CHEMWATCH

Bulletin Board

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On February 1, 2022, Japan's Ministry of Economy, Trade and Industry (METI) consulted to revise the Ministerial Ordinance Specifying the Method of Provision of Information on the Properties and Handling of Designated Chemical Substances, etc under the Pollutant Release and Transfer Register (PRTR) Law to allow SDS delivered via email or web in addition to fax. The deadline for comments is March 3, 2022.

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Chemlinked, 10 February 2022
https://chemical.chemlinked.com/news/chemical-news/japan-consults-on-sdss-delivery-in-digital-forms

Japan Consults on Annual Reporting Exemptions for 133 Substances under CSCL

2022-02-10

On January 7, 2022, Japanese Ministry of Economy, Trade and Industry (METI), Ministry of Health, Labor and Welfare (MHLW) and Ministry of Environment(MOE) consulted on adding 133 substances to the list of substances exempt from annual reporting under the Chemical Substances Control Law (CSCL). Comments are due by February 6, 2022, and the final list is expected to be released in late March, 2022. The list is generally updated on a yearly basis. As of March 31, 2021, there were 3,110 substances on the list.

Read More

Chemlinked, 10 February 2022

https://chemical.chemlinked.com/news/chemical-news/japan-consults-on-annual-reporting-exemptions-for-133-substances-under-cscl

Malaysia consulting on draft revised list of carcinogenic substances

2022-01-12

Closing date for public comments is 24 February

On February 1, 2022, Japan's Ministry of Economy, Trade and Industry (METI) consulted to revise the Ministerial Ordinance Specifying the Method of Provision of Information on the Properties and Handling of Designated Chemical Substances, etc under the Pollutant Release and Transfer Register (PRTR) Law to allow SDS delivered via email or web in addition to fax. The deadline for comments is March 3, 2022.

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Malaysia's Department of Occupational Safety and Health (Dosh) is consulting until 24 February on a draft revised list of prohibited carcinogenic substances under the Occupational Safety And Health (Prohibition of Use of Substance) Order 1999.

The Order, which sits under the Occupational Safety and Health Act 1994 (Osha), "covers the prohibition of use of [carcinogenic] substances. It bans the use of certain carcinogenic substances and stipulates how [companies] can use them for specific activities," the director of the Dosh's chemical management division, Hazlina Yon, told Chemical Watch.

Read More

Chemical Watch, 12-01-22

https://chemicalwatch.com/401250/malaysia-consulting-ondraftrevised-list-of-carcinogenic-substances

AMERICA

Complexities of PFAS research focus of congressional hearing

2022-02-02

Complexities of studying per- and polyfluoroalkyl substances (PFAS) were shared by NIEHS grantees and other experts during a congressional hearing. Witnesses discussed how increased research and development can better inform regulation and strengthen methods for cleaning up PFAS in the environment.

The Dec. 7 hearing was held jointly by the Subcommittees on Environment and on Research and Technology, which are part of the Committee on Science, Space, and Technology in the U.S. House of Representatives.

PFAS are a large class of manmade chemicals used in a variety of industrial and consumer products, such as firefighting foam and food packaging. The substances are known as forever chemicals because they are slow to break down and can accumulate in animals and humans.

"There are many outstanding questions related to PFAS fate and transport; toxicity; exposure pathways; treatment and destruction; remediation;

Witnesses discussed how increased research and development can better inform regulation and strengthen methods for cleaning up PFAS in the environment.

and essential use," said Chairwoman Mikie Sherrill (D-NJ) during her opening remarks. "To answer these questions, we must support an interdisciplinary, collaborative, and integrated approach. It is critical to develop partnerships between state and local entities, academia, nongovernmental stakeholders, and the federal government."

Participants described challenges associated with detecting PFAS, assessing their toxicity, and removing them from the environment. They emphasized the importance of government funding for research that informs health-protective policies and the need to share information with the public so that individuals can prevent harmful exposures.

Read More

NIEHS, 2 February 2022

https://factor.niehs.nih.gov/2022/2/science-highlights/pfas-research/index.htm

Managing risk in an age of missing information

2022-02-01

In 1998 Google was founded, Jesse "the Body" Ventura was elected Governor of Minnesota, "Titanic" swept the Oscars, I graduated from college, and the EPA was first alerted to the health hazards of toxic fluorinated chemicals, known as PFAS.

PFAS have been an emerging contaminant throughout my career in risk management, environmental, health and safety compliance. However, it is only within the last decade that PFAS have really captured the attention of policymakers.

In October of 2021, EPA released its "PFAS Road Map" detailing a timeline for the agency to set standards and guidelines surrounding PFAS in drinking water, wastewater, air and other releases. This road map is a glimpse into the future. However, we have the experience of the past year as we navigated one of the first actionable federal regulations that covered PFAS: the addition of 172 PFAS chemicals to the Emergency Planning and Community Right-to-Know Act (EPCRA) Toxic Release Inventory (TRI) reports that are required of covered industries that produce, manufacture or otherwise use related materials.

It became clear that information from suppliers was a significant data gap in preparing these reports and assessing PFAS risks.

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Under EPCRA, suppliers are required to notify customers subject to reporting that a product contains a covered chemical such as these specific PFAS. Supplier notifications commonly take the form of safety data sheets or product labeling, product literature or notification letters. As we assisted our industrial clients with their annual TRI Reports, it became clear that information from suppliers was a significant data gap in preparing these reports and assessing PFAS risks.

Read More

GSA Business, 1 February 2022

https://gsabusiness.com/news/sponsored-content/81639/

Maine predicts a steep price to fight forever chemicals

2022-02-01

Tackling the forever chemical problem in Maine could cost up to $20 million a year, state officials say.

That amount would pay for soil and water testing, and bottled water and filtration systems at Maine farms, factories and landfills where forever chemicals have tainted the well water, according to Maine Department of Environmental Protection Commissioner Melanie Loyzim.

And that preliminary estimate is probably too low, Loyzim warned state lawmakers Monday. It doesn't include compensation for property owners who suffer a drop in property values or farmers whose fields have been rendered unsafe for growing crops or raising livestock.

"It's like a nightmare you can't wake up from," Loyzim told the Environment and Natural Resources Committee. "People's homes and livelihoods have been destroyed and the scale of the tragedy keeps growing with every sample we take."

Maine has just begun its investigation into the more than 700 locations across the state where sludge, septic tank sewage and industrial waste was applied to farm fields as fertilizer. The investigation of these sites, and nearby wells, will take years, Loyzim said.

The problem is hitting Maine farmers hard. A dairy farmer surrendered a herd of milking cows to the state for euthanasia and an organic farm in Unity just pulled its vegetables from market shelves after testing revealed unsafe levels of PFAS in their products, Loyzim said.

It doesn't include compensation for property owners who suffer a drop in property values or farmers whose fields have been rendered unsafe for growing crops or raising livestock.

"We can quickly provide bottled water and treatment systems installed in the homes of people with contaminated wells," Loyzim said during the two-hour briefing. "But that's only a little thing for someone who has lost everything."

Forever chemicals, or PFAS, are long-lasting chemicals with a unique ability to repel oil, grease and water. They can be found in industrial products like firefighting foam, and many common household items, like stain-resistant carpets or waterproof clothing.

Read More

Yahoo News, 1 February 2022

https://news.yahoo.com/maine-predicts-steep-price-fight-095400787.html

US to reimpose limits on power plants' mercury emissions

2022-02-01

The US government announced Monday it wants to revive a regulation limiting air emissions of mercury and other toxic substances from fossil fuel-fired power plants that had been undermined by the previous administration.

The Environmental Protection Agency (EPA) "is proposing to reaffirm that it is appropriate and necessary to regulate emissions of hazardous air pollutants from coal- and oil-fired power plants," the agency said in a statement.

In May 2020, under former US president Donald Trump's administration, the phrase "appropriate and necessary" had been removed, thus nullifying the application of a regulation called the Mercury and Air Toxic Standards (MATS).

MATS was first introduced in 2021 under then-president Barack Obama, with whom current US leader Joe Biden worked as vice president.

MATS regulates mercury emissions levels, which scientists have linked to effects on the nervous system, especially in children.

The Environmental Protection Agency (EPA) "is proposing to reaffirm that it is appropriate and necessary to regulate emissions of hazardous air pollutants["]

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"Controlling these emissions improves public health for all Americans by reducing fatal heart attacks, reducing cancer risks, avoiding neurodevelopmental delays in children," the EPA said in a statement.

Before taking effect, the agency's proposal will first undergo a mandatory period of public debate.

The current emissions standards will initially remain unchanged, but the EPA is considering making them "more stringent."

The EPA's announcement comes as Biden's environmental reform plan remains stalled in Congress, despite months of negotiations.

Since taking office, Biden has made fighting climate change a priority for his administration.

Read More

Phys Org, 1 February 2022

https://phys.org/news/2022-02-reimpose-limits-power-mercury-emissions.html

EUROPE

EU plans to ban use of synthetic pesticides in parks

2022-02-07

UK urged to follow suit as Brussels draws up proposal to cut overall use of the chemicals by 50%

The use of synthetic pesticides in parks and other green public spaces in urban areas is to be banned in the EU, with member states obliged to cut overall use by 50%, according to a leaked draft regulation.

The move is said by the European Commission to be necessary owing to the failure of a number of EU member states to act on previous guidance on reducing the use of chemical pest control.

Officials say in the draft regulation that as a result of the proposals, "EU consumers could see increasing food prices, which might lead to increased imports from third countries with less strict regulation of pesticide use."

Under the regulation, pesticides would also be banned in nature protection areas.

But officials have said they will examine ways to mitigate the impact, adding that the EU needs "to shift to a fair, healthy and environmentally friendly food system". Under the regulation, pesticides would also be banned in nature protection areas.

About 70 towns and cities in the UK are taking steps to reduce pesticide use, but there is not a prohibition in law. A spokesperson for the Pesticide Action Network UK (PAN UK) called on the British government to follow Brussels' lead.

He said: "PAN UK has been calling for such a measure for many years and to see the European Commission bringing forward plans to end the unnecessary use of pesticides in urban areas is very welcome. It will be a huge benefit for the citizens and environment of the EU. PAN UK would like to see the UK follow suit and end the use of pesticides in our towns and cities."

The draft EU regulation, which will need to win the support of member states and the European parliament, received a mixed reaction from environmental activists in mainland Europe.

Concerns have been raised over the lack of strictures put on farmers to use methods such as crop rotation and mechanical weeding. Potential loopholes around the 50% target have also been identified, relating to lack of confidence in the collection of accurate data.

Sarah Wiener, a Green MEP, said she feared the regulation would amount to empty promises. She said: "The commission's proposal on the sustainable use of pesticides in the EU is anything but watertight. On the one hand, the commission acknowledges that the old directive gives the member states too much leeway and consequently wants to turn it into a regulation. On the other hand, the commission lists only insufficient measures to implement this basically good idea.

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The Guardian, 7 February 2022

https://www.theguardian.com/environment/2022/feb/04/eu-plans-to-ban-use-of-synthetic-pesticides-in-parks

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Turkish dumpsites contaminated with toxic chemicals from UK waste, says Greenpeace

2022-02-09

Greenpeace UK is calling on the government to enact the Environment Bill and use the powers within it to ban all plastic waste exports, not just to non-OECD members.

A report released by Greenpeace Mediterranean today (9 February), Game of Waste, suggests five sites in southern Turkey are 'extensively contaminated' with hazardous chemical pollutants, following what Greenpeace calls the 'illegal dumping and open burning' of imported plastic waste.

Last year Greenpeace investigators said they found UK grocery packaging dumped in the same five areas.

Greenpeace says that scientists found that levels of toxic chemicals* in the soil and ash at some of these locations are 'thousands of times higher' than control sites.

Samples of soil, ash, water and sediment collected from the five sites were examined by scientists from both Greenpeace Research Laboratories and an independent laboratory, the campaigners say.

They tested to identify 'as many chemical pollutants as possible', and also measured the concentrations of more than 60 chemical pollutants generally associated with plastic packaging or the burning of plastics.

The presence of a wide range of toxic chemicals was identified in ash and soil samples from all five locations, Greenpeace says.

Dr Kevin Brigden, one of the scientists who carried out the analysis, said: "Many of the chemical pollutants found in the samples of ash and underlying soil are highly resistant to breaking down in the environment and can build up in animals and humans over time.

"Levels of these pollutants were very high at some of these sites where plastic imported from countries including the UK gets dumped."

Circular, 9 February 2022

https://www.circularonline.co.uk/news/turkish-dumpsites-contaminated-with-toxic-chemicals-from-uk-waste-says-greenpeace/

Scientists found that levels of toxic chemicals* in the soil and ash at some of these locations are 'thousands of times higher' than control sites.

INTERNATIONAL

Europe's revolutionary BPA proposal puts more scrutiny on US regulatory inaction

2022-10-02

If a scientific opinion recently proposed by European officials is upheld, the recommended daily dose of bisphenol-A, or BPA, in Europe will be more than a million-fold lower than what U.S. regulators say is safe.

And the change in accepted exposure would all but ensure the chemical cannot be used in any food contact products.

"There's nothing different about the physiology of an American compared to a European," Laura Vandenberg, a professor at University of Massachusetts Amherst School of Public Health & Health Sciences, told EHN. "So, if it's hazardous in Europe, it's hazardous for us."

A significant gap already existed between the European Union and the U.S. in what regulators considered a safe dose of the plastic additive commonly used in everything from can linings to plastic water bottles. The draft opinion, released in December by the European Food Safety Authority, or EFSA, is "just moving it all the way to the left," said Vandenberg. She added that their conclusion is "very solidly backed up by science," and, in fact, has been now for at least a decade.

The change in accepted exposure would all but ensure the chemical cannot be used in any food contact products.

"And it's really different compared to the FDA [U.S. Food and Drug Administration]," she said.

BPA is an endocrine disruptor, meaning it alters the proper functioning of our hormones, and is linked to a host of health problems, including cancer, diabetes, obesity, reproductive, nervous and immune system impacts, and behavioral problems. Scientists like Vandenberg have published studies on such health effects for decades.

So, that begs the question: How can two major regulatory bodies look at the science and come to such vastly different conclusions? Where is the disconnect?

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Environmental Health News, 10 February 2022

https://www.ehn.org/bpa-efsa-fda-2656541533/different-approaches-to-testing-bpa-impacts

The Teflon chemical PTFE is often touted as a safe cousin of toxic PFAS. But is it really?

2022-10-02

As regulators and growing public awareness have put the screws on some of the more well-known PFAS chemicals, other variants are marketed as safe and are rarely scrutinised. One such chemical is PTFE – an unregulated chemical in the PFAS family – which is used in a plethora of consumer products, giving materials that desired non-stick function.

The question is – is PTFE really as safe as manufacturers claim?

When you drive your car, hurl yourself down a ski slope or cook your dinner you have most likely come into contact with the chemical PTFE. You can find it in such diverse products as non-stick cookware, ski wax, car interiors and dental floss.

PTFE, or polytetrafluoroethylene (promise you don't need to remember that), belongs to a subgroup of PFAS called fluorinated polymers, and PTFE is by far the most popular one in the group; it makes up approximately half the market.

One of the most familiar uses is in Teflon, but that's just one of its applications. PTFE is a chemical substance that has unique properties that make it very popular in a wide range of products. It has excellent heat resistance, electrical insulation properties and is extremely water repellent. Its non-stick properties make it ideal for coatings on items such as baking trays and other kitchen utensils. You can also find it in membranes in outdoor jackets and other textiles.

