SCIENCE NEWS

New Treatment for Severe Asthma

According to Statistics Canada, 8per cent of Canadians aged 12 or older–approximately 2.4 million people–have been diagnosed with asthma. Of that, approximately 25 per cent are considered to be severe cases of asthma.

Current treatments for severe asthma often include high doses of corticosteroids, such as prednisone, to control exacerbations. Reducing the need for corticosteroids with alternative treatments is preferable, since these medications are associated with serious side effects from prolonged use–including multi-organ toxicities and immunosuppression.

Dr Parameswaran Nair, staff respirologist at St. Joseph's Healthcare Hamilton and professor of medicine at McMaster University, along with a team of researchers found that an antibody called dupilumab is effective in treating severe asthma in place of high doses of prednisone. The results were published in the *New England Journal of Medicine*, one of the world's most influential medical publications.

Researchers sought participants who had been using oral corticosteroids (prednisone) to treat severe asthma for at least six months prior to the study. In addition to their standard regimen of corticosteroids, patients received either dupilumab or a placebo during the 24 week trial. The corticosteroid dose was gradually reduced during weeks four to 20, and maintained at a low level for the final four weeks.

"The ability of dupilumab to increase lung function as markedly as it did in this study, even in the face of [corticosteroid] withdrawal, indicates that it appears to be inhibiting key drivers of lung inflammation," the researchers noted.

Dupilumab works to treat asthma by blocking two specific proteins (called interleukin-4 and interleukin-13) that are associated with inflammation of the airways.

This technique was based on Dr Nair's previous work published in the *New England Journal of Medicine* in 2009 and in 2017. Those studies found that blocking another protein, interleukin-5, allowed patients with high

eosinophil levels in their blood and airways to reduce their corticosteroid dose. Eosinophils are a type of white blood cell involved with the production of interleukins. High eosinophil levels are directly linked to an increased risk of severe asthma.

Unlike the previous studies, dupilumab was shown to be effective regardless of patients' eosinophil levels. Despite the reduced prednisone dose, patients in this study not only experienced a decrease in asthma exacerbations, but their lung function also improved significantly.

"Ultimately, our goal is to find new treatment pathways that allow us to circumvent the use of corticosteroids," said Dr Nair. "Since dupilumab showed a significant improvement on asthma control regardless of eosinophil levels, we may be able to use this treatment for a wider range of patients than we previously thought possible. This might be due to the broad effects on inflammation in asthma of the two proteins that we were able to block with dupilumab. The treatment was not associated with any serious side effects."

Dr Nair and his team presented the details of their study at the American Thoracic Society's international conference in San Diego this past week. There, researchers and clinicians from around the world gathered to discuss respiratory illnesses and the latest breakthroughs in treatment.

"This work highlights the clinical and research excellence in pulmonary diseases that exists at St Joseph's and the Firestone Institute," explained Dr Jack Gauldie, vice president (research) at St. Joseph's Healthcare Hamilton and a professor emeritus of McMaster University.

"Dr Nair is one of the world's best clinicians in the field of severe asthma and his studies on modification of immune regulation, targeting two important immune factors, bring an immense impact directly from the lab to the patient in managing this difficult and dangerous form of asthma. We are immensely proud of these advances in pulmonary medicine."

Social Media use Increases Depression and Loneliness, Study Finds

Few prior studies have attempted to show that social-media use harms users' well-being, and those that have either put participants in unrealistic situations or were limited in scope, asking them to completely forego Facebook and relying on self-report data, for example, or conducting the work in a lab in as little time as an hour.

"We set out to do a much more comprehensive, rigorous study that was also more ecologically valid," says Hunt, associate director of clinical training in Penn's Psychology Department.

To that end, the research team, which included recent alumni Rachel Marx and Courtney Lipson and Penn senior Jordyn Young, designed their experiment to include the three platforms most popular with a cohort of undergraduates, and then collected objective usage data automatically tracked by iPhones for active apps, not those running the background.

Each of 143 participants completed a survey to determine mood and well-being at the study's start, plus shared shots of their iPhone

battery screens to offer a week's worth of baseline social-media data. Participants were then randomly assigned to a control group, which had users maintain their typical social-media behaviour, or an experimental group that limited time on Facebook, Snapchat, and Instagram to 10 minutes per platform per day.

For the next three weeks, participants shared iPhone battery screenshots to give the researchers weekly tallies for each individual. With those data in hand, Hunt then looked at seven outcome measures including fear of missing out, anxiety, depression, and loneliness.

"Here's the bottom line," she says. "Using less social media than you normally would leads to significant decreases in both depression and loneliness. These effects are particularly pronounced for folks who were more depressed when they came into the study."

Hunt stresses that the findings do not suggest that 18- to 22-year-olds should stop using social media altogether. In fact, she built the study as she did to stay away from what she considers an unrealistic goal. The work does, however, speak to the idea that limiting screen time on these apps could not hurt.

"It is a little ironic that reducing your use of social media actually makes you feel less lonely," she says. But when she digs a little deeper, the findings make sense. "Some of the existing literature on social media suggests there's an enormous amount of social comparison that happens. When you look at other people's lives, particularly on Instagram, it's easy to conclude that everyone else's life is cooler or better than yours."

Because this particular work only looked at Facebook, Instagram, and Snapchat, it is not clear whether it applies broadly to other social-media platforms. Hunt also hesitates to say that these findings would replicate for other age groups or in different settings. Those are questions she still hopes to answer, including in an upcoming study about the use of dating apps by college students.

Despite those caveats, and although the study did not determine the optimal time users should spend on these platforms or the best way to use them, Hunt says the findings do offer two related conclusions it could not hurt any social-media user to follow.

For one, reduce opportunities for social comparison, she says. "When you're not busy getting sucked into clickbait social media, you're actually spending more time on things that are more likely to make you feel better about your life." Secondly, she adds, because these tools are here to stay, it's incumbent on society to figure out how to use them in a way that limits damaging effects. " In general, I would say, put your phone down and be with the people in your life.

—Melissa G. Hunt is the associate director of clinical training in the Department of Psychology in the School of Arts and Sciences at the University of Pennsylvania.

—Rachel Marx and Courtney Lipson graduated from the University of Pennsylvania in 2018.

—Jordyn Young is a member of the University of Pennsylvania Class of 2019.

Melting Arctic Sea Ice during the Summer of 2018

As sea ice in the Arctic retreats further and melts faster every decade, scientists are racing to understand the vulnerabilities of one of the world's most remote and unforgiving places. A study appearing July 29 in the journal *Heliyon* details the changes that occurred in the Arctic in September of 2018, a year when nearly 10 million kilometres of sea ice were lost over the course of the summer. Their findings give an overview at different timescales of how sea ice has receded over the 40 years of the satellite era and show how the summer's extensive decline is linked to global atmospheric processes as far south as the tropics.

