ABC

HD **Does religion save the pain?**

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Experiments in space reveal genetic master switches in pathogens and vaccines

X-ray lasers provide the pics while avoiding radiation damage

TD

San Diego Zoo breeds success

Last call for science writing entries

Hungry Science Beast for Radio pt2

Get religious to minimise the pain

[Music: Ave Maria, from Vespers by Rachmaninoff.]

Robyn Williams: If you feel pain, real pain inflicted by a curious psychologist, will it be worse if you are an atheist? Could that pain be reduced for Catholics if they are peering at a picture of the Madonna? That's what a fellow at Oxford has found. Choose Mary for pain relief. Atheists do better with David Attenborough. They also took yoga instruction to prisons in a series of unlikely experiments.

The Science Show on RN, where we start in space. Okay, tell me this; how many people live up on the Space Station and what do they do? Josh Zepps wanted to find out. He presents Huff Post Live. And he called them up.

Josh Zepps: This is Huff Post Live, I'm Josh Zepps. And anyone who has seen Gravity has had a tiny little taste of what life is like several hundred miles above the surface of the Earth. But while we were trying to experience it vicariously via Sandra Bullock's 3-D eyes against the green screen, a tiny handful of people truly know what it feels like to be in space. We are joined now incredibly by three astronauts who are currently on board the International Space Station. They are Koichi Wakata, Mike Hopkins and Rick Mastracchio. Thanks to all three of you for being with us.

Richard Mastracchio: Well, thank you very much, it's great to be with you.

Josh Zepps: Mike, can you just tell us, where are you guys actually located on the station? It looks like you are just floating around in midair. Where are you and what are you doing?

Michael Hopkins: Yes, we are actually in the US laboratory, so this is where we do a lot of experiments, but it's also where a lot of the systems are located that help keep us alive.

Josh Zepps: Rick, we've got a lot of questions coming in naturally from viewers as they watch this online. One of them says, 'What health studies are you currently working on?'

Richard Mastracchio: We're doing quite a bit of studies related to how our bodies change in zero G. For example, we do ultrasounds on our eyeballs, ultrasounds on our spines, on our heart. Of course we are constantly doing blood draws and urine samples to see how our bodies change and are affected by the zero G environment.

Josh Zepps: Is this to study the impact on your health of potentially much longer trips in space, is that the point?

Richard Mastracchio: Exactly. You know, right now most of our missions are about six months long. Pretty soon we are going to have one-year missions. I believe next year we will start a one-year mission, and then eventually we may even go longer and longer. And this is so we can see how the body is affected by the weightlessness and the environment of space, and also how we can protect other crew members, how we can keep them healthy for these long-duration missions that it's going to take to get to Mars and beyond.

Josh Zepps: How do you stay healthy in zero G ?

Koichi Wakata: Yes, we have a pretty extensive exercise program using aerobic machines, bicycle machines, a treadmill, as well a resistive exercise device. We exercise almost two hours every day to stay healthy.

Josh Zepps: Did you ever imagine, Koichi, growing up in Japan that this would be something that you would end up doing?

Koichi Wakata: Oh, flying in space has always been my dream ever since I saw the Apollo lunar landing when I was five years old. I thought it was impossible as a Japanese boy to reach into orbit, but here together with my American friends and the Russian friends here I am so happy to be part of this wonderful team.

Josh Zepps: Mike, I've got a question coming in from one of our viewers, Jan Cummins says, