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HD **Gravity waves – or not?**

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Gravitational waves detected?

New Technology Centre rises from ashes of Mt Stromlo

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Celebrating 400 years of the logarithm

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Curious link between swarming locusts and agriculture

The key role of fungi in forest ecology

Sharks packed to the gills with highly tuned sensors

Robyn Williams: Well, it's not the Higgs, but finding gravity waves would have been close. So, what went wrong? You may recall a fuss a few weeks ago, hailed as a message from the beginning of time. So, what was it?

Today's Science Show also brings you a giant stick insect, sharks, and the 400th birthday of your favourite bit of maths, or it should be; the logarithm. Bang. That was 13.8 **billion** years ago, and measuring the aftermath of the Bang seemed to have produced results. So, what went wrong, and what are gravity waves? Paul Davies:

Paul Davies: They said they'd found gravitational waves emanating from the Big Bang itself. I should mention that gravitational waves are ripples in the curvature of space-time, so they are not waves of stuff, they're waves of space-time itself, and they are caused when large masses slosh around. Typically think of a star imploding to form a black hole or a pair of stars orbiting each other. But the granddaddy of all sources of gravitational waves is the Big Bang, a lot of stuff sloshing around there. But there's a subtlety which, if these results hold up, makes this a very, very significant discovery, and that subtlety has to do with quantum mechanics. So down at the level of atoms and molecules one of the key things that's going on is uncertainty, Heisenberg's famous uncertainty principle which, with a bit of handwaving, you can read as fluctuations; where is an atom, is it here, is it there, is it everywhere? It's jiggling around all over the place in a fundamentally uncertain manner. The same thing with space-time.

Now, we believe that just after the Big Bang there was a period called inflation, which is that the universe doubled in size in a tiny fraction of a second, a trillion trillion trillionth of a second, roughly. And if this was the case, then quantum fluctuations in that expansion would have led to the spontaneous production from quantum mechanics of gravitational waves at that time. And an echo of that production could be seen today in the pattern of radiation, heat radiation left over from the Big Bang. The claim is they found it.

Robyn Williams: Well, if you want to look at that explanation again, you can see it in the cover story of Cosmos magazine written by Paul Davies in last month's addition. Einstein is on the cover.

Well, they said they found it. Before we ask what really convinced them they'd found it, I would have thought that gravity waves, being so fundamental, so huge, should be quite easily visible.

Paul Davies: The problem is that gravity is such a weak force, so we can think of electromagnetic waves as a good analogue, that's how our listeners are hearing us now, ripples in the electromagnetic field. But electromagnetism is a roughly 40 powers of tens stronger than gravitation. So although gravitational waves are certainly going right through us as we sit here and are shuddering us and the room and the building, we don't notice this because gravity is so weak as a force. So to detect gravitational waves you need very, very sensitive equipment. And for decades physicists have been building equipment to directly detect gravitational waves arriving on Earth. Haven't succeeded yet, but there is indirect evidence that they really exist because there's an object called the binary pulsar which is a pair of neutron stars that are spiralling in together because they are emitting gravitational waves and losing energy. So we are convinced they are out there, the question is have they been detected from the Big Bang itself.

Robyn Williams: You said equipment to detect them. Now, this equipment was near the South Pole. Why wasn't it in Boston, Massachusetts? Far more convenient!

Paul Davies: They need to be at the South Pole because they are looking at the heat radiation left over from the Big Bang. That's radiation that hails from about 400 thousand years after the Big Bang but would still carry an imprint of that much earlier gravitational wave activity. And so the question is how do you observe this stuff. And there are two ways of doing it. One is from the ground or maybe a balloon, and the other is from a satellite. Much cheaper to do it from the ground but you can only stare at one patch of sky. And a good place to do it is Antarctica because it's daylight for six months of the year and night for six months of the year. And so it's generally a good place to do this type of astronomy.

Robyn Williams: Well, they made the claim a few weeks ago and they did so even before they'd published, and now there is doubt. Could you tell us what the doubt might be?

Paul Davies: It's always hard in astronomy and cosmology to make sure that what you are looking at from the proverbial edges of the universe isn't mimicked by something much closer to home. And the team that produced these results were well aware that there is a mimicking effect of just dust in the Milky Way, because what they are looking at is a pattern of polarisation. I think we are all familiar with the idea that light and heat is the same thing, can be polarised, people wear polarised sunglasses for example, and light and heat becomes polarised if it scatters off anything. It could just be electrons, it could be dust, it could be a window, it acquires polarisation.

So when this heat radiation from the Big Bang passes through the Milky Way, of course it picks up some polarisation. So it's all down to the pattern. You've got to look quite precisely at the pattern. Now, gravitational waves twist the pattern of polarisation in a very distinctive manner, but so does this foreground dust, or at least it can mimic that twisting effect. And now there is some uncertainty as to whether they really took into account this foreground dust well enough.

Robyn Williams: Princeton says that Harvard is wrong.

Paul Davies: Well, what we have to wait for is the definitive confirmation or disconfirmation. And fortunately there is another way of doing this, there's a satellite called Planck, a European space agency satellite. It's been up there in space for a while, beavering away, collecting very rich data about this cosmic microwave background heat radiation. And they should have the capability of saying yes or no for this particular claim. And they've got it for the whole sky, not just a patch above the South Pole. So very soon I think we are going to hear an announcement along the lines of 'we got it wrong' or 'we got it right' or 'we need more money for more work'. Probably the last of those!

Robyn Williams: I've never heard that before! And if they do discover gravity waves, one way or the other, it will be a really big deal, won't it.

Paul Davies: There is no doubt whatsoever that first of all discovering a prediction made by Einstein—and I think it was 1917, 1918, way, way back—is finally confirmed…that's one thing. But the other is that here suddenly we have a probe of the Big Bang, not just at 400,000 years like the heat radiation, nor even at one second which you can get from the cosmic abundances of the various elements, but going back to a trillion trillion trillionth of a second, this is the very threshold of creation, in one great leap, going back to a relic or a probe of that very, very earliest moment, just after the universe came into existence. That would be really exciting.

Robyn Williams: Well, on Tuesday, Paul Davies, you're talking at the University of New South Wales about six very big questions. Is that one of them?

Paul Davies: It is indeed. One of the questions, indeed the first, as is appropriate, is what happened before the Big Bang, because we keep using this term 'Big Bang', and at dinner parties I'**m** always berated; 'Well, what happened before the Big Bang? You cosmologists think you are so clever, tell us what happened before,' as if that would stump us, but of course we've thought about it, and there are two answers to that. One is nothing. In other words, that the Big Bang might just have been the ultimate origin of space-time, matter and energy, all physical things just popped into existence then. And the other is, well, there was something there before, but of course that's just pushes the problem of 'why does the universe exist, how did it come to exist' back into an earlier phase.

It may be that there was never an ultimate beginning, that we might live in a multiverse with lots of bangs scattered throughout space and time and we are just one of them. Our universe is only a microcosm in this limitless sea of universes. Maybe that's it. Maybe that's not it. We don't know the answer to that, that's why it's a big question and not a big answer. And that's the first. But it's tied very much with the second of the questions which is, okay, whether there's one universe or many, we still have the problem about the mechanism that brings it into being. It's all very well to say, oh, it just began, wave your hands, forget about it.

But everything that we do when we study these sorts of problems relies on the laws of physics. We sort of assume those laws are given to us, they are there, we use them as if they are just sort of lying around, but where do they come from? What is the origin of these laws? Did the laws just pop into existence with the universe in a sort of package of miracles that just happens to be? Well, scientists don't like miracles. So we think what is the explanation of those laws?

And at that point, if you're sitting around having a discussion over coffee, say, at a physics department, everyone starts shouting and arguing with everyone else because there is no really agreed approach to what do we do about the laws. The job of the physicists is to take the laws and apply them, but asking 'where do the laws come from' seems like dangerous territory. But when you're talking about the ultimate origin of things, you can't ignore that one. So that's problem number two.

Robyn Williams: Without giving the whole story away, what about just a headline of the last four?

Paul Davies: Yes, then I'm going to come onto life, how did life begin, which connects with are we alone in the universe? Is ET out there somewhere waving? And then I want to talk about cancer. You might think, well, why is cancer a big question? It's a big problem of course for everybody on the planet, but actually it turns out it's a very fundamental phenomenon. I think cancer is a window on the past, and it ties in with the origin of multicellularity. That's one of the really big questions in biology. And the last is what I think is the toughest question of all, which is the origin of consciousness. What is consciousness, why does it happen, and will we one day be able to produce it in an artificial system?

Robyn Williams: Talking about consciousness, and my final question; how do you maintain in your brain, which I can see in front of me is pretty huge, but nonetheless, all of that astrophysics and all of that cancer and biology at the same time?

Paul Davies: It doesn't seem all that hard. The main problem in cancer biology is learning all those long words because at the end of the day if you are a physicist working on fundamental problems you go right back to basics, you ask the basic big questions that underpin things and leave it to others to get the answers to the little technical details.

Robyn Williams: Well, the lecture is on 29th July at the University of New South Wales in the evening. Thank you very much, Paul Davies.

Paul Davies: My pleasure, thank you.

Robyn Williams: And Paul Davies talks about the six big questions at the University of New South Wales at 6pm on Tuesday.

And this week, still thinking about the cosmos, a rebirth after the holocaust in Canberra. Carl Smith was there.

Carl Smith: The 2003 Canberra bushfires destroyed hundreds of homes as they blazed through the fringes of the nation's capital. One of Australia's most important sites for astronomy research, the Mount Stromlo Observatory, was lost. 11 years on, the ANU's director of astronomy and astrophysics Professor Matthew Collis says the observatory's buildings have been completely restored.

Matthew Collis: It took out our telescopes, it took out our workshops and it was devastating in fact for the community as a whole. But it recovered remarkably quickly. Although we no longer have telescopes up here on Mount Stromlo, our telescopes have been built up at our other **site**, at Siding Spring Observatory, and here on this mountain we concentrated on rebuilding all our technology capabilities.

Carl Smith: The opening of the Advanced Instrumentation and Technology Centre today marks both the end of restoring the observatory **site** and a revitalisation of Australia's space industry.

Matthew Collis: We're well beyond where we were before. We have better facilities in every respect. We have bigger and better telescopes.

Carl Smith: The centre is the first of its kind in the country and it will allow Australians to autonomously build world-class space technology, including satellites.

Matthew Collis: With the facilities in this building we can do everything from designing through to launch testing of satellites. This will allow Australia to get more directly involved in the space industry, and that's a big deal.

Carl Smith: Ian Macfarlane, the Federal government's Industry Minister, says Australia's growing space industry could be one of the country's big exporters.

Ian Macfarlane: Well, **billions**, literally tens of **billions** of dollars. It would rate up there with the exports of pharmaceuticals, with the value of the automotive industry. $4-$5 **billion**, but with the potential to grow to 10 times that amount over the next 20 years. So it is an incredibly important industry, one of which is the quiet achiever in Australia yet it's one all Australians should be proud of because we are world excellence leaders in this area.

Carl Smith: Professor Collis says Australia needed a space industry hub like the new centre to help coordinate research and commercialisation projects.

Matthew Collis: Everything from the analysis of geophysical data for the minerals industry through to weather forecasting through to insurance, people looking at fire patterns on the ground. It's a very diverse industry, but it's incredibly important and it's only going to grow in importance in coming years.

Carl Smith: Alongside the reopening, two new initiatives were announced.

Matthew Collis: So the Minister has announced two major new projects, one a $5 **million** instrument for the Giant Magellan Telescope, and the other a $6 **million** satellite laser ranging facility for the Koreans. These are our launch pad for this centre. They will allow us on the one hand to do imaging that's 10 times sharper than the Hubble space telescope on the Giant Magellan Telescope, and for the Koreans it will allow us to track small pieces of space junk that could damage the satellites and the International Space Station.

Carl Smith: The scars of the 2003 Canberra fires are still visible at Mount Stromlo. But researchers and scientists working there are looking onward and upward.

Robyn Williams: And that was Carl Smith, ABC news Canberra, who is always looking upwards. As are we, The Science Show on RN. We also look backwards to anniversaries, and this one is of the log. Makes sense to me, but what about you? Let's ask a young person.

Stephanie Pradier: Guess what I did last month? Learned to use a slide rule. A slide what? A slide rule. Why? Because the logarithm turned 400 this year. My name is Stephanie Pradier and I was born in Melbourne in 1985. On the one hand, I was lucky. I missed out on perms, mullets, legwarmers and double denim. And on the other hand I was even luckier; I grew up with a pocket calculator, touch typing lessons, and now an app for just about anything I can dream off. Ha! The software on my laptop that checks my spelling didn't even quibble about the use of the word 'app'.

So when invited to help celebrate this momentous anniversary, my research was done the old-fashioned way; I googled. It turns out the logarithm is not just a button on a calculator with electronics and silicon behind it, it is a super handy tool to perform division, multiplication and various trigonometric calculations. And there is a whole culinary tradition behind the logarithm. It has a chef (the Scot John Napier), utensils (bones and slide rules), and a recipe book (log tables). These utensils were used by students the world over until very recently. In fact one of the last forced to use a slide rule in his HSC exams gave me mine. Sitting down with it initially was perplexing, but mastering it was so much fun. Novel, a little frustrating, but fun.

For those listeners not familiar with the slide rule, I shall explain. It's a manual pocket calculator that works because of the logarithm. There are no buttons, you don't press it, you slide it. Historically the log brought me first to John Napier and his bones. It was then I discovered the magic of this story. The magic, for a child born when I was born, has been completely lost. And got me thinking; perhaps if we taught kids the romance of mathematics, the stories of the people behind the numbers, their interest would be sparked, they would learn better and retain the concerts with greater vigour and aptitude.

So what on earth does that button with the letters LOG on it actually do? Currently I can perform multifaceted and complex calculations in nanoseconds, correct to umpteen decimal places without training or straining my brain. However, 401 years ago, before Napier's marvellous invention, these same calculations were lengthy, laborious, and nowhere near as accurate or precise.

Logarithms let us perform calculations that would have been practically impossible without a calculator. And when we think about it, the calculator itself would have been impossible without the logarithm. Take two large numbers, say bigger than 1,000. Have you got them? 401 years ago you would have to multiply them out by hand, or worse still, perform long division. Imagine all those lines, carrying the remainders, multiplying by the devisors, subtracting, bringing numbers down. All those steps would take all day. Then, following Napier's invention, it became simple. Now you could sift your way through the log tables, find the logarithm of the two numbers and simply add or subtract them. Then use the same table backwards to find the product or the quotient. Yep, that's what he did. With his miraculous tables of logarithms, Napier transformed days of error-prone calculations. He offered simple elegant solutions which enabled astronomers, physicists and anyone doing mathematics to double their lives, as the mathematician Laplace put it.

The significance of Napier's book and his bones has been lost on today's youth, myself included. To me it's sad. We grew up with the pocket calculator, not slide rules, bones and log tables. And now with our pockets full of silicon chips, we perform **millions** of calculations per second as a matter of course. The slide rule, my nifty new friend, breathes life into these calculations. Okay, I'**m** a little bit into numbers. But by sliding different sections it lets us find the products and quotients of numbers between the base 10 mile posts. And accompanied with log tables we can manipulate these numbers in useful ways, easily.

Doing the calculations in this way might be more time-consuming than punching or touching numbers on a machine, but if we were taught the history of how this and other functions like it came into being, if we got to play with slide rules and log tables in our formative years, I reckon we would fall for numbers, fall for the romance and the magic that is clearly there, just below the silicon chip. Having learnt about Napier's contribution and having taught myself how to use the slide rule, it is obvious to me that these stories and hands-on calculations are essential.

What we have here is a catch-22. The logarithm has driven developments in science and engineering for centuries, so if it were not for Napier's time-saving invention we most likely wouldn't have our pocket calculators. But precisely because of our pocket calculators, Napier's recipe has been forgotten, along with the log tables, slide rules and those god-awful hairdos.