As awareness around the problematic effects of PFAS chemicals has started to grow, the notion of PTFE as safe to use has persisted among its proponents, even though there is not much evidence for anything, really. There are still many unknowns when it comes to the effects of PTFE, as is often the case with chemicals.

There are still many unknowns when it comes to the effects of PTFE, as is often the case with chemicals.

"There are no regulations in place that require chemical producers to disclose PTFE production"

Unfortunately you can't just consider the finished product – the frying pan in your hand. You have to look beyond this "use phase", before the PTFE was applied to the product. The thing is that a chemical has two more such phases in its life: the production and the waste phase. When you bring these additional phases, and the available science, into the analysis, well, then PTFE, you're not looking so great there, buddy.

Read More

Chemsec, 10 February 2022

https://chemsec.org/the-teflon-chemical-ptfe-is-often-touted-as-a-safe-cousin-of-toxic-pfas-but-is-it-really/

ECHA Publishes Update to the Appendix for Nanoforms

2022-02-04

The European Chemicals Agency (ECHA) has published a January 2022 update to the Appendix for nanoforms applicable to the Guidance on Registration and Substance Identification (version 2.0). The main changes to the document include additional guidance on the joint submission of data, clarifications regarding the need for one data set per nanoform or set of nanoforms, and information on the registration of sets of nanoforms versus single nanoforms. Changes to the Appendix are limited to Sections 2 and 5 of the currently published document. ECHA intends the document to provide guidance on how to interpret the term "nanoform" for registration purposes and provide advice on how to create "sets of nanoforms" for the purpose of registration. The document outlines what is expected in terms of characterization of the nanoforms and sets of nanoforms in the registration dossier. Finally, the document provides important information related to the joint submission of data on nanoforms, as well as on confidentiality aspects.

Read More

Nano and Other Emerging Chemical Technologies Blog, 4 February 2022

https://nanotech.lawbc.com/2022/02/echa-publishes-update-to-the-appendix-for-nanoforms/

Publication of initial assessments of substances added to the EU REACH Candidate list in 2021

2022-02-10

HSE, with the Environment Agency, has assessed 11 substances and substance groups that were submitted for identification as Substances of Very High Concern (SVHCs) in EU REACH.

The assessments consider if formal identification as SVHCs is an appropriate action for these substances under UK REACH.

The assessments have been published on the HSE website, along with supporting information on SVHCs in UK REACH*:*

- Assessments of substances added to the EU Candidate List in 2021
- UK REACH substances of very high concern (SVHC)

HSE is opening calls for evidence and invites interested parties to respond

As a result of these assessments, HSE and the Environment Agency have identified 4 priority substances or substance groups requiring regulatory management options analysis (RMOA).

Preparation of RMOAs: call for evidence

HSE is opening a call for evidence on 4 substances and substance groups that have recently been identified as SVHCs by the EU.

HSE, with the Environment Agency, is preparing RMOAs for the substances and substance groups below.

To inform these RMOAs, **HSE is opening calls for evidence** and invites interested parties to respond with general information and information on specific topics.

- DOTL
  Dioctyltin dilaurate, stannane, dioctyl-, bis(coco acyloxy) derivs., and any other stannane, dioctyl-, bis(fatty acyloxy) derivs. wherein C12 is the predominant carbon number of the fatty acyloxy moiety
  Closes 10 April
- 1,4-dioxane
  Closes 10 April
- SBAA
  Small brominated alkylated alcohols
  Closes 10 April
- PDDP
  Phenol, alkylation products (mainly in para position) with C12-rich branched or linear alkyl chains from oligomerisation, covering any individual isomers and/or combinations thereof
  Closes 10 April

The RMOAs will assess the best regulatory approach for these substances and substance groups in GB. They will determine the use profile in GB for each substance and substance group, whether any of these uses are creating a risk to human health and/or the environment and will identify the best regulatory approach to manage any identified risks.

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As part of this call for evidence we would also like to know if you are willing to be contacted by HSE and the Environment Agency to discuss information that you have submitted.

HSE, 10 February 2022

https://www.hse.gov.uk/

Janet's Corner

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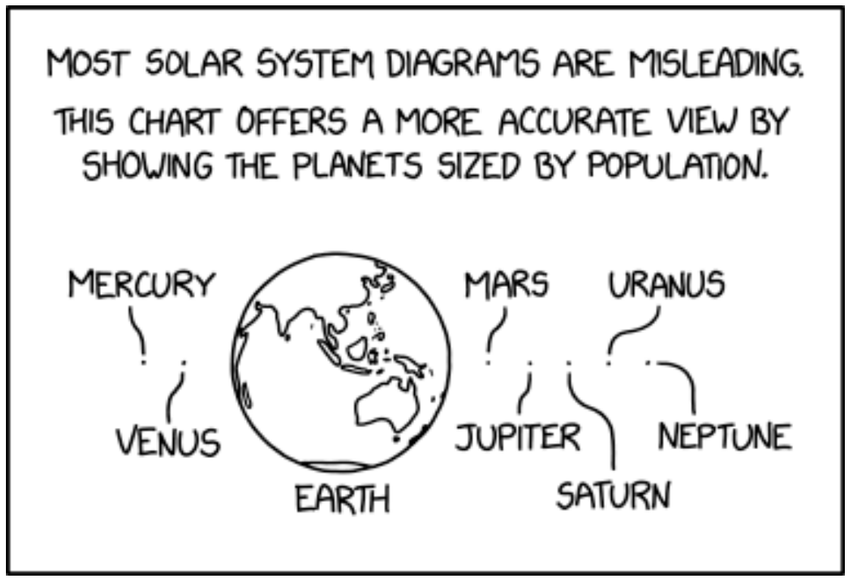
Solar System Cartogram

2022-02-18



https://xkcd.com/2439/

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Hazard Alert

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Hexachlorobenzene

2022-02-18

Hexachlorobenzene (HCB), is a chlorocarbon with the molecular formula C_6Cl_6. [1] It is a fully chlorinated industrial hydrocarbon chemical, which is insoluble in water, but is very soluble in fat, oils, and organic solvents. Hexachlorobenzene is one of the most persistent environmental pollutants, and bioaccumulates in the environment, in animals, and in humans. It is not currently manufactured as a commercial product in the United States, and virtually all commercial production ended in the late 1970s. However, some hexachlorobenzene is produced as a by-product or impurity in the manufacture of chlorinated solvents and other chlorinated compounds, including several pesticides currently in use (pentachloronitrobenzene, chlorothalonil, Dacthal®, picloram, pentachlorophenol, atrazine, simazine, and lindane). [2] HCB has been banned globally under the Stockholm Convention on persistent organic pollutants. [1]

USES [3]

There are currently no commercial uses of hexachlorobenzene. It was previously used as a pesticide but is no longer registered for this use. In addition, HCB was used in the production of fireworks, ammunition, rubber, aluminium, and dyes, and in wood preservation. Hexachlorobenzene was widely used as a pesticide to protect the seeds of onions and sorghum, wheat, and other grains against fungus. It is formed as a by-product during the manufacture of chemicals used as solvents (to dissolve other substances), other chlorine-containing compounds, and pesticides. Furthermore, it is formed as a by-product in the waste streams of chloralkali and wood-preserving plants, and when burning municipal waste.

Hexachlorobenzene (HCB), is a chlorocarbon with the molecular formula C6Cl6.

HCB IN THE ENVIRONMENT [4]

- Hexachlorobenzene can remain in the environment for a long time.
- It breaks down very slowly.
- It does not dissolve in water very well, so most of it will remain in particles on the bottom of lakes and rivers.
- Hexachlorobenzene sticks strongly to soil.
- High levels can build up in fish, marine mammals, birds, lichens, and animals that eat lichens (like caribou) or fish.

- It can also build up in wheat, grasses, some vegetables, and other plants.

SOURCES & ROUTES OF EXPOSURE

Sources of Exposure [4,5]

- Inhalation exposure to hexachlorobenzene may occur through proximity to industrial sites where it is formed as a by-product or to waste facilities where it is disposed.
- Occupational exposure, via inhalation and dermally, can occur at industries where hexachlorobenzene is produced as a by-product.
- Exposure to hexachlorobenzene can also occur through consuming foods tainted with hexachlorobenzene including fish and dairy products or meat from cattle grazing on contaminated pastures.
- Drinking small amounts in contaminated water.
- Eating or touching contaminated soil.
- For babies, drinking contaminated breast milk from exposed mothers.
- Hexachlorobenzene has been listed as a pollutant of concern to EPA's Great Waters Program due to its persistence in the environment, potential to bioaccumulate, and toxicity to humans and the environment

Routes of Exposure [6]

- Inhalation – A minor route of exposure for the general population.
- Oral – The predominant route of exposure for the general population through ingestion of contaminated food.
- Dermal – Skin contact with contaminated soil may be an important route of exposure, for those living near waste sites, especially children

HEALTH EFFECTS [5]

Acute Effects

- No information is available on the acute (short-term) effects of hexachlorobenzene in humans.
- Acute animal tests in rats and mice have shown hexachlorobenzene to have low-to-moderate acute toxicity from oral exposure.

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Chronic Effects

- Humans who ingested hexachlorobenzene in heavily contaminated bread during a 4-year poisoning incident were sickened with a liver disease with associated skin lesions (porphyria cutanea tarda).
- Very little data is available on the health effects of hexachlorobenzene in humans or animals following inhalation exposure.
- Animal studies have reported effects on the liver, skin, immune system, kidneys, and blood from chronic oral exposure to hexachlorobenzene.
- EPA has determined that there is inadequate data to establish a Reference Concentration (RfC) for hexachlorobenzene.
- The California Environmental Protection Agency (CalEPA) has established a chronic inhalation reference exposure level of 0.003 milligrams per cubic metre (mg/m^3) for hexachlorobenzene.
- The Reference Dose (RfD) for hexachlorobenzene is 0.0008 milligrams per kilogram body weight per day (mg/kg/d) based on liver effects in rats.

Reproductive/Developmental Effects

- One human study reported abnormal physical development in young children who ingested contaminated bread during a 4-year poisoning incident.
- Hexachlorobenzene has been found to decrease the survival rates of newborn animals and to cross the placenta and accumulate in foetal tissue in several animal species.
- Neurological, teratogenic, liver, and immune system effects have been reported in the offspring of animals orally exposed to hexachlorobenzene while they were pregnant.

Cancer Risk

- Human data regarding the carcinogenic effects of hexachlorobenzene are inadequate.
- Hexachlorobenzene, when administered orally, has been shown to induce tumours of the liver, thyroid, and kidney in several animal species.
- EPA has classified hexachlorobenzene as a Group B2, probable human carcinogen.
- EPA calculated an inhalation unit risk estimate of 4.6×10^{-4} $(\mu g/m^3)^{-1}$.

SAFETY [7]

First Aid Measures

- Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
- Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Get medical aid.
- Ingestion: If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid.
- Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Exposure Controls & Personal Protection

Engineering Controls

Use adequate general or local exhaust ventilation to keep airborne concentrations below the permissible exposure limits.

Personal Protective Equipment

- Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
- Skin: Wear appropriate protective gloves to prevent skin exposure.
- Clothing: Wear appropriate protective clothing to prevent skin exposure.
- Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

REGULATION

United States [4,8]

- The EPA has recommended that drinking water should not contain more than 0.05 milligrams of hexachlorobenzene per litre of water (0.05 mg/L) in water that children drink, and should not contain more than 0.2 mg/L in water that adults drink for longer periods (about 7 years). The EPA has set a maximum contaminant level of 0.001 mg/L in drinking water.
- The EPA requires that spills or accidental releases into the environment of 10pounds or more of hexachlorobenzene be reported to the EPA.
- ACGIH: The American Conference of Governmental Industrial Hygienists has set a time weighted average threshold limit value (TLV) of 0.002 mg/m^3; Skin; Appendix A3 - Confirmed Animal Carcinogen with Unknown Relevance to Humans

Australia [3]

- No national guidelines.

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Earth's inner core is 'superionic', a state of matter somewhere between solid and liquid, study suggests

2022-02-10

We've known for a while that Earth's deepest depths, its "solid iron" inner core, isn't made of pure iron — and now scientists say it might not be solid either.

Simulations by a team of researchers in China suggest our planet's innards are somewhere between solid and liquid in a "superionic" state.

The research has been published in the journal Nature.

Yu He, a physicist at the Chinese Academy of Sciences and co-author of the study, said the calculations were "a new starting point to understand the inner core".

This study, and others like it, Dr He added, might one day help earth scientists solve some fundamental but complex problems, such as when the inner core started to take shape.

But the new study can't completely explain all the inner core's quirks.

Why states of matter matter

On the surface of the Earth, we generally deal with three states of matter: solid, liquid and gas.

Take water, for instance. As ice in a cool drink, water molecules are arranged in a regular, 3D crystal. When that ice melts to become liquid water, those molecules can now move around, but are still in close proximity.

And as a gas, like the water vapour that gives humid days their oppressive stickiness, those mobile water molecules are free to move far away from each other.

But when substances are subjected to intense pressure or heat, they can switch into other, weirder states of matter.

Such as superionic matter, which is somewhere between liquid and solid.

In superionic water, molecules split apart into oxygen and hydrogen atoms.

The oxygen atoms crystallise into a 3D structure — like you'd see in a solid — while hydrogen atoms move freely around, like a liquid.

Superionic water ice could make up the bulk of giant icy planets, such as Neptune and Uranus.

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Superionic water ice could make up the bulk of giant icy planets, such as Neptune and Uranus.

And some geophysicists think the very centre of Earth, its inner core, is superionic too.

Instead of water, though, the inner core is made of a metal alloy: mostly iron, a bit of nickel, and a few other much lighter elements, such as hydrogen and carbon, mixed in there too.

It's the iron atoms that form the 3D "solid" structure in a superionic state, and the lighter elements that flow around it like liquid.

Earthquakes used to probe Earth's core

Earth's inner core reaches temperatures similar to the surface of the Sun, and pressures 3.7 million times what we experience at sea level.

Physically digging to the inner core is impossible, and we can't yet recreate its conditions in the lab.

So to get an idea of what the inner core is like, scientists measure how seismic waves, generated by earthquakes, change in speed and direction as they rumble through the centre of the planet.

This information can tell scientists how dense the inner core's iron alloy is, as well as its stiffness, said Hrvoje Tkalcic, a geophysicist at the Australian National University who was not involved in the work.

"And then we also have mineral physics, geodynamics and mathematical geophysics trying to work together to figure out what the heck is happening at the centre of our planet," Professor Tkalcic said.

Dr He and his crew used computer simulations to see how seismic waves might travel through an alloy made of iron, hydrogen, carbon and oxygen under immense pressure and heat.

They're not the first to do this: other studies have done similar, albeit with fewer lighter elements included.

The new study's conclusions are in line with what scientists have deduced from earthquakes: that the core is less dense than pure iron, so lighter elements must be mixed in, and it's relatively soft.

"And that's good. That's a step forward," Professor Tkalcic said.

But there's still a mystery

Something the new study can't fully explain is a peculiar but distinct feature of the inner core.

The speed at which a seismic wave moves through the inner core depends on its direction through the planet.

For instance, a wave travelling between north and south magnetic poles will ripple faster through the inner core than a wave travelling across the globe from equator to equator — even if they're travelling the same distance.

It's a phenomenon called seismic anisotropy, and why it happens, no-one's really sure.

Dr He and colleagues suggest lighter, liquid-like elements are not evenly distributed through the superionic inner core.

Instead, they're concentrated into a flattened sphere around the middle, which puts the brakes on waves passing through.

But how exactly how — and why — lighter elements might accumulate that way is not specified.

In any case, the middle of the planet definitely requires more scrutiny, Dr He said.

"I think more studies are needed to explain other seismic features, such as seismic anisotropy, in the inner core."

abc.net.au, 11 February 2022

https://abc.net.au/

'It's just extraordinary': Ancient crocodile's last meal may have been a dinosaur

2022-02-12

Australian scientists say they've discovered a new species of crocodile, and its last meal may have been a dinosaur.

The crocodile, called a Broken Dinosaur Killer, was recovered on a sheep station in outback Queensland, and is believed to be more than 95 million years old.

Researchers say while piecing together the fossilised croc, they made a startling discovery — the partial remains of a young ornithopod dinosaur inside its stomach.

The crocodile, called a Broken Dinosaur Killer, was recovered on a sheep station in outback Queensland, and is believed to be more than 95 million years old.

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"It's just extraordinary," researcher Matt White from The Australian Age of Dinosaurs Museum said.

"This is the first time that a crocodile has been discovered with dinosaur remains in its stomach," Dr White said.

"It's a world first."

Last meal a clue to prehistoric diets

The fossil was first discovered near Winton in 2010 by palaeontologists, and took more than six years to piece together.

It's the first skeletal remains of an ornithopod reported in the region and the first evidence that crocodiles ate dinosaurs in Australia.

"This prehistoric crocodile and its last meal will continue to provide clues to the relationships and behaviours of animals that inhabited Australia millions of years ago," Dr White said.

The discovery also suggests dinosaurs were an important part of the Cretaceous food web.

"Dinosaurs weren't exactly top of the food chain but were part of an intricate web of mammals, pterosaurs, birds and crocodiles," he said.

"What we've been able to demonstrate is the direct evidence of [crocodiles'] food source and that they were able to eat anything that came close enough."

There is evidence that ornithopods, which were small plant eaters with beaks and cheeks full of teeth, roamed Earth more than 100 million years ago.

"Ornithopods were very cute little dinosaurs, probably a little bit bigger than a chicken at about 1.2 kilograms," Dr White said.

"It would have looked something like Ducky from The Land Before Time.

"So you can imagine poor little Ducky crawling up onto the side of the bank and then a crocodile coming up and chomping it."

New technology used in discovery

Dr White said the bones were too fragile to be removed from the ground by conventional methods, so researchers used new technology to piece together an X-ray image of the fossil.

The scanned data files were then used by Dr White to digitally prepare the specimen, a process that can take months of processing, so that a 3D reconstruction of the bones could be made.

"The technology that we're using is drawing new life into what we can see within these fossils," Dr White said.

"We may have other fossils out there around the world that actually have remains in their stomach and this new technology may help us discover that.

"It's going to change how things are done."

abc.net.au, 12 February 2022

https://abc.net.au/>

Crickets tipped to replace kale, acai, blueberries as mainstream superfoods in 2022

2022-02-07

There's been a buzz about the nutritional benefits of insects for years, but 2022 is the year creepy-crawlies are finally tipped to make it onto mainstream supermarket shelves.

Eighty per cent of the world's population already eat insects as a part of their everyday diet.

Food scientist and entomologist Skye Blackburn found herself asking why Australians were not among them after trying insects for the first time in Thailand in 2007.

"I sent away some crickets and mealworms for nutritional testing and when I got the results back I was actually shocked that no-one was eating them as a source of food here in Australia," she says.

"They were just so nutrient-dense, they had everything that your body could possibly need."

How do you 'farm' insects?

Unlike cattle properties and broadacre cropping, insects do not need much space.

Because of this, insect farms are common in cities. One could be next to your house!

"They have twice the protein of beef, more calcium than milk, they have three times more iron than spinach, and have all nine amino acids," he says.

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Ms Blackburn now has her own insect farm 'The Edible Bug Shop' in Western Sydney.

"We convert unused warehouse spaces into insect protein farms," she says.

"We have these specially designed enclosures that stack from the floor all the way up to the roof.

"It means that we're really efficient on space."

While a typical farmer might have 400 head of cattle, Ms Blackburn says she does not know how many crickets she has but knows they are in the millions.

"We currently have about 30 tonnes of crickets before they are processed in our warehouse," she says.

To ensure her business is future-proofed, Ms Blackburn has invented technology for her farm.

"We've developed robotic technologies and artificial intelligence that helps us feed and clean and monitor the crickets so that they have a really happy and healthy life," she says.

Nutritional goldmine

Ms Blackburn was one of the first in the western world to farm insects for human consumption.

Insect farming is now becoming more and more popular with farms popping up all over Australia.

Stirling Tavener has just started an insect farm in Cairns and says they are the next big superfood.

"They have twice the protein of beef, more calcium than milk, they have three times more iron than spinach, and have all nine amino acids," he says.

Channy Sandhu, founder of edible insect product business Hoppa Foods, agrees.

"[Insect protein] is clean protein, which is good for your gut. It's easily digestible and backed with sustainability and environmental factors," Mr Sandhu says.

"It becomes a no-brainer for people to try it."

Gold star for sustainability

By 2050, another 2 billion people will be on our planet and that means 60–70 per cent more food will be needed for the growing population.

So how does insect farming help us get there?

"Insects can be reared on food that would otherwise be lost in production systems, so we can recover some of that food waste or food loss and rear insects on those," Professor Michelle Colgrave leader of CSIRO future protein mission explains.

This 'circular' concept of farming is what Ms Blackburn loves about her farm.

"We're taking waste products and creating a completely new source of food," she says.

"If you replace just one meat-based meal a week with a meal that uses crickets as your source of protein you actually save over 100,000 litres of drinking water a year.

"We're not taking up farmland to farm them.

"They create 1/100th of the amount of greenhouse gases when you compare them to traditional livestock as well."

Why don't Aussies eat more crickets?

Unlike eastern food markets where consuming whole insects is common, Professor Colgrave says Australian consumers do not like to go outside their comfort zone.

"One of the major concerns I think we have here in Australia is the 'ick' or 'yuck' factor," she says.

"It's not something that we are accustomed to eating and often we consider insects as pests."

To overcome this, Ms Blackburn says consumers just need to think of insects as an additional protein source.

"You don't have to have all the legs and wings and antennas in there to be getting all the benefits of edible insects," she says.

"So we take familiar foods that you would eat every day, like corn chips, pasta, or granola, and we enrich it using invisible insect proteins. You wouldn't even know that it's there."

Mr Sandhu started his business, Hoppa Foods, in 2018.

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He says uptake is growing thanks to years of education about nutritional benefits.

"We wanted to bridge that gap between insects and something that consumers were already used to in terms of how the product looked, felt and tasted," he says.

"The nutritional benefits outweigh the fear factor that most people have.

"Once they try it once they realise that there was nothing to fear and there is no whole insect in sight."

2022 the year of the cricket

The Australian insect industry is tipped to reach a $10 million per annum target over the next five years according to Agrifutres Australia.

So is 2022 the year more Aussies will pop some mealworms into their mouths?

"I definitely think that 2022 is the year of the edible insects. You'll be noticing that they're hopping onto shelves around Australia right now," Ms Blackburn says.

"So they will definitely be more accessible; you'll be able to purchase them with your regular shopping."

Mr Sandhu says if sales are any indication to go by, 2022 will be his best year yet.

"Over the past three years, we've just seen our sales go up, which clearly is a reflection that the market is there, and year on year it is growing," he says.

"We have probably seen an increase of about 20 per cent in our sales compared to last year.

"I've got no doubt in my mind, this is the future of our food."

abc.net.au, 7 February 2022

https://abc.net.au/

We counted 20 billion ticks of an extreme galactic clock to give Einstein's theory of gravity its toughest test yet

2021-12-14

For more than 100 years, Albert Einstein's general theory of relativity has been our best description of how the force of gravity acts throughout the Universe.

General relativity is not only very accurate, but ask any astrophysicist about the theory and they'll probably also describe it as "beautiful". But it has a dark side too: a fundamental conflict with our other great physical theory, quantum mechanics.

General relativity works extremely well at large scales in the Universe, but quantum mechanics rules the microscopic realm of atoms and fundamental particles. To resolve this conflict, we need to see general relativity pushed to its limits: extremely intense gravitational forces at work on small scales.

We studied a pair of stars called the Double Pulsar which provide just such a situation. After 16 years of observations, we have found no cracks in Einstein's theory.

Pulsars: nature's gravity labs

In 2003, astronomers at CSIRO's Parkes radio telescope, Murriyang, in New South Wales discovered a double pulsar system 2,400 light years away that offers a perfect opportunity to study general relativity under extreme conditions.

To understand what makes this system so special, imagine a star 500,000 times as heavy as Earth, yet only 20 kilometres across. This ultra-dense "neutron star" spins 50 times a second, blasting out an intense beam of radio waves that our telescopes register as a faint blip every time it sweeps over Earth. There are more than 3,000 such "pulsars" in the Milky Way, but this one is unique because it whirls in an orbit around a similarly extreme companion star every 2.5 hours.

According to general relativity, the colossal accelerations in the Double Pulsar system strain the fabric of space-time, sending gravitational ripples away at the speed of light that slowly sap the system of orbital energy.

This slow loss of energy makes the stars' orbit drift ever closer together. In 85 million years' time, they are doomed to merge in a spectacular cosmic

After 16 years of observations, we have found no cracks in Einstein's theory.

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pile-up that will enrich the surroundings with a heady dose of precious metals.

We can watch this loss of energy by very carefully studying the blinking of the pulsars. Each star acts as a giant clock, precisely stabilised by its immense mass, "ticking" with every rotation as its radio beam sweeps past.

Using stars as clocks

Working with an international team of astronomers led by Michael Kramer of the Max Planck Institute for Radio Astronomy in Germany, we have used this "pulsar timing" technique to study the Double Pulsar ever since its discovery.

Adding in data from five other radio telescopes across the world, we modelled the precise arrival times of more than 20 billion of these clock ticks over a 16-year period.

To complete our model, we needed to know exactly how far the Double Pulsar is from Earth. To find this out, we turned to a global network of ten radio telescopes called the Very Long Baseline Array (VLBA).

The VLBA has such high resolution it could spot a human hair 10km away! Using it, we were able to observe a tiny wobble in the apparent position of the Double Pulsar every year, which results from Earth's motion around the Sun.

And because the size of the wobble depends on the distance to the source, we could show that the system is 2,400 light years from the Earth. This provided the last puzzle piece we needed to put Einstein to the test.

Finding Einstein's fingerprints in our data

Combining these painstaking measurements allows us to precisely track the orbits of each pulsar. Our benchmark was Isaac Newton's simpler model of gravity, which predated Einstein by several centuries: every deviation offered another test.

These "post-Newtonian" effects – things that are insignificant when considering an apple falling from a tree, but noticeable in more extreme conditions – can be compared against the predictions of general relativity and other theories of gravity.

One of these effects is the loss of energy due to gravitational waves described above. Another is the "Lense-Thirring effect" or "relativistic

frame-dragging", in which the spinning pulsars drag space-time itself around with them as they move.

In total, we detected seven post-Newtonian effects, including some never seen before. Together, they give by far the best test so far of general relativity in strong gravitational fields.

After 16 long years, our observations proved to be amazingly consistent with Einstein's general relativity, matching Einstein's predictions to within 99.99%. None of the dozens of other gravitational theories proposed since 1915 can describe the motion of the Double Pulsar better!

With larger and more sensitive radio telescopes, and new analysis techniques, we could keep using the Double Pulsar to study gravity for another 85 million years. Eventually, however, the two stars will spiral together and merge.

This cataclysmic ending will itself offer one last opportunity, as the system throws off a burst of high-frequency gravitational waves. Such bursts from merging neutron stars in other galaxies have already been detected by the LIGO and Virgo gravitational-wave observatories, and those measurements provide a complementary test of general relativity under even more extreme conditions.

Armed with all these approaches, we are hopeful of eventually identifying a weakness in general relativity that can lead to an even better gravitational theory. But for now, Einstein still reigns supreme.

theconversation.com, 14 December 2021

https://theconversation.com/<a/>

Here's what will happen when SpaceX rocket crashes into the moon

2022-02-14

It's not often that the sudden appearance of a new impact crater on the Moon can be predicted, but it's going to happen on March 4, when a derelict SpaceX Falcon 9 rocket will crash into it.

The rocket launched in 2015, carrying Nasa's Deep Space Climate Observatory (DSCOVR) probe into a position 1.5 million kilometers from the Earth, facing the Sun. But the expended upper stage of the rocket had insufficient speed to escape into an independent orbit around the Sun, and was abandoned without an option to steer back into the Earth's

Its precise movements have been hard to predict, because they were influenced by lunar and solar gravity as well as the Earth's.

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atmosphere. That would be normal practice, allowing stages to burn up on re-entry, thus reducing the clutter in near-Earth space caused by dangerous junk.

Since February 2015, the 14 meters long, derelict upper stage, massing nearly four tonnes, has therefore been in a wide orbit about the Earth. Its precise movements have been hard to predict, because they were influenced by lunar and solar gravity as well as the Earth's.

But we can now tell that it is going to hit the Moon on March 4 at a speed of about 2.6 kilometers per second. This will make a crater about 19 meters in diameter – a prospect that has provoked outrage in social media circles from people who are appalled that human negligence will disfigure the Moon in this way.

Misplaced concern

It is, however, surely more environmentally friendly for a dead rocket to end up on the Moon than being scattered through Earth's upper atmosphere in the form of metal oxide particles, which is what happens during a re-entry burn up. The Moon also lacks an atmosphere to shield it from space debris, so it is accumulating naturally occurring impact craters all the time.

The Lunar Reconnaissance Orbiter has already imaged a 19 meter crater formed when a half a tonne lump of asteroid rock traveling about ten times faster than the Falcon 9 struck the surface in March 2013. Over the past decade, hundreds of smaller impacts, by chunks of rock weighing as little as half a kilogram, have been spotted by NASA's lunar impact monitoring project.

The coming impact will be on the lunar far side, so we wont be able to see it happen. But spacecraft orbiting the Moon will be able to image the impact crater afterwards. Will we learn anything new? There have been several previous deliberate crashes onto the Moon, so we know what to expect.

For example, the considerably larger upper stages of rockets used in the Apollo landing missions were crashed so that vibrations detected by seismometers installed on the surface could be used to investigate the lunar interior. The Apollo seismometers were turned off long ago, and is not clear whether the seismometer on China's Chang'e 4 far side lunar lander will be able to provide any useful data this time.

A precisely targeted, deliberate crash was also achieved in 2009 when NASA's LCROSS mission sent a projectile into a permanently shadowed polar crater – making a smaller crater on its icy floor and throwing up a plume that proved to contain the hoped for water vapor.

Biological contamination

So I'm not bothered by one more crater being made on the Moon. It already has something like half a billion craters that are ten meters or more in diameter. What we should worry about is contaminating the Moon with living microbes, or molecules that could in the future be mistaken as evidence of former life on the Moon.

Most nations have signed up to planetary protection protocols that seek to minimize the risk of biological contamination from Earth to another body (and also from another body back to Earth). The protocols are in place for reasons both ethical and scientific. The ethical argument is that it would not be right to put at risk any ecosystem that may exist on another body by introducing organisms from Earth that might thrive there. The scientific argument is that we want to study and understand the natural conditions on each other body, so we should not risk compromising or destroying them by wanton contamination.

