviors seen in untreated Pitt-Hopkins model mice. The exception was innate nest-building behavior, in which the treated mice seemed abnormal at first, although their abilities were restored to normal within a few weeks.

The treatment at least partly reversed two other abnormalities seen in untreated mice: altered levels of the genes regulated by TCF4 and altered patterns of neuronal activity as measured in electroencephalograph (EEG) recordings.

"These findings offer hope that a future gene therapy will provide significant benefits to individuals with Pitt-Hopkins syndrome even when delivered postnatally; it won't require



SMARTWATCH FOR PLANTS

New 'smartwatch for plants' monitors water content in leaves and pings the owner

Sometimes it can be difficult to track whether a plant has had too much or too little water. Visual signs, such as shriveling or browning leaves, don't start until most of the plant's water is gone, while yellowing takes place after it has been drenched. To address this tricky dilemma, scientists have created a new 'smartwatch for plants', which monitors the water content in leaves and pings the owner when the plant is in need of a drink.

In a similar way to how smartwatches track the electrical activity of a wearer's heart through electrodes that sit against the skin, the wearable plant sensor can be attached to leaves. It then wirelessly transmits data to a smartphone app, allowing the owner to keep tabs on hydration levels.

The new 'wearable sensor' for plant leaves is the latest in a string of gadgets that claim to help gardeners monitor the health of their plants, which also include smartphone-connected soil sensors and 'smart' self-watering

plant pots'. Previously, researchers had developed metal electrodes to monitor water content in leaves, but the electrodes had problems staying attached, which reduced the accuracy of the data.

Researchers from the Brazilian Nanotechnology National Laboratory, led by Renato Lima, wanted to identify an electrode design that was reliable for long-term monitoring of plants' water stress, while also staying put. They created two types of electrodes: one made of nickel deposited in a narrow, squiggly pattern, and the other cut from partially burnt paper that was coated with a waxy film.

When the team affixed both electrodes to detached soybean leaves with clear adhesive tape, the nickel-based electrodes performed better, producing larger signals as the leaves dried out. The metal ones also adhered more strongly in the wind, which the researchers said was likely because the thin squiggly design of the metallic film

allowed more of the tape to connect with the leaf surface.

Next, the experts created a plant-wearable device with the metal electrodes and attached it to a living plant in a greenhouse. The device wirelessly shared data to a smartphone app and website, which revealed the percentage of water content lost.

The researchers say that monitoring water content on leaves can even indirectly provide information on exposure to pests and toxic agents. Because the plant-wearable device provides reliable data indoors, they now plan to test the devices in outdoor gardens and on crops to determine when plants need to be watered, potentially saving resources and increasing yields.

Reference: Biocompatible Wearable Electrodes on Leaves toward the On-Site Monitoring of Water Loss from Plants

<https://pubs.acs.org/doi/10.1021/acsami.2c02943>

A VICIOUS CYCLE OF OXYGEN LOSS THREATENS WATER QUALITY IN LAKES

Researchers recently confirmed that the world's lakes are rapidly losing oxygen. What does it mean for water quality that oxygen is declining globally?

Scientists have recently confirmed that the world's lakes are rapidly losing oxygen. With a seven-year, whole-ecosystem study, a team of freshwater scientists at Virginia Tech has been one of the first to take the next step in asking: What does it mean for water quality that oxygen is declining globally?

Sticky with sediment, the bottom waters of lakes are more than their deepest, darkest layer. They bury massive portions of the carbon, nitrogen, and phosphorus found in runoff rolling in from the land. As one of nature's critical nutrient sinks, lakes earn their reputation as "sentinels" of their surroundings, said freshwater scientist Cayelan Carey.

"We think of lakes as sentinels because they truly integrate all of the changes that happen on land," said Carey, an

associate professor of biological sciences at the Virginia Tech College of Science and an affiliated scientist with the Fralin Life Sciences Institute. "Lakes do this really great job of receiving and processing all of this carbon, nitrogen, and phosphorus, preventing them from going downstream and reaching the ocean."

But that work could be dismantled by anoxia, the loss of oxygen availability. Dreaded by scientists for years and recently confirmed as widespread by data from hundreds of lakes, anoxia is sucking oxygen from the world's fresh waters.

It's a phenomenon linked to the warming of waters brought on by climate change and to excess pollutant runoff from land use. Warming waters diminish fresh water's capacity to hold oxygen, while the breakdown of nutrients in the runoff

by freshwater microbes gobbles up oxygen.

In a seven-year field experiment that manipulated oxygen levels in the bottom waters of a nearby reservoir, Carey's team found that with anoxic conditions came effects they had expected: the sediments release a lot of nutrients and carbon. But they weren't as prepared for the extent of the changes. They observed the lake going from a sink — which retains more nutrients and carbon than it exports — to a source of nutrients downstream, starting a cycle in which anoxia in one lake could beget anoxia in another.

"I had no expectation that there would be this much change in water chemistry," Carey said. "And to see it consistently and to see it over the seven years of the study — the effect of anoxia was multiple orders of magnitude greater than

what I originally predicted."

FUSING FRESHWATER AND DATA SCIENCE

Making those discoveries relied on the team's design of an experiment that was novel in a few ways. It had to be done at whole-ecosystem scale, conducted not just with samples tested in a lab or in small enclosures of a lake's bottom waters, but with access to the whole body of water. Carey's team did field experiment in the Falling Creek Reservoir in Vinton, Virginia, where team members manipulated oxygen levels in the lake's bottom waters using an engineered oxygenation system that could withdraw water from the bottom, inject dissolved oxygen into it at super-saturated concentrations onshore, and return the oxygenated water to the bottom without altering water temperature.

Manipulating only the

oxygen levels in bottom waters, thus disentangling the effects from those of changing temperature, is crucial to understanding anoxia's impact, said Carey, a Roger Moore and Mojdeh Khatam-Moore Faculty Fellow in the College of Science. "By manipulating oxygen without altering temperature, we can understand and isolate what its effects will be. We can truly say that what we're seeing is a result of a changing oxygen and not due to other extraneous factors happening in the lake."

But analyzing anoxia's effects doesn't stop at upping or lowering oxygen levels and monitoring water chemistry. With a field experiment, there's always data you need but can't collect, Carey said. It's difficult to sample and measure "those nitty-gritty sediment-water interactions" without disturbing them in the field. There's also the issue of

logistics: Carey couldn't send someone to collect data every single day for seven summers.

So the team fed the data it had collected into a model Carey describes as a "video game of a lake," which simulated those important but tricky interactions. "Underlying the video game were a bunch of equations we could manipulate to understand which processes were most important when the reservoir had low versus high oxygen levels," she said.

The model also enabled the team to get data every hour. "That allowed us to be able to really understand how quickly the lake responded to changes in oxygen," Carey said.

A ROLE REVERSAL

The researchers observed huge changes to the concentrations of nutrients released from bottom waters with anoxia, including a six-fold increase in nitrogen export. Over time, the lake went from a net sink of phosphorus and carbon to a net source of both nutrients to downstream water bodies.

"What we saw was that the lake was unable to do its important job of serving as this sink of carbon, nitrogen, and phosphorus, as it would have done if there was oxygen there," Carey said. "The changes were really remarkable for all three of the elements individually, but we saw that in aggregate, the lake's ability to serve as this sink was really changing."

All of that carbon, nitrogen, and phosphorus, once buried at the bottom, was not only released up into the water column — which

potentially feeds toxic algal blooms, harms freshwater wildlife, and compromises reservoirs as drinking water sources — but the nutrients moved downstream, Carey explained. Herein lies the vicious cycle of anoxia begetting anoxia: As more nutrients reach other lakes, rivers, and streams, each waterbody's microbes will consume more and more

oxygen to break them down.

Knowing the severity of this impact should move us to act on land use, Carey believes. "Our study reveals this mechanism by which upstream lakes are harming downstream lakes, and if this is going on broadly, then we basically

have to do everything we can to protect lakes from receiving even more phosphorus, fertilizers, and sediments," she said. "I'm hoping we can light a fire with folks. These processes are happening that we didn't even know about."

Reference: "Anoxia decreases the magnitude

of the carbon, nitrogen, and phosphorus sink in freshwater" 25 May 202, Global Change Biology.

DOI: 10.1111/gcb.16228

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WORLD'S LARGEST PLANT 180 KM LONG

A single plant expanded to stretch 180 km. This makes it the world's largest known plant.



Somehow this single seedling grew to cover an area of 200 km² (77 miles²), stretching through waters that are quite different in temperature and salinity. Based on its size and growth rate, the researchers estimate that it is 4,500 years old.

These underwater seagrass meadows grow in two ways: by sexual reproduction, which helps them generate new gene combinations and genetic diversity, and also by extending their rhizomes, the underground stems from which roots and shoots emerge.

To find out how many different individual plants are growing in a seagrass meadow, you have to test their DNA. Researchers did this for meadows of ribbon weed seagrass called *Posidonia australis* in the shallow sun-drenched waters of the Shark Bay World Heritage Area, in Western Australia.

The result shocked the researchers: it was all one plant. One single plant has expanded over a stretch of 180 km (112 miles) making it the largest known plant on Earth.

Scientists collected shoot samples from ten seagrass meadows from across Shark Bay, in waters where the salt levels range from normal ocean salinity to almost twice as salty. In all samples, they studied 18,000 genetic markers

to show that 200 km² (77 miles²) of ribbon weed meadows expanded from a single, colonizing seedling.

HOW DID IT EVOLVE?

What makes this seagrass plant unique from others, other than its enormous size, is that it has twice as many chromosomes as its relatives. This makes it what scientists call a "polyploid."

Most of the time, a seagrass seedling will inherit half the genome of each of its parents. Polyploids, however, carry the entire genome of each of their parents.

There are many polyploid plant species, such as potatoes, canola, and bananas. In nature, they often reside in places with extreme environmental conditions.

Polyploids are often sterile, but can continue to grow indefinitely if left undisturbed. This seagrass has done just that.

HOW OLD IS THIS PLANT?

The sandy dunes of Shark Bay flooded some 8,500 years ago, when the sea level rose after the last ice age. Over the following millennia, the expanding seagrass meadows made shallow coastal banks and sills through creating and capturing sediment, which made the water saltier.

There is also a lot of light in the waters of Shark Bay, as well as low levels of nutrients and large temperature fluctuations. Despite this hostile environment, the plant has been able to thrive and adapt.

It is challenging to determine the exact age of a seagrass meadow, but scientists estimate the Shark Bay plant is around 4,500 years old, based on its size and growth rate.

Other huge plants have been reported in both marine and land systems, such as a 6,000-tonne quaking aspen in Utah, but this seagrass appears to be the largest to date.

Other huge seagrass plants have also been found, including a closely related Mediterranean seagrass called *Posidonia oceanica*, which covers more than 15 km (9 miles) and may be around 100,000 years old.

WHY DOES THIS MATTER?

In the summer of 2010–11, a severe heatwave hit land and sea ecosystems along the Western Australian coastline.

Shark Bay's seagrass meadows suffered widespread damage in the heatwave. Yet the ribbon weed meadows have started to recover.

This is somewhat surprising, as this seagrass does

not appear to reproduce sexually – which would normally be the best way to adapt to changing conditions.

Scientists have observed seagrass flowers in the Shark Bay meadows, which indicates the seagrass are sexually active, but their fruits (the outcome of successful seagrass sex) are rarely seen.

Researchers' single plant may in fact be sterile. This makes its success in the variable waters of Shark Bay quite a conundrum: plants that don't have sex tend to also have low levels of genetic diversity, which should reduce their ability to deal with changing environments.

However, scientists suspect that their seagrass in Shark Bay has genes that are extremely well-suited to its local, but variable environment, and perhaps that is why it does not need to have sex to be successful.

Even without successful flowering and seed production, the giant plant appears to be very resilient. It experiences a wide range of water temperatures (from 17°C/63°F to 30°C/86°F in some years) and salt levels.

Despite these variable conditions and the high light levels (which are typically stressful for seagrass), the plant can maintain its physiological processes and thrive. So how does it

cope?

Researchers hypothesize that this plant has a small number of somatic mutations (minor genetic changes that are not passed on to offspring) across its 180 km (112 mile) range that help it persist under local conditions.

However, this is just a hunch and researchers are tackling this hypothesis experimentally. They have set up a series of experiments in Shark Bay to really understand how the plant survives and thrives under such variable conditions.

THE FUTURE OF SEAGRASS

Seagrasses protect the coasts from storm damage, store large amounts of carbon, and provide a habitat for a great diversity of wildlife. Conserving and also restoring seagrass meadows has a vital role in climate change mitigation and adaptation.

Seagrasses are not immune from climate change impacts: warming temperatures, ocean acidification, and extreme weather events are significant challenges for them.

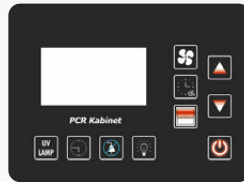
However, the detailed picture we now have of the great resilience of the giant seagrass of Shark Bay provides us with the hope they will be around for many years to come, especially if serious action is taken on climate change.

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SCIENTISTS UNLOCK MYSTERIES OF PLANT GROWTH AND HEALTH

The discovery will help develop heat-tolerant crops and improve algal biofuel production



Plants, like all other known organisms, utilize DNA to pass on traits. Animal genetics often focuses on parentage and lineage, but this can be challenging in plant genetics since plants can be self-fertile, unlike most animals.

Many plants have unique genetic abilities that make speciation easier, such as being well suited to polyploidy. Plants are special in that they can synthesize energy-dense carbohydrates via photosynthesis, which is accomplished through the usage of chloroplasts. Chloroplasts have their own DNA which allows them to serve as an additional reservoir for genes and genetic diversity, as well as creates an additional layer of genetic complexity not seen in animals. Despite its difficulty, plant genetic research has significant economic implications. Many crops can be genetically modified to increase yield and nutritional value as well as gain pest, herbicide, or disease resistance.

Genes contain all of the instructions that an organism needs to survive, develop, and reproduce. But identifying a gene and understanding what it does are two very different things. Many genes include unexplained instructions,

and their functions are unknown to scientists. Recent research conducted by UC Riverside, Princeton University, and Stanford University has revealed the functions of hundreds of genes in algae, some of which are also found in plants. The breakthrough will aid attempts to genetically modify algae for biofuel production and generate climate-resistant agricultural crop types.

"Plant and algae genetics are understudied. These organisms make the foods, fuels, materials, and medicines that modern society relies on, but we have a poor understanding of how they work, which makes engineering them a difficult task," said corresponding author Robert Jinkerson, an assistant professor of chemical and environmental engineering at UC Riverside. "A common way to learn more about biology is to mutate genes and then see how that affects the organism. By breaking the biology we can see how it works."

The researchers conducted tests that generated millions of data points using algal mutants and automated tools. The researchers were able to uncover the functional role of hundreds of poorly characterized genes and identi-

fy several new functions of previously known genes by analyzing these datasets. These genes have roles in photosynthesis, DNA damage response, heat stress response, toxic chemical response, and algal predator response.

Several of the genes they discovered in algae have counterparts in plants with the same roles, indicating that the algal data can help scientists understand how those genes function in plants as well.

Automated approaches to analyzing tens of thousands of mutants quickly, known as high-throughput methods, are typically used to understand gene function on a genome-wide scale in model systems like yeast and bacteria. This is quicker and more efficient than studying each gene individually. High-throughput methods do not work very well in crop plants, however, because of their larger size and the difficulty of analyzing thousands of plants.

The researchers, therefore, used a high-throughput robot to generate over 65,000 mutants of *Chlamydomonas reinhardtii*, a type of single-celled green algae closely related to plants and easy to alter genetically. They subject-

ed the mutants to 121 different treatments, which resulted in a dataset of 16.8 million data points. Each mutant had a unique DNA barcode that the team could read to see how that mutant was doing in a specific environmental stress condition.

The group discovered new gene functions in hundreds of genes. For example, they learned that a gene widely found throughout multicellular organisms helps repair damaged DNA. Another 38 genes, when disrupted, caused problems with using energy from light, indicating that these genes played roles in photosynthesis.

Yet another cluster of genes helped the algae process carbon dioxide, a second crucial step in photosynthesis. Other clusters affected the tiny hairs, or cilia, the algae use to swim. This discovery could lead to a better understanding of some human lung and esophageal cancers, which might be partially caused by defective cilia motility.

A newly discovered gene cluster protected the algae from toxins that inhibit cytoskeleton growth. These genes are also present in plants and the discovery could help scientists develop plants that grow

well even in some contaminated soils.

Many of the gene functions discovered in algae are also conserved in plants. This information can be used to engineer plants to be more tolerant to heat or cold stress, temperature stress, or improve photosynthesis, all of which will become increasingly important as climate change threatens the world's food supply.

A better understanding of algae genetics will also improve engineering strategies to make them produce more products, like biofuels.

"The data and knowledge generated in this study is already being leveraged to engineer algae to make more biofuels and to improve environmental stress tolerance in crops," said Jinkerson.

Reference: "Systematic characterization of gene function in the photosynthetic alga *Chlamydomonas reinhardtii*" 5 May 2022, Nature Genetics.

DOI: 10.1038/s41588-022-01052-9

NEW LIGHT-POWERED CATALYST DESIGN MAY AID IN MANUFACTURING

When coated onto plastic tubing, the catalysts could act on chemicals flowing through, helping to synthesize drugs and other compounds.

A new type of photoredox catalyst, designed by MIT chemists, may make it easier to incorporate light-driven reactions into continuous flow manufacturing processes. The key is their insolubility, which allows them to be used over and over again.

Light-driven chemical reactions provide a powerful tool for chemists developing novel methods of producing pharmaceuticals and other important molecules. Harnessing this light energy requires photoredox catalysts, which can absorb light and transfer the energy to a chemical reaction.

Now, MIT chemists have designed a new type of photoredox catalyst that could make it easier to incorporate light-driven reactions into manufacturing processes. Unlike most existing photoredox catalysts, the new class of materials is insoluble, so they can be used over and over again. Such catalysts could be used to coat tubing and perform chemical transformations on reactants as they flow through the tube.

A catalyst is a substance that speeds up a chemical reaction. Catalysis is the

process of accelerating a reaction by using a catalyst. Photoredox catalysts work by absorbing photons and then using that light energy to power a chemical reaction.

"Being able to recycle the catalyst is one of the biggest challenges to overcome in terms of being able to use photoredox catalysis in manufacturing. We hope that by being able to do flow chemistry with an immobilized catalyst, we can provide a new way to do photoredox catalysis on larger scales," says Richard Liu, an MIT postdoc and the joint lead author of the new study.

The new catalysts, which can be tuned to perform many different types of reactions, could also be incorporated into other materials including textiles or particles.

HYBRID MATERIALS

Photoredox catalysts work by absorbing photons and then using that light energy to power a chemical reaction, analogous to how chlorophyll in plant cells absorbs energy from the sun and uses it to build sugar molecules.

Chemists have developed

two main classes of photoredox catalysts, which are known as homogeneous and heterogeneous catalysts. Homogeneous catalysts usually consist of organic dyes or light-absorbing metal complexes. These catalysts are easy to tune to perform a specific reaction, but the downside is that they dissolve in the solution where the reaction takes place. This means they can't be easily removed and used again.

Heterogeneous catalysts, on the other hand, are solid minerals or crystalline materials that form sheets or 3D structures. These materials do not dissolve, so they can be used more than once. However, these catalysts are more difficult to tune to achieve the desired reaction.

To combine the benefits of both of these types of catalysts, the researchers decided to embed the dyes that make up homogeneous catalysts into a solid polymer. For this application, the researchers adapted a plastic-like polymer with tiny pores that they had previously developed for performing gas separations. In this study, the researchers demonstrated that they

could incorporate about a dozen different homogeneous catalysts into their new hybrid material, but they believe it could work more many more.

"These hybrid catalysts have the recyclability and durability of heterogeneous catalysts, but also the precise tunability of homogeneous catalysts," Liu says. "You can incorporate the dye without losing its chemical activity, so, you can more or less pick from the tens of thousands of photoredox reactions that are already known and get an insoluble equivalent of the catalyst you need."

The researchers found that incorporating the catalysts into polymers also helped them to become more efficient. One reason is that reactant molecules can be held in the polymer's pores, ready to react. Additionally, light energy can easily travel along the polymer to find the waiting reactants.

"The new polymers bind molecules from solution and effectively preconcentrate them for reaction," Swager says. "Also, the excited states can rapidly migrate throughout the polymer. The combined mobility of the excited state and partitioning of

the reactants in the polymer make for faster and more efficient reactions than are possible in pure solution processes."

HIGHER EFFICIENCY

The researchers also showed that they could tune the physical properties of the polymer backbone, including its thickness and porosity, based on what application they want to use the catalyst for.

As one example, they showed that they could make fluorinated polymers that would stick to fluorinated tubing, which is often used for continuous flow manufacturing. During this type of manufacturing, chemical reactants flow through a series of tubes while new ingredients are added, or other steps such as purification or separation are performed.

Currently, it is challenging to incorporate photoredox reactions into continuous flow processes because the catalysts are used up quickly, so they have to be continuously added to the solution. Incorporating the new MIT-designed catalysts into the tubing used for this kind of manufacturing could allow photoredox

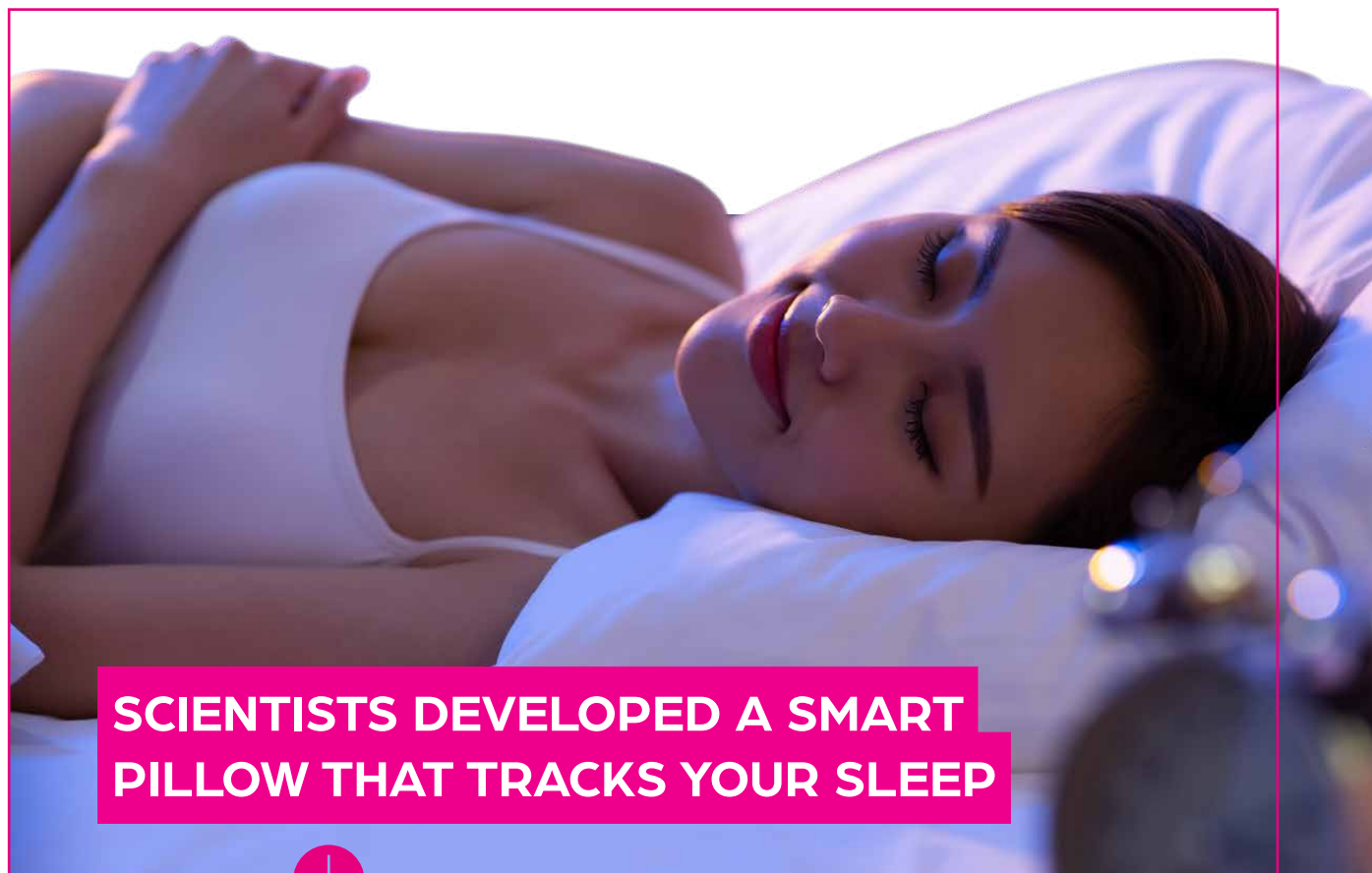


reactions to be performed during continuous flow. The tubing is clear, allowing light from an LED to reach the catalysts and activate them.

"The idea is to have the catalyst coating a tube, so you can flow your reaction through the tube while the catalyst stays put. In that way, you never get the catalyst ending up in the product, and you can also get a lot higher efficiency," Liu says.

The catalysts could also be used to coat magnetic beads, making them easier to pull out of a solution once the reaction is finished, or to coat reaction vials or textiles. The researchers are now working on incorporating a wider variety of catalysts into their polymers, and on engineering the polymers to optimize them for different possible applications.

Reference: "Solution-processable microporous polymer platform for heterogenization of diverse photoredox catalysts" by Richard Y. Liu, Sheng Guo, Shao-Xiong Lennon Luo and Timothy M. Swager, 27 May 2022, *Nature Communications*.



SCIENTISTS DEVELOPED A SMART PILLOW THAT TRACKS YOUR SLEEP



Although recent research suggests that 7 hours is the ideal sleep time for adults, many people find it difficult to get even that much on a regular basis.

Fortunately, scientists are working on the problem, and one of the ways is through better monitoring of sleep. A new self-powering smart pillow that tracks the position of the head could help.