So in a time when we do not celebrate our mathematical heroes, join me in saying happy 400th logarithm. Let's use this anniversary to raise the appreciation of mathematics across the general population, and to breathe new life into Napier's bones.

Robyn Williams: Stephanie Pradier, who fosters interest in maths in Melbourne and has just got a brilliant degree in physics.

And Melbourne is also the place to look for stick insects. Just ask Matt Smith. I know you're dead keen on stick insects, as you should be, and the story of this one is amazing.

Rohan Cleave: Come in, into the world of the Lord Howe **Island** Stick Insect.

Matt Smith: I should have expected humidity.

I'**m** at Melbourne Zoo in one of a number of glasshouses dedicated to a single species of animal, the Lord Howe **Island** Stick Insect. The humidity is set at a balmy 80%, because that's how it is at Lord Howe **Island** and that's how the stick insect likes it.

Rohan Cleave: This is the young ones when they first hatch, a few hours old.

Matt Smith: Okay, so those are tiny, a couple of centimetres long.

Rohan Cleave: They are the little ones. And these are the adults.

Matt Smith: I'**m** being introduced to the animals by entomologist Rohan Cleave. He opens one box to show me about 30 dark-brown giant stick insects, all huddled together in the dark.

Wow!

Rohan Cleave: There's a massive change from when they first hatch out of the egg. They are very bright green, around two centimetres, and then they grow into this very impressive stick insect. This is a female, and they go very, very black, and at this point they will only come out at night to feed, search, and to mate and things like that.

These are a very heavy stick insect species, about 25 grams they will get up to when they are fully grown, and around 15 centimetres for the females. The males are a little bit smaller than the females, but what the males have is really, really big spines on their hind legs.

Matt Smith: The Lord Howe **Island** Stick Insect is a big deal, and to understand why you need to know its back story. We'll start it with a message from Dame Jane Goodall, which was recently played at the launch of a book called Return of the Phasmid, the book is by Rick Wilkinson and covers the story of this insect. Here's Jane Goodall:

Jane Goodall: I first heard about the Lord Howe giant stick insect from Nicholas Carlile back in 2007. Originally it lived in the lush tropical vegetation of Lord Howe Island, but then rats were introduced and they soon discovered that the huge phasmid made a tasty meal. And as the rats multiplied, the stick insects gradually vanished, until it seemed that the Lord Howe phasmid was totally extinct.

And then, during a dangerous midnight climb, Nicholas found a small group of the insects surviving in a small patch of vegetation on Ball's Pyramid. Anything less like the original habitat would be hard to imagine; a rugged spire of mostly bare rock rising out of the ocean, 23 miles away from their original home.

Nicholas Carlile: It was considered that it may be on Ball's Pyramid, but no live animals had been found.

Matt Smith: And this is Nicholas Carlile. He is a senior research scientist at the Office of Environment and Heritage in New South Wales, and back in 2001, along with David Priddel, he was one of the discoverers of the living specimens of the Lord Howe Island Stick Insect on Ball's Pyramid.

Nicholas Carlile: My role in the expedition was to manage getting onto the Pyramid, which is 23 kilometres from the main island, you are dealing with vertical cliff faces that you have to pretty well jump onto and then clamber up to a rock platform, and hopefully only stay there for 24 hours, but at worst three days, because your window of opportunity out in the open ocean (we are 500km from the mainland) is very small.

Matt Smith: Is it a logistically complicated hunk of rock to get onto?

Nicholas Carlile: It is very complicated. It's a kilometre long, half a kilometre wide, and 550 metres high. Most of it is totally inaccessible. You jump onto the rock when the boat was at the highest point of a wave before it drew away from the cliff face, and you'd clamber up, and once we got everybody up we then had the gear tossed up to us. And there was some 15 containers of water and food and bed rolls. That was the easy bit.

The hard bit was actually going to look for something that nobody had ever found living on the Pyramid. So about 9 o'clock that night we started to climb back up the Pyramid. We just had a head torch. This is pre digital days, so I had a little instamatic camera which only had three shots left on it. And we were going up vertical faces, which is quite difficult in the dark with a head torch because you've got the light right on your face, it effects your night vision, it's really hard to pick your foot and handholds, because we were going up some very steep faces.

And when we got close to the ledge where this bush was and we could see a big cricket sitting out on the edge chewing on something, and I went, 'Oh bugger, look at that, it's going to be a cricket!' And then we got a little bit closer and there on the outside of the melaleuca was this shiny black insect, the biggest thing I'd ever seen in my life, because we are not used to really big invertebrates in Australia. I mean, there are much bigger stick insects elsewhere in the world, but for me it was just amazing. And we were just totally gobsmacked. And Dean is a little bit more reserved than me, but I was swearing my head off, I was so excited at what we were seeing. Because basically if you want to see invertebrates that size, you've got to go back to when invertebrates ruled the world. You know, these are large insects that can't fly which, if there are rats and mice around they're an immediate meal. So you just don't find them, particularly on the Australian mainland.

And we searched around and there was a big female up on the bush and there was one really low to the ground, she had dust on her, so she had obviously been walking on the ground. And I went to pick her up, and I wasn't sure if these things could bite, because I'm used to living in Sydney and there are cockroaches that can give you a good bite, and it started to turn its head around and I dropped it and it started scurrying away…that was the other thing, we expected them to move really slowly, and these things moved really fast, like a cockroach, very quickly. And Dean slammed his foot down just in front of it, and it came up to the shoe and stopped, and we took a photo. So that was one of the three photos that we had, was Dean's sandshoe and this stick insect. As an iconic species for Lord Howe you can't go past this stick insect, it's pretty good.

Matt Smith: A few years later in 2003, permission is finally granted to remove four Lord Howe Island Stick Insects from Ball's Pyramid and attempt to breed them into captivity. Two were sent to Sydney where they died within a week, and the other two were sent to Melbourne Zoo. They were named Adam and Eve, and now, 11 years later, there is a population of more than 700. Rohan Cleave talks about the success of the breeding program and the research that they've been doing.

Rohan Cleave: You have to imagine a species that you find in the wild that there is no recorded information. So we didn't really know too much about them. One of our staff members actually changed his working life to work completely nights for the first month. We knew a particular species of plant that they may have fed on, which is the Melaleuca howeana which is on Ball's Pyramid, but that's pretty much it. We started with two, we are now in 2014 and we've had over 11,000 nymphs hatch out here at Melbourne Zoo. This is our 11th generation and we are breeding really, really well.

Matt Smith: You said that you've been experimenting with a few trees along the way. Did you find that there was something that worked better with what they had on Lord Howe Island?

Rohan Cleave: Absolutely. So the primary plant was Melaleuca howeana. The other plant that we use a lot that propagates and grows really, really quickly is tree lucerne, they go really well on that. And the other plant we've introduced recently is ficus. When we do experiments we start with the young. We run an individual through on one particular plant until they get adult, and those adults lay eggs, and then if those eggs hatch then we deem that as a successful trial. At the zoo we've trialled over 70-odd plants already, different species. A lot of those haven't worked. But again, it comes down to our best guess on what might equate diet-wise to this particular species.

Matt Smith: As far as I understand it, every insect that you see here is descended from Adam and Eve, the bug Adam and Eve, not the biblical. What do you do with genetic diversity then? Is that an issue?

Rohan Cleave: Not so much with invertebrates. Invertebrate DNA and genetics is slightly different to what you would see in mammals. That was something that we thought may come into play early, and there are times when we've felt genetics may be a bit of an issue, but we are now in our 11th generation and we are still seeing beautiful animals hatch, go all the way through, have no issues with any deformities…and that's the thing we don't see with invertebrates, you don't see deformities with regards to genetics.

We also have run other different trials on parthenogenesis or female-only populations; could they survive in theory without introduction of males? And yes, they can, which is quite common in other stick insect species as well, but all offspring will be female, and that's how certain populations survive with a female-only population.

Matt Smith: Is there the intention at any point to release them back to the natural habitat, to Lord Howe Island?

Rohan Cleave: That's the hope. There are a few things that have to happen before then. So now we concentrate on the captive breeding side of things, and then if that all comes together then yes, one day we do hope to see this species back on Lord Howe Island.

Matt Smith: It's an amazing achievement that you've got here, and it's a great example of a success story.

Rohan Cleave: This is such a positive conservation story. It's great for invertebrate conservation. We've gone along and done our thing knowing that hopefully down the track this could be seen as a model conservation program.

Robyn Williams: Rohan Cleave at Melbourne Zoo, with Matt Smith. And, as you heard, it's very important to know what insects eat, especially if they are locusts, then perhaps you can work out how to stop clouds of millions of them stripping every leaf or blade from your farm. That's what James Elser and Arianne Cease are doing at the Arizona State University, with help from Sydney. So, how did they begin?

James Elser: Well, we are following up on some exciting work that my colleague and former PhD student did where she showed something quite surprising which is that low-nitrogen diets, low-protein diets seem to be favoured and preferred by and maximise the performance of locusts in inner Mongolia, China. And then furthermore she showed that these low-protein, low-nitrogen diets, grasses, are favoured when grasslands are over-grazed by livestock, and so it connects livestock management practices possibly to locust outbreaks by an unexpected mechanism. And so now we want to dig deeper into this and see how it works.

Robyn Williams: Well, rumour had it that of course the locusts would go for the highest richness of food available.

James Elser: That's what we thought, but that's not what they say when you ask them. So if you ask the locusts politely with the right experimental design they tend to tell you that they like to eat the plant that has the lowest protein content and they tend to like grass that's from a field that has not been fertilised with nitrogen, and that if you force them to eat the food that has the high protein, they don't do very well, they don't grow so fast. And so personally I'd rather listen to the locusts than to you about how you feel about this.

Robyn Williams: Well, indeed, talk to the locusts. The first thing is to define a locust. What is a locust?

Arianne Cease: One way to think about it is all locusts are grasshoppers but not all grasshoppers are locusts. So locusts are types of grasshoppers that when exposed to specific environmental cues as juveniles will develop into animals that are grouping together and develop into migratory swarms.

Robyn Williams: And how many different kinds of grasshoppers are there?

Arianne Cease: There's about 10,000 species of grasshoppers worldwide.

Robyn Williams: That's extraordinary, I had no idea it was that many.

Arianne Cease: Yes, they're found in virtually every ecosystem around the globe and on every continent outside of Antarctica.

Robyn Williams: And how many of those different species actually do the kind of swarming that you described?

Arianne Cease: Usually there's about 15 to 20 species on that list.

Robyn Williams: Okay, so they can be grasshoppers when they are solitary and something comes over them and they swarm and they descend on fields and they look, as Jim just said, for the less nutritious lunch.

Arianne Cease: What our question was was what causes build-up of locust populations, and so what are the early triggers that lead to development of migratory swarms, before we get these massive swarms that are seeking outcrops and anything green left in the area. What's happening at the early stages? And specifically we are interested in how humans are affecting the environments and how that may in turn influence whether or not we get these population outbreaks. And so in doing research in inner Mongolia, locusts were most prevalent in these heavily grazed pastures. So heavily grazed by sheep in the case of inner Mongolia. So that's where we went to go collect the locusts.

And it was a bit puzzling to me because the field where we were collecting the locusts was over-grazed, it seemed degraded, there was not as much grass there compared to a field that was right next to there that had been protected for about 30 years. So there was ample grass and to us it looked like a lush and nutrient-rich environment, but the locusts we were working with, the specific species wouldn't cross the fence.

And so we started to think about different hypotheses for why that might be. So things like different temperature, maybe they like the open habitat. And while some of those factors may be at play, the one that we found that was very consistent was they were eating the plants that were in the heavily grazed areas and they almost refused to eat plants collected from un-grazed areas. And going further using artificial diets we found that it was really the ratio of protein to carbohydrate that they wanted to optimise, so they were looking for these really low-protein, high-carbohydrate diets. So we found that that was a strong link in inner Mongolia.

And so our next step was firstly to test this mechanism in other regions around the world. We've been working with Steve Simpson and the Australian plague locusts in Australia, and then we are working in Senegal in West Africa where I was a Peace Corps volunteer. And so we are studying these closely related locusts and similar types of habitats that have a similar pattern, as we found in **China**, to see if the same mechanism might be at play.

And then in addition to that we are adding in a whole other side of the research which we are really excited about, so we are working with economists and social scientists to understand how grazing decisions are made, how livestock markets might be connected and how locust outbreaks might influence all of these, and vice versa.

Robyn Williams: Yes, because the picture we have is of a cornfield or something like that, and the locusts come pouring down and there's nothing left. That's the cliché, if you like. And that's not true?

Arianne Cease: That could be true. If there's nothing left, locusts, once you have a swarm, they are really difficult to deal with, and they will eat anything so that they don't starve. North Americans in the early frontier days, there's reports of the Rocky Mountain locusts eating clothes off the clothesline, but that's not their preferred diet. So once you get these massive numbers of hungry locusts they will descend on crops and eat whatever they can, but what we are interested in is initially what causes, what allows the build-up of these populations. And of course if we have clotheslines everywhere and we are feeding locusts clothes we are not going to see the build-up of populations, we are not going to get the swarms. So we want to start at the beginning and then try and understand what allows them to initiate outbreaks and development of swarms.

Robyn Williams: Jim, the excitement of working with social scientists and economists…I haven't heard many scientists actually say things like that, but what will they give you?

James Elser: In general…I mean, this is generally what we now realise about the environment, is that all kinds of things in the environment are driven by human action, and so you really ultimately have to get in and find out what it is that drives human decision-making. And one possibility of course is that decision-making about livestock and other things are just completely disconnected from the environment where things are playing out. Market forces are operating globally. What happens with sheep in **China** or sheep in Australia is driven by demand for meat in North America or New York City or someplace. And so those disconnections could drive things, could go completely haywire.

But on the other hand, if there's local forces being felt regionally in the areas where environmental impacts are playing out, then regulators or agencies or other entities in those areas, like in Australia, could decide, well, we don't care about the fact that lamb is really high priced now, we have to sort of have a different approach to how we allow that feedback to operate and how many sheep can be put on the land.

Robyn Williams: Because if you are doing something that causes locusts to swarm, then you want to stop that and do it quickly.

James Elser: Right, but also the problem is that the people who suffer the negative impacts of the locusts swarm are not necessarily the same people who are benefiting from the livestock rearing and the sheep grazing et cetera. So it's very complicated. The feedback loops are not necessarily present. And one thing we want to study is what is the structure of the feedback loops in the existing system in different governmental contexts and different countries. If those feedback systems are lacking, what kind of institutions or changes in the structure of markets or of regulation might need to be put in place so that costs of livestock over-grazing, the feedback is established in such a way that you end up in a place with a more reasonable level of sustainable grazing in any given place.

Robyn Williams: That was an interesting clue that you talked about before, about the balance between the protein and the carbohydrate, because if you think of the Atkins diet, which Steve Simpson, your mentor in many ways, a professor at the University of Sydney, talked about many times, you get the feeling of being full by eating protein. That's for us and presumably for the locusts as well. And what you want is the nice balance of the ingredients so that you can eat enough to satisfy yourself, so you get topped up on the protein you need as well as some of the others. Is that right?

Arianne Cease: That's right. And one way that we can understand how locusts balance their diet is similar to how we might look at it in humans. So we can give ourselves a selection of food and then choose among that to come up with a balance of nutrients. Locusts are actually pretty smart, as are most organisms, if we are given the choice the locusts are going to eat a diet that is best for promoting growth and survival and reproduction. And so we can ask the locusts what their preferred ratio of protein and carbohydrate they need to think about balancing.

So we can give them a choice of two diets, one that is low in protein and high in carbohydrate, and the other that's the converse. And then we can take that information and we can go back to the field and we can say, okay, what kinds of plants are these locusts targeting? And then we can determine what nutrients the grasshoppers or the locusts are able to get out of these grasses and see if that matches what their optimal balance of these nutrients is. And of course Steve Simpson and many others have been using this framework in organisms from slime moulds to humans, really powerful nutritional framework.