The biggest recent breach of the COSPAR protocols was in 2019 when the privately funded Israeli lunar lander Beresheet crashed on the Moon, carrying DNA samples and thousands of tardigrades. Those are half millimeter long organisms that can tolerate, though not be active in, the vacuum of space. These, and presumably also the microbes that lived in their guts, are now scattered across the Beresheet crash site.

Most likely none of these will end up in a niche where there is enough water for them to revive and become active, but that is not a risk we should be taking. The DSCOVR Falcon 9 was not sterile upon launch, but nor did it carry a biological cargo. It's also been seven years in space, so by now the risk of biocontamination is vanishingly small – but the more things we send to the Moon, the more careful we must be and the harder it will be to enforce any rules.

livescience.com, 14 February 2022

https://livescience.com/

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5 million shipwrecked Legos still washing up 25 years after falling overboard

2022-02-13

A once-in-a-century wave that pummeled a cargo ship in 1997 caused the worst toy-related environmental disaster of all time. As the vessel Tokio Express pitched and rolled near the United Kingdom's southwestern coast, 62 shipping containers tumbled off the ship — and one of them dumped nearly 5 million plastic Lego pieces into the ocean.

Soon after the event, which some referred to as the Great Lego Spill, beachgoers in Cornwall, U.K., began finding brightly-colored plastic Legos. Even now, 25 years after the Feb. 13 disaster, numerous Legos from the spill still appear on beaches in Cornwall.

Coincidentally, many of those sea-tossed Lego pieces were nautically-themed. There were tens of thousands of octopuses, life jackets, scuba tanks, diving fins and pirate cutlasses, along with terrestrial shapes such as flowers, "witches' brooms" and dragons, said British beachcomber and writer Tracey Williams, author of "Adrift: The Curious Tale of the Lego Lost at Sea" (Unicorn Publishing Group, 2022).

Williams began collecting beach Legos in 1997 in South Devon, U.K., soon after the spill; more than a decade later, she launched the Lego Lost at Sea Facebook group, where people shared photos of the Legos that they found on British beaches, Williams told Live Science.

"In 2010, I moved to Cornwall to be close to my family, and on my first trip to the beach I noticed Legos from the spill again," Williams said. "I was amazed that it was still washing up after all that time."

On that fateful day in 1997, the Lego bricks and objects had been loaded onto the Tokio Express in Rotterdam, the Netherlands, and they were bound for New York. But disaster struck about 20 miles (32 kilometers) off the coast of western Cornwall, in the form of a rogue wave, Cornwall Live reported in 2014.

For centuries, rogue waves — immensely tall and dangerous ocean waves that seemingly appeared out of nowhere — were thought to exist only in maritime legends. However, evidence in recent decades has shown that these waves do exist, though their unpredictability makes them difficult to track and study, according to the National Ocean Service (NOS). Also known as extreme storm waves, rogue waves are thought to form out of merging swells; the resulting wall of water can measure dozens of feet

The captain of the Tokio Express described the Feb. 13 rogue wave as a "once in a 100-year phenomenon"

high and may rise suddenly and unexpectedly from a direction other than that of visible surface waves, the NOS says.

The captain of the Tokio Express described the Feb. 13 rogue wave as a "once in a 100-year phenomenon" that first rocked the ship 60 degrees in one direction and then 40 degrees in the opposite direction, according to the BBC. The ship's manifest listed 4,756,940 Lego pieces that were lost at sea, of which 3,178,807 were light enough to float, Cornwall Live reported. In 2015, the BBC mapped more than 40 beach locations in Cornwall where people had reported collecting wayward Lego bits. Williams and her family have probably collected thousands of Legos since the time of the spill, she told Live Science.

Beachcombers initially found the lighter-weight pieces, such as slippers, flowers, lifejackets and octopuses. Black and green dragons, which were also a common sight on beaches but were slightly heavier by comparison, may have also floated because they contained air pockets, Williams said.

"What we're finding now are the pieces that sank as well as the pieces that floated," she said. "It's providing us with an insight into what happens to plastic in the ocean, how far it drifts — both on the surface of the ocean but also along the seabed — and what happens to it as it breaks down." But one of the big problems with plastic pollution is that it can take centuries to degrade in the ocean, and as it deteriorates it releases chemicals that can harm animals' hormones and disrupt their reproduction, according to the American Chemical Society.

In fact, it may be even longer than a few hundred years until the lost Lego pieces break down. When scientists recently analyzed the structure of weathered beach Legos using X-ray fluorescence, they found that it could take up to 1,300 years for Legos from the 1997 spill to degrade entirely, researchers reported in July 2020 in the journal Environmental Pollution.

livescience.com, 13 February 2022

https://livescience.com/>

Robots help some sick children 'attend' school. Kids are working with scientists to make them better

2022-02-10

In a sunny room at the Boys & Girls Club in Calistoga, a tiny city in California's Napa Valley, Veronica Ahumada is setting up her robot when a bespectacled little boy wanders in to ask what she's doing. Ahumada

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points to the device—basically a tricked-out tablet on a meter-tall post, mounted onto gyroscopic roller wheels—and he yelps like he's seen a ghost. "She has a robot!" he hollers, bolting out the door.

Soon, about 40 tweens fill the room. Many are Latino like Ahumada, and they are here for after-school child care while their parents work. When she invites them to guess what the robot is for, their ideas bubble over: to play video games! To go to the supermarket! To help people get around! To take orders at a restaurant! To take over the world!

Ahumada, who studies health informatics and human-robot interactions at the University of California (UC), Davis, acknowledges each child's suggestion, then explains: "I use these robots for children just like you," but who can't go to school because they have serious illnesses such as cancer or heart problems. Those children can send the robot instead, she says, and join their classmates virtually, from home. The group falls silent. "Whaaaaat?" they croon in a collective tune of disbelief.

In fact, rolling robot avatars allow ill children to attend school remotely in a few hundred classrooms across the United States and a smattering of other countries. The gadgets, called telepresence robots, were designed to allow doctors to conduct rounds from a distance and corporate executives to visit remote facilities. They show a remote user's face and let the user see, listen, and speak as if they were present. Ahumada and a few other researchers think the devices could provide classroom access to a long-overlooked group of children. "We've never in the history of the world had the opportunity for children with these serious medical conditions to go to school with their peers," Ahumada says.

Children who use the technology have called it life-changing because of the social connections it allows. "It's like I'm actually there—that's why I like it so much," an 8-year-old told Ahumada. In addition to taking part in lessons as if they were in the classroom, children can zip around to chat with friends and join their peers for lunch, chorus, or recess.

"There's probably a specific band of kids [for whom] this could be transformational," says Gary Maslow, a pediatric psychiatrist at Duke University who studies how children adapt to chronic illness. But researchers haven't yet proved these tools help academically, socially, or emotionally, he says. And the technology itself has limitations: The robots weren't designed for children and don't work well in schools with spotty Wi-Fi.

Children who use the technology have called it life-changing because of the social connections it allows.

Ahumada is "trying to figure out how to overcome those obstacles," says Justin Reich, an expert in educational technology at the Massachusetts Institute of Technology. Aiming to flesh out how best to integrate telepresence robots into classrooms, she and her colleagues have been probing how dozens of children with different illnesses, along with their families, classmates, and teachers, engage with the devices. In 2020, she teamed up with health care roboticist Laurel Riek at UC San Diego to design a machine with features tailored for children, including speakers that can carry sound over a classroom's din, an "arm" for reaching and grasping, and a user interface operable by children with a range of ages and abilities.

She is also planning to join forces with clinicians to pin down whether the benefits that children report in her studies translate into gains in mental health, grades, or other measurable areas. If they do, she says, schools may eventually be required to provide robots, creating a market as well as a vision for the technology. "It's much bigger than I originally imagined," she says.

OVER THE PAST 2 YEARS, as the pandemic turned the world inside out, children and families accustomed to attending school, sports, and scouts got a taste of isolation and homebound life. But by Ahumada's count, about 2.5 million U.S. children with serious medical issues already experienced significant stretches of isolation before the pandemic. Teachers tell them not to worry about school and just to focus on getting better—a supportive sentiment, but one that underscores their exile from normalcy. Classmates often don't know why they disappear from school or what their daily life is like.

Ahumada knows the experience well. Congenital heart defects that went undiagnosed until adulthood kept her home for weeks at a time during elementary school. She was too weak to do more than read or doze on the couch in her family's one-bedroom home, waiting for her two brothers to come home with worksheets from her teacher. The days were lonely and achingly boring.

Children whose medical conditions keep them out of school are an amorphous group. Some get better and go back to school; others, sadly, succumb to their illness. Still others cycle in and out, as Ahumada did. U.S. public school districts generally provide such children several hours per week of instruction by a visiting teacher. But the system is spotty, and students often fall behind. According to research by Maslow and others, having a chronic illness in childhood puts people at a serious

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disadvantage. "They are less likely to attend college, half as likely to graduate college, less likely to be employed, and have lower income," he says.

Children stuck at home also miss out on another aspect of school. "Humans have evolved to be social creatures," says Maja Matarić, a roboticist and computer scientist at the University of Southern California. Social development goes hand in hand with cognitive learning, she says, and it benefits from a physical presence in school.

Ahumada was lucky: Her own illness subsided by middle school and her childhood normalized. She went to college and eventually landed a job at Montana's Department of Public Health and Human Services. She soon found herself musing about technology and her solitary childhood. The department was expanding health care access by placing video consoles in clinics it was struggling to staff. Her colleagues expected patients would prefer in-person appointments, but later, when the state reverted to them, some people grumbled about losing the relationship with their distant doctor.

If patients can use video to bond with remote doctors, Ahumada thought, perhaps children at home could forge relationships with classmates and teachers the same way. "I wanted to know," she says, "if it was good enough for physicians, was it good enough for kids? Do we have the technology to completely transform the daily experience of these children?"

Making a robot friend

For a robot to stand in effectively for a child in a classroom, it needs to be more than an iPad on wheels. Here are some key features of a child-friendly version of today's telepresence robots.

1 Camera

The camera should pan and tilt to move like an eyeball and compensate for the robot's lack of a neck.

2 Sound

Speakers should adjust the child's speaking volume based on background noise in the classroom and allow the child to translate typed text to speech. The microphone should pick out single voices and minimize background noise.

3 Arm and hand

An extendable arm and hand should be dexterous enough to pick up small objects and squeeze gently enough to avoid breaking them.

4 Adjustable height

Both the screen and arm should be adjustable vertically between sitting and standing position for children of a wide range of ages.

5 Wi-Fi connectivity

The robot must connect to public and encrypted Wi-Fi, as well as transition seamlessly between routers as the robot moves.

6 Agility

The robot should move at a relatively fast walking speed—with wheels that can handle outdoor surfaces.

Ahumada wanted to study the idea in graduate school, but she struggled to find an adviser. Eventually, she connected with Mark Warschauer at UC Irvine, who investigates how digital technologies can enable learning and social inclusion. His team wasn't studying remote access for children, he told her—no one he knew of was—but he offered her a spot in his lab.

Colleagues were skeptical, though. One likened research on telepresence robots to "studying TV carts." Another told her the work would have no impact because "so few" students have illnesses that require them to stay home. Even Warschauer didn't seem fully convinced, she says, until he saw a Verizon ad from the 2013 Super Bowl, which featured a child maneuvering a robot through school from a hospital bed. "Mark had never seen my idea conceptualized before," Ahumada says. "We were so excited—we were like, 'It's a thing!'"

The device in the ad was manufactured by VGo, a small company that had already begun to sell robots to schools for ill students but hadn't done research to discover how well the devices met their aims. (The company has since been acquired by Vecna Technologies.) Ahumada contacted VGo, which connected her with a school district in Texas that had just purchased several robots. The program had started with a girl in elementary school who was using a robot while undergoing cancer treatment. Her classmates were so grateful their friend could remain among them during her illness that they raised more than $1000 to help buy another robot for other ill children to use.

Ahumada decided to base her first case study there, using interviews to probe how ill children and their community used the devices. The logistics

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were complicated. Because the robot captures the classroom on video, families of every student had to consent to its presence. Recruiting robot users was another challenge. Like most families with a seriously ill child, the ones in this district "were just trying to survive," Warschauer says. "They weren't thinking about participating in research projects." But by the end of 2013, Ahumada had completed the study, interviewing five sick students from second to ninth grade about their experiences with the VGo robots, as well as five parents, 10 teachers, 35 classmates, and six school administrators.

The ill students all told Ahumada about relief the robot brought from social isolation. One child's mother said she didn't realize her son was depressed until she saw him blossom with the robot, spending much more time alert and engaged with school. The study also revealed classmates and teachers quickly came to treat the robot not as a moving hunk of plastic and metal, but as the student it represented. Children and adults referred to it by the student's name, and many classmates went out of their way to help when the robot got stuck. "My research kind of gives me hope for humanity," Ahumada says. "The majority of kids are so thoughtful."

Not every experience was positive. A ninth grade girl decided to return the robot because of the unwanted attention it brought—classmates teasingly called her a "vacuum cleaner," for example. And a fifth grade boy was bullied by a classmate who kept smearing the robot's lens with ketchup.

MATARIĆ, TOO, HAS EXPLORED how the technology works in schools, using robots made by a company called Ohmnilabs. She and her colleagues first had design experts operate a classroom robot remotely, as a child would, to identify technical features that would help children and teachers use them more effectively. These included a signal like raising one's hand to get a teacher's attention and a camera that swivels to look at a classmate. A study that gave robots to four children to use in their classrooms over 2 to 8 weeks also identified the need for a speaker that can regulate the volume of its voice according to whether a child is whispering questions about English homework or being chased on the playground.

All four children found the experience very positive, the researchers saw, but deploying the robots involved extensive coordinating and troubleshooting, as well as navigating school district politics. They weren't ready to use out of the box, Matarić says.

Ahumada's work similarly finds a mix of promise and complexity, as have the few other studies that have looked at telepresence robots used in

schools. Since her pilot study in Texas, she has gathered perspectives from 91 children with illnesses across the United States who have used telepresence robots, along with their families, classmates, teachers, and school administrators. The important design needs those interviews revealed identify some of the same features that Matarić pinpointed. But the children's most common demand was for a robotic arm that would allow them to engage with the world—reaching, grabbing, tagging. Children want something that enables "not just seeing and hearing and moving around on your own, but also being able to touch the world and to receive sensations," Riek says.

The children also voiced values that might appear frivolous but could help them maintain social connections. One child requested a robot feature that's sure to be a design challenge—the ability to do a bunny hop. And 53 of a subset of 82 children Ahumada interviewed described using the robot to play, either with classmates or alone, she and Riek report in a paper under review. One child told Ahumada that using the robot showed their friends they remained the same person they were before they got sick. Peers, too, seek that connection. "Little kids hug the robot because they're so happy to see their friend," Ahumada says.

AS THE WORLD ENTERS the third year of the pandemic, remote attendance through video conferencing platforms has become routine. That change may actually harm the prospects for telepresence robotics in schools, Ahumada says. Video conferencing is cheaper than robots, and teachers now have experience using it. When several schools she works with reopened, they chose to leave students who were remote for medical reasons on video rather than bring back the robots.

The pandemic has also revealed an important limitation of virtual learning, Reich notes. "Teachers have a very hard time managing classes when some people are in person and some people are at a distance," he says. The difficulty may persist even with a single remote student on a robot.

But better telepresence technology could help, Reich adds. "I could imagine some future where these things are way better than Zoom." What if, he wonders, "holding a virtual reality controller, you point your finger at something, and the robot takes its finger and points at it?"

In September 2020, Ahumada and Riek received a $1.2 million grant from the National Science Foundation to develop a telepresence robot with features specifically designed for remote learning for children. They are starting with a prototype called Stretch, made by Hello Robot, that was designed for older adults and people with disabilities to use around their

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home. For now, Stretch lacks a display screen, but it has a retractable arm that moves smoothly up and down a sturdy metal spine. At the end of the arm sits a gripper consisting of two small rubber cups on bendy strips of metal.

In Ahumada's office, a graduate research assistant, Jingjing Xie, explores Stretch's capabilities. Sitting on a chair with the classic board game Trouble at her feet, she uses the robot's controller to bring the arm down to the board and move a yellow peg. It's clumsy, like a claw machine at an arcade, and the gripper's rubber cups can't press the popper that rolls the dice.

Stretch is a work in progress. Over the next year, based on Ahumada's studies to date, she and Riek will settle on features that a child needs to feel present and engaged in learning, and they will modify Stretch to include them. Remote students will test their prototypes and weigh in. "These kids are the pros," Ahumada says. Long before the pandemic, before many families gave virtual school a thought, "they were already the pioneers."

Some alterations should be straightforward, such as adding a screen to show the face of the child at home. Other specs will surely require inventing technology. And the researchers want to make the robot's physical presence cool and fun for children, something they can feel proud of as an extension of themselves among their peers. "We want the child to feel like they're not this weird thing inside a robot, but they are part of the class," Riek says.

Still, despite Ahumada's investment in telepresence robots, she would happily abandon them if something more nimble came along. "Today it's robots," she likes to say, "but tomorrow it could be holograms." It's all in support of a bigger goal. When she visits classrooms with a robot in play, she sees sick children mentioning their nausea or showing classmates a port for delivering medicine or a scar from a recent surgery. Classmates breezily ask their robot-embodied friends how they are doing. Healthy and sick children form a single community. "If we don't scoot illness away," she says, "will we be more compassionate?"

science.org, 10 February 2022

https://science.org/

Gut microbe linked to depression in large health study

2022-02-04

The trillions of bacteria in and on our bodies can bolster our health and contribute to disease, but just which microbes are the key actors has been elusive. Now, a study involving thousands of people in Finland has identified a potential microbial culprit in some cases of depression.

The finding, which emerged from a study of how genetics and diet affect the microbiome, "is really solid proof that this association could have major clinical importance," says Jack Gilbert, a microbial ecologist at the University of California, San Diego, who was not involved with the work.

Researchers are finding ever more links between brain conditions and gut microbes. People with autism and mood disorders, for example, have deficits of certain key bacteria in their guts. Whether those microbial deficits actually help cause the disorders is unclear, but the findings have spawned a rush to harness gut microbes and the substances they produce as possible treatments for a variety of brain disorders. Indeed, researchers recently reported in Frontiers in Psychiatry that fecal transplants improved symptoms in two depressed patients.

Guillaume Méric didn't set out to find microbes that cause depression. A microbial bioinformatician at the Baker Heart & Diabetes Institute, he and his colleagues were analyzing data from a large health and lifestyle study from Finland. Part of a 40-year effort to track down underlying causes of chronic disease in Finnish people, the 2002 study assessed the genetic makeup of 6000 participants, identified their gut microbes, and compiled extensive data about their diets, lifestyles, prescription drug use, and health. Researchers tracked the health of participants until 2018.

Méric and his colleagues combed the data for clues to how a person's diet and genetics affect the microbiome. "There have been very few studies that have examined [all these factors] in such detail," Gilbert says. Two sections of the human genome seemed to strongly influence which microbes are present in the gut, the researchers report this week in Nature Genetics. One contains the gene for digesting the milk sugar lactose, and the other helps specify blood type. (A second study, also published today in Nature Genetics, identified the same genetic loci by analyzing the relationship between the genomes and gut microbes of 7700 people in the Netherlands.)

Méric's team also explored which genetic variants might affect the abundance of certain microbes—and which of those variants were linked

Researchers are finding ever more links between brain conditions and gut microbes.

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to 46 common diseases. When it came to depression, two bacteria that cause infections in hospitalized patients, Morganella and Klebsiella, seemed to play a causal role, the researchers say. One of them, Morganella, was significantly increased in a microbial survey of the 181 people in the study who later developed depression.

"This is really exciting," says Jeroen Raes, a microbiologist at KU Leuven who was not involved with the study. "The beauty of the work," he adds, is that Méric and colleagues made the connection between increased levels of the bacterium and patients undergoing depression.

Morganella has already been implicated in depression. As far back as 2008, researchers investigating a possible link between depression and inflammation found depressed people had stronger immune responses to chemicals produced by Morganella and other gram-negative bacteria in the gut. Thus, the newest study seems to be "further proof" that inflammation caused by gut microbes can influence mood, Gilbert says.

But the field is still in its infancy, says Gerard Clarke, a microbiome researcher at University College Cork, as there are many forms of depression and many possible ways that microbes could affect this disease. The "holy grail" is to identify a missing microbe that could be given as supplement, he says. But it's less clear how Morganella could be eliminated from the gut to relieve symptoms. "That's a bit more challenging."

science.org, 4 February 2022

https://science.org/

European fusion reactor sets record for sustained energy

2022-02-09

In experiments culminating the 40-year run of the Joint European Torus (JET), the world's largest fusion reactor, researchers announced today they have smashed the record for producing controlled fusion energy. On 21 December 2021, the U.K.-based JET heated a gas of hydrogen isotopes to 150 million degrees Celsius and held it steady for 5 seconds while nuclei fused together, releasing 59 megajoules (MJ) of energy—roughly twice the kinetic energy of a fully laden semitrailer truck traveling at 160 kilometers per hour. The energy in the pulse is more than 2.5 times the previous record of 22 MJ, set by JET 25 years earlier. "To see shots in which

"To see shots in which it sustains high power for a full 5 seconds is amazing," says Steven Cowley, director of the Princeton Plasma Physics Laboratory (PPPL).

it sustains high power for a full 5 seconds is amazing," says Steven Cowley, director of the Princeton Plasma Physics Laboratory (PPPL).

JET's achievement doesn't mean fusion-generated electricity will flow into the grid anytime soon, however. Researchers had to put roughly three times as much energy into the gas as the reaction produced. But the result gives them confidence in the design of ITER, a giant fusion reactor under construction in France, which is supposed to pump out at least 10 times as much energy as is fed in. "This is very good news for ITER," says Alberto Loarte, head of ITER's science division. "It strongly confirms our strategy."

Fusion has long been promoted as a future green energy source. If the same nuclear reaction that powers the Sun could be duplicated on Earth, it could provide plentiful energy with small amounts of nuclear waste and no greenhouse gases. But producing net energy has proved elusive. In August 2021, researchers at the National Ignition Facility, which triggers fusion by heating and crushing tiny pellets of fuel with 192 converging laser beams, reported they had gotten to 71% of this break-even mark, closer than anyone else, but only for an instant.

JET and ITER represent a different approach, one that is more suitable for sustained energy production. Both are tokamaks: doughnut-shaped vessels wrapped in a grid of powerful magnets that hold the superhot ionized gas, or plasma, in place and prevent it from touching and melting the vessel walls. Researchers in the 1980s believed JET and a rival machine at PPPL (now dismantled) would quickly reach breakeven. JET got close in 1997, generating a short, 1.5-second burst that reached two-thirds of the input power.

But slow progress spurred researchers in the 1990s to design ITER, a giant tokamak 20 meters wide that holds 10 times as much plasma as JET. A larger plasma volume, models predicted, would maintain fusion conditions longer by making it harder for heat to escape. The $25 billion ITER, funded by China, the European Union, India, Japan, South Korea, Russia, and the United States, is due to start operation in 2025 but won't produce large amounts of power until 2035, when it is due to start burning the energy-producing isotopes deuterium and tritium (D-T).

JET's early operation taught ITER's designers a key lesson. JET was lined with carbon because it resists melting. But it turned out to "soak up fuel like a sponge," says Fernanda Rimini, JET's plasma operations expert. So ITER's designers opted to use the metals beryllium and tungsten.

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No one knew how they would perform, however, and JET provided a testbed. Starting in 2006, engineers upgraded its magnets, plasma heating system, and inner wall to make it as ITER-like as possible. When it restarted in 2011, the signs were not good, says Cowley, who was then director of the Culham Centre for Fusion Energy, which runs JET on behalf of the European Union's EuroFusion agency. "We couldn't get into the same [high power] regimes."

Painstakingly, the JET team worked out what was going on. They found that high energy plasma ions were knocking out tungsten ions from the wall, causing them to radiate energy and bleed heat out of the plasma. Over many years, the team worked out a coping strategy. By injecting a thin layer of gas, such as nitrogen, neon, or argon, close to the vessel wall, they could cool the outermost edge of the plasma and stop ions from hitting the tungsten. "Bit by bit we clawed back performance," Cowley says.

In September 2021, JET researchers set out to see what their redesigned machine could do. That meant switching fuel, to D-T. Most fusion reactors run on ordinary hydrogen or deuterium, which allows them to explore the behavior of plasmas while avoiding the complications of tritium, which is both radioactive and scarce. But JET staff were itching to test their machine in real power-producing conditions. First, they had to revive the reactor's tritium-handling facilities, not used for 2 decades, which extract unburned tritium and deuterium ions from waste gas after each shot and recycle them.

The recent successes set the stage for ITER and show its designers' gamble on a full metal wall ought to pay off. "This confirms we took the right level of risk," Loarte says. But for JET, the D-T run is something of a swan song. Joe Milnes, head of JET operations, says the reactor will have one more experimental run, from mid-2022 to the end of 2023, before closing. "It's been the most successful fusion experiment ever," he says, but it's time "to hand the baton to ITER."

science.org, 09 February 2022

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Next-generation spinal implants help people with severe paralysis walk, cycle, and swim

2022-02-07

Three men paralyzed in motorcycle accidents have become the first success stories for a new spinal stimulation device that could enable

faster and easier recoveries than its predecessors. The men, who had no sensation or control over their legs, were able to take supported steps within 1 day of turning on the electrical stimulation, and could stroll outside with a walker after a few months, researchers report today. The nerve-stimulating device doesn't cure spinal cord injury, and it likely won't eliminate wheelchair use, but it raises hopes that the assistive technology is practical enough for widespread use.

"This [result] I would call a big deal," says Vivian Mushahwar, a biomedical engineer and neuroscientist at the University of Alberta, Edmonton, who was not involved in the work. "This adds a level of refinement that allows for these approaches … to make it to the clinic and hopefully help a large number of people."

When trauma severely damages the bundle of nerves that make up a person's spinal cord, the brain's electrical signals no longer reach the body's muscles, resulting in paralysis. But epidural stimulation devices, thin sheets of electrodes implanted beneath the vertebra of the lower spine, can re-create those commands beyond the injury site and trigger leg movements. When such stimulation is turned on, even some patients with "complete" paraplegia—no movement or sensation in the lower body—have been able to walk after extensive training and with assistance from supportive devices or a therapist.

But spinal cord stimulators, developed in the 1980s to treat chronic pain, weren't designed with spinal cord injury in mind, says Grégoire Courtine, and neuroscientist at the Swiss Federal Institute of Technology, Lausanne. One problem with existing implants is their shape: They consist of a narrow silicone strip that targets the center of the spinal cord to disrupt pain signals ascending to the brain. To trigger leg and torso movements, researchers need to stimulate the dorsal roots, pairs of thick sensory fibers extending from either side of the spinal cord. Existing electrode strips are also too short to reach the dorsal roots that control the trunk and enable bending and straightening the torso, Courtine says.

So he and his colleagues designed a longer and wider implant, roughly the size of a pointer finger. To position electrodes along its surface so they would precisely stimulate the dorsal roots, the researchers studied cadavers and images of healthy spines. Once they had the new design, they used computer models to predict the ideal position of the implant on each patient's spinal cord.

Finally, the team designed software to activate the electrodes in set patterns that produce movements such as standing up and stepping.

Some patients with "complete" paraplegia—no movement or sensation in the lower body—have been able to walk after extensive training

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Typical epidural implants deliver uniform, repetitive pulses of electricity, says Peter Grahn, a neuroscientist at the Mayo Clinic. Patterned stimulation might help retrain damaged networks of nerves in the spinal cord to better receive and interpret signals descending from the brain that are preserved after spinal cord injury, he says. But just how the electrical stimulation interacts with spinal networks, and in turn the relative advantages of the two approaches, aren't clear yet, he adds.

In 2018, this patterned stimulation approach got a big test: People with spinal cord injuries who had some residual leg sensation or movement were able to walk and cycle. But the participants in the new study had more severe, complete injuries, all of which occurred at least 1 year before their enrollment. With the new, larger implant and custom-positioned electrodes, all three could take steps on a treadmill within the first day after the stimulation was turned on—albeit with harnesses that supported more than half of their weight, the team reports today in Nature Medicine.

"That is remarkable to see within 1 day with a severe injury like this," says Megan Gill, a research physical therapist at the Mayo Clinic who was not involved in the study. Previous studies have shown leg movements early on for people with complete paralysis, but this is the first time Gill has heard of such patients stepping their legs in an upright, "loaded" position in the first day of therapy.

After 4 to 6 months, all three participants were able to walk across the ground using only a walker for stability. It took participants in previous studies more than 1 year to achieve overground stepping, Mushahwar notes. "Intense therapy for a year and a half is a little bit impractical under current health care systems, at least in the U.S." she says. The new work makes such therapy "meaningful from a health care management perspective." And such daily movement is valuable to patients with spinal cord injuries: Even short walks can lead to better cardiovascular function, more bowel and bladder control, increased bone density, and less risk of pressure injuries from prolonged sitting.

Using different stimulation patterns, the participants in the new study could swim, cycle, and do leg presses and sitting forward bends. One patient was even able to climb a staircase. But with the stimulation off, their abilities remain limited. One regained some ability to activate leg muscles, but not to make functional movements. And two participants in a previous study who had incomplete paralysis could eventually stand without stimulation. How much ability spinal cord stimulation can restore long-term is unclear, Courtine says. It may depend on severity of the

original injury and how soon after that injury the device is implanted, he adds.

For now, sending commands to the device is cumbersome. Users must select their desired movement on a tablet, which sends Bluetooth commands to a transmitter worn around the waist. That device must be positioned next to a "pulse generator" implanted in the abdomen, which then activates electrodes along the spine. Setting up to use the stimulation takes 5 to 10 minutes, Courtine says.

But the next generation of devices should allow users to activate the pulse generator by giving voice commands to a smartwatch, says Courtine, who is also chief scientific officer of the medical technology company ONWARD. In 2024, the company plans to test this newer mobility system in a multisite clinical trial of 70 to 100 participants that the team hopes will lead to U.S. regulatory approval.

science.org, 07 February 2022

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What is the quantum apocalypse and should we be scared?

2022-01-27

Imagine a world where encrypted, secret files are suddenly cracked open - something known as "the quantum apocalypse".

Put very simply, quantum computers work completely differently from the computers developed over the past century. In theory, they could eventually become many, many times faster than today's machines.

That means that faced with an incredibly complex and time-consuming problem - like trying to decrypt data - where there are multiple permutations running into the billions, a normal computer would take many years to break those encryptions, if ever.

