SCIENCE NEWS

Scientists Identify How Dietary Restriction Slows Brain Aging and Increases Lifespan

Date: 11 January 2024

Source: Buck Institute for Research on Aging

Summary: Restricting calories is known to improve health and increase lifespan, but much of how it does so remains a mystery, especially in regard to how it protects the brain. Buck scientists have uncovered a role for a gene called OXR1 that is necessary for the lifespan extension seen with dietary restriction and is essential for healthy brain aging.

"When people restrict the amount of food that they eat, they typically think it might affect their digestive tract or fat buildup, but not necessarily about how it affects the brain," said Kenneth Wilson, Ph.D., Buck postdoc and first author of the study, published online on 11 January 2024 in *Nature Communications*. "As it turns out, this is a gene that is important in the brain."

The team additionally demonstrated a detailed cellular mechanism of how dietary restriction can delay aging and slow the progression of neurodegenerative diseases. The work, done in fruit flies and human cells, also identifies potential therapeutic targets to slow aging and age-related neurodegenerative diseases.

"We found a neuron-specific response that mediates the neuroprotection of dietary restriction," said Buck Professor Pankaj Kapahi , Ph.D., co-senior author of the study. "Strategies such as intermittent fasting or caloric restriction, which limit nutrients, may enhance levels of this gene to mediate its protective effects."

"The gene is an important brain resilience factor protecting against aging and neurological diseases," said Buck Professor Lisa Ellerby, Ph.D., co-senior author of the study.

Understanding variability in response to dietary restriction

Members of the team have previously shown mechanisms that improve lifespan and healthspan with dietary restriction, but there is so much variability in response to reduced calories across individuals and different tissues that it is clear there are many yet to be discovered processes in play. This project was started to understand why different people respond to diets in different ways.

The team began by scanning about 200 strains of flies with different genetic backgrounds. The flies were raised with two different diets, either with a normal diet or with dietary restriction, which was only 10 per cent of normal nutrition. Researchers identified five genes which had specific variants that significantly affected longevity under dietary restriction. Of those, two had counterparts in human genetics.

The link between brain aging, neurodegeneration and lifespan

To figure out how a gene that is active in neurons affects overall lifespan, the team did a series of in-depth tests. They found that OXR1 affects a complex called the retromer, which is a set of proteins necessary for recycling cellular proteins and lipids. “The retromer is an important mechanism in neurons because it determines the fate of all proteins that are brought into the cell,” said Wilson. Retromer dysfunction has been associated with age-related neurodegenerative diseases that are protected by dietary restriction, specifically Alzheimer’s and Parkinson’s diseases.

Overall, their results told the story of how dietary restriction slows brain aging by the action of mtd/OXR1 in maintaining the retromer. “This work shows that the retromer pathway, which is involved in reusing cellular proteins, has a key role in protecting neurons when nutrients are limited,” said Kapahi.

The team found that mtd/OXR1 preserves retromer function and is necessary for neuronal function, healthy brain aging, and lifespan extension seen with dietary restriction.

“Diet is influencing this gene. By eating less, you are actually enhancing this mechanism of proteins being sorted properly in your cells, because your cells are enhancing the expression of OXR1,” said Wilson.

The team also found that boosting mtd in flies caused them to live longer, leading researchers to speculate that in humans excess expression of OXR1 might help extend lifespan. “Our next step is to identify specific compounds that increase the levels of OXR1 during aging to delay brain aging,” said Ellerby.

Global Groundwater Depletion is Accelerating, but is Not Inevitable

Date: 24 January 2024

Source: University of California - Santa Barbara

Summary: Groundwater is rapidly declining across the globe, often at accelerating rates. Writing in the journal *Nature*, UC Santa Barbara researchers present the largest assessment of groundwater levels around the world, spanning nearly 1,700 aquifers. In addition to raising the alarm over declining water resources, the work offers instructive examples of where things are going well, and how groundwater depletion can be solved. The study is a boon for scientists, policy makers and resource managers working to understand global groundwater dynamics.

The team compiled data from national and subnational records and the work of other agencies. The study took three years, two of which were spent just cleaning and sorting data. That is what it takes to make sense of 300 million water level measurements from 1.5 million wells over the past 100 years.

Next came the task of translating the deluge of data into actual insights about global groundwater trends. The researchers then scoured over 1,200 publications to reconstruct aquifer boundaries in the regions of inquiry and evaluate groundwater level trends in 1,693 aquifers.

Their findings provide the most comprehensive analysis of global groundwater levels to date, and demonstrate the prevalence of groundwater depletion. The work revealed that groundwater is dropping in 71 per cent of the aquifers. And this depletion is accelerating in many places: the rates of groundwater decline in the 1980s and '90s sped up from 2000 to the present, highlighting how a bad problem became even worse. The accelerating declines are occurring in nearly three times as many places as they would expect by chance.

Groundwater deepening is more common in drier climates, with accelerated decline especially prevalent in arid and semi-arid lands under cultivation — "an intuitive finding," said co-lead author Scott Jasechko, an associate professor in the university's Bren School of Environmental Science and Management. "But it is one thing for something to be intuitive. It is quite another to show that it is happening with real-world data."

On the other hand, there are places where levels have stabilised or recovered. Groundwater declines of the 1980s and '90s reversed in 16 per cent of the aquifer systems the authors had historical data for. However, these cases are only half as common as would be expected by chance.

Communities can spend a lot of money building infrastructure to hold water above ground. But if you have the right geology, you can store vast quantities of water underground, which is much cheaper, less disruptive and less dangerous. The stored groundwater can also benefit the region's ecology. In fact, while preparing a research brief in 2014, Perrone found that aquifer recharge can store six times more water per dollar than surface reservoirs.

Tucson's groundwater recharge is a boon for the local aquifer; however, withdrawals have caused the mighty river to dwindle above ground. The Colorado rarely reaches its delta in the California Gulf anymore. "These groundwater interventions can have tradeoffs," Jasechko acknowledged.

Another option is to focus on reducing demand. Often this involves regulations, permitting and fees for groundwater use, Perrone explained. To this end, she is currently examining water law in the western U.S. to understand these diverse interventions. Regardless of whether it comes from supply or demand, aquifer recovery seemed to require intervention, the study revealed.

The authors complemented measurements from monitoring wells with data from the Gravity Recovery and Climate Experiment (GRACE). The GRACE mission consists of twin satellites that precisely measure the distance between them as they orbit the Earth. In this way, the crafts detect small fluctuations in the planet's gravity, which can reveal the dynamics of aquifers at large scales.

"The beauty of GRACE is that it allows us to explore groundwater conditions where we do not have in-situ data," Perrone said. "Our assessment complements GRACE. Where we do have in-situ data, we can explore groundwater conditions locally, a crucial level of resolution when you are managing depletion." This local resolution is critical, as the authors found out, because adjacent aquifers can display different trends.

That said, groundwater level trends do not present the whole picture. Even where aquifers remain stable, withdrawing groundwater can still affect nearby streams and surface water, causing them to leak into the subsurface, as Perrone and Jasechko detailed in another *Nature* paper in 2021.

The authors also analysed precipitation variability over the past four decades for 542 aquifers. They found that 90 per cent of aquifers where declines were accelerating are in places where conditions have gotten drier over the last 40 years. These trends have likely reduced groundwater recharge and increased demand. On the other hand, climate variability can also enable groundwater to rebound where conditions become wetter.

This study of monitoring wells complements a paper Perrone and Jasechko released in 2021. That study represented the largest assessment of global groundwater wells, and made the cover of the journal *Science*. "The monitoring wells are telling us information about supply. And the groundwater wells are telling us information about demand," Perrone said.

"Taken together, they allow us to understand which wells have run dry already, or are most likely to run dry if groundwater-level declines occur," Jasechko added.

Perrone and Jasechko are now examining how groundwater levels vary over time in the context of climate change. Connecting these rates of change to the depths of actual wells will provide better predictions of where groundwater access is at risk.

Discovery of a Third RNA Virus Linage in Extreme Environments

Date: 31 January 2024

Source: University of Tsukuba

Summary: A research group led by University of Tsukuba has discovered a novel RNA viral genome from microbes inhabiting a high-temperature acidic hot spring. Their study shows that RNA viruses can live in high-temperature environments (70°C – 80°C), where no RNA viruses have been observed before. In addition to the two known RNA virus kingdoms, a third kingdom may exist. There are numerous RNA virus species on Earth. However, their diversity and evolution as well as roles in the ecosystem remain unclear.

In this study, using an original method, researchers have discovered a novel RNA viral genome from thermoacidophilic microbes (close to the last universal common ancestor of life) in the hot springs of Unzen and Kirishima fumaroles. This RNA virus was named hot spring RNA virus (HsRV) and was presumed to infect thermoacidophilic bacteria.

This study shows that RNA viruses can inhabit high-temperature environments, where life is believed to have originated. Furthermore, HsRV considerably differs from all other RNA viruses belonging to the two established RNA virus kingdoms, indicating the existence of a previously overlooked third RNA virus kingdom. Future studies will attempt to culture host strains that harbor HsRV and elucidate the virological properties and ecology of HsRV.

Scientists Develop Artificial 'Worm Gut' to Break Down Plastics

Date: 8 February 2024

Source: Nanyang Technological University

Summary: By feeding worms with plastics and cultivating microbes found in their guts, researchers from NTU's School of Civil and Environmental Engineering (CEE) and Singapore Centre for Environmental Life Sciences Engineering (SCELSE) have demonstrated a new method to accelerate plastic biodegradation.