Robyn Williams: And with any luck and some help from the professors you can avoid planting the menu that will change a few grasshoppers into a cloud of rampaging monsters. Professor James Elser and Arianne Cease at the Arizona State University in Phoenix.

Our PhD this week is Stephanie Suter, who is also involved with nutrition, but a fungi in the mountains. Here's why:

Stephanie Suter: The secret life of a fungi. Toadstools, mushrooms, camembert, mouldy **bread**, or an itchy foot problem, these are the images often conjured up by the word 'fungi'. But when I talk about fungi I like to talk about waterborne fungi, the focus of my PhD, specifically aquatic hyphomycetes.

Aquatic hyphomycetes are biological **group** of fungi that are unique in terms of their life-cycle. They have no terrestrial stage and their entire life cycle occurs in water. In freshwater environments across the globe, hyphomycetes are essential for the decomposition of organic material, particularly plant and leaf litter. In terms of biology we know that their spores attach to the leaf surface, they penetrate the leaf tissue with hyphal extensions and they chemically break down the leaf, extracting nutrients while increasing their own biomass. This softening of leaf tissues allows water bugs to consume the leaf material, taking advantage of the fungal enzymes to access nutrients. The fungi themselves can also act as a food source, with their own biomass replacing that of the leaf tissue and increasing the protein content.

For my PhD project I was interested in how this seemingly simple process occurred, not only in Australian streams with the eucalypt-dominated leaf input, but also in alpine streams over a full seasonal cycle. I was interested in the physical and chemical changes occurring within snow gum leaves. I wanted to see how seasonal variation affected the fungal community and the roll-on effect this has on leaf litter decomposition.

To do this I conducted a series of field experiments in streams in the Australian Alps on the Bogong High Plains in Victoria. These extremes are harsh environments for organisms to survive in, given their exposure to extreme seasonal weather variation and a lack of available nutrients from the water column itself.

The summer and autumn communities showed the greatest activity, with warm stream temperatures promoting high reproductive outputs and decomposition activity. In contrast, not surprisingly, the winter samples showed an almost dormant community, with initial colonisation occurring but a relatively unchanging biomass within the leaves. So it would appear that the fungi are successfully attaching and colonising, maintaining their biomass within the leaf with seemingly no activity occurring after this point.

Having determined the physical changes taking place during snow gum decomposition, I wanted to know more about the chemical changes happening within the leaf tissues. Through collaboration with staff on the infrared beamline at the Australian synchrotron, I was lucky enough to view the chemical changes occurring within the leaves as they are broken down. In the past these changes have been inferred using laboratory-based extractions and measurements.

By using the infrared light source at the Australian synchrotron I was able to build a chemical map of the inside of the leaf. I could actually see where the fungal hyphae were located in relation to leaf tissues, as the synchrotron provided a kind of chemical heat map for selected areas, showing me where carbohydrates, protein and lignin are rich and where they are found within the leaf's internal structure. By doing this I was able to find that when it comes to fungal decomposition, all roads lead to the carbohydrate-rich xylem fibres in the mid-vein area of the leaf.

In terms of stream food webs, these leaves could potentially represent a food source for stream macroinvertebrates, with leaf accumulations representing a form of larder or an immediate food resource come spring.

By doing this I hope to increase the knowledge and understanding of fungal ecology and eucalypt decomposition in Australia and Australian alpine streams. By understanding the processes that are present in our unique stream environments, hopefully it will make us more adept at managing and protecting our important water resources.

Robyn Williams: Stephanie Suter, who did her PhD at La Trobe's Albury-Wodonga campus, and is now watching water supplies at the Corangamite Catchment Management Authority.

[Music: Jaws theme]

Well, you can stop that right now, because sharks are not just scary monsters, they are also biological wonders, as Shaun Collin has been showing in the west. But how do you first find your shark?

Shaun Collin: Yes, well, that's a very good question. Firstly you have to attract the sharks to where you are and this is generally done using an olfactory cue, some sort of bait. And so once the sharks are actually nearby, if we are testing some of our sensory deterrents, for instance, they will interact with our rigs which are suspended within the water column, and their behaviour around these rigs is recorded on stereo cameras. And using sophisticated software we can actually analyse a lot of the data that shows how close they get, how much time they spend within the region.

Robyn Williams: Now, you might think that sharks are, by definition, primitive fish. I know 'primitive' is a very explosive term because these creatures have been around for an awful long time. They are very sophisticated, and just because they are made of cartilage doesn't necessarily mean that they are in any way inferior to the bony ones. But when it comes to the brains, I haven't actually heard terribly much about whether they are sophisticated or not. What's the answer?

Shaun Collin: Well, the answer is that they are not primitive, they in fact have sensors that bony fish don't have and of course we don't have. A couple of those sensors include the lateral line, which is a sense for measuring small changes in hydrodynamic disturbance around the animal, but also another sense called electroreception. And so the brain and the peripheral sense organs, the electrode receptors, are actually able to detect extremely weak electric fields in the water which are emanating from live prey within the water column. And the levels of sensitivity are extreme. They can detect weak electric fields down to the nanovolt range.

Robyn Williams: So very sophisticated in that sense. Clearly wonderfully adapted to their environment. Tell me, there's one thing that really intrigues me watching lots of films or even sometimes in safe areas like the Galapagos or even Lord Howe **Island** where you swim with reef sharks, they don't seem to be hunting all the time, they are just drifting around, benign, and you think; when are you going to go off and eat a fish? It seems hardly ever to happen.