But a future quantum computer, in theory, could do this in just seconds.

Such computers could be able to solve all sorts of problems for humanity. The UK government is investing in the National Quantum Computing Centre in Harwell, Oxfordshire, hoping to revolutionise research in the field.

But there is also a dark side.

Data thieves

A number of countries, including the US, China, Russia and the UK, are working hard and investing huge sums of money to develop these super-fast quantum computers with a view to gaining strategic advantage in the cyber-sphere.

Every day vast quantities of encrypted data - including yours and mine - are being harvested without our permission and stored in data banks, ready for the day when the data thieves' quantum computers are powerful enough to decrypt it.

"Everything we do over the internet today," says Harri Owen, chief strategy officer at the company PostQuantum, "from buying things online, banking transactions, social media interactions, everything we do is encrypted.

"But once a functioning quantum computer appears that will be able to break that encryption... it can almost instantly create the ability for whoever's developed it to clear bank accounts, to completely shut down government defence systems - Bitcoin wallets will be drained."

Every day vast quantities of encrypted data - including yours and mine - are being harvested without our permission and stored in data banks

It's a prognosis echoed by Ilyas Khan, chief executive of the Cambridge and Colorado-based company Quantinuum. "Quantum computers will render useless most existing methods of encryption," he says.

"They are a threat to our way of life."

Quantum-proofing

Seriously? That does sound completely apocalyptic, so why haven't we heard more about this?

The answer is that yes, OK, this would indeed be the case if no precautions were being taken. "If we weren't doing anything to combat it then bad things would happen," says a Whitehall official who asked not to be named.

In practice, mitigation efforts are already in train and have been for some years. In the UK, all government data classified as "top secret" is already "post-quantum" - that is, using new forms of encryption which researchers hope will be quantum-proof.

Angela Merkel stands next to two men in front of a complex, somewhat messy array of pipes and wires

Tech giants like Google, Microsoft, Intel and IBM are working on solutions, as well as more specialist companies like Quantinuum and Post-Quantum.

Most importantly, there is currently something of a post-quantum cryptography "beauty parade" taking place at the US National Institute for Science and Technology (NIST) just outside Washington DC. The aim is to establish a standardised defence strategy that will protect industry, government, academia and critical national infrastructure against the perils of the quantum apocalypse.

All of this will not be cheap.

Quantum computing is expensive, laborious and generates large amounts of heat. Developing quantum-safe algorithms is one of the major security challenges of our time.

But experts say the alternative - doing nothing - is simply not an option.

bbcnews.com, 27 January 2022

https://bbcnews.com/

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Why do we love the great outdoors? New research shows part of the answer is in our genes

2022-02-09

Do you love spending time in nature? Or are you a city slicker, happier in the concrete jungle than the great outdoors? Back in 1986, the US biologist EO Wilson proposed that humans have an innate connection with the natural world, an idea known as biophilia.

Almost every aspect of our lives depends on nature, from food and shelter to fuel and clothing. Yet some of us are much more "into" spending time in nature than others.

To try to understand why, we studied more than 1,100 pairs of twins to find out how much of our connection to nature might depend on our DNA. We found almost half the variation in people's connection to nature can be put down to genetics.

Nature is good for you

There is strong evidence even a wander in the local park can be beneficial for our mental and physical health. Yet with work and family responsibilities and packed social schedules, most of us do not regularly spend time in nature.

We wondered why some people spend more time in nature than others, and what underpins the fact some of us feel more strongly connected to nature.

Perhaps our affinity for nature is inherited. Or perhaps we get it from environmental factors – such as beautiful forests – in the places we live. Or again it might come from our cultural milieu such as the books we read or the TV programs we watch.

Finding answers to these questions might help us work out how to get some nature back into people's lives.

Studying twins

We studied more than 1,100 pairs of twins to understand the origin of affinity for nature, and report the results in a study published today in PLoS Biology. It turns out identical twins are much more similar to each other in the strength of their connection to nature than non-identical twins.

Statistical analysis of the results showed 46% of the variation in connection to nature, as measured on a psychological scale, can be explained by

There is strong evidence even a wander in the local park can be beneficial for our mental and physical health.

genetic factors. Even the amount of time we spend in our own backyards and visiting local parks seems to have a strong genetic basis.

Why the strong genetic influence on our love for nature? Well, one can imagine a strong affinity with nature conferring a significant survival advantage for early humans. This might have led to the formation of complex networks of genes that govern how we relate to nature, and how we behave in it.

Despite the clear role of genetics, our results show other factors actually shape most of our affinity to nature. These might include childhood holiday destinations, the examples set by our parents, friends and other family members, educational experiences, and whether we live in a biodiverse area.

This is good news, because many of these things are under our own control.

Nature and health

Nature–based health interventions such as green gyms or environmental volunteering can improve physical, mental and social health and well-being. Nature-play initiatives such as the Green Passport for Queensland kids can give children powerful experiences of nature that could benefit their health over the long term.

A deeper question, and one we don't yet have a clear answer to, is whether spending time in nature fosters our sense of environmental concern, and in turn, support for nature conservation.

The US ecologist James Miller has argued interactions with nature are crucial in sparking support for protecting nature. Yet an Australian study led by environmentalist Jessica Pinder showed conservation concern among Australian undergraduates was more strongly associated with social and cultural experiences in childhood than with the amount of time a person spends in nature. Clearly, there is much more to learn in this area.

Ultimately, we now know despite a genetic basis for our affinity to nature, much of it also depends on other factors that are decidedly under our own control. So make a resolution today to rekindle your connection to the great outdoors!

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blog.csiro.au, 9 February 2022

https:// blog.csiro.au

Mysteries of Stephen Hawking's doodle-filled blackboard may finally be solved

2022-02-13

A new museum exhibit hopes to uncover the secrets behind the doodles, in-jokes and coded messages on a blackboard that legendary physicist Stephen Hawking kept untouched for more than 35 years.

The blackboard dates from 1980, when Hawking joined fellow physicists at a conference on superspace and supergravity at the University of Cambridge in the U.K., according to The Guardian. While attempting to come up with a cosmological "theory of everything" — a set of equations that would combine the rules of general relativity and quantum mechanics — Hawking's colleagues used the blackboard as a welcome distraction, filling it with a mishmash of half-finished equations, perplexing puns and inscrutable doodles.

The befuddling blackboard has just gone on public display for the first time ever as the centerpiece of a new exhibition on Hawking's office

Still preserved more than 40 years later, the befuddling blackboard has just gone on public display for the first time ever as the centerpiece of a new exhibition on Hawking's office, which opened Feb. 10 at the Science Museum of London. The museum will welcome physicists and friends of Hawking — who died in 2018 at the age of 76 — from around the world in hopes that they may be able to decipher some of the hand-scrawled doodles.

What, for example, does "stupor symmetry" mean? Who is the shaggy-bearded Martian drawn large at the blackboard's center? Why is there a floppy-nosed squid climbing over a brick wall? What is hiding inside the tin can labeled "Exxon supergravity?" Hopefully, the world's great minds of math and physics can rise to the occasion with answers.

The blackboard joins dozens of other Hawking artifacts on display, including a copy of the physicist's 1966 Ph.D. thesis on the expansion of the universe, his wheelchair and a personalized jacket given to him by the creators of "The Simpsons" to honor his multiple appearances on the show. The exhibit will run until June 12 at the Science Museum in London, before

hitting the road with stops at several other museums in the U.K., according to The Guardian.

Hawking was born in England on Jan. 8, 1942. While studying cosmology at the University of Cambridge in 1963, he was diagnosed with motor neuron disease, more commonly known as Lou Gehrig's disease or amyotrophic lateral sclerosis (ALS). Then just 21, Hawking was expected to live just two more years. He continued to live and work for more than five decades, publishing pioneering work on black holes, the Big Bang theory and general relativity.

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Skyrmions can generate true random numbers

2022-02-08

Whether for use in cybersecurity, gaming, or scientific simulation, the world needs true random numbers, but generating them is harder than you might think. Now, a group of physicists has developed a technique that can potentially generate millions of random digits per second by harnessing the behavior of skyrmions.

Their research, published in Nature Communications, reveals previously unexplored dynamics of single skyrmions, the researchers say. Discovered around a half-decade ago, skyrmions have sparked interest in physics as a path toward next-generation computing devices that take advantage of the magnetic properties of particles—a field known as spintronics.

"There has been a lot of research into the global dynamics of skyrmions, using their movements as a basis for performing computations," says Gang Xiao, chair of the physics department at Brown University and senior author of the research. "But in this work, we show that purely random fluctuations in the size of skyrmions can be useful as well. In this case, we show that we can use those fluctuations to generate random numbers, potentially as many as 10 million digits per second."

TRUE RANDOM NUMBERS

Most random numbers produced by computers aren't random in the strictest sense. Computers use an algorithm to generate random numbers based on an initial starting place, a seed number. But because the

Most random numbers produced by computers aren't random in the strictest sense.

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algorithm used to generate the number is deterministic, the numbers aren't truly random. With enough information about the algorithm or its output, it could be possible for someone to find patterns in the numbers that the algorithm produces. While pseudorandom numbers are sufficient in many settings, applications like data security—which uses numbers that can't be guessed by an outside party—require true random numbers.

Methods of producing true random numbers often draw on the natural world. Random fluctuations in electrical current flowing through a resistor, for example, can be used to generate random numbers. Other techniques harness the inherent randomness in quantum mechanics—the behavior of particles at the tiniest scale.

This new study adds skyrmions to the list of true random number generators.

TINY SKYRMIONS

Skyrmions arise from the "spin" of electrons in ultra-thin materials. Spin can be thought of as the tiny magnetic moment of each electron, which points up, down or somewhere in between. Some two-dimensional materials, in their lowest energy states, have a property called perpendicular magnetic anisotropy—meaning the spins of electrons all point in a direction perpendicular to the film. When these materials are excited with electricity or a magnetic field, some of the electron spins flip as the energy of the system rises. When that happens, the spins of surrounding electrons are perturbed to some extent, forming a magnetic whirlpool surrounding the flipped electron—a skyrmion.

Skyrmions, which are generally about 1 micrometer (a millionth of a meter) or smaller in diameter, behave a bit like a kind of particle, zipping across the material from side to side. And once they're formed, they're very difficult to get rid of. Because they're so robust, researchers are interested in using their movement to perform computations and to store data.

This new study shows that in addition to the global movement of skyrmions across a material, the local behavior of individual skyrmions can also be useful. For the study, which was led by postdoctoral fellow Kang Wang, the researchers fabricated magnetic thin films using a technique that produced subtle defects in the material's atomic lattice. When skyrmions form in the material, these defects, which the researchers call pinning centers, hold the skyrmions firmly in place rather than allowing them to move as they normally would.

The researchers found that when a skyrmion is held in place, they fluctuate randomly in size. With one section of the skyrmion held tightly to one pinning center, the rest of the skyrmion jumps back and forth, wrapping around two nearby pinning centers, one closer and one farther away.

"Each skyrmion jumps back and forth between a large diameter and a small diameter," Wang says. "We can measure that fluctuation, which occurs randomly, and use it to generate random numbers."

The change in skyrmion size is measured through what's known as the anomalous Hall effect, which is a voltage that propagates across the material. This voltage is sensitive to the perpendicular component of electron spins. When the skyrmion size changes, the voltage changes to an extent that is easily measured. Those random voltage changes can be used to produce a string of random digits.

The researchers estimate that by optimizing the defect-spacing in their device, they can produce as many as 10 million random digits per second, providing a new and highly efficient method of producing true random numbers.

"This gives us a new way of generating true random numbers, which could be useful for many applications," Xiao says. "This work also gives us a new way of harnessing the power of skyrmions, by looking at their local dynamics as well as their global movements."

The National Science Foundation supported the work.

futurity.org, 8 February 2022

https://futurity.org

We couldn't have the Beijing Olympics without snow machines. How do they work, and what's the environmental cost?

2022-02-14

Snow machines have exploited the laws of thermodynamics to paint the slopes of Beijing white for this year's Winter Olympics.

Beijing might seem like an odd place for the winter games. The city receives almost no annual snowfall and has an average temperature just below 0 , even in the winter month of February.

The uninitiated might think of snow machines as giant freezers with fans attached, guzzling cities' worth of electricity to refrigerate entire mountainsides.

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Chinese authorities have used more than 350 snow machines to prepare courses for the world's athletes. This practice has become more common over the past few Winter Olympics, with the Sochi and Pyeongchang games relying on 80% and 98% artificial snow, respectively.

But isn't all this artificial snow terribly expensive? If you own an air conditioner and keep half an eye on your energy bill, you'd expect snowmaking to be hugely energy-intensive. The uninitiated might think of snow machines as giant freezers with fans attached, guzzling cities' worth of electricity to refrigerate entire mountainsides.

This isn't really the case. Efficient machines in suitable climates (such as Beijing's) can use as little as 1.5 kilowatt-hours per cubic metre of snow produced. In Beijing's climate, you could coat a Sydney apartment in a few inches of snow with the same energy the air conditioning would use in an hour.

But that's not to say there's no environmental cost. More on that later.

How do snow machines work?

Artificial snow is no chemical trick. The slopes of this year's event are coated in pure frozen water.

Fundamentally, snow machines work by using a clever thermodynamic exploit, leveraging the natural cooling that happens when water evaporates. And because their cooling power comes from evaporation, they can operate at relatively warm temperatures, up to 1 (provided the humidity is low enough).

Here's how it works. Snow machines expel a fine water mist into the cold, dry atmosphere. Some of the water in each droplet quickly evaporates, carrying away heat and lowering the temperature of the rest of the droplet to below its freezing point. This process is known as "evaporative cooling", and is the same mechanism that cools us when we sweat.

Because the energy loss required to form ice in this process is driven by evaporation, snow machines don't have to expend energy to freeze water. They only require energy to power the fans and compressors that disperse the water droplets.

However, as any winter Olympian will tell you, snow is more than just frozen water. And snow machines must produce a blanket of powder worthy of the world's greatest athletes.

They achieve this by using a "nucleator", which is basically any substance that makes it easier to form an ice crystal. Without this, the droplets in the mist would end up as supercooled water and clump into large droplets before freezing. This would create undesirably dense and icy snow.

Nucleators can be chemical or biological, but in Beijing no such aids are being used. Instead, tiny ice crystals are being used as nucleators. These nucleator ice crystals themselves are formed by yet more thermodynamic manipulation, wherein pressurised water is forced through a nozzle, quickly reducing the pressure and breaking it into tiny droplets.

When the pressure of a gas is rapidly reduced, its temperature also drops – which is why deodorant from a pressurised spray can feels cold. In this case, the sudden drop in temperature cools the atomised water well below 0 , rapidly freezing it into the nucleator ice crystals.

In the final step of the snow-making process, these ice crystals mix with the water mist and are propelled through the air, with the water freezing and falling as artificial snow. Propulsion is achieved either through the use of compressed air, in the case of snow lances, or through blower-type machines with large fans.

The snow that forms in this process isn't quite the same as real snow, because artificial snow forms quickly from liquid droplets, instead of slowly from water vapour. As a result, the shape of artificial snow particles is different to that in natural snow. The former has no beautiful single-crystal structures, only tiny (polycrystalline) snowballs.

The sustainability question

As our climate warms and weather patterns shift, we're becoming increasingly dependent on artificial snow to meet the demands of holidaymakers and sportspeople. These Winter Olympics are the first ever to rely on 100% fake snow. And while snowmaking isn't as environmentally catastrophic as it might first seem, it's not without drawbacks.