At the peak of its melting season, in July 2018, the Arctic was losing sea ice at a rate of 105,500 square kilometres per day – an area bigger than Iceland or the state of Kentucky. "On the ground, I am sure it would have looked like an excellent summer month in the Arctic, in general, but over the past four decades, September sea-ice loss has accelerated to a rate of 12.8 per cent per decade and 82,300 square kilometres per year," says co-author Avinash Kumar, a senior scientist at the National Centre for Polar and Ocean Research (NCPOR) in India.

The researchers followed the warm water currents of the Atlantic north to the Arctic Ocean and tracked the ice as it subsequently retreated through the Chukchi, East Siberian, Laptev, Kara, and Barents seas. Thanks to higher temporal resolution and greater satellite coverage than had previously been available, they could also measure the ice's decline through variables such as its thickness, concentration, and volume in addition to its extent throughout the Arctic. This dramatic loss of sea ice culminated at the end of the boreal summer, when in September, the ice had been reduced to a mere third of its winter extent.

Then, the team compared the decline to the previous four decades of data. "In the summer of 2018, the loss of sea ice was three times higher than the reported loss at the beginning of the satellite era," says Kumar. "Our study shows that both the minimum sea-ice extent and the warmest September records occurred in the last twelve years."

"Every year, news pops up of a new record of high temperature or fastest loss of sea ice in the Arctic region, but in the global system, each portion of the planet receiving climate feedback will lead to changes in the other parts as well," Kumar says. "If the sea-ice decline continues at this pace, it can have a catastrophic impact by raising air temperatures and slowing down global ocean circulation." These global impacts are partly why he became interested in trying to decipher the mysteries of the polar regions as a doctoral student studying the coastal zone in India. Now, he works at NCPOR, whose scientific programs, he says, are "truly trans-hemispheric, cutting across from north to south."

The researchers also turned their attention to the atmosphere, where they were able to gain insight into the processes that contribute to the loss of Arctic sea ice. They found not only that September of 2018 was the third warmest on record, but that there was a temperature difference within the Arctic itself: the temperature of the air above the Arctic Ocean (~3.5°C) was slightly higher than that of the Arctic land (~2.8°C).

Their findings provide further evidence that ocean warming around the globe has influenced the natural cycle of the wind and pressure patterns in the Arctic. El Niños, or warm phases in long-term temperature cycles stemming from tropical regions, have long been known to drive extreme weather events around the world and are occurring with greater frequency as the world warms. El Niño cycles in the equatorial Pacific Ocean can carry warm air and water from tropical circulations to the Arctic, spurring the sea ice to melt. As the ice retreats, it cascades the Arctic into a positive feedback loop known as Arctic amplification, whereby the reduced ice extent gives way to darker ocean waters that absorb more of the sun's radiation. As it retains more heat, temperatures rise and more ice melts, causing the Arctic region to heat up faster – about four times so – than the rest of the world.

"If the decline of sea ice continues to accelerate at a rate of 13 per cent per decade in September, the Arctic is likely to be free of ice within the next three decades," Kumar says. And just as sea-ice retreat is largely the result of anthropogenic pressures from across the globe, its impacts will be felt worldwide: this work adds to the mounting body of evidence that changes in the Arctic sea ice could be detrimental to weather patterns spanning the globe. He says, "The changes taking place in the Arctic can lead to other changes in lower latitudes, such as extreme weather conditions. The world should be watching tropical countries like India, with our research centre saddled close to the beaches of Goa, and trying to understand– even in a small way–more about climate change and the polar regions."

This work was supported by the National Centre for Polar and Ocean Research, Goa, the Ministry of Earth Science, New Delhi, and the University Grants Commission, New Delhi.

Rainforest Destruction from Gold Mining Hits All-time High in Peru

Small-scale gold mining has destroyed more than 170,000 acres of primary rainforest in the Peruvian Amazon in the past five years, according to a new analysis by scientists at Wake Forest University's Center for Amazonian Scientific Innovation (CINCIA).

That's an area larger than San Francisco and 30 per cent more than previously reported.

"The scale of the deforestation is really shocking,"said Luis Fernandez, executive director of CINCIA and research associate professor in the department of biology. "In 2013, the first comprehensive look at Peruvian rainforest lost from mining showed 30,000 hectares. Five years later, we have found nearly 100,000 hectares of deforested landscape."

The scientists at CINCIA, based in the Madre de Dios region of Peru, have developed a new data fusion method to identify areas destroyed by this small- or artisanal-scale mining. Combining existing CLASlite forest monitoring technology and Global Forest Change data sets on forest loss, this new deforestation detection tool is 20-25 per cent more accurate than those used previously.

Both CLASlite and the Global Forest Map use different kinds of information from light waves to show changes in the landscape. "Combining the two methods gives us really good information about the specific kind of

deforestation we're looking for," said Miles Silman, associate director of science for CINCIA and director of Wake Forest's Center for Energy, Environment, and Sustainability (CEES). Silman has researched biodiversity and ecology in the Western Amazon and Andes for more than 25 years.

Artisanal-scale gold mining has been hard to detect because its aftereffects can masquerade as natural wetlands from a satellite view. But the damage is extensive. Small crews of artisanal miners do not expect to hit the mother lode. Rather, miners set out to collect the flakes of gold in rainforest.

"We're not talking about huge gold veins here," Fernandez said. "But there's enough gold in the landscape to make a great deal of money in a struggling economy. You just have to destroy an immense amount of land to get it."

To get the gold, they strip the land of trees or suck up river sediment, and then use toxic mercury to tease the precious metal out of the dirt. The results are environmentally catastrophic.

"You take out everything aboveground–vast amounts of rainforest – and then you take the soil, run it through a sluice and wash away all that is good in it. What you have left is an alien environment," Silman said. "All the scenery should look like broccoli. It looks like desert."

Artisanal-scale gold mining took root in the Peruvian Amazon in the early 2000s, coinciding with construction of a new modern highway connecting Peru and Brazil. The Interoceanic Highway made Peru's once remote rainforest and protected lands accessible to anyone. Where it used to take two weeks by all-terrain vehicle to travel from Cuzco to Puerto Maldonado, the capital of Madre de Dios, during the rainy season, it now takes only six hours aboard an air-conditioned luxury bus.

Because artisanal-scale gold mining requires no heavy machinery and thus involves minimal outlay, it has provided a revolving-door opportunity for poor workers from the Andean highlands to seek their fortune in Madre de Dios. When they return home, they leave a patchwork of mercury-polluted ponds and sand dunes, the landscape denuded of trees and most other vegetation.

CINCIA has partnered with Peru's Ministry of the Environment to try to understand how the new tool developed by its scientists can be used to identify deforestation caused by artisanal-scale gold mining and take effective action to curb the damage.

"We want to integrate high-quality scientific research into the processes the government is using for environmental conservation in Madre de Dios," Fernandez said. "If they can institutionalize these technological innovations, they can more reliably address threats to the rainforest. You have to respond quickly and you have to respond effectively."

CINCIA scientists also are studying native species that can be used for post-mining reforestation. The 115-acre experiment at CINCIA's headquarters is the largest in the Americas.

Pluto Should Be Reclassified as a Planet, Experts Say

In 2006, the International Astronomical Union, a global group of astronomy experts, established a definition of a planet that

required it to 'clear' its orbit, or in other words, be the largest gravitational force in its orbit.

Since Neptune's gravity influences its neighbouring planet Pluto, and Pluto shares its orbit with frozen gases and objects in the Kuiper belt, that meant Pluto was out of planet status. However, in a new study published online Wednesday in the journal *Icarus*, UCF planetary scientist Philip Metzger, who is with the university's Florida Space Institute, reported that this standard for classifying planets is not supported in the research literature.

Metzger, who is lead author on the study, reviewed scientific literature from the past 200 years and found only one publication – from 1802 – that used the clearing-orbit requirement to classify planets, and it was based on since-disproven reasoning.

He said moons such as Saturn's Titan and Jupiter's Europa have been routinely called planets by planetary scientists since the time of Galileo.

"The IAU definition would say that the fundamental object of planetary science, the planet, is supposed to be defined on the basis of a concept that nobody uses in their research," Metzger said. "And it would leave out the second-most complex, interesting planet in our solar system." "We now have a list of well over 100 recent examples of planetary scientists using the word planet in a way that violates the IAU definition, but they are doing it because it's functionally useful," he said. "It's a sloppy definition," Metzger said of the IAU's definition. "They didn't say what they meant by clearing their orbit. If you take that literally, then there are no planets, because no planet clears its orbit."

The planetary scientist said that the literature review showed that the real division between planets and other celestial bodies, such as asteroids, occurred in the early 1950s when Gerard Kuiper published a paper that made the distinction based on how they were formed.

However, even this reason is no longer considered a factor that determines if a celestial body is a planet, Metzger said.

Study co-author Kirby Runyon, with Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, said the IAU's definition was erroneous since the literature review showed that clearing orbit is not a standard that is used for distinguishing asteroids from planets, as the IAU claimed when crafting the 2006 definition of planets.

"We showed that this is a false historical claim," Runyon said. "It is therefore fallacious to apply the same reasoning to Pluto," he said. Metzger said that the definition of a planet should be based on its intrinsic properties, rather than ones that can change, such as the dynamics of a planet's orbit. "Dynamics are not constant, they are constantly changing," Metzger said. "So, they are not the fundamental description of a body, they are just the occupation of a body at a current era."

Instead, Metzger recommends classifying a planet based on if it is large enough that its gravity allows it to become spherical in shape.

"And that's not just an arbitrary definition," Metzger said. "It turns out this is an important milestone in the evolution of a planetary body, because apparently when it happens, it initiates active geology in the body."

Pluto, for instance, has an underground ocean, a multilayer atmosphere, organic

compounds, evidence of ancient lakes and multiple moons, he said.

"It's more dynamic and alive than Mars," Metzger said. "The only planet that has more complex geology is the earth."

Children's Violent Video Game Play Associated with Increased Physical Aggressive Behaviour

Although most researchers on the subject agree that playing violent video games appears to increase physical aggression, a vocal minority continues to dispute this. To examine issues raised by the counterclaims on this topic, Dartmouth researchers conducted a meta-analysis of 24 studies from around the world from 2010 to 2017 with over 17,000 participants, ages nine to 19 years-old. The studies all examined how violent video game play affected changes in real-world physical aggression over time, ranging from three months to four years. Examples of physical aggression included incidents such as hitting someone or being sent to the principal's office for fighting, and were based on self-reports by children, parents, teachers and peers.

Dartmouth's study examined three specific critiques of the literature on video game play and aggression:

- To address claims that previous meta-analyses overestimate the association of violent video game play and aggression because they include 'non-serious' measures of aggression, this meta-analysis was limited to studies that measured reports of overt, physical aggression over time. Despite this more stringent criterion, findings supported the hypothesis that playing violent games is associated with subsequent increases in physical aggression.
- To investigate claims that effects are often inflated because many studies do not take into account other variables predictive of aggressive behaviour, Dartmouth researchers compared analyses that included or did not include information on such variables and found that taking these data into account had only a minor effect on the size of the observed relation between violent video game play and aggression.
- To evaluate claims that the estimated effect of violent game play on aggression is inflated because of a bias against publishing studies that fail to find a relation of violent game play and aggression, Dartmouth researchers conducted a variety of different tests and found no evidence of publication bias.

In addition to providing evidence that violent video game play is associated with increased aggression over time, the study also reports that this effect appears to be significantly different for various ethnic groups: the largest effect was observed among white participants, with some effect noted among Asians and no effect observed among Hispanics. Although speculative, the authors suggest that this effect may reflect a greater emphasis on maintaining empathy toward victims of aggression among Eastern and Hispanic cultures in contrast to an emphasis on 'rugged individualism' in Western cultures.

"Although no single research project is definitive, our research aims to provide the

most current and compelling responses to key criticisms on this topic. Based on our findings, we feel it is clear that violent video game play is associated with subsequent increases in physical aggression," said lead author Jay G. Hull, the Dartmouth Professor of Psychological and Brain Sciences, and associate dean of faculty for the social sciences at Dartmouth.

"The most notable critic of the violent video game aggression literature conducted studies in primarily Hispanic populations and found no evidence of this association. If all of my studies showed null findings, I too, would be skeptical," said co-author James D. Sargent, the Scott M. and Lisa G. Stuart Professor of Pediatric Oncology and director of the C. Everett Koop Institute at Dartmouth. "I hope our findings prompt skeptics to reevaluate their position, especially since some of our other research indicates that violent video game play may increase deviance with implications for multiple risk behaviours," added Sargent.

The study builds on the research team's growing body of work that investigates the impact of video games on children's behaviour, including the link between mature-rated, risk-glorifying video games and deviant behaviour (e.g., smoking, drinking, and risky sex) and the association between playing these type of video games and reckless driving among teens.

Forensics: New Tool Predicts Eye, Hair and Skin Colour from a DNA Sample of an Unidentified Individual

The tool is designed to be used when standard forensic DNA profiling is not helpful because no reference DNA exists against which to compare the evidence sample.

The HIrisPlex-S DNA test system is capable of simultaneously predicting eye, hair and skin colour phenotypes from DNA. Users, such as law enforcement officials or anthropologists, can enter relevant data using a laboratory DNA analysis tool, and the webtool will predict the pigment profile of the DNA donor.

"We have previously provided law enforcement and anthropologists with DNA tools for eye color and for combined eye and hair color, but skin color has been more difficult," said forensic geneticist Susan Walsh from IUPUI, who co-directed the study. "Importantly, we are directly predicting actual skin color divided into five subtypes – very pale, pale, intermediate, dark and dark to black – using DNA markers from the genes that determine an individual's skin coloration. This is not the same as identifying genetic ancestry. You might say it's more similar to specifying a paint color in a hardware store rather than denoting race or ethnicity."

"If anyone asks an eyewitness what they saw, the majority of time they mention hair color and skin color. What we are doing is using genetics to take an objective look at what they saw," Walsh said.

The innovative high-probability and high-accuracy complete pigmentation profile webtool is available online without charge.

The study, "HIrisPlex-S System for Eye, Hair and Skin Colour Prediction from DNA: Introduction and Forensic Developmental Validation," is published in the peer-reviewed journal *Forensic Science International: Genetics.*

"With our new HIrisPlex-S system, for the first time, forensic geneticists and genetic anthropologists are able to simultaneously generate eye, hair and skin color information

from a DNA sample, including DNA of the low quality and quantity often found in forensic casework and anthropological studies," said Manfred Kayser of Erasmus MC, co-leader of the study.

Synthetic Microorganisms Allow Scientists to Study Ancient Evolutionary Mysteries

Scientists at Scripps Research and their collaborators have created microorganisms that may recapitulate key features of organisms thought to have lived billions of years ago, allowing them to explore questions about how life evolved from inanimate molecules to single-celled organisms to the complex, multicellular lifeforms we see today.

By studying one of these engineered organisms—a bacterium whose genome consists of both ribonucleic acid (RNA) and deoxyribonucleic acid (DNA)—the scientists hope to shed light on the early evolution of genetic material, including the theorized transition from a world where most life relied solely on the genetic molecule RNA to one where DNA serves as the primary storehouse of genetic information.

Using a second engineered organism, a genetically modified yeast containing an endosymbiotic bacterium, they hope to better understand the origins of cellular power plants called mitochondria. Mitochondria provide essential energy for the cells of eukaryotes, a broad group of organisms—including humans—that possesses complex, nucleus-containing cells.

The researchers report engineering the microbes in two papers, one published on 29 October, 2018 in the *Proceedings of the National Academy of Sciences* (PNAS) and another published on 30 August, 2018 in the *Journal of the American Chemical Society* (JACS).

"These engineered organisms will allow us to probe two key theories about major milestones in the evolution of living organisms—the transition from the RNA world to the DNA world and the transition from prokaryotes to eukaryotes with mitochondria," says Peter Schultz, PhD, senior author on the papers and president of Scripps Research. "Access to readily manipulated laboratory models enables us to seek answers to questions about early evolution that were previously intractable."

The origins of life on earth have been a human fascination for millennia. Scientists have traced the arc of life back several billion years and concluded that the simplest forms of life emerged from earth's primordial chemical soup and subsequently evolved over the eons into organisms of greater and greater complexity. A monumental leap came with the emergence of DNA, a molecule that stores all of the information required to replicate life and directs cellular machinery to do its bidding primarily by generating RNA, which in turn directs the synthesis of proteins, the molecular workhorses in cells.

In the 1960s, Carl Woese and Leslie Orgel, along with DNA pioneer Francis Crick, proposed that before DNA, organisms relied on RNA to carry genetic information, a molecule similar to but far less stable than DNA, that can also catalyze chemical reactions like proteins. "In science class, students learn that DNA leads to RNA which in turn leads to proteins—that's a central dogma of biology—but the RNA world hypothesis turns that on its head," says

Angad Mehta, PhD, first author of the new papers and a postdoctoral research associate at Scripps Research. "For the RNA world hypothesis to be true, you have to somehow get from RNA to a DNA genome, yet how that might have happened is still a very big question among scientists."

One possibility is that the transition proceeded through a kind of microbial missing link, a replicating organism that stored genetic information as RNA. For the JACS study, the Scripps Research-led team created Escherichia coli bacteria that partially build their DNA with ribonucleotides, the molecular building blocks typically used to build RNA. These engineered genomes contained up to 50 per cent RNA, thus simultaneously representing a new type of synthetic organism and possibly a throwback to billions of years ago.

Mehta cautions that their work so far has focused on characterizing this *chimeric* RNA-DNA genome and its effect on bacterial growth and replication but hasn't explicitly explored questions about the transition from the RNA world to the DNA world. But, he says, the fact that E. coli with half of its genome comprised of RNA can survive and replicate is remarkable and seems to support the possibility of the existence of evolutionarily transitional organisms possessing hybrid RNA-DNA genomes. The Scripps Research team is now studying how the mixed genomes of their engineered E. coli function and plans to use the bacteria to explore a number of evolutionary questions.

For instance, one question is whether the presence of RNA leads to rapid genetic drift-large changes in gene sequence in a population over time. Scientists theorize that massive genetic drift occurred quickly during early evolution, and the presence in the genome of RNA could help explain how genetic change occurred so quickly.

In the paper published in *PNAS*, the researchers report engineering another laboratory model for an evolutionary milestone thought to have occurred more than 1.5 billion years ago. They created a yeast dependent for energy on bacteria living inside it as a beneficial parasite or 'endosymbiont.' This composite organism will allow them to investigate the ancient origins of mitochondria-tiny, bacteria-like organelles that produce chemical energy within the cells of all higher organisms.

Mitochondria are widely thought to have evolved from ordinary bacteria that were captured by larger, single-celled organisms. They carry out several key functions in cells. Most importantly, they serve as oxygen reactors, using O_2 to make cells' basic unit of chemical energy, the molecule ATP. As crucial as mitochondria are to cells, their origins remain somewhat mysterious, although there are clear hints of descent from a more independent organism, widely assumed to have been a bacterium.

Mitochondria have a double-membrane structure like that of some bacteria, and—again, like bacteria—contain their own DNA. Analyses of the mitochondrial genome suggest that it shares an ancient ancestor with modern Rickettsia bacteria, which can live within the cells of their hosts and cause disease. Stronger support for the bacterial origin of mitochondria theory would come from experiments showing that independent bacteria could indeed be transformed, in an evolution-like progression, into mitochondria-like symbionts. To that end,

the Scripps Research scientists engineered E. coli bacteria that could live in, depend upon, and provide key assistance to, cells of Saccharomyces cerevisiae, also known as baker's yeast.

The researchers started by modifying E. coli to lack the gene encoding thiamin, making the bacteria dependent on the yeast cells for this essential vitamin. At the same time, they added to the bacteria a gene for ADP/ATP translocase, a transporter protein, so that ATP produced within the bacterial cells would be supplied to their yeast—cell hosts—mimicking the central function of real mitochondria. The team also modified the yeast so that their own mitochondria were deficient at supplying ATP. Thus the yeast would be dependent on the bacteria for normal, mitochondria-based ATP production.

The team found that some of the engineered bacteria, after being modified with surface proteins to protect them from being destroyed in the yeast, lived and proliferated in harmony with their hosts for more than 40 generations and appeared to be viable indefinitely. "The modified bacteria seem to accumulate new mutations within the yeast to better adapt to their new surroundings," says Schultz.

With this system established, the team will try to evolve the E. coli to become mitochondria-like organelles. For the new E. coli endosymbiont, adapting to life inside yeast could allow it an opportunity to radically slim its genome. A typical E. coli bacterium, for example, has several thousand genes, whereas mitochondria have evolved a stripped-down set of just 37.

The Scripps Research team rounded out the study with further gene-subtraction experiments, and the results were promising: they found they could eliminate not just the E. coli thiamin gene but also the genes underlying the production of the metabolic molecule NAD and the amino acid serine, and still get a viable symbiosis.

"We are now well on our way to showing that we can delete the genes for making all 20 amino acids, which comprise a significant part of the E. coli genome," says Schultz. "Once we've achieved that, we'll move on to deleting genes for the syntheses of cofactors and nucleotides, and within a few years we hope to be able to get a truly minimal endosymbiotic genome."

The researchers also hope to use similar endosymbiont-host systems to investigate other important episodes in evolution, such as the origin of chloroplasts, light-absorbing organelles that have a mitochondria-like role in supplying energy to plants.

Novel Hiv Vaccine Candidate is Safe and Induces Immune Response in Healthy Adults and Monkeys

New research published in *The Lancet* shows that an experimental HIV-1 vaccine regimen is well-tolerated and generated comparable and robust immune responses against HIV in healthy adults and rhesus monkeys. Moreover, the vaccine candidate protected against infection with an HIV-like virus in monkeys.

Based on the results from this phase 1/2a clinical trial that involved nearly 400 healthy adults, a phase 2b trial has been initiated in southern Africa to determine the safety and efficacy of the HIV-1 vaccine candidate in 2,600 women at risk for acquiring HIV. This

is one of only five experimental HIV-1 vaccine concepts that have progressed to efficacy trials in humans in the 35 years of the global HIV/AIDS epidemic.

Previous HIV-1 vaccine candidates have typically been limited to specific regions of the world. The experimental regimens tested in this study are based on 'mosaic' vaccines that take pieces of different HIV viruses and combine them to elicit immune responses against a wide variety of HIV strains.

"These results represent an important milestone. This study demonstrates that the mosaic Ad26 prime, Ad26 plus gp140 boost HIV vaccine candidate induced robust immune responses in humans and monkeys with comparable magnitude, kinetics, phenotype, and durability and also provided 67 Per cent protection against viral challenge in monkeys," says Professor Dan Barouch, Director of the Center for Virology and Vaccine Research at Beth Israel Deaconess Medical Center and Professor of Medicine at Harvard Medical School, Boston, USA who led the study.

He adds: "These results should be interpreted cautiously. The challenges in the development of an HIV vaccine are unprecedented, and the ability to induce HIV-specific immune responses does not necessarily indicate that a vaccine will protect humans from HIV infection. We eagerly await the results of the phase 2b efficacy trial called HVTN705, or 'Imbokodo', which will determine whether or not this vaccine will protect humans against acquiring HIV."

Almost 37 million people worldwide are living with HIV/AIDS, with an estimated 1.8 million new cases every year. A safe and effective preventative vaccine is urgently needed to curb the HIV pandemic.

In the 35 years of the HIV epidemic, only four HIV vaccine concepts have been tested in humans, and only one has provided evidence of protection in an efficacy trial — a canarypox vector prime, gp120 boost vaccine regimen tested in the RV144 trial in Thailand lowered the rate of human infection by 31 Per cent but the effect was considered too low to advance the vaccine to common use.

A key hurdle to HIV vaccine development has been the lack of direct comparability between clinical trials and preclinical studies. To address these methodological issues, Barouch and colleagues evaluated the leading mosaic adenovirus serotype 26 (Ad26)-based HIV-1 vaccine candidates in parallel clinical and pre-clinical studies to identify the optimal HIV vaccine regimen to advance into clinical efficacy trials.

The APPROACH trial recruited 393 healthy, HIV-uninfected adults (aged 18-50 years) from 12 clinics in east Africa, South Africa, Thailand, and the USA between February 2015 and October 2015. Volunteers were randomly assigned to receive either one of seven vaccine combinations or a placebo, and were given four vaccinations over the course of 48 weeks.

To stimulate, or 'prime', an initial immune response, each volunteer received an intramuscular injection of Ad26.Mos.HIV at the start of the study and again 12 weeks later. The vaccine containing 'mosaic' HIV Env/Gag/Pol antigens was created from many HIV strains, delivered using a nonreplicating common-cold virus (Ad26).

To 'boost' the level of the body's immune response, volunteers were given two additional vaccinations at week 24 and 48 using various combinations of Ad26.Mos.HIV or a different vaccine component called Modified Vaccinia Ankara (MVA) with or without two different doses of clade C HIV gp140 envelope protein containing an aluminium adjuvant.

Results showed that all vaccine regimens tested were capable of generating anti-HIV immune responses in healthy individuals and were well tolerated, with similar numbers of local and systemic reactions reported in all groups, most of which were mild-to-moderate in severity. Five participants reported at least one vaccine-related grade 3 adverse event such as abdominal pain and diarrhea, postural dizziness, and back pain. No grade 4 adverse events or deaths were reported.

In a parallel study, the researchers assessed the immunogenicity and protective efficacy of the same Ad26-based mosaic vaccine regimens in 72 rhesus monkeys using a series repeated challenges with simian-human immunodeficiency virus (SHIV) – a virus similar to HIV that infects monkeys.

The Ad26/Ad26 plus gp140 vaccine candidate induced the greatest immune responses in humans and also provided the best protection in monkeys–resulting in complete protection against SHIV infection in two-thirds of the vaccinated animals after six challenges.

The authors note several limitations, including the fact that that the relevance of vaccine protection in rhesus monkeys to clinical efficacy in humans remains unclear. They also note that there is no definitive immunological measurement that is known to predict protection against HIV-1 in humans.

Writing in a linked Comment, Dr George Pavlakis and Dr Barbara Felber from the National Cancer Institute at Frederik, Maryland, USA say: "Efficacy studies are necessary to determine protective ability in humans and also for the discovery of correlates of protection and for determining whether the same or different immune correlates apply for different vaccine regimens. It remains to be determined whether improved efficacy over RV144 will be achieved by either of the present efficacy trials (NCT02968849; NCT03060629). New vaccine concepts and vectors are in development and can progress to efficacy trials, which is an important process since development of an AIDS vaccine remains urgent. Despite unprecedented advances in HIV treatment and prophylaxis, the number of people living with HIV infection continues to increase worldwide. Implementation of even a moderately effective HIV vaccine together with the existing HIV prevention and treatment strategies is expected to contribute greatly to the evolving HIV/AIDS response. It is therefore essential that a commitment to pursue multiple vaccine development strategies continues at all stages."

This study was funded by Janssen Vaccines and Prevention BV, US National Institutes of Health, Ragon Institute of MGH, MIT and Harvard, Henry M Jackson Foundation for the Advancement of Military Medicine, US Department of Defense, and International AIDS Vaccine Initiative.

Viruses – Lots of Them – are Falling from the Sky

An astonishing number of viruses are circulating around the earth's atmosphere – and falling from it – according to new research from scientists in Canada, Spain and the U.S.

The study marks the first time scientists have quantified the viruses being swept up from the earth's surface into the free troposphere, that layer of atmosphere beyond earth's weather systems but below the stratosphere where jet airplanes fly. The viruses can be carried thousands of kilometres there before being deposited back onto the earth's surface.

"Every day, more than 800 million viruses are deposited per square metre above the planetary boundary layer – that's 25 viruses for each person in Canada," said University of British Columbia virologist Curtis Suttle, one of the senior authors of a paper in the International Society for Microbial Ecology Journal that outlines the findings.

"Roughly 20 years ago we began finding genetically similar viruses occurring in very different environments around the globe," says Suttle "This preponderance of long-residence viruses travelling the atmosphere likely explains why it is quite conceivable to have a virus swept up into the atmosphere on one continent and deposited on another.

Bacteria and viruses are swept up in the atmosphere in small particles from soil-dust and sea spray.

Suttle and colleagues at the University of Granada and San Diego State University wanted to know how much of that material is carried up above the atmospheric boundary layer above 2,500 to 3,000 metres. At that altitude, particles are subject to long-range transport unlike particles lower in the atmosphere.

Using platform sites high in Spain's Sierra Nevada Mountains, the researchers found billions of viruses and tens of millions of bacteria are being deposited per square metre per day. The deposition rates for viruses were nine to 461 times greater than the rates for bacteria.

"Bacteria and viruses are typically deposited back to earth via rain events and Saharan dust intrusions. However, the rain was less efficient removing viruses from the atmosphere," said author and microbial ecologist Isabel Reche from the University of Granada.

The researchers also found the majority of the viruses carried signatures indicating they had been swept up into the air from sea spray. The viruses tend to hitch rides on smaller, lighter, organic particles suspended in air and gas, meaning they can stay aloft in the atmosphere longer.

Leg Exercise is Critical to Brain and Nervous System Health

In a new take on the exercise truism 'use it, or lose it,' researchers show neurological health is an interactive relationship with our muscles and our world.

Ground breaking research shows that neurological health depends as much on signals sent by the body's large, leg muscles to the brain as it does on directives from the brain to the muscles. Published today in *Frontiers in Neuroscience*, the study

fundamentally alters brain and nervous system medicine – giving doctors new clues as to why patients with motor neuron disease, multiple sclerosis, spinal muscular atrophy and other neurological diseases often rapidly decline when their movement becomes limited.

"Our study supports the notion that people who are unable to do load-bearing exercises – such as patients who are bed–ridden, or even astronauts on extended travel–not only lose muscle mass, but their body chemistry is altered at the cellular level and even their nervous system is adversely impacted," says Dr Raffaella Adami from the Università degli Studi di Milano, Italy.

The study involved restricting mice from using their hind legs, but not their front legs, over a period of 28 days. The mice continued to eat and groom normally and did not exhibit stress. At the end of the trial, the researchers examined an area of the brain called the sub-ventricular zone, which in many mammals has the role of maintaining nerve cell health. It is also the area where neural stem cells produce new neurons.

Limiting physical activity decreased the number of neural stem cells by 70 per cent compared to a control group of mice, which were allowed to roam. Furthermore, both neurons and oligodendrocytes – specialized cells that support and insulate nerve cells – didn't fully mature when exercise was severely reduced.

The research shows that using the legs, particularly in weight-bearing exercise, sends signals to the brain that are vital for the production of healthy neural cells, essential for the brain and nervous system. Cutting back on exercise makes it difficult for the body to produce new nerve cells – some of the very building blocks that allow us to handle stress and adapt to challenge in our lives.

"It is no accident that we are meant to be active: to walk, run, crouch to sit, and use our leg muscles to lift things," says Adami. "Neurological health is not a one-way street with the brain telling the muscles 'lift,' 'walk,' and so on."

The researchers gained more insight by analyzing individual cells. They found that restricting exercise lowers the amount of oxygen in the body, which creates an anaerobic environment and alters metabolism. Reducing exercise also seems to impact two genes, one of which, CDK5Rap1, is very important for the health of mitochondria – the cellular powerhouse that releases energy the body can then use. This represents another feedback loop.

These results shed light on several important health issues, ranging from concerns about cardio-vascular impacts as a result of sedentary lifestyles to insight into devastating diseases, such as spinal muscular atrophy (SMA), multiple sclerosis, and motor neuron disease, among others.

"I have been interested in neurological diseases since 2004," says co-author Dr Daniele Bottai, also from the Università degli Studi di Milano. "The question I asked myself was: is the outcome of these diseases due exclusively to the lesions that form on the spinal cord in the case of spinal cord injury and genetic mutation in the case of SMA, or is the lower capacity for movement the critical factor that exacerbates the disease?"

This research demonstrates the critical role of movement and has a range of potential implications. For example, missions to send astronauts into space for months or even years should keep in mind that gravity and load-bearing exercise play an important role in maintaining human health, say the researchers.

"One could say our health is grounded on earth in ways we are just beginning to understand," concludes Bottai.

Engineering a Plastic-eating Enzyme

Scientists have engineered an enzyme which can digest some of our most commonly polluting plastics, providing a potential solution to one of the world's biggest environmental problems.

The discovery could result in a recycling solution for millions of tonnes of plastic bottles, made of polyethylene terephthalate, or PET, which currently persists for hundreds of years in the environment.

The research was led by teams at the University of Portsmouth and the US Department of Energy's National Renewable Energy Laboratory (NREL) and is published in *Proceedings of the National Academy of Sciences* (PNAS).

Professor John McGeehan at the University of Portsmouth and Dr Gregg Beckham at NREL solved the crystal structure of PETase – a recently discovered enzyme that digests PET – and used this 3D information to understand how it works. During this study, they inadvertently engineered an enzyme that is even better at degrading the plastic than the one that evolved in nature.

The researchers are now working on improving the enzyme further to allow it to be used industrially to break down plastics in a fraction of the time.

Professor McGeehan, Director of the Institute of Biological and Biomedical Sciences in the School of Biological Sciences at Portsmouth, said: "Few could have predicted that since plastics became popular in the 1960s huge plastic waste patches would be found floating in oceans, or washed up on once pristine beaches all over the world.

"We can all play a significant part in dealing with the plastic problem, but the scientific community who ultimately created these 'wonder-materials', must now use all the technology at their disposal to develop real solutions."

The researchers made the breakthrough when they were examining the structure of a natural enzyme which is thought to have evolved in a waste recycling centre in Japan, allowing a bacterium to degrade plastic as a food source.

PET, patented as a plastic in the 1940s, has not existed in nature for very long, so the team set out to determine how the enzyme evolved and if it might be possible to improve it.

The goal was to determine its structure, but they ended up going a step further and accidentally engineered an enzyme which was even better at breaking down PET plastics.

"Serendipity often plays a significant role in fundamental scientific research and our discovery here is no exception," Professor McGeehan said.

"Although the improvement is modest, this unanticipated discovery suggests that there

is room to further improve these enzymes, moving us closer to a recycling solution for the ever-growing mountain of discarded plastics."

The research team can now apply the tools of protein engineering and evolution to continue to improve it.

The University of Portsmouth and NREL collaborated with scientists at the Diamond Light Source in the United Kingdom, a synchrotron that uses intense beams of X-rays 10 billion times brighter than the sun to act as a microscope powerful enough to see individual atoms.

Using their latest laboratory, beamline I23, an ultra-high-resolution 3D model of the PETase enzyme was generated in exquisite detail.

Professor McGeehan said: "The Diamond Light Source recently created one of the most advanced X-ray beamlines in the world and having access to this facility allowed us to see the 3D atomic structure of PETase in incredible detail. Being able to see the inner workings of this biological catalyst provided us with the blueprints to engineer a faster and more efficient enzyme."

Chief Executive of the Diamond Light Source, Professor Andrew Harrison, said: "With input from five institutions in three different countries, this research is a fine example of how international collaboration can help make significant scientific breakthroughs.

"The detail that the team were able to draw out from the results achieved on the I23 beamline at Diamond will be invaluable in looking to tailor the enzyme for use in large-scale industrial recycling processes. The impact of such an innovative solution to plastic waste would be global. It is fantastic that UK scientists and facilities are helping to lead the way."

With help from the computational modelling scientists at the University of South Florida and the University of Campinas in Brazil, the team discovered that PETase looks very similar to a cutinase, but it has some unusual features including a more open active site, able to accommodate human-made rather than natural polymers. These differences indicated that PETase may have evolved in a PET-containing environment to enable the enzyme to degrade PET. To test that hypothesis, the researchers mutated the PETase active site to make it more like a cutinase.

And that was when the unexpected happened – the researchers found that the PETase mutant was better than the natural PETase in degrading PET.

Significantly, the enzyme can also degrade polyethylene furandicarboxylate, or PEF, a bio-based substitute for PET plastics that is being hailed as a replacement for glass beer bottles.

Professor McGeehan said: "The engineering process is much the same as for enzymes currently being used in bio-washing detergents and in the manufacture of biofuels – the technology exists and it's well within the possibility that in the coming years we will see an industrially viable process to turn PET and potentially other substrates like PEF, PLA, and PBS, back into their original building blocks so that they can be sustainably recycled."

The paper's lead author is postgraduate student jointly funded by the University of Portsmouth and NREL, Harry Austin.

He said: "This research is just the beginning and there is much more to be done in this area. I am delighted to be part of an international team that is tackling one of the biggest problems facing our planet."

New Smart Contact Lens for Diabetics Introduced

This breakthrough has been jointly conducted by Professor Jang-Ung Park in the School of Materials Science and Engineering and Professor Franklin Bien in the School of Electrical and Computer Engineering at UNIST in collaboration with Professor Jung Heon Lee in the School of Advanced Materials Science and Engineering at Sungkyunkwan University.

According to the research team, this innovative smart lens with built-in pliable, transparent electronics can monitor glucose levels from tears in the eye. The device has not yet been tested in humans. However, the research team expects that the release of this device will offer diabetics a pain-free way to measure their glucose levels with the blink of an eye. Their findings have been published in *Science Advances* on 25 January, 2018.

For patients with diabetes, monitoring and controlling blood sugar levels are extremely important because having high blood glucose levels for extended periods of time can lead to a host of diabetes complications. An enzyme based finger-pricking method is the most commonly used technology in diabetic assessment. However, such approach has been said to reduce compliance among diabetic patients.

In the last several decades, many attempts have been made to monitor glucose levels in tears with smart contact lenses, but they are often not used due to poor wearability.

To solve contact lens discomfort issues, Professor Park and his research team have unveiled a new smart contact lens that uses electrodes made up of highly stretchable and transparent materials. This clear, flexible lens also contains a glucose sensor that sends electrical signals to an LED. With this sensor, patients can transmit their health information in real-time using the embedded wireless antenna in the lens. Electric power that activates the LED pixel and the glucose sensor is wirelessly transmitted to the lens through the antenna. After detecting the glucose concentration in tear fluid above the threshold, this LED pixel turns off.

In the study, the research team has successfully tested their prototype lens on a live rabbit via non-invasive in-vivo testing. The rabbit showed no signs of abnormal behaviour during repeated eye blinks and the LED pixel turned off when tear fluids with glucose concentration was over the threshold. In addition, during the wireless operations, this smart contact lens could still maintain the eye temperature stably without abrupt heating.

"These smart contact lenses are made of transparent nanomaterials and therefore do not obstruct the wearer's view," says Jihun Park in the Combined M.S./Ph.D. of Materials Science and Engineering, the first author of the study. "Besides, because the system uses wireless antenna to read sensor information, no separate power source, like battery is required for the smart contact lens sensors."

"The in vivo tests using a live rabbit ... provided the substantial promise of future smart contact lenses for noninvasive health care monitoring using human eyes and tears," says the research team.

"Our smart contact lens provides a platform for wireless, continuous, and noninvasive monitoring of physiological conditions, as well as the detection of biomarkers associated with ocular and other diseases," says Professor Park. "It also offers the potential for expanded applicability in other areas, such as smart devices for drug delivery and augmented reality."

He adds, "We are now a step closer to the implementation of a fictional idea for a smart contact lens in the films, like "Minority Report" and "Mission: Impossible."

Ecosystems Are Getting Greener in the Arctic

Researchers develop technique to better predict how plants in cold regions respond to warming

In recent decades, scientists have noted a surge in Arctic plant growth as a symptom of climate change. But without observations showing exactly when and where vegetation has bloomed as the world's coldest areas warm, it is difficult to predict how vegetation will respond to future warming. Now, researchers at the U S Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and UC Berkeley have developed a new approach that may paint a more accurate picture of Arctic vegetation and our climate's recent past – and future.

In a study published online on 20 August in *Nature Climate Change*, the researchers used satellite images taken over the past 30 years to track – down to a pixel representing approximately 25 square miles – the ebb and flow of plant growth in cold areas of the northern hemisphere, such as Alaska, the Arctic region of Canada, and the Tibetan Plateau.

The 30-year historic satellite data used in the study were collected by the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometre. The data was processed by Boston University, and is hosted on NEX – the NASA Earth Exchange data archive.