Shaun Collin: Actually you're right. Generally when we are interacting with the ocean, you don't often see them feeding. That might be a by-product of your presence there which might disturb them, which is fair enough. But they are not always probing their environment for food. They actually have the ability to interact socially. In fact we've made some discoveries recently that the electroreceptive sense may in fact play a role in this social communication where we've found a sexual dimorphism with the input of the electroreceptors into the brain of females versus males. And so the signal that they give off and their ability to detect that signal is actually different in male and female cartilaginous fishes.

And so these type of interactions will be taken place all the time. They may be searching for food, but this may in fact draw them for a long distance. The sense of olfaction is a very ancient sense but it's also a very sensitive sense where they can actually travel hundreds of metres, maybe even kilometres in search of food. And these odour plumes can bring them very long distances in search of their prey.

Robyn Williams: Also of course the other fish seem not to be at all worried. Everyone is kind of drifting around very quietly.

Shaun Collin: Well, that's true. I mean, the sharks are a very important part of our ecosystem. They are a natural part. They clean up the environment in the way that would predate on sick or dying fish, and make sure the genetic pool is fresh at all times. But no, they generally live in harmony with their environment, and all the interactions that I've had with sharks while diving or swimming have all actually been very positive.

Robyn Williams: You've got legs, you've got arms!

Shaun Collin: Absolutely, and we quite routinely interact with sharks in the wild, and most of the time we in fact would like to get close to actually observe their natural behaviours since there is still a lot we don't know about these amazing species.

Robyn Williams: You haven't lost a student in years.

Shaun Collin: No, not at all, in fact they are the first ones into the water.

Robyn Williams: A final question, you said right at the beginning that you had experiments with various sensations that might repel sharks. What are they?

Shaun Collin: Yes, we've actually tried to use a lot of basic knowledge that we are collecting on the profile of different species, you know, how they in fact find prey using their range of senses. And we've been able to bring some of this knowledge to bear on the development of deterrents. So this is an ability to use evidence-based work to understand what signals these animals are actually using to find prey and, in some cases, even mistake a human for prey, and test a whole range of novel deterrents that we are in the midst of developing, and even testing existing repellent devices that have been on the market for some time, both to provide some confidence if the public is going to **buy** these devices, and secondly try to improve on those by giving the public more choice and potentially even look into a multisensory approach in deterring sharks from coming to close to humans.

Robyn Williams: I think they are deterred by film crews!

Shaun Collin: It could be! In fact we've had some trouble in finding sharks to interact with our rigs, but we are quite buoyed by the results so far.

Robyn Williams: Perfecting shark deterrents in Perth. Shaun Collin is a distinguished fellow and Winthrop Professor at the University of Western Australia.

Celebrating sharks. And as for that culling of sharks, hear Barbara Block in California on what's at **stake**.

Barbara Block: Our lab is a lab that actually has expertise in large pelagic fish, tunas, white sharks and salmon sharks as well as makos.

Robyn Williams: Where do you study the white sharks?

Barbara Block: We study the white sharks off our California coast. Right outside my window is the Monterey Bay. We have in a region from Monterey up to the Farallon Islands one of the higher density of white sharks.

Robyn Williams: Were you surprised by the uproar coming from Australia this year about white sharks and the possible killing thereof to save human surfers from possible dangers?

Barbara Block: Well, because in our area we have similar issues of beach interactions and concerns about white sharks, I was surprised. I believe that white shark populations around the globe are not that large in number, that all great predators have yet to be really quantified in terms of their numbers across the planet, in terms of large pelagic fishes. So to actually remove the white sharks from the ocean at a time when we really don't know how many there are seems to me to be premature.

Robyn Williams: And unwise?

Barbara Block: No comment.

Robyn Williams: Indeed. Are there easy to catch?

Barbara Block: In our location what we do is we attract the white shark to our research vessel, we are able to bring the white sharks in close and then take photographic pictures of their fins, and in doing so we've built up a catalogue of photo IDs through the year, and with the mathematical techniques we estimate in our backyard there are about 220 adult and sub-adult white sharks.

I think for Australia a similar research is ongoing, and as you develop a plan in Australia for the nation, it should take into account the diversity of the white shark genetically across both sides of the country to be sure that we have assessment numbers that are accurate. And then before taking out members of the population we need to really understand more about the biology of the white shark.

Robyn Williams: We get big stories every time a white shark takes a surfer or a swimmer, but is there evidence about how much white sharks actually like eating human beings?

Barbara Block: What I will say is that as a whole or what we know in California is white sharks prefer marine mammals such as sea lions and elephant seals. Most of the interactions that we've described and heard about here on the California coast tend to be mistaken identity. So I think that we as American swimmers don't go in to regions that are areas of pupping grounds or areas where there is large concentrations of marine mammals.

We have to remember that oceans are wild places, and ecosystems that are healthy are rare and that some of the protections around Australia are the most remarkable forms of conservation that we see anywhere on the planet, such as the Great Barrier Reef, the MPAs. And at a time when Australia is a country that's leading how we protect oceans, it certainly needs to invest in understanding how many white sharks there are, building research programs around their shark populations before potentially removing the sharks from the planet.

Robyn Williams: That was Professor Barbara Block at the Monterey Bay Aquarium, and she knows Australia very well.

Next week The Science Show goes to Germany to meet more Nobel Prize winners than you can count.

The Science Show is produced by David Fisher and Timothy Nicastri. I'm Robyn Williams.

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