

UK Research and Innovation



The impact of UK-US research collaboration

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Foreword

The UK and the US are two research powerhouses: our scientists have won an impressive 358 Nobel Prizes¹ and, between us, we host all of the world's top 10 universities². The US is the number one choice for co-authorship for UK researchers and joint publications have a citation impact 2.75 times greater than the global average³.

As the case studies in this brochure show, working together has much more tangible impacts than simply increasing citations – UK-US collaborations have been able to increase our understanding of Alzheimer's disease, revive a dying language, improve the lives of people with speech impairments and much more.

These impacts were only possible through the combination of unique expertise from both countries and the cross-fertilisation of ideas across geographical and disciplinary boundaries. Transatlantic collaboration can help researchers in niche fields find others working in the same space; it can challenge researchers to question their assumptions and adopt new approaches; it can increase the reach and reputation of a research project.

These case studies also emphasise the important role that research funders play in creating an environment where such collaboration can flourish. All of the research projects described here have received support from UK Research and Innovation (UKRI). In most cases, UKRI funding was complemented by support from funders in the US – including the National Science Foundation, National Institutes of Health and US Department of Agriculture – as well as other partners in the UK and EU.

I'm very proud of the role that UKRI USA has played in establishing collaborative funding opportunities between UKRI and US funders, with the express purpose of facilitating partnerships between researchers in our two countries.

I look forward to continuing to work with our partners in the US to build on and grow this relationship, so that we can support many more impactful projects – like the ones described here – in the future.

Chloë Somers
Director, UK Research and Innovation USA

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One of the advantages that we have through a UK-US alliance is a larger international impact.
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¹ <https://www.nobelprize.org/prizes/lists/all-nobel-prizes/>

² <https://cwur.org/2018-19.php>

³ <https://www.elsevier.com/research-intelligence?a=507321>



Chatty business

How voice systems allow speech-impaired people to communicate in the workplace

Users can select day-to-day phrases such as “How’s it going?” and “Would you like that photocopied?”

In the winter of 1963, 21-year-old Stephen Hawking was diagnosed with ALS, a motor neuron disease. Over the years, the famous physicist and author who passed away in March 2018, became bound to a wheelchair and came to rely on a computerized voice system to communicate, which he described as helping him “communicate better now than before I lost my voice.”

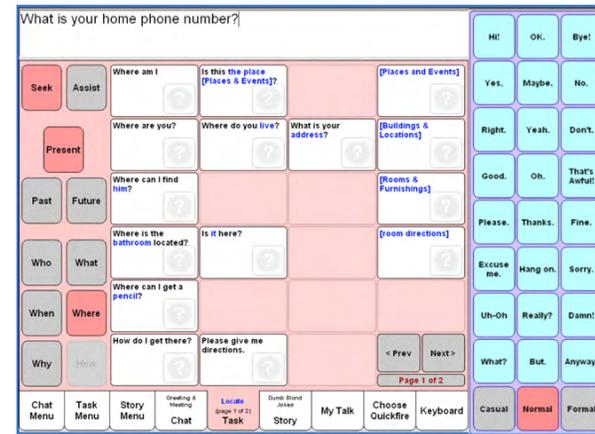
These voice systems — known as Augmentative and Alternative Communication or AAC — are designed for people who, like Hawking, have a degenerative neuron disease or have Multiple Sclerosis, Cerebral Palsy, or some other condition that severely impairs their speech.

While several of these voice systems exist, in the early 2000s, a team of US and UK researchers joined forces to create CONTACT, a computer program that would elevate the quality of communication from message making — where users express themselves one word at a time — to interactive talk, which would allow them to select commonly used phrases, resulting in faster and more substantive communication.

So, for instance, a user could quickly select day-to-day phrases such as “Hello,” “Good-bye,” and “How’s it going?” It’s what the late John Todman, a key member of the team and a giant in the world of AAC systems referred to as “quickfire comments.” The research tool, which was focused on the workplace, also allowed users to select phrases such as “Would you like that photocopied” or “There’s someone on the phone for you.”

“Real communication is all about interacting and personalities and jokes and teasing, which requires speed and intelligence in the system,” says Norman Alm, a computer scientist and now-retired academic from Dundee University and one of four researchers on the team.

Image courtesy of Jeff Higginbotham



“It was a meeting of two determined minds.”

CONTACT, an AAC system that researchers in the US and UK developed, allows users to carry out functional, day-to-day conversations with relative ease. The system also allows them to set the tone of a conversation to casual, normal, or formal.

The team came about when Todman met Jeff Higginbotham, a professor of Communicative Disorders at the University of Buffalo, at an international conference on AAC, and suggested they work together with Alm as well as Portia File, a computer scientist at Abertay University in Dundee.

Higginbotham had been working with his colleague David Wilkins to build Frametalker, a language system that allowed users to carry out topic-specific conversations. Meanwhile, Todman, then a psychology professor at the University of Dundee and Alm’s colleague, was developing TALK, which enabled users to carry out casual conversations that weren’t necessarily focused on a particular topic. While the end goal of the systems seemed different on the surface, both were focused on increasing speed and fluidity of communication. CONTACT incorporated elements of both systems to predict words based on user frequency and context.

When renowned experts in their field come together, the collaboration isn’t always easy. “It was a meeting of two very determined minds,” says Higginbotham, referring to himself and Todman. “There were a lot of heated arguments ... but it was always to make everything better.” The team also collaborated with a US-based engineering firm Enkidu Research as part of the effort.

While AAC technologies have evolved significantly in the last few decades from picture boards and typewriters, for instance, to apps available on smartphones and tablets, the ultimate goal — as yet the Holy Grail — is to make conversation as fluid as possible. For an AAC user that would potentially mean increasing the speed of communication from an average two words per minute to 30 or 50 words per minute. (The average person without a speech impediment talks at a rate of 150-180 words per minute.) In fact, research shows that during a conversation, people are

expected to take no longer than a second or two to respond either with words or gestures before being held accountable for their “delayed” response.

Today, CONTACT is part of InterAACt, a larger language framework, owned by Tobii Dynavox, one of the world’s largest AAC companies. The system not only enables speech-impaired users to communicate more easily but, by extension also benefits friends and family. According to Alm, while AAC system users only account for one-third of one percent of the world’s population, “worldwide that’s a lot of people, and for them, it’s a huge problem because if you can’t communicate, you can’t be human.”

This research was supported by UKRI’s Engineering and Physical Sciences Research Council and the European Union.

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A welcome upgrade to smoother flying

Recently developed algorithm helps aviation weather forecasters predict – and avoid – turbulent skies

Millions of people around the world are afraid of flying. For some, it's the feeling of being trapped in a small space for hours; for others, it's a sense of powerlessness. Throw turbulence into the mix – bumpiness as the plane rumbles through rough pockets of air, the sudden drops reminiscent of a ride on a roller coaster – and anxiety levels rise further.

Depending on the intensity, turbulence can range from being a source of discomfort for a few moments to causing serious injuries to passengers and flight attendants, as was the case on a recent Miami flight bound for Buenos Aires. Photos showed oxygen masks hanging from the cabin ceiling, food trays strewn across the floor, and general disarray everywhere.

“Air turbulence is the leading cause of injury to passengers and flight attendants,” says Paul Williams, a professor of atmospheric science at the University of Reading in the UK. The costs associated with turbulence, including damage to aircraft, treatment of passengers and cabin crew, missed workdays as a result of injuries, and delayed arrivals, are probably in the region of a billion dollars worldwide annually.

Pilots currently rely on turbulence forecasts that are issued every hour and mapped out 18 hours ahead. But, turbulence tends to be transient, so these forecasts aren't always accurate.

As a solution, in 2008, a transatlantic team of researchers including Williams; John Knox, a professor in the department of Geography

at the University of Georgia; and Donald McCann, an aviation weather forecaster and founder of McCann Aviation Weather Research, Inc., developed an algorithm to better predict turbulence. They focused their efforts on clear air turbulence, which is invisible and, as a result, more challenging to navigate.

Developing the algorithm involved studying a complicated chain of events. For starters, clear air turbulence typically occurs in a jet stream – narrow bands of strong air currents. Forces that steer the jet stream can make it unsteady or unbalanced. An unbalanced jet stream emits a wave called a gravity wave. Moving gravity waves cause changes in wind speed, also known as wind shear, which, in turn, leads to turbulence.

In order to predict this turbulence, researchers had to take a forecast of the jet stream up to 18 hours ahead and apply a mathematical equation to determine where the jet stream was becoming unbalanced.

The idea to develop the algorithm first took root when Knox read Williams' PhD thesis on the generation of gravity waves in an unbalanced jet stream. In his thesis, Williams had briefly mentioned the idea of an algorithm to predict turbulence. Knox, who had previously worked with McCann on clear air turbulence, says, “A lightbulb went off, and I said, ‘Man, we gotta get these people together.’”

Within a few years, the trio had developed the algorithm, which is now used as part of the US Aviation Weather Service's turbulence forecasting system, Graphical Turbulence Guidance or GTG. This forecasting system is expected to replace international forecasting systems within the next year or two. In addition, a Minneapolis-based private weather company, DTN, which serves more than 90 airlines and business jet operations, also uses the algorithm.

The algorithm has not only improved the flying experience of billions of passengers, but it will prove to be especially critical in

decades to come as climate change – known to further intensify wind shears and subsequently increase turbulence – worsens. “Like all good things in life it was a complete accident that this collaboration happened,” says Williams. “I didn't plan it, but it's meant such a lot to me.”

This research was supported by UKRI's Natural Environment Research Council and the Royal Society.



A weather radar in a flight simulator at the UK's Brighton City Airport shows clouds and storms ahead of the plane. In 2008, researchers in the UK and US developed an algorithm that could predict clear air turbulence, which is invisible and challenging for pilots to navigate.

Image courtesy of Cass Productions

Researchers dig deep to avoid arsenic in Bangladesh's groundwater



While shallow tubewells contain dangerously high levels of arsenic, groundwater at depths of 150 to 200 meters is considerably safer



In the late 1990s, Ross Nickson, then a master's student of hydrogeology at University College London, traveled across Bangladesh armed with 50 or so bottles that he filled with groundwater. Only a few years prior, scores of Bangladeshis had begun to show symptoms of arsenic poisoning — including skin lesions, melanomas, and cancer — and researchers had discovered that the groundwater, which, it turned out, had dangerously high levels of arsenic, was to blame. Nickson was there to study the water to determine what was causing these high levels of arsenic.

Arsenic is a naturally occurring element, and groundwater almost anywhere in the world has measurable amounts of arsenic. In high doses and over an extended period of time, it's extremely toxic. The World Health Organization's recommended limit of arsenic in drinking water is 10 micrograms per liter.

"In the London basin we have measurable amounts of arsenic," says William Burgess, Nickson's professor at UCL, who has spent many years studying arsenic in the Bengal basin. "But it's an order of magnitude less than the WHO drinking water limit. So, we're talking about 1 microgram per liter instead of 10."

Compare that to Bangladesh where a lot of the groundwater contains arsenic levels as high as 100 or 1,000 micrograms per liter. With more than 20 million people in Bangladesh exposed to these high levels, it's what WHO has referred to as "mass poisoning on an unprecedented scale."

Bangladesh has especially high levels of arsenic in its groundwater largely because of the chemical makeup — and breakdown — of sand that's deposited from rivers like the Ganges and the Brahmaputra into the Bengal Basin. Unfortunately, residents of Bangladesh rely on this water that they pump manually from tubewells for drinking, washing, cooking, and irrigation. There are about 10 million tubewells across the country of which about 5 million pump up highly contaminated water.

Hand-pumped tubewells typically pump water from a depth of less than 100 meters. But, in the early 2000s, researchers found that water at depths of 150 to 200 meters contained a lot less arsenic. After decades of research, "it rapidly became clear that you could drill deeper within the sedimentary basin in Bangladesh, and you would normally reach groundwater which has ordinary low-level natural background levels of arsenic in groundwater," says Burgess.

These findings now serve as a resource and guide for official government agencies as

“**Mass poisoning on an unprecedented scale.**”

well as for non-governmental organizations (NGOs) such as UNICEF, which have played a key role in working to mitigate the arsenic crisis in Bangladesh. In addition, the findings

have helped the Bangladesh government implement deep groundwater pumping strategies — including advice on how deep wells must go to pump good quality water — as well as improve monitoring practices.

A woman pumps water from a shallow tubewell in Bangladesh. The groundwater in Bangladesh has high levels of arsenic; however, recent research shows that deeper groundwater has arsenic levels that are considerably lower and is, therefore, safe to drink.

But, there are still some unanswered questions. For instance, would pumping water from deeper levels draw down the arsenic from the surface and potentially contaminate even the deep groundwater as it was pumped? That's what Burgess has been working on, along with US researchers Holly Michael, a professor of environmental engineering at the University of Delaware and Clifford Voss, a senior scientist with the US Geological Survey's hydrological research program.

As researchers continue to work that out, there's hope for arsenic-safe water. "The good side of the mechanism that we identified for the release of arsenic is that as the water comes out of the ground in a reduced state carrying the arsenic in solution, all you have to do is oxidize that water and the dissolved iron will oxidize to iron oxide," says Burgess, adding that the oxidized iron will precipitate out as a rusty colored sludge and it will take with it a large amount of the dissolved arsenic. "That is a very commonly used water purification technique in any industrialized country." Still, Bangladesh doesn't yet have the infrastructure to install the large treatment and filtration systems that would be needed and, until it does, people will have to rely on small domestic-level treatment facilities or privately installed deep tubewells — or wait for the government to install more deep groundwater tubewells.

This research was supported by UKRI's Natural Environment Research Council and Engineering and Physical Sciences Research Council, as well as the UK Department for International Development (through the Association of Commonwealth Universities and the British Geological Survey).

Image courtesy of Sonia Hoque/REACH



What lab animals & people don't have in common

Researchers develop a step-by-step approach to assess the different impacts that a drug or a chemical might have on animals versus people



Image courtesy of USDA

Laboratory animals play a critical role when it comes to testing the potential toxicity of a drug or chemical in our food and in the environment. But, often, a chemical compound will have a different impact on an animal than it would on us, given biological differences as well as the way in which our bodies process and remove compounds. What's more, relying on observations of toxic effects doesn't always give the full picture because symptoms, in some cases, show up early or late for one species and not at all for another.

As a solution, in the mid 2000s, an international team of researchers developed a framework that broke down chemical interactions into steps that could be individually evaluated. The idea behind the framework was that all toxicological responses could be described in a series of quantifiable changes that occur in both experimental animals and humans. And, while each step wouldn't necessarily elicit some kind of toxic response, evaluating and comparing these distinct steps in animals and humans could result in a more relevant comparison and ultimately predict how humans were likely to respond compared to animals more accurately.

Consider long-term brain damage, for example. Symptoms of the condition could take over a decade to show up in humans and a matter of months in rats. But, by breaking the process down into steps, researchers could potentially notice changes in cells within a few weeks or months. "So, we might see an early change in humans without seeing the later change, and that allows us to compare what's going on even if they're not severely damaged," says Alan Boobis, a professor of Toxicology at Imperial College London and a key member of the team.

Today, this framework is applied widely including as part of risk assessments implemented by food and drug safety authorities across the world as well as by companies looking to get a better understanding of chemicals before introducing them to the market.

In 2011, Dow Chemical Company applied the framework to evaluate the impact of its pesticide Sulfoxaflor before it was assessed by the UN Food and Agriculture Organization and World Health Organization Joint Meeting on Pesticide Residues. The pesticide caused tumors in experimental rats and had an effect on a developing fetus; however, the framework helped conclude that those changes were specific to the lab animals and didn't apply to humans.

"This framework allows the transparent evaluation of the information and the communication of the conclusions in a very clear way," says Boobis. As a result, it is also used in educational and training programs as well as workshops designed for academics and regulators.

It was at one such event in the mid-2000s that Boobis met Kevin Crofton, a toxicologist, then with the US Environmental Protection Agency. They were both at an event organized by the International Life Sciences Institute, a non-profit organization that brings academics, industry and regulatory people together. Not long after, the World Health Organization put together a working group and invited Boobis and Crofton to be part of an effort to help assess the effects of simultaneous exposure to several chemicals. Given their related backgrounds, they decided to collaborate on developing the framework

and went on to work on several related projects such as the application of the framework concepts to develop the next generation of non-animal assessment methods.

"It is extremely helpful to have an international perspective," says Boobis. "Apart from individual expertise of individuals involved, there's also the issue of bringing the perspective of different parts of the world, which is really important if we're trying to get a framework that's generally acceptable and not just acceptable in one part of the world."

Over the last few decades, requirements to approve drugs and chemicals in our food and the environment have become more substantial, says Boobis. As a result, more companies are using the framework to understand chemical effects better and explore alternatives, where possible, resulting in better control and improved risk assessments.

This research was supported by UKRI's Medical Research Council and Biotechnology and Biological Sciences Research Council, and the UK Food Standards Agency.

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Lab animals, such as this rabbit, are often used in experiments designed to better understand impacts of drugs and chemicals on humans. But extrapolating findings from animals to people can be challenging, so researchers have developed a step-by-step approach that allows for more informed and relevant predictions and analyses.



Death by a thousand microorganisms

What researchers have done to tackle emerging plant disease

Model helps forest managers control the pathogen responsible for Sudden Oak Death.

Shades of brown coat a once green forest landscape in California and Oregon as millions of oak trees fall victim to a deadly plant pathogen, *Phytophthora ramorum*. It has become a familiar sight in the region: barks of trees oozing black cankers, often accompanied with bright orange and red patches, and brown spots spreading across the leaves. This is Sudden Oak Death, and it has decimated thousands of square miles of forests.

The disease was first noticed in the mid-1990s in California and shortly after in Oregon. *P. ramorum* is also found on rhododendrons, camellias, and other nursery plants, and researchers think one of these infected plants, probably planted in a garden adjacent to a national forest, allowed it to — literally — jump the fence. This water-loving pathogen produces spores in moist conditions that spread easily through wind-driven rain.

The term Sudden Oak Death is a bit of a misnomer. It isn't always sudden: trees can be infected for as long as two to five years before showing signs of disease, and they don't always die. "It was given the name because the oaks appeared to go from green to brown in a matter of weeks," says David Rizzo, a plant disease expert at the University of California, Davis. What's more, although oaks are primarily at risk, the pathogen has been found to infect close to 200 different plant species. In fact, in the UK, where it was discovered shortly after California, the pathogen is found on Japanese and European larch trees, and several conifer species including Douglas fir.

Rizzo had been studying Sudden Oak Death for a few years, focusing on the biology of the spread: when spores are formed, under what environmental conditions they spread, and how far they move, for instance. Then, in the early 2000s, he came across a paper that looked at modeling rat populations to better understand and manage the spread of bubonic plague. Rather than focusing on an infected human who doesn't spread the disease further, the technique focused on the carrier of the disease — in this case an infected flea.

"That's exactly what we observed with Sudden Oak Death," says Rizzo. "It appeared that the oaks were a dead end. They would get infected, but they didn't spread it." Instead, he was seeing leaves that would get infected but didn't die. "Those were the spreaders," he says. "And I thought, 'wow this is really similar.'"

Rizzo reached out to Chris Gilligan, head of the epidemiology and modeling group at the University of Cambridge and an author on the paper. After exchanging a few emails, Gilligan met Rizzo in the US at a conference on Sudden Oak Death, and they discussed the idea of developing a model to predict and manage the disease better. Rizzo brought in Ross Meentemeyer, an expert in geospatial analytics and landscape ecology, now at North Carolina State University. "Having the three groups together, we were really able to accomplish a lot," says Rizzo.

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As part of the collaborative effort, the team designed a mathematical model to predict factors such as where — based on its current trajectory — the disease might spread next, how long before it got to an area, and what trees were most at risk. These predictions helped inform management practices. For instance, by predicting areas likely to be impacted next, forest officials could pretreat the area to minimize damage. So far, the model is used to inform policy makers about the risks of emerging diseases like Sudden Oak Death that has also impacted trees in Florida. In addition, the US Forest Service uses the model not only to detect potential spread of the disease but also to implement measures to control it. Similarly, in the UK, the model is used to inform eradication and control policies.

Managing an emerging disease in a large natural landscape can be challenging. At most, researchers can carry out experiments in small patches of affected areas but expanding that to thousands of acres is almost impossible. "For trees, especially in a large natural landscape, you do an experiment, and it might be 20 years or 10 years to see if it worked or not," says Rizzo. "So, we have to do these various simulations to test those to come up with the best scenarios."

Rizzo expects that aspects of the model could potentially be applied to the study of other emerging diseases. Regardless of the disease, there's one key takeaway, says Rizzo. "If you see an emerging disease, you'd better jump on it fast. The longer you wait, the more difficult it is to control."

This research was supported by UKRI's Biotechnology and Biological Sciences Research Council, the UK Department of Environment, Food, and Rural Affairs, and the US Department of Agriculture.

Trees in California's Los Padres National Forest fall victim to the plant pathogen *Phytophthora ramorum*, which has decimated millions of trees across California and Oregon. Researchers have developed a model to predict and manage the spread of the disease.

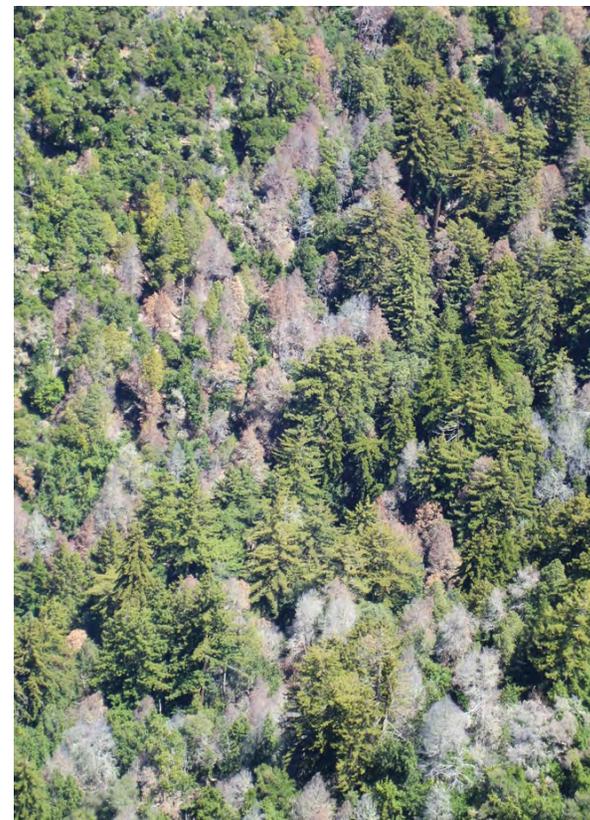


Image courtesy of US Forest Service



How studying the disappearing Kiowa language helped revive it

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The basic question is how does so much meaning get into so little sound?

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Stories told in this unique tribal language are brimming with complex and elegant sentences typical of Kiowa

There once lived a brother-sister warrior duo who often accompanied each other on battles and skirmishes. On one such battle, they were separated. The woman returned home, but her brother didn't. Wracked with grief and convinced that the mountain goats were really her brother calling, she went to the mountains in search of him — never to be seen again. In a tragic twist, the woman's brother ultimately returned home.

This is the story behind a haiku-like, two-line Kiowa song — the language of a Native American tribe and indigenous people of the Great Plains. Similar songs once sung by the tribe run the risk of being forgotten as the number of fluent speakers of Kiowa dwindle. (Today there are an estimated 30 or so fluent speakers.) What's more, says Daniel Harbour, a professor in the Cognitive Science of Language at Queen Mary University of London, "It's not like language goes and everything else stays intact. There's a break in transmission of culture as a whole."

Harbour has spent the last two decades studying the unique grammar and structure of Kiowa. It's what's referred to as a "free word order" language, where words can move around in a sentence without, generally, changing the meaning.

But that's not what makes Kiowa truly unique. In fact, many languages such as Georgian and Sanskrit are free word order languages. It's that in Kiowa you take all the subjects and objects — who and how many people are doing something to whom as well as for whom and how many of them, and squeeze all of that into a single syllable in front of the verb. So, for instance, in the sentence, "I'm writing a letter to you," the verb prefix is "yán" (pronounced yaan); but in the sentence, "We're writing a letter to you," the verb prefix is "gyát" (pronounced gyaat).

"There's this enormous calculus that Kiowa speakers carry around in their head of these tiny syllables," says Harbour. "And the basic question is how does so much meaning get into so little sound?" He calls it superfusion — where a wealth of information is fused together into a tiny syllable.

What's more, Kiowa has elegant and complex sentences where a verb is surrounded on either side by an identical structure, such that it acts like a mirror. "I don't know of any other language that does this, where you get both patterns simultaneously," says Harbour. "That raises serious theoretical questions about how language is constructed."

Early on in his research on Kiowa, Harbour reached out to Laurel Watkins, a professor of anthropology and linguistics at Colorado College, who had done extensive research in Kiowa. Soon after, Harbour, Watkins, and David Adger — Harbour's postdoctoral advisor at Queen Mary University of London — began collaborating to better understand the connection between grammar and discourse in Kiowa.

"Having worked alone on the Kiowa language for over 25 years before the start of this project, I have been reinvigorated and delighted by this collaboration," says Watkins. "The coming together of Harbour and Adger's formal approach and my descriptive orientation has led to the discovery and illumination of many aspects of Kiowa that might otherwise have been missed."

As part of the effort, the team used recordings made between the 1950s and 1980s, working closely with fluent tribal speakers to process the material. The project not only increased knowledge of the Kiowa tradition of storytelling but also helped raise awareness of the truly remarkable nature of the language and, in the process, fueled interest within the community. Today, there are a range of resources available — from brief videos of simple words and sentences in Kiowa and stories narrated by elders to an active Facebook page for the community and beyond.

"It is especially gratifying to see that this community-wide interest and activity is now self-sustaining, from Kiowa language classes held in several locations in Kiowa country to continuing consultation on questions of Kiowa grammar and usage with the Kiowa language instructor, Dane Poolaw, at the University of Oklahoma," says Watkins.

In addition, linguistics projects like this also serve as a repository of words, sentence structure, and other related information. "Sometimes we get the opportunity to work with speakers and learners and help them directly, and that's the best of all," says Harbour. "But at other times, we're just silos; we're people who collect information, stop it from being lost, and make sure it's there in a format that people can access in years to come."

This research was supported by UKRI's Arts and Humanities Research Council.

Image courtesy of Laurel Watkins

These booklets contain stories — written in Kiowa and English — that were often shared among members of the Kiowa tribe. The booklets were distributed within and outside the community as a way to raise awareness of the tribe's rich culture and traditions.



New blood test could speed up liver disease diagnosis

Test could someday be sold as a kit and used to monitor liver wellness



Vincent Rotello (right) along with researchers Yingying Geng (left) and Aritra Nath Chattopadhyay (center) prepare the liver sensor as part of their effort to detect liver disease in serum samples.

Image courtesy of Vincent Rotello



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Liver disease is often referred to as a silent killer — gradually destroying the organ’s tissue without showing any symptoms on the outside. By the time symptoms show up, the disease has already caused significant damage, making recovery difficult and, often, impossible.

Unlike cancer and heart disease, liver-related deaths are on the rise. Until recently, the only accurate way to diagnose the disease was through a blood test, such as the Enhanced Liver Fibrosis or ELF test, or by doing an invasive liver biopsy.