At first, the satellite data showed what they expected – that as Arctic climates warmed, tree and plant growth increased. After comparing these observations with state-of-the-art climate models developed for CMIP5 – the Coupled Model Intercomparison Project Phase 5 – what they discovered next surprised them.

Their data analysis revealed that 16 per cent of earth's vegetated land where plant growth was limited by cold temperatures three decades ago is no longer predominantly temperature-limited today, a result that was not reproduced by the CMIP5 models tested. "Our findings suggest that CMIP5's predictions may have significantly underestimated changes in the Arctic ecosystem, and climate models will need to be improved to better understand and predict the future of the Arctic," said first author Trevor Keenan, a faculty scientist in Berkeley Lab's Earth and Environmental Sciences Area and an assistant professor in UC Berkeley's department of Environmental Science, Policy, and Management.

Keenan and Riley used the satellite data to build a new observational benchmark that quantifies the growing expanse of vegetated land in the northern hemisphere. They also estimated changes in the proportion of the

earth's surface where plant growth will no longer be limited by cold temperatures over the 21st century. Keenan and Riley project that by the year 2100, only 20 per cent of vegetated land in the northern hemisphere will still be limited by cold conditions that have been in place there for centuries; the remaining 80 per cent will no longer experience sufficiently cold temperatures, and with earlier springs, plants will grow sooner, in unexpected places and to an unexpected degree.

"Although the greening might sound like good news as it means more carbon uptake and biomass production, it represents a major disruption to the delicate balance in cold ecosystems," said Keenan. "Temperatures will warm sufficiently so that new species of trees could move in and compete with vegetation that had previously dominated the landscape. This change in vegetation would also affect insects and animals that relied on native vegetation for food."

Scientists collaborating through the World Climate Research Programme developed the CMIP5 models to help researchers around the world gain a better understanding of the relationship between carbon emissions and global warming, among other goals. International consortiums such as the IPCC (International Panel on Climate Change) have also used CMIP5 projections to inform policy decisions. Keenan said that while the CMIP5 models provided researchers with a broad overview of the problem, they do not always accurately represent the important roles plants play in reflecting light back into the atmosphere, sending water back into the atmosphere, and absorbing carbon dioxide.

"No one has looked at high-latitude systems from this angle before as they are very complex, but they're important as they control multiple feedbacks to the earth system," said co-author William Riley, a senior scientist in Berkeley Lab's Earth and Environmental Sciences Area.

Now that Keenan and Riley have established a standard approach for assessing climate models, they plan to explore how they can use more advanced statistical techniques, such as machine learning, to quantify how soil organic matter properties, atmospheric carbon dioxide, wildland fires, and temperature, will affect climate in the 21st century.

Southern California Coast Emerges as a Toxic Algae Hot Spot

New research shows domoic acid from ocean algae is a growing problem

A new, comprehensive survey led by USC scientists shows the Southern California coast harbors some of the world's highest concentrations of an algal toxin dangerous to wildlife and people who eat local seafood.

Episodic outbreaks of algae-produced toxins make headlines every few years when stricken marine animals wash ashore between Santa Barbara and San Diego. The USC research is the most thoroughgoing assessment yet and reveals the growing scale of the problem over the last 15 years. The researchers say their findings can help protect human health and environment by improving methods to monitor and manage harmful algal blooms.

The findings are a 'smoking gun' linking domoic acid produced by some types of algae to deaths of marine birds and mammals, according to David Caron, a biologist at the

USC Dornsife College of Letters, Arts and Sciences, and postdoctoral researcher Jayme Smith, the study's main authors.

"We are seeing an increase in harmful algal blooms and an increase in severity," Caron said. "The Southern California coast really is a hot spot and our study also shows that the concentrations of particulate domoic acid measured in the region are some of the highest – if not the highest – ever reported." The findings appear in *Harmful Algae*.

Domoic acid is produced by microscopic Pseudo-nitzschia, needle-like diatoms in the water; half of the species in its genus can produce the neurotoxin. It can stain the ocean, a condition generically called 'red tide,' although this particular toxin is brown. The substance accumulates in shellfish and moves up the food chain, where it attacks the nervous system of fish, birds, seals and sea lions. It can cause amnesic shellfish poisoning (ASP) in people. ASP symptoms include rapid onset of headaches, abdominal pain, cramping, nausea or vomiting; severe symptoms include permanent short-term memory loss, seizures, coma or shock in 48 hours. Although human fatalities are rare, the California Department of Public Health monitors coastal waters and shellfish for the toxin.

The research encompasses the years 2003 to 2017 between Santa Barbara and the Mexico border, and includes new samples and tests collected over the past three years to supplement historical data. The study suggests that while natural processes lead to the formation of blooms, they could be exacerbated by nutrients discharged from human-made sources, including runoff and sewage outfalls.

Among the key findings:

- Pseudo-nitzschia is the culprit behind domoic acid. It's been present along the Southern California coast for decades, but its role in wildlife mortality is recent and increasing.
- The world's highest domoic acid measurement in water occurred near San Pedro in March 2011. It was 52.3 micrograms per litre – about five times higher than a level of concern.
- Through the years, researchers found a strong correlation between domoic acid in the water and impaired marine wildlife on shore.
- Domoic acid is ever-present offshore, either in shellfish or the water. Some years it is abundant, while other years it is scarce.
- Conditions are worse in the spring, due to seasonal upwelling of nutrients that spur plankton growth. The toxin is less abundant in the summer and winter.
- Domoic acid in shellfish can occur at high concentrations off the coast of San Diego, Orange and Los Angeles counties, but it tends to be more prevalent in Ventura and Santa Barbara counties due to local environmental conditions.
- Man-made sources of nutrients contribute to algal blooms, but that does not explain disparities in time and location of some of the domoic acid outbreaks. Other environmental factors are likely in play.
- The algae and its toxin diminish on the West Coast when water temperatures

exceed 68 degrees Fahrenheit, apparently due to temperature sensitivity of the microorganisms.

Also, a warming Pacific Ocean appears to be helping spread Pseudo-nitzschia species farther north. For example, harmful algal blooms have been widespread along the west coast of North America from Central California to Alaska in the past two years, according to the study. Separately, harmful algae blooms have been reported along the Gulf Coast this summer and the governor of Florida declared a state of emergency for affected counties last week.

The USC study brings together diverse data and observations that shed light on the environmental conditions that promote harmful algal blooms. Of note, an extreme drought across the US. Southwest between 2014 and 2016 resulted in very low concentrations of domoic acid off the Southern California coast. The findings imply a link between surface waters flowing to the ocean, or other drought-related conditions, and coastal algal blooms.

Those nuances and uncertainties need further exploration to explain the regional and year-to-year variations favouring toxic algae – key steps before more reliable health forecasts can occur, the USC scientists say.

"Our findings summarize our present level of understanding with respect to this important animal and human health risk in Southern California waters and identify several avenues of research that might improve understanding, prediction and eventually prevention of these harmful events," Smith said.

Source: *Science Daily Online*