The human body needs sleep as much as it needs food and water. Yet many people fail to get enough, causing both mind and body to suffer. People who struggle for shut-eye could benefit from monitoring their sleep, but they have limited options for doing so. In a new study in *ACS Applied Materials & Interfaces*, one team describes a potential solution: a self-powering smart pillow that tracks the position of the head.

Studies have linked chronic lack of sleep to physical ailments, such as diabetes and heart

disease, as well as mental health issues. Those interested in getting a better handle on what's happening to them at night have two primary options. They can take a sleep test conducted in a medical facility, or they can use an app through a smartphone or smart watch — a much more convenient, but less accurate choice. Recognizing the need, many groups have begun developing new sleep monitoring systems using triboelectric nanogenerators (TENGs). These self-powering systems have taken the form of eye masks, belts, patches, and even bed sheets. Ding Li, Zhong Lin Wang, and their colleagues wanted to adapt this approach to create a less restrictive, more comfortable version that focuses on the movement of the head during sleep.

To construct this new smart pillow, the researchers formulated a flexible, porous polymer triboelectric layer. Movement between the head and this layer changes the electric field around nearby electrodes, generating a current. They strung together several of these self-powering sensors to create a flexible and breathable TENG (FB-TENG) array that can be placed atop an ordinary pillow. This system could generate voltage that corresponded to the amount of applied pressure, and it could track the movement of a finger tracing out letters. The FB-TENG also could capture the pressure distribution of a fake human head as it shifted position.

This smart pillow could have uses beyond tracking sleep, the scientists

say. For example, the system could monitor patients with diseases that affect the movement of the head, such as the degenerative neck disorder cervical spondylosis. What's more, the smart pillow could be adapted to offer an early warning system for those at risk of falling out of bed, they say.

Reference: "Smart Pillow Based on Flexible and Breathable Triboelectric Nanogenerator Arrays for Head Movement Monitoring during Sleep" by Haiying Kou, Haiming Wang, Renwei Cheng, Yanjun Liao, Xue Shi, Jianjun Luo, Ding Li and Zhong Lin Wang, 14 May 2022, *ACS Applied Materials & Interfaces*.

DOI: 10.1021/acsami.2c03056

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