In the spring of 2018, researchers in the US and UK unveiled a method to detect liver damage that’s designed to be easily accessible, easy to administer, and can return results within a half hour.

Using nanotechnology, the test relies on polymers to detect a “fingerprint” or a pattern in a serum that’s characteristic of liver fibrosis. The polymers are coated with fluorescently labeled compounds that bind substances in the serum. When the binding occurs, a fluorescent signal is generated. The signal’s pattern denotes the degree of fibrosis in the patient from whom the serum is taken. So, for example, a person without liver disease would have one pattern of fluorescence, while the serum of an infected person would show another pattern. Those fluorescent patterns also show increasing intensity as the disease progresses.

“Our hope with the polymer test is that we would be able to adapt it so that it could be done maybe in a clinic or at the bedside, and that it could be done relatively quickly,” says William Rosenberg, Professor of Liver Diseases in the Institute for Liver and Digestive Health at University College London. Rosenberg also developed the ELF test, which has been widely used in Europe and Australia, and recently received a “breakthrough device” designation from the US Food and Drug Administration. However, the ELF test needs to be run on a large automated analyzer in a stable lab, making it less accessible to the general community.

The idea to develop a polymer-based test took shape when William Peveler — then a post doc in Rosenberg’s lab — suggested using nanotechnology to detect very scarce molecules in serum samples of patients with liver disease. Across the Atlantic, Vincent Rotello, a chemistry professor at the University of Massachusetts in Amherst was working on identifying patterns in serum samples, so the three combined their areas of expertise — Peveler in nanotechnology; Rosenberg in liver disease; and Rotello in array-based sensing — to develop the test.

“It was a meeting of two groups that were just ready to meet each other,” says Rotello, of himself and the UK researchers. The team is now working to further validate their findings. The next step would be to

develop it into a kit format that can be sold at clinics and hospitals and would involve a simple pinprick — much like a glucose test. In addition, says Rotello, “this can be really important in the developing world where you don’t have access to complex laboratory tests and certainly don’t want to do a biopsy.” The test could potentially be used in a wide range of healthcare settings to screen for liver disease amongst people at risk including those with diabetes, obesity, heavy drinkers and people taking medications that can injure the liver.

The team also hopes to use the method to detect liver wellness by programming the sensor to monitor baseline levels and detect when there’s a change — similar to a car’s “check engine” light.

“What our system does is it lowers the bar for testing for liver disease,” says Rotello. “So instead of waiting for symptoms to develop, you can actually monitor liver wellness.”

This research was supported by the Royal Society, UKRI’s Engineering and Physical Sciences Research Council, the University of Glasgow, UCLH NIHR Biomedical Research Center, and the US National Institutes of Health.



From armpit cheese to computer-eating bacteria

Interdisciplinary teams experiment with nature



Odor artist Sissel Tolaas and synthetic biologist Christina Agapakis create cheese in the lab as part of the Synthetic Aesthetics project.

Images courtesy of Alexandra Daisy Ginsberg

As part of a multi-year project, researchers explored the role of design in the field of synthetic biology.

Have you ever wondered what cheese made from bacteria on our toes might smell like; or perhaps what DNA sounds like as it whizzes past you? Would you drink out of a cup made from bacteria that could almost instantly transform water into a probiotic drink?

These and other mind-boggling questions were the product of Synthetic Aesthetics, a multi-year, international project that launched in 2009 and explored the role of design in synthetic biology — broadly defined as the engineering of living things. (Think of bits of DNA code, for example, as programmable, much like computer software.)

As part of the project, synthetic biologists were paired with artists and designers — including a smell artist, an architect, and a composer — to form a total of six teams. Spending an equal amount of time in each other's workspace, the pairs were given the freedom to take their work in any direction they chose. The goal of the project was to explore what it meant to design nature and the participants were interested in how to do this sustainably, by harnessing nature's properties rather than exploiting or manipulating it.

"As a group we said we wanted the project to be like a wedge in the door that stops synthetic biology from closing; that stops synthetic biology from becoming boring," says Jane Calvert, a professor of science and technology

studies at the University of Edinburgh and the UK Principal Investigator on the project. Consider the cheese. As part of their experiment, synthetic biologist Christina Agapakis and odor artist and researcher Sissel Tolaas made cheese out of bacteria found on people's toes, armpits, belly buttons, and tongues — parts of the body that tend to be moist and, therefore, hold bacteria. The range of smells was wide: Calvert described armpit cheese, for instance, as smelling "yogurty and fresh," while toe cheese was "disgusting and strong."

The idea behind the experiment was to think about our relationship to our microbiome as well as explore the boundaries between ourselves and the food we eat. In fact, many of the stinkiest cheeses are associated with bacteria that have similar smells to parts of our bodies such as our toes and armpits. That's probably because we have some of the same microorganisms as cheeses — likely the product of artisanal cheese making and the subsequent transfer of bacteria between the cheesemaker's hands and the cheese.

Other projects included creating cynobacteria that digested computer circuit boards and a look into the future when inanimate machines including cars and computers could potentially be replaced by living machines. "The project reveals ... that professionals in art and creative design can create significant value by leading work to consider what might be wished for, especially when most can't yet imagine," says Drew Endy. Endy is a bioengineering professor at Stanford University who served as the US Principal Investigator on the project.

Because of the strong multidisciplinary nature of the project, individuals had different objectives and takeaways. As a social scientist, Calvert saw the project as a way of challenging the scientific community, seeing it as an "inreach" rather than an outreach project. The synthetic biologists embraced the opportunity to be more imaginative about the science while the artists and designers questioned some commonly held assumptions about synthetic biology.

“We didn't know what was going to come out of it.”

Other members of Calvert and Endy's team who oversaw the project included Alistair Elfick,

a bioengineer at the University of Edinburgh and co-Investigator; Pablo Schyfter, a social scientist, also at Edinburgh; and London-based designer and artist Alexandra Daisy Ginsberg. In 2014, the team published a book, "Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature," in which they discussed the project in detail. In addition, teams have presented and exhibited their work at conferences, art exhibits across the world, and festivals as a way to explore the potential reach of synthetic biology in our daily lives.

"We didn't know what was going to come out of it," says Calvert, who had never worked with artists and designers before. But, she says, it was that three-way collaboration between synthetic biologists, artists and designers, and social scientists that allowed each to get something out of it. "Something different from what we expected."

The Synthetic Aesthetics project was supported by UKRI's Engineering and Physical Sciences Research Council and the US National Science Foundation.

These cheeses made from bacteria found on different parts of the body — including designer Alexandra Daisy Ginsberg's armpit, philosopher and social scientist Pablo Schyfter's toe, synthetic biologist Christina Agapakis' hand, and odor artist Sissel Tolaas' nose — took a few days to make as part of the Synthetic Aesthetics project.





Ministers and other officials participate in the inauguration ceremony of Brazil's National Truth Commission. Researchers in the US and UK developed a database that provides information on the different justice mechanisms such as truth commissions and amnesty laws that countries implement to address past human rights violations.