First, artificial snow is made of water, which is undeniably a critical resource. The International Olympic Committee's (IOC) sustainability report for this year's games estimates the city of Zhangjiakou, the epicentre of the Beijing games, will use 730,000m^3 of surface water for snowmaking alone (almost 300 Olympic size swimming pools).

The amount of water used across the entire Beijing area will be much greater (although there are significant efforts to recapture snow melt, and avoid using an excessive amount of drinking water to make snow).

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Second, in warmer climates chemical additives are required to help snow form and stay frozen. And while these aren't actively toxic, there's still doubt regarding their safety.

Finally, snow machines produce a lot of snow. Early reports from Chinese media claimed only 200,000m^3 of water would be needed for snowmaking. But the IOC's pre-game report indicates this figure is upwards of 800,000m^3.

Depending on which figure is used, the density of the snow created, and how much water is lost to evaporation, the total amount of snow produced could be anywhere from 0.5 to 3 million cubic metres. So while the machines do produce snow efficiently, the total energy usage is still significant.

According to the IOC, in Beijing this electricity demand is being met through 100% sustainable production. This is encouraging, and will hopefully help accelerate the global adoption of environmentally friendly technologies.

theconversation.com, 14 February 2022

https://theconversation.com

A deadly bacteria has been infecting children for more than 1,400 years

2022-02-02

The tragic death of a 6-year-old boy in early medieval England has given scientists the earliest direct clue to the history of the pathogen Haemophilus influenzae type b. Dated to about 550, it's the oldest case of this bacterial infection, called Hib, ever diagnosed, researchers report February 2 in Genome Biology.

The next confirmed case occurred more than 1,300 years later in 1892, when H. influenzae was first identified. Despite the similar name and symptoms to influenza, the bacterium doesn't cause flu. But Hib can cause other serious illnesses such as pneumonia and meningitis — especially in young children (SN: 1/9/02). Since the late 1980s, a vaccine against Hib has largely sidelined the pathogen (SN: 5/25/11).

DNA in a tooth from the boy, who was buried in a plague cemetery in Cambridgeshire, indicates that Hib was infecting people at the same time as the first historically documented pandemic due to plague, caused by the bacterium Yersinia pestis (SN: 12/2/19). The relationship between H.

The relationship between H. influenzae and humans, the pathogen's only host, is probably much older than that, says Meriam Guellil

influenzae and humans, the pathogen's only host, is probably much older than that, says Meriam Guellil, a paleogeneticist at the University of Tartu in Estonia.

Unsurprisingly, the boy's tooth also contained genetic remains of Y. pestis. He probably contracted the Hib infection first, Guellil and colleagues say. While respiratory infections rarely leave marks, the boy's kneecaps had fused to the thighbones above them. Such damage can happen when Hib escapes the respiratory system and infects joints, which would have taken weeks. This boy was already quite ill when he caught Y. pestis, but "plague, probably, was what killed him," Guellil says.

This kind of research opens a window into how pathogens evolve to start pandemics or die out over thousands to millions of years. The work is a "great advance" for archaeology, history and the study of ancient diseases, says Pontus Skoglund, an expert in ancient genomics at the Francis Crick Institute in London who was not involved in the study. "The well-authenticated detection of Haemophilus influenzae in an early medieval child promises that it will be detectable in more cases in history, and potentially prehistory," he says.

sciencenews.org, 2 February 2022

https://sciencenews.org

Can microdosing psychedelics boost mental health? Here's what the evidence suggests

2022-02-05

When Jaclyn Downs, a 43-year-old nutritionist in Lancaster, Pennsylvania, stumbled upon the concept of microdosing psilocybin, or taking a tiny amount of a psychedelic for a subtle effect, she immediately recalled an incident in college where friends made tea with "magic mushrooms," which contain the drug. Downs had only one sip, but she spent the rest of the night feeling grounded, peaceful, and present. Looking back, she realized what she had experienced was a microdose.

Three years ago Downs began microdosing to prepare for certain situations, such as when she had to stay later at a social event than she might want to. The drug soothed her angst and made her a better conversationalist, she says. Six months ago, she began a more structured routine, taking a tincture of microdose psilocybin every three days. It has made her calmer and more accepting, she says, especially when her six- and nine-year-old daughters argue with one another or push back on her

In recent years, psychedelic drugs have evolved from a taboo topic to one gaining acceptance in mainstream quarters of society.

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requests. "Before I was more reactive—getting angry or irritated—but now I respond more evenly," Downs says. "The general atmosphere of our home is more positive."

In recent years, psychedelic drugs have evolved from a taboo topic to one gaining acceptance in mainstream quarters of society. Psychedelics are even heading for general medical approval, having been designated as a "breakthrough therapy" by the U.S. Food and Drug Administration.

But many who are intrigued by the promise of psychedelics—a category that includes psilocybin, lysergic acid diethylamide (LSD), ayahuasca, mescaline, and other substances that alter consciousness—are eager to reap the benefits without having to take a dose strong enough to provoke an hours-long journey down the rabbit hole. A growing number are turning to microdosing, regularly ingesting five to 10 percent of the mind-bending amount in a quest to enhance well-being, improve work, or diminish depression and other psychological demons without triggering the drug's full effects.

But experts say there is little scientific evidence so far to support this approach.

"As far as we know, there are not many risks associated with microdosing. But it's not at all clear, aside from user testimonials, that there are benefits," says John Krystal, chair of psychiatry at the Yale School of Medicine, who has closely followed the field.

A key reason is that microdosing, as it is done in real life, is challenging to study. Users generally consume a dose for one or two mornings, skip the next one or two, and repeat this regimen for months or years. Because psychedelics are illegal, U.S. law prohibits researchers from giving them to people to take on this schedule at home. But providing the drug and overseeing users day after day in a laboratory isn't practical, says Albert Garcia-Romeu, a researcher at the Center for Psychedelic and Consciousness Research at Johns Hopkins Bayview Medical Center in Baltimore.

That presents a problem for both the scientists and the microdosers. When active users respond to surveys about their experiences for observational research, the scientists can't be sure each person is taking the same amount. After all, there aren't standardized products a person can pick up at the local pharmacy. It' s especially challenging for someone to determine an exact psilocybin microdose from a batch of dried

mushrooms or a lick of an LSD tab, says Jerome Sarris, executive director of the Psychae Institute in Melbourne, Australia.

A growing phenomenon

No one knows how many people in the U.S. currently microdose, although its popularity seems to be growing. An analysis in 2018 of a Reddit discussion group devoted to microdosing recorded 27,000 subscribers; in early 2022, the group had 183,000. At a recent business conference focusing on psychedelic drugs in Miami, when audience members were asked how many currently microdose, hundreds of hands went up.

"When it first became popular about a decade ago, microdosing was hush hush, with tech entrepreneurs and businesspeople the primary users," says Steven Holdt, the 24-year-old founder of Tune In Psychedelics, an app that lets microdosers track their dosing schedules and record drug effects for their own information. In the past few years, a broad range of people have jumped on board, Holdt says, thanks to podcasts on the topic, articles in mainstream newspapers, and writer Ayelet Waldman's popular book, A Really Good Day, which chronicled how microdosing LSD lifted her intractable depression.

Erica Zelfand, a naturopathic physician in Portland, Oregon, says dozens of her patients currently microdose, mostly in a bid to improve their depression or attention deficit disorder. Zelfand supports their efforts but makes it clear they are lab rats in a grand experiment. "I let them know that we don't have the research yet. And we especially don't know the long-term risks," she says. To help build a body of knowledge, she encourages patients to report their experiences on crowdsourced research sites like microdose.me or microdosingsurvey.com.

High versus low doses

None of the current studies on microdosing reach standards that enable scientists to draw firm conclusions. But results from recent studies using a single high-dose psychedelic have illuminated the mental-health potential of these long-shunned drugs. One potent dose of synthetic psilocybin along with psychological support improved treatment-resistant depression, according to unpublished results from a randomized study of more than 200 people released in November by the company Compass Pathways, whose proprietary formulation is one of the F.D.A. breakthrough-therapy designees. And in May 2021 scientists reported in the journal Nature that a high dose of MDMA (aka Molly or Ecstasy,

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which is not a classic psychedelic but produces a similar effect) greatly diminished severe post-traumatic stress disorder (PTSD).

But these results can't be generalized to microdoses, says Matthew Johnson, acting director of the Johns Hopkins Center, which has conducted numerous studies on high-dose psychedelics.

A review of psychedelic research that Sarris published in January 2022 underscored problems facing studies that seek to discover both micro- or high-dose effects of a psychedelic drug: few large randomized trials have been done in humans.

Studies of medications in people typically begin with what is known as a phase one clinical trial, designed to determine levels of safety and tolerability in a small number of people. Such a study has not yet been undertaken for microdosing, although the drug manufacturer Diamond Therapeutics announced in November that it is about to embark on such a trial, minutely escalating the quantity of psilocybin until the ideal microdose, one that causes positive effects with the fewest negative ones, is found.

A handful of laboratory studies that included a small number of healthy people have sought to uncover the effects of microdosing after taking one or a few doses. A 2020 review published in Therapeutic Advances in Psychopharmacology counted 14 of these small experimental studies, with most finding that microdosing LSD or psilocybin yields subtle positive changes to emotions and to thought processes involved in problem-solving. The reviewers noted that some users did feel anxious or overly euphoric. Since all studies were done in healthy individuals it isn't known whether microdosing might consistently benefit people with mental-health concerns.

One European study of 30 people, published in April 2021, found that people who microdosed psychedelics for several weeks were more in awe when viewing videos and artworks than during the weeks they took a placebo. But the study was flawed because many people were able to figure out what they were taking based on side effects like increased sweating so the researchers were unable to separate people's actual experiences from their expectations.

Placebo effect?

Larger studies have primarily asked current users about their experiences. One tapped more than a thousand microdosers who reported increased

energy, better work results, and more positive moods. Another compared 4,000 microdosers to a similar group of nonusers and found that among people with prior mental-health issues, those who microdosed reported having lower levels of anxiety and depression.

But in addition to the issue of users taking non-standardized doses, participants were all microdosing before the studies began, so they may have been biased. "We have to be cautious about not overinterpreting the encouraging retrospective reports that have appeared in the literature," Yale's Krystal says. "The concern about first-person experiences is that there is often tremendous potential for placebo effects to color the interpretation."

In fact, the best study of microdosing to date shows just this effect. This was a "citizen science initiative" involving some 200 LSD and psilocybin microdosers. Some of the participants were chosen at random by scientists at Imperial College London to swap their drugs for placebos, with neither group knowing for sure which they were getting. After a month everyone was surveyed about their well-being, life satisfaction, cognition, and other factors. Psychological outcomes improved significantly for people taking the psychedelics—but they also did for those downing the placebos.

This was a clever way to study a large number of microdosers in the current regulatory environment, says Garcia-Romeu, who helped to evaluate the research for the journal eLife. The fact that so many placebo-takers reported benefits "calls into question the whole phenomenon of microdosing," he says.

Nonetheless, imaging studies do make clear that something is happening.

In one, 20 healthy people were scanned with an fMRI several hours after taking a microdose of LSD or a placebo. The amygdala, considered the emotion center of the brain, changed how it interacted with other brain regions in the microdosers, indicating the potential to better regulate negative emotions, says study coauthor Katrin Preller, a neuropsychologist at the University of Zurich. In fact, those whose brains experienced the improved connectivity also subjectively reported feeling more upbeat, Preller says. Another study used electroencephalography (EEG) to measure brain activity in 22 LSD microdosers and documented more activity in the brain than usually occurs during rest, something also seen with high-dose psychedelics.

The effects of microdosing

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Despite the paucity of research, people are turning to microdoses for a variety of reasons. Holdt says microdosing psilocybin helps him have fun around other people. He suffers from social anxiety, so without the drugs his mind constantly ruminates about all the things he might say or do. "Microdosing helps me stop that inner monologue so I can be more comfortable and present," he says. He has had the same effect using high-dose psychedelics, which he first experienced in high school, but says the subtler effects of microdosing make it easier to incorporate into everyday life. "You don't need to take a day off work or have someone watching you [to make sure a trip doesn't turn ugly]," he says.

Many microdosers find it helps them with work. Dusty, a 40-year-old audio engineer in Philadelphia (who asked that only his nickname be used), says the tiny bit of LSD he takes once each week boosts his productivity, desire to collaborate, and creativity on the job. For example, when setting up sound systems for live concerts, "there are a million little problems that you need to solve every day, and there's not always a good road map," he says. On days he microdoses, he's noticed he has "a little extra excitement to solve a problem that leads to long-term solutions, rather than just making it work for now."

Others microdose to self-treat mental-health conditions. Karen Gilbert, a 69-year-old retired nurse in Lopez Island, Washington, is hoping microdosing psilocybin, which she started in November, might help with the depression she has suffered for more than two decades. One of Zelfand's patients, Gilbert says she noticed a difference almost immediately. "For the first time in a long time I am excited about the projects I want to do, which are feeling like opportunities rather than obligations," she says.

Zelfand herself tried microdosing a few times but didn't enjoy the effects. "I don't feel well when I do it. It seems to make me a little edgy," she says.

Some of Zelfand's patients have had similar unwanted experiences. People with general anxiety disorders and, especially, bipolar disorder should probably avoid microdosing because it can lead to agitation or mania, she says.

Experts also worry that microdosing on a regular basis for a long period of time could theoretically weaken heart valves, like the damage caused by the diet drugs phentermine and fenfluramine (Phen/Fen) in the 1990s. Both Phen/Fen and psychedelics act on one of the body's serotonin receptors, known as 5-HT2B, Johns Hopkins' Garcia-Romeu says.

Even if microdosing proves to be safe and effective, some experts fear widespread recreational use could render it useless later in life if it turns out to be valuable for important mental-health purposes but people are tolerant to it after frequent use. "If we introduce more of these types of substances, that might undercut their therapeutic efficacy when we really need them for medicine, such as for end-of-life distress," says Conor Murray, a neuroscientist at UCLA who conducted the EEG research.

And while they don't trigger the same wild thoughts and images as taking high doses of these drugs do, some microdosers have reported some impairment, Johnson says. "If this turns out to be the case, it may be hard to drive, take care of your toddler, or make important decisions at work."

Plus, of course, psychedelics are illegal, which means there's no quality control on supply. What's more, "people have lost their jobs because they're microdosing, and they can and do get incarcerated," Garcia-Romeu says.

But even those who are concerned about the growing use of psychedelics say microdosing may eventually prove beneficial for some people. Johnson from Johns Hopkins thinks depression might be relieved by microdosing—although he's much more jazzed about the prospect that a person could get more relief after one or two high-dose sessions, something his research is bearing out.

Krystal believes until more is known about microdosing, people should hold off. "Right now, it should only be done in the context of experimental research," he says. "There, protections can be in place, and the data generated will inform our understanding about these doses and drugs."

Additional microdosing studies could also yield insights about our brains. For example, experts don't fully understand the role of another serotonin receptor activated by psychedelics, 5-HT2A, Johnson says. "We have a whole lot to learn about [this receptor]. Is it involved with naturally occurring mystical experiences like near death experiences, even alien abduction encounters?" he wonders. "How can we use microdosing research to understand more about the nature of the human mind?"

nationalgeographic.com, 05 February 2022

https://nationalgeographic.com

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A diamondlike structure gives some starfish skeletons their strength

2022-02-10

Some starfish made of a brittle material fortify themselves with architectural antics.