Previous studies have shown that *Zophobas atratus* worms — the larvae of the darkling beetle commonly sold as pet food and known as 'superworms' for their nutritional value — can survive on a diet of plastic because its gut contains bacteria capable of breaking down common types of plastic. However, their use in plastics processing has been impractical due to the slow rate of feeding and worm maintenance.

NTU scientists have now demonstrated a way to overcome these challenges by isolating the worm's gut bacteria and using them to do the job without the need for large-scale worm breeding.

NTU Associate Professor Cao Bin at the School of CEE and Principal Investigator at SCELSE said, "A single worm can only consume about a couple of milligrams of plastic in its lifetime, so imagine the number of worms that would be needed if we were to rely on them to process our plastic waste. Our method eliminates this need by removing the worm from the equation. We focus on boosting the useful microbes in the worm gut and building an artificial 'worm gut' that can efficiently break down plastics."

The study, published in *Environment International* in January, is aligned with the University's commitment to fostering innovation and translating research into practical solutions that benefit society under its NTU2025 five-year strategic plan.

Developing an artificial worm gut

To develop their method, the NTU scientists fed three groups of superworms different plastic diets — High-density polyethylene (HDPE), Polypropylene (PP) and Polystyrene (PS) — over 30 days. The control group was fed a diet of oatmeal.

The NTU scientists selected the plastics as they are among the most common plastics in the world, used in everyday items like food boxes and detergent bottles. HDPE is a type of plastic known for its high-impact resistance, making it difficult to break down.

After feeding the worms plastic, scientists extracted the microbiomes from their gut and incubated them in flasks containing synthetic nutrients and different types of plastics, forming an artificial 'worm gut'. Over six weeks, the microbiomes were left to grow in the flasks at room temperature.

Increase in plastic-degrading bacteria

The scientists found that compared to the control group, the flasks which contained the gut microbiomes from the plastic-fed worms showed a significant increase in plastic-degrading bacteria.

Furthermore, the microbial communities colonising the plastics in the flasks were simpler and more tailored to the specific type of plastic than the microbes found on plastics that had been fed directly to the worms. When the microbial communities are simpler and targeted to a specific type of plastic, this translates to potential for more efficient plastic degradation when used in real-life applications.

First author of the study Liu Yinan, Research Fellow at the School of CEE and SCELSE, said, "Our study represents the first reported successful attempt to develop plastic-associated bacterial communities from gut microbiomes of plastic-fed worms. Through exposing the gut microbiomes to specific conditions, we were able to boost the abundance of plastic-degrading bacteria present in our artificial 'worm gut', suggesting that our method is stable and replicable at scale."

The researchers say their proof-of-concept lays the foundation for developing biotechnological approaches that use worms' gut microbiomes to process plastic waste.

For their next steps, the researchers want to understand how the bacteria in the superworm's gut break down the plastics at the molecular level. Understanding the mechanism will help scientists engineer plastic-degrading bacterial communities to break down plastics efficiently in the future.

You May Be Breathing in More Tiny Nanoparticles From Your Gas Stove Than From Car Exhaust

Date: 27 February 2024

Source: Purdue University

Summary: "Combustion remains a source of air pollution across the world, both indoors and outdoors. We found that cooking on your gas stove produces large amounts of small nanoparticles that get into your respiratory system and deposit efficiently," said Brandon Boor, an associate professor in Purdue's Lyles School of Civil Engineering, who led this research.

Based on these findings, the researchers would encourage turning on a kitchen exhaust fan while cooking on a gas stove.

The study, published in the journal *PNAS Nexus*, focused on tiny airborne nanoparticles that are only 1–3 nanometers in diameter, which is just the right size for reaching certain parts of the respiratory system and spreading to other organs.

Recent studies have found that children who live in homes with gas stoves are more likely to develop asthma. But not much is known about how particles smaller than 3 nanometers, called nanocluster aerosol, grow and spread indoors because they are very difficult to measure.

"These super tiny nanoparticles are so small that you are not able to see them. They are not like dust particles that you would see floating in the air," Boor said. "After observing such high concentrations of nanocluster aerosol during gas cooking, we can not ignore these nano-sized particles anymore."

Using state-of-the-art air quality instrumentation provided by the German company GRIMM AEROSOL TECHNIK, a member of the DURAG GROUP, Purdue researchers were able to measure these tiny particles down to a single nanometer while cooking on a gas stove in a "tiny house" lab.

They collaborated with Gerhard Steiner, a senior scientist and product manager for nano measurement at GRIMM AEROSOL.

Called the Purdue zero Energy Design Guidance for Engineers (zEDGE) lab, the tiny house has all the features of a typical home but is equipped with sensors for closely monitoring the impact of everyday activities on a home's air quality. With this testing environment and the instrument from GRIMM AEROSOL, a high-resolution particle size magnifier — scanning mobility particle sizer (PSMPS), the team collected extensive data on indoor nanocluster aerosol particles during realistic cooking experiments.

This magnitude of high-quality data allowed the researchers to compare their findings with known outdoor air pollution levels, which are more regulated and understood than indoor air pollution. They found that as many as 10 quadrillion nanocluster aerosol particles could be emitted per kilogram of cooking fuel — matching or exceeding those produced from vehicles with internal combustion engines.

This would mean that adults and children could be breathing in 10–100 times more nanocluster aerosol from cooking on a gas stove indoors than they would from car exhaust while standing on a busy street.

"You would not use a diesel engine exhaust pipe as an air supply to your kitchen," said Nusrat Jung, a Purdue assistant professor of civil engineering who designed the tiny house lab with her students and co-led this study.

Purdue civil engineering PhD student Satya Patra made these findings by looking at data collected in the tiny house lab and modeling the various ways that nanocluster aerosol could transform indoors and deposit into a person's respiratory system.

The models showed that nanocluster aerosol particles are very persistent in their journey from the gas stove to the rest of the house. Trillions of these particles were emitted within just 20 minutes of boiling water or making grilled cheese sandwiches or buttermilk pancakes on a gas stove.

Even though many particles rapidly diffused to other surfaces, the models indicated that approximately 10 billion to 1 trillion particles could deposit into an adult's head airways and tracheobronchial region of the lungs. These doses would be even higher for children — the smaller the human, the more concentrated the dose.

The nanocluster aerosol coming from the gas combustion also could easily mix with larger particles entering the air from butter, oil or whatever else is cooking on the gas stove, resulting in new particles with their own unique behaviours.

A gas stove's exhaust fan would likely redirect these nanoparticles away from your respiratory system, but that remains to be tested.

"Since most people do not turn on their exhaust fan while cooking, having kitchen hoods that activate automatically would be a logical solution," Boor said. "Moving forward, we need to think about how to reduce our exposure to all types of indoor air pollutants. Based on our new data, we had advise that nanocluster aerosol be considered as a distinct air pollutant category."

Quantum Tornado Provides Gateway to Understanding Black Holes

Date: 20 March 2024

Source: University of Nottingham

Summary: Scientists have for the first time created a giant quantum vortex to mimic a black hole in superfluid helium that has allowed them to see in greater detail how analogue black holes behave and interact with their surroundings.

Research led by the University of Nottingham, in collaboration with King's College London and Newcastle University, have created a novel experimental platform: a quantum tornado. They have created a giant swirling vortex within superfluid helium that is chilled to the lowest possible temperatures. Through the observation of minute wave dynamics on the superfluid's surface, the research team has shown that these quantum tornados mimic gravitational conditions near rotating black holes. The research has been published today in *Nature*.

Lead author of the paper, Patrik Svancara from the School of Mathematical Sciences at the University of Nottingham explains: "Using superfluid helium has allowed us to study tiny surface waves in greater detail and accuracy than with our previous experiments in water. As the viscosity of superfluid helium is extremely small, we were able to meticulously investigate their interaction with the superfluid tornado and compare the findings with our own theoretical projections."

The team constructed a bespoke cryogenic system capable of containing several litres of superfluid helium at temperatures lower than -271 °C. At this temperature liquid helium acquires unusual quantum properties. These properties typically hinder the formation of giant vortices in other quantum fluids like ultracold atomic gases or quantum fluids of light, this system demonstrates how the interface of superfluid helium acts as a stabilising force for these objects.

Svancara continues, "Superfluid helium contains tiny objects called quantum vortices, which tend to spread apart from each other. In our set-up, we have managed to confine tens of thousands of these quanta in a compact object resembling a small tornado, achieving a vortex flow with record-breaking strength in the realm of quantum fluids."

Researchers uncovered intriguing parallels between the vortex flow and the gravitational influence of black holes on the surrounding spacetime. This achievement opens new avenues for simulations of finite-temperature quantum field theories within the complex realm of curved spacetimes.

Silke Weinfurtner, leading the work in the Black Hole Laboratory where this experiment was developed, highlights the significance of this work, "When we first observed clear signatures of black hole physics in our initial analogue experiment back in 2017, it was a breakthrough moment for understanding some of the bizarre phenomena that are often challenging, if not impossible, to study otherwise. Now, with our more sophisticated experiment, we have taken this research to the next level, which could eventually lead us to predict how quantum fields behave in curved spacetimes around astrophysical black holes."