Image courtesy of Wilson Dias/ABR



Justice will prevail, but in what form?

Researchers examine how countries seek retribution for past national atrocities

Five decades of civil war has left Colombia with deep and painful wounds. Recently, the Latin American country set up a truth commission to address the deaths, kidnappings, sexual assaults, and other crimes that accompanied the war in hopes that victims can begin to recover from the trauma and rebuild their lives.

Truth commissions are part of what's referred to as transitional justice mechanisms. These mechanisms are efforts to restore a country that's suffered through human rights violations and conflicts by seeking justice for victims. Apart from truth commissions, criminal trials and amnesty policies are two of the most commonly implemented justice mechanisms. "The idea is to build toward stronger democracies and human rights cultures in the aftermath of mass atrocity," says Leigh Ann Payne, a professor of sociology at the University of Oxford.

Payne has spent decades studying authoritarian rule and human rights violations across the world. In 2012, she and colleague Kathryn Sikkink, a human rights academic at Harvard University, began building a database of transitional justice mechanisms that countries have implemented so far. For instance, South Africa set up a truth commission after the end of apartheid; South Korea set one up in response to Major General Park Chung-Hee's military coup against the government in 1961 when many people were detained and tortured; and Rwanda began genocide trials in response to atrocities against Tutsi and Hutu populations.

What's more, says Payne, "there have been uses of these mechanisms in countries that haven't gone through a transition and are, in fact, stable democracies." For instance, the database also included countries like the US that set up a truth commission in response to the civil rights violence in the 1950s and 60s while Australia implemented an "Apology Day" as part of its effort to address its unjust treatment of aboriginals.

Payne and Sikkink met in graduate school in the 1980s. Years later, during a discussion about work, they discovered that they were both working on building a database of transitional justice mechanisms. They decided to complete their work and then collaborate to develop a new, more robust database. With more funding and, as a result, more resources and a larger team at their disposal, the duo also examined alternative accountabilities — justice mechanisms that went beyond the three that were most commonly used. These included customary justice; civil trials instead of criminal trials; and reparations policies.

Spain implements some of these alternative accountabilities. "A blanket amnesty law protects perpetrators of past violence from justice, based on the notion that the country would otherwise be trapped in the past in revenge," says Payne. But the country

“The idea is to build toward stronger democracies and human rights cultures in the aftermath of mass atrocity.”

implemented an alternative memory law that allowed victims' families to seek to find the bodies of those killed during the country's civil war and dictatorship.

In several instances, Rwanda also takes a less traditional approach by relying on its "gacaca" or "grass court" system, which is a community-led customary or traditional justice mechanism. Perpetrators confess their wrongdoing to the community and ask for forgiveness, in the process contributing to truth, healing, and reconciliation.

"The idea of some of these customary justice programs is that what's more meaningful to victims of these atrocities isn't that somebody ends up in jail; but that that somebody has to commit to building a stronger community, to try to repair the harm," says Payne.

Payne and Sikkink's work has had significant impact on international policies and practices. "We have provided scientific backing to a set of processes and determined under what conditions they are most likely to have the greatest effect," says Payne. In addition, their collaboration is vital as they work with international and domestic

governments. "One of the advantages that we have through a UK-US alliance is a larger international impact," says Payne. "It's not just an academic project in the US, but, as an international alliance, we can have an impact around the world."

As a result, the team is often invited to share their findings with congressional peace committees, constitution courts, truth commissions, and business people. Over the years, they have contributed to workshops with prosecutors and journalists, they have worked with victim groups and other members of the community as well as been involved in UN and the World Bank projects.

Impact and success vary depending on circumstances; however, regardless of whether transitional justice mechanisms are used in isolation or in combination with alternative accountability mechanisms, there's one big takeaway from their research. "[It] is that doing something contributed positively to human rights culture and democracy," says Payne. "And that doing nothing tended to end up harming those processes of building democracies and human rights cultures."

This research was supported by UKRI's Arts and Humanities Research Council and the US National Science Foundation.

How to emerge from a deep recession

Economists have found that lowering interest rates isn't always enough for a struggling economy to recover

A little over a decade ago, the world witnessed a recession that came to be seen as the worst financial crisis since the Great Depression of the 1930s. Stock markets crashed, and banks lost hundreds of billions of dollars on toxic assets and bad loans.

In addition to huge financial losses, a recession is usually accompanied by high rates of unemployment along with a shortfall of outputs where the economy is no longer producing much-needed goods and services such as houses, automobiles, and industrial machinery.

"It's fundamentally a waste of resources," says George Evans, an economics professor at the University of Oregon. "It hits some people more than others but at the most basic level it's really a waste."

Then there's a deep recession, which is what the 2007-2008 financial crisis ended up being. In a deep recession output falls by over 10 percent and unemployment rates rise drastically. The challenge with a recession — however deep or otherwise — is that it's almost impossible to predict. "You know one is going to come because

they do," says Evans. "That's the nature of macroeconomy." But, he says, "as soon as we know a recession is coming, it's too late not to have a recession. But we can moderate its impact."

In the early 2000s, Evans began to examine measures that a government can implement to moderate the impact of a deep recession. While in the case of a recession, it's usually sufficient to cut short-term interest rates in a way that stimulates the economy and puts it back on the road to recovery, Evans found that with a deep recession that kind of monetary policy may need to be combined with aggressive fiscal policy and other financial policies.

In fact, that's exactly what US policymakers did during the most recent financial crisis. In addition to reducing short-term interest rate to near zero, the U.S. Federal Reserve — the central bank of the U.S. — implemented multiple policies that helped ease stress that comes with a recession. For instance, the Federal Reserve, at the time headed by Ben Bernanke, more than doubled federal deposit insurance to \$250,000 as a way to reassure people and small businesses that they wouldn't lose their deposits.

The insurance was also temporarily extended to cover money market mutual funds that a lot of people had invested in either directly or indirectly. "That was just quick changes to try to restore confidence in people in the banking system," says Evans. In addition, the US Treasury implemented a \$700 billion Troubled Asset Relief Program or TARP to stabilize banks, and the Federal government provided a \$787 billion fiscal stimulus of increased government spending and tax cuts over 2009-2011.

“As soon as we know a recession is coming, it's too late not to have a recession. But we can moderate its impact.”

The Federal Reserve also implemented a quantitative easing policy, which involved purchases of various financial assets, including longer-term treasury bonds and some mortgage-backed securities, as a way to stimulate the economy by reducing interest rates on a range of assets including longer-term treasury bonds.

As part of his research on deep recessions, Evans worked with Seppo Honkapohja, an economist and Member of the Board at the Bank of Finland, and Kaushik Mitra, who holds a Chair in Economics at the University of Birmingham, on the outlook of individuals and firms during a recession. They found that the key to managing a recession — and subsequently averting a depression — is to manage expectations. If people believe their funds or jobs, for instance, aren't secure, they're less likely to continue their spending or make large investments. "How optimistic or pessimistic households or firms matters a lot," says Evans.

The economists found that this optimistic or pessimistic response isn't necessarily based on rational expectations but rather relies on past experience to forecast the future. It's what's referred to as an adaptive learning approach and, according to Evans, it's critical to consider how this approach influences fiscal and monetary policies.

In fact, in 2011, the team launched a conference series, "Expectations in Dynamic Macroeconomic Models" at the University of St. Andrews, where Mitra was formerly based, to explore how best to model policies based on the adaptive learning approach. The conference series — largely supported by James Bullard, President of the Federal Reserve Bank, St. Louis — has rotated through venues around the world including San Francisco, St. Louis, Amsterdam, Oregon, and Helsinki where the team has discussed their findings with central bank research economists and policy makers.

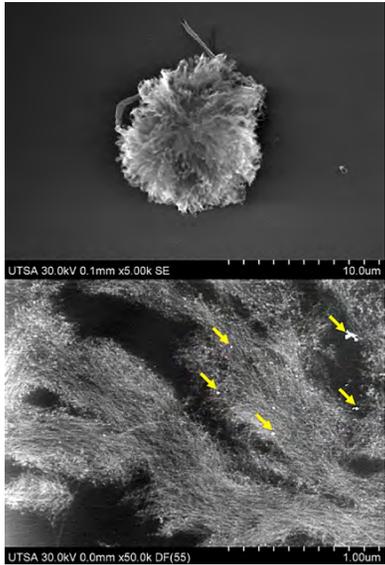
"Most policy makers in central banks have really liked this adaptive learning approach," says Evans. "It looks to them like a plausible way to look at how firms and households form expectations and change how optimistic or pessimistic they are."

This research was supported by UKRI's Economic and Social Research Council and the US National Science Foundation.

Lehman Brothers was one of many banks hit by the financial crisis of 2007-2008. While recessions are difficult to predict, researchers in the US and UK found that policymakers can moderate their impact not only by reducing interest rates but also by implementing aggressive fiscal and other financial policies.



Image courtesy of David Shankbone



A scan of an amyloid plaque core (top) — taken from the brain of an Alzheimer's patient — shows the presence of metal deposits (arrows, bottom photo).

Image courtesy of Plascencia-Villa et al 2016, *Scientific Reports*

How metals in the brain might play a part in Alzheimer's



Researchers found both chemically reduced iron and various calcium compounds in brain tissue, neither of which are normally found in the brain

Peer into the brain of an Alzheimer's patient and you'll see a high density of insoluble deposits or plaques — abnormally formed clusters of a protein called amyloid — and tangles, abnormal accumulations of a protein called tau. Alzheimer's patients also show atrophy of the cortex and general shrinkage of the brain. All this leads to a loss of short-term memory and changes in behavior, among other things.

But that's not all. Our brains contain a number of metals including copper, iron, and zinc — all of which have different roles in helping the brain function. And changes in the levels and the chemical form of these metals are tied to neurological disease. For instance, brains of Alzheimer's patients have altered distributions and chemical states of iron.

In a recent effort to better understand how metals are organized in the brains of Alzheimer's patients, researchers extracted amyloid plaques from two deceased patients and scanned them using Scanning Transmission X-ray Microscopy or STXM — an extremely powerful microscope that uses x-rays rather than visible light.

The high-resolution nanoscale scans — carried out at the Advanced Light Source in Berkeley, California, and at beamline I08 at the Diamond Light Source synchrotron in Oxfordshire — showed microscopic particles of chemically reduced iron species distributed throughout the plaque samples. The species found included a magnetic iron oxide called magnetite, which isn't normally found in the brain. The scans also revealed plaque regions that were unexpectedly rich in calcium compounds.

According to George Perry, a neuroscientist at the University of Texas at San Antonio, the findings suggest, "there's

“To have people with this breadth of expertise, who have got immersed enough in a project to really take the time to understand each other's areas and contributions, has been essential.”

a strong interaction between amyloid and metals critical to the development of the disease.” Perry has done extensive work on Alzheimer's disease and published hundreds of papers on the topic along with the late Mark Smith, who was also an expert on Alzheimer's.

In the late 2000s, Smith introduced Perry to Joanna Collingwood, now a Reader at the University of Warwick's School of Engineering. Perry and Collingwood joined forces with Jon Dobson, a bioengineer

at University of Florida, and Neil Telling at Keele University. They combined their different areas of expertise — for example Perry's in the biology of the disease, Dobson's in the mineralization, and Collingwood's and Telling's in the synchrotron techniques — to delve deeper into the mechanisms that are causing a change in the iron chemistry.

“To have people with this breadth of expertise, who have got immersed enough in a project to really take the time to understand each other's areas and contributions, has been essential,” says Collingwood.

These recent findings not only help advance our understanding of metals in the brain but also inform future treatments of the disease. According to the Alzheimer's Association, the disease accounts for 60 to 80 percent of dementia cases, and currently has no known cure.

“At this time when the community is desperately trying to treat people and ideally protect them from developing the disease ... anything that can offer a way of managing factors that make cells more vulnerable would be a great step forward,” says Collingwood.

This research was supported by UKRI's Engineering and Physical Sciences Research Council, Diamond Light Source, the Alzheimer's Society, the Alzheimer's Association, the Semmes and Lowe Foundations, the US National Institute on Minority Health and Health Disparities, and the US Department of Energy.



Members of the UK research team watch a fragile plaque core sample being loaded into the Diamond Light Source STXM.

Image courtesy of Neil Telling

Antarctica's icy lakes are brimming with life

International collaborations shed light on continent's subglacial lakes and melting glaciers



Researchers offload supplies from an Ilyushin Il-76 aircraft at an Antarctic base. The supplies were needed for a preliminary geophysical survey of Lake Ellsworth.

Image courtesy of Martin Siegert



A Basler BT76 (or DC3) sits at a research camp in Antarctica. An international team of researchers recently began to use these long-range aircraft to acquire ice-surface and sub-ice geophysical data.

Image courtesy of Jamin Greenbaum

This research was supported by UKRI's Natural Environment Research Council and the National Science Foundation.

“
It's just the way it is with Antarctic work; it's more like a space program than any other area of science.
”

In frigid Antarctica, life exists in the most unexpected places: deep below sea ice in often interconnected lakes that span the continent. Here, below the Antarctic surface, organisms thrive despite the intense cold darkness and isolation from the atmosphere.

The discovery of life in subglacial lakes is the product of international collaboration that began in the mid-2000s and involved the work of three major groups: a Russian team that set off to explore Lake Vostok, the largest of Antarctica's 400 or so subglacial lakes; a British team that looked at Lake Ellsworth; and a US team that sampled Lake Whillans. The groups often worked together — sharing advisory panels and exchanging ideas on tools and techniques.

But drilling into these lakes is no easy feat. For starters, scientists must get drilling equipment across several hundred miles of sea ice over to the lake where they must also set up temporary labs; then, because of icy conditions, they have a roughly 24-hour window before drilled holes close up again and refreeze. And, perhaps, most important of all, they must be very careful to make sure their equipment as well as their techniques don't contaminate these pristine environments.

“If we go into them without the necessary measures to protect them, then we'll ruin them,” says Martin Siegert, a glaciologist and professor at Imperial College London and co-director of the Grantham Institute for Climate Change and Environment. “And we'll ruin them in their own sake — there's enough of the planet that's already been ruined — but we'll also ruin them for future scientific purposes.”

To keep that from happening, in July 2011, the Scientific Committee on Antarctic Research developed a code of conduct for drilling in the Antarctic. This code, which has been adopted by over 50 countries that are signatories of the Antarctic Treaty, calls for hot water drilling as one of many protective measures along with meticulous cleaning and medical-grade sterilization of research instruments.

In February 2012, Russian researchers drilled into Lake Vostok, becoming the first to access a subglacial lake. However, there was some controversy over their use of kerosene as an antifreeze drilling fluid with concerns that lake samples were contaminated as a result. Later that year, the British team, led by Siegert, faced their own set of challenges at Lake Ellsworth when their drill failed to work.

“It took us 10 years to get that project up and running in the first place and it will probably take another 10 years to do a repeat,” says Siegert. “It's just the way it is with Antarctic work; it's more like a space program than any other area of science.”

In January 2013, a US team successfully drilled into Lake Whillans, using methods that adhered to the Antarctic Treaty's drilling code of conduct. Their samples showed close to 4,000 species of single-celled life.

While the findings were exciting, the big science is still to be done. “We want to test whether these lakes are truly habitats for microbes or whether the microbes are just passing through them,” says Siegert. Researchers are also working to better



understand the sediments of the lake's floor that will likely contain records of ice sheets going back millions of years.

Siegert is also working on measuring the bottom of the ice sheet over large distances. In fact, until recently, scientists had managed to measure only half of the continent's ice sheet largely due to one key logistical challenge: the aircraft that were used to survey the area had short ranges of less than 2,000 kilometers (approximately 1,200 miles). As a result, says Siegert, “50 percent of the ice sheet had never been measured before. And we knew nothing about it.”

In 2008, Siegert teamed up with Donald Blankenship, a senior research scientist at the University of Texas at Austin. Rather than using a short-range aircraft, they used a Basler BT-76 (DC3) — a longer range aircraft that could cover more than 2,000 kilometers without having to stop to refuel. A few years later, they were the first to survey Totten Glacier in East Antarctica — one of the continent's largest glaciers. Survey results show that the glacier is retreating at an alarming rate as part of it sits on the ocean, and the warm ocean waters are causing it to melt. As climate change raises the temperature of ocean waters, this glacier could cause sea levels to rise by 5 meters. And, says Siegert, the rest of East Antarctica has enough ice that “if the whole thing melts, sea levels can go up by 60 meters.”

Such large-scale surveys are not only challenging but crucial, and international cooperation plays a key role in their success. “Looking back, it was an amazing achievement,” says Siegert. “And it's still going.”



What can first-ever galaxies tell us about our universe?

Astronomers find recently discovered faint galaxies are also some of the oldest

About 75,000 light years away, in what might be considered the backyard of the Milky Way, are some of the faintest galaxies ever observed. Recently, astronomers in the US and UK discovered that these faint satellite galaxies, first observed about a decade ago, that orbit the Milky Way are also some of the oldest entities that exist in the universe.

These galaxies — Segue-1, Bootes I, Tucana II and Ursa Major I — are tiny, which is perhaps why astronomers discovered them relatively recently. “We’ve had increasingly sensitive and sophisticated surveys to be able to pick them up,” says Sownak Bose, a postdoctoral fellow at the Center for Astrophysics | Harvard & Smithsonian and part of the transatlantic team that researched these first-ever galaxies.

To make discoveries like this, astronomers not only rely on highly powerful telescopes to observe galaxies but also on theoretical models to understand how the galaxies are distributed. As part of that effort, Bose, along with his former PhD advisor Carlos Frenk, Director of the Institute for Computational Cosmology at Durham University, and Alis Deason, Royal Society University Research Fellow also at Durham University, created artificial universes using theoretical modeling to mimic our own universe. While working on these simulated galaxies, the astronomers noticed a characteristic shape in their distribution: tiny and faint galaxies were on one side of the diagram and brighter galaxies were on the other. “That shape is what helps you determine essentially when these galaxies have formed,” says Bose, noting that faint galaxies seemed to form the bulk of stellar content very early on — when the universe was about 100 million years old — and the brighter galaxies seemed to form stars later on and continue until the present day. Based on this distinct signature in their theoretical models, the team was able to categorize real galaxies in the same way.

This recent discovery supports the current model for the evolution of the universe. As part of that model — known as the Lambda-Cold Dark Matter Model — the first objects to form are very tiny. Bigger objects form over time through the constant merger of these smaller entities.

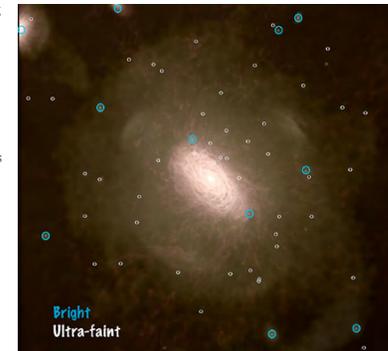
“This idea that there’s a hierarchy in terms of how structures formed is one of the fundamental predictions of the cold dark matter model,” says Bose.

There are still several unanswered questions, however. For instance, does the population of these galaxies tell us something about our own galaxy such as how the Milky Way formed? What do the different formations within the Milky Way tell us about the abundance of these first-ever galaxies?

“One of the nice elements of this research is that it highlights the complementarity between theory and data,” says Bose. “With the wealth of information being uncovered by observational facilities on a regular basis, we are now able to test our theoretical paradigms in previously uncharted regimes.”

This research was supported by UKRI’s Science and Technology Facilities Council and Harvard University.

“**With the wealth of information being uncovered by observational facilities on a regular basis, we are now able to test our theoretical paradigms in previously uncharted regimes.**”



Satellite galaxies orbit a computer-simulated galaxy that’s designed to mimic our universe. Recently, researchers in the US and UK found that some of the tiniest and faintest galaxies (see white circles) in the vicinity of the Milky Way are also some of the oldest, possibly forming when the universe was about 100 million years old — compared to its current age of 13.8 billion years. The brighter galaxies (see blue circles) were formed later on.

Image courtesy of the Auriga Project

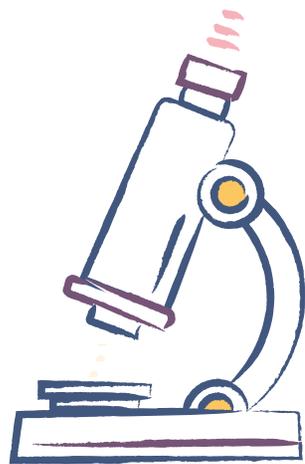
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