Beneath a starfish's skin lies a skeleton made of pebbly growths, called ossicles, which mostly consist of the mineral calcite. Calcite is usually fragile, and even more so when it is porous. But the hole-riddled ossicles of the knobby starfish (Protoreaster nodosus) are strengthened through an unexpected internal arrangement, researchers report in the Feb. 11 *Science*.

"When we first saw the structure, we were really amazed," says Ling Li, a materials scientist at Virginia Tech in Blacksburg. It looks like it's been 3-D printed, he says.

Li and colleagues used an electron microscope to zoom in on ossicles from several dozen dead knobby starfish. At a scale of 50 micrometers, about half the width of a human hair, the seemingly featureless body of each ossicle gives way to a meshlike pattern that mirrors how carbon atoms are arranged in a diamond.

But the diamondlike lattice alone doesn't fully explain how the ossicles stay strong.

Within that lattice, the atoms that make up the calcite have their own pattern, which resembles a series of stacked hexagons. That pattern affects the strength of the calcite too. In general, a mineral's strength isn't uniform in all directions. So pushing on calcite in some directions is more likely to break it than force from other directions. In the ossicles, the atomic pattern and the diamondlike lattice align in a way that compensates for calcite's intrinsic weakness.

It's a mystery how the animals make the diamondlike lattice. Li's team is studying live knobby starfish, surveying the chemistry of how ossicles form. Understanding how the starfish build their ossicles may provide insights for creating stronger porous materials, including some ceramics.

"When we first saw the structure, we were really amazed," says Ling Li, a materials scientist at Virginia Tech in Blacksburg. It looks like it's been 3-D printed, he says.

We can learn a lot from a creature like a starfish that we may think is primitive, Li says.

sciencenews.org, 10 February 2022

https://sciencenews.org

Did Neanderthals and modern humans take turns living in a French cave?

2022-02-09

A single, broken molar found buried within a windswept rock shelter in southeastern France could push back the first evidence of modern humans in Europe by nearly 10,000 years.

According to an international team, the tooth and dozens of stone tools from the same sedimentary layer belonged to a member of Homo sapiens who lived some 54,000 years ago, a time when Neanderthals were thought to have been the sole occupants of Europe. The findings also paint a remarkable picture of the intimacy of modern humans and their Neanderthal neighbors, suggesting they may have traded occupancy of the cave several times—once in as little as a year.

"I found this paper absolutely fascinating," says Kristin Krueger, a dental paleoanthropologist at Loyola University Chicago. "From what I can tell, this is solid evidence … that modern humans made it to Europe earlier than thought."

For others, the excitement is tempered with caution, especially given that the claim relies chiefly on a single modern human tooth. "There are several 'ifs' here," says paleogeneticist Carles Lalueza-Fox of the University of Barcelona. "To make a stronger case, we should have at least more solid skeletal or genetic evidence."

After arising in Africa, modern humans trekked into the Middle East as early as 180,000 years ago, where they may have first met and mated with the Neanderthals, who already lived in Europe and Asia. (Today, non-Africans carry the legacy of those matings, having inherited about 2% of their DNA from our closest cousins.) But moderns were late arrivals in Europe, where until now the earliest evidence of their remains and artifacts came from Bulgaria's Bacho Kiro Cave, dated to about 45,000 years old.

The discoveries that could change that picture come from a rocky overhang known as Grotte Mandrin in the verdant Rhône River Valley.

Since 1990, excavations of the cave's floor have delved into 12 sedimentary layers deposited between 80,000 and 35,000 years ago.

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Since 1990, excavations of the cave's floor have delved into 12 sedimentary layers deposited between 80,000 and 35,000 years ago.

In 2006, what archaeologists call layer E yielded a trove of precisely sharpened stone points and animal bones. Six years later, they found a partial molar—a baby tooth. "We spent 15 years excavating this layer," says Ludovic Slimak, a paleoanthropologist at the University of Toulouse, Jean Jaurès. "We went slowly because it's very rich and there's a lot of very little material."

Slimak and colleagues radiocarbon dated animal bones with butchery marks from layer E to between 57,000 and 52,000 years ago. Luminescence dating of sediments in the layer, which determines when quartz minerals were last exposed to sunlight, returned the same date range. Meanwhile Clément Zanolli, a paleoanthropologist at the University of Bordeaux, analyzed the layer E molar and eight other teeth found in other layers. Although the molar was broken, it retained a telltale part of its cusp called the talonid. The modern human talonid gives their teeth a squarer outline than those of Neanderthals. "[This] tooth is quite square," Zanolli says, indicating it belonged to a young modern human. In contrast, all the teeth from layers above and below layer E had distinctly Neanderthal characteristics.

Layer E's stone tools back up the tooth's identification, Slimak says: They are smaller, more precisely made, and more standardized than the tools from the layers bearing Neanderthal teeth, which resemble Neanderthals' characteristic Mousterian tools. "With Neanderthal tools, every tool is a creation," Slimak says. "If you look at 1000 tools, each will be completely different. But with a Homo sapiens industry … it's superstandardized, superregular."

Tools and teeth from the next few layers above layer E suggest Neanderthals at some point reoccupied Grotte Mandrin. Then, in layers dated to about 42,000 years ago, the tools once again appear to have been made by modern humans; they resemble the "proto-Aurignacian" tools found in other modern human sites from the same time period, Slimak says.

Together, that evidence shows modern humans had reached southern France about 54,000 years ago, the researchers report today in Science Advances. The settlers probably came from the east and traveled up the Rhône River Valley from the Mediterranean coast, Slimak says. After modern humans first moved into the shelter, they and Neanderthals took turns for another 10,000 years.

"The authors make a strong case for the dates," Krueger says. "They provide the stratigraphic sequence, completed over many, many years of excavation, [and] also use multiple methods for dating each layer."

But the layer E molar is key to the argument. Shara Bailey, a dental paleoanthropologist at New York University who developed methods to distinguish modern and Neanderthal teeth, isn't certain the molar came from a modern human. Too much of it is missing, she says. "It would be so cool if it were true … but it's not a slam dunk."

If members of our species really did make an early appearance in the cave, they may have had close contact with Neanderthals, one intriguing data point suggests. Thin layers of mineral deposits form along the walls of rock shelters like Grotte Mandrin, recording the passage of wet and dry seasons, a bit like tree rings. These mineral layers can trap soot from fires burning inside the caves, offering microscopic records of campfires past. This new technique, known as fuliginochronology, was first described in 2018 by one of the paper's co-authors, Ségolène Vandevelde, an archaeologist at the University of Paris-Saclay.

Tiny chunks of mineral fell from the cave wall into each excavated layer. The sequence of soot layers in wall chunks from layer E overlapped with the sequence in chunks from the layer immediately beneath it, which held Neanderthal tools. That suggests only a brief period passed between the formation of the layers and therefore between the exit of the Neanderthals and the entrance of moderns—perhaps no more than a single calendar year. "They probably met at some point, but we cannot say for sure they met in the cave," Slimak says.

Rachel Wood, a radiocarbon scientist at Australian National University, calls the study "remarkable." But she isn't confident the researchers can pinpoint the timing of soot layers from 54,000 years ago to within 1 year given the evidence they've presented so far. "Given the uncertainties … I'd be skeptical about this supporting a short transition between the two [layers]."

The paper's findings could be revolutionary for our understanding of the transition between the last Neanderthals and the first moderns in Europe, says Francesco d'Errico, an archaeologist also at the University of Bordeaux. But he and others want far more evidence. "If the pattern proposed is confirmed by future discoveries, we will certainly need to change our view of this transition," he says. "Such a paradigm shift

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is entirely possible but requires … more sites and more unequivocal evidence."

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Is a universal coronavirus vaccine on the horizon?

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Every time a new variant comes along, COVID-19 vaccine and drug makers reassess their "recipes" to see if they work against an evolving virus—like Omicron, which has spread quickly around the globe in little more than a month.

Since the start of the pandemic in December 2019, the SARS-CoV-2 coronavirus that causes COVID-19 has mutated multiple times, giving rise to different variants. Because most vaccines were designed to recognize the original SARS-CoV-2 spike protein, or at least parts of it, more mutated variants like Omicron are better at escaping protection offered by the vaccines, although they still prevent severe disease.

Last month, vaccine makers talked about tweaking the formula to have an Omicron-specific vaccine handy, if needed. "But Omicron won't be the last variant," says Stephen Zeichner, an infectious disease specialist at the University of Virginia Medical Center. "It's pretty clear that the virus continues to evolve and going forward there is a need for a universal COVID-19 vaccine or even a universal coronavirus vaccine."

Since 2020, in preparation for the next deadly coronavirus outbreak, which experts think is only a matter of time, some scientists started developing vaccines that protect against multiple coronaviruses. Many efforts currently focus on known sarbecoviruses, which include SARS-CoV-1 and SARS-CoV-2, and some SARS-like bat viruses that have the potential to jump from animals to humans.

Early tests in animal models are showing promising results. "The great thing about having such vaccines is that they could handle potentially new [SARS-CoV-2] variants as well as the next horrible spillover viruses that'll come down the road," says structural biologist Pamela Björkman at the California Institute of Technology, who is developing a universal vaccine for some SARS-like viruses.

Blocking new variants and future coronaviruses with spillover potential

Since the start of the pandemic in December 2019, the SARS-CoV-2 coronavirus that causes COVID-19 has mutated multiple times, giving rise to different variants.

Omicron, the latest version of the virus classified as a variant of concern by the World Health Organization on Nov. 26, 2021, has nearly 50 genetic mutations compared to the original SARS-CoV-2 strain. More than 30 of these are on the club-shaped spikes protruding from the virus' surface that facilitate its entry into host cells. The spike is also the region of the virus that COVID-19 vaccines target to prevent serious disease.

Human coronaviruses were first identified in the mid-1960s and rarely caused severe disease. But that changed in 2002, when a fatal respiratory illness caused by a new coronavirus SARS-CoV linked to cave-dwelling bats emerged in China and spread to 29 countries, infecting nearly 8,000 people, and leaving more than 700 dead. A decade later, another new coronavirus, MERS-CoV—that emerged in Saudi Arabia and presumably originated in bats—has infected more than 2,000 people in 37 countries and killed nearly 900 to date. The danger posed by coronaviruses originating in animals became even more apparent with SARS-CoV-2, which has resulted in nearly 332 million confirmed worldwide cases and more than five million deaths since its emergence in late 2019.

While short-sightedness and limited funding have hindered the development and testing of these vaccines, recent investments like the non-profit Coalition for Epidemic Preparedness Innovation's $200 million program and the National Institutes of Health's $36.3 million research fund means that pan-coronavirus virus vaccines—at least for SARS-like viruses—may be a reality sooner than many imagined.

One vaccine, multiple coronaviruses

The goal of such vaccines is to generate a broad immune response against multiple coronaviruses and its variants.

The effort that is farthest along is a vaccine developed by researchers at the Walter Reed Army Institute of Research, which has been tested in humans as part of a Phase I trial. The vaccine, which borrows technology developed for making universal flu vaccines, entails a soccer ball-shaped nanoparticle with 24 faces decorated with multiple copies of the original SARS-CoV-2 spike protein. Peer reviewed research conducted in monkeys showed the vaccine's ability to generate antibodies that neutralize and block the entry of SARS-CoV and SARS-CoV-2 and its major variants (excluding Omicron, which was not tested) into animal cells. "The repetitive and ordered display of the coronavirus spike protein on a multi-faceted nanoparticle may stimulate immunity in such a way as to translate into significantly broader protection," Kayvon Modjarrad, co-inventor of the vaccine, stated in a press release. His team is currently analyzing the

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Phase I data. National Geographic reached out to Walter Reed multiple times for more details, but they declined to comment until the results of the Phase I trials are published.

Other universal coronavirus vaccine efforts involve targeting a slow evolving, genetic and structurally similar region on the viruses—where antibodies bind as part of a body's immune response to a foreign invader—or additionally engaging the body's immune cells called T cells.

Zeichner, for instance, is focusing on the fusion peptide region, which is part of the coronavirus spike protein that aids the entry of the virus into host cells, to develop a pan-coronavirus vaccine. "It is extremely conserved among all coronaviruses," he says. "It doesn't mutate very much." Along with colleagues, he tested a proof-of-concept vaccine using a SARS-CoV-2 fusion peptide and early results indicated that in pigs the vaccine provided some protection against a different coronavirus, called porcine epidemic diarrhea virus, that doesn't infect humans. His team is now collaborating with researchers at Virginia Tech and the International Vaccine Institute in Seoul to further develop and continue testing the vaccine against different SARS-CoV-2 variants and other coronaviruses.

Björkman and her colleagues, on the other hand, are focusing on a more specific target: the spike protein's receptor-binding domain (RBD). It's the region of the spike to which most antibodies bind to prevent SARS-CoV-2 from entering the host cell; it is also the region within which mutations occur, giving rise to variants. For the vaccine, they used RBD proteins from up to eight viruses—including the original SARS-CoV-2 and other SARS-like coronaviruses isolated from bats—that were fused onto a nanoparticle with 60 faces. By injecting this vaccine into mice, Björkman and her colleagues found the animals produced diverse antibodies, which in follow-up experiments blocked infections caused by several SARS-like viruses, including coronavirus strains not used to create the vaccines.

To Björkman, this suggests that the animal's immune system might be learning to recognize common features between the coronaviruses and that her mosaic vaccine, with pieces selected from multiple viruses, might be useful when new SARS-like viruses or new SARS-CoV-2 variants emerge. Her team is currently gearing up to test the vaccine in humans.

Vaccine researcher Kevin Saunders at the Duke Human Vaccine Institute is also focusing on the RBD, but a very specific part of it, to make a pan-SARS-like virus vaccine. When the pandemic began in early 2020, Saunders and his colleagues began hunting for antibodies that would inactivate SARS-like viruses. They examined antibodies present in frozen stored cells of an

individual who recovered from SARS-CoV infection and another individual previously infected with COVID-19.

They identified a potent antibody dubbed DH1047 occurring in cells from both patients that could block infections in which mice that had been injected with several bat and human coronaviruses, including SARS-CoV-2 variants. A closer look revealed the antibody bound to the same small section of the spike protein's RBD in different coronaviruses, which became the vaccine target.

By injecting monkeys with multiple copies of this SARS-CoV-2 RBD piece fused to a nanoparticle, Saunders and his colleagues demonstrated the vaccine's ability to protect against not just SARS-CoV-2 but several other coronavirus infections. The team is now testing different iterations of this nanoparticle vaccine by introducing RDB sections from other coronaviruses to broaden the host's immune response.

"Sometimes you make hundreds of versions of these [vaccines] and test them in animals before deciding on a version to study in humans," says Julie Ledgerwood, deputy director and chief medical officer at the National Institutes of Health's Vaccine Research Center. It's not simple, she says.

Meanwhile, scientists are also trying to figure out how these vaccines could cover not just SARS-like viruses but MERS and other more distantly-related coronaviruses too. "The sequence diversity and structural differences between coronaviruses that fall into different groups is going to be a challenge," Saunders says. Some scientists propose a different vaccine for different coronavirus families.

For now, though, the need for at least a pan-SARS-like coronavirus vaccine cannot be ignored. "We're no longer thinking of this as 'it'll be great to have this for the next pandemic,'" Saunders says. "We're thinking of this as a great tool to stop this pandemic."

nationalgeographic.com, 20 January 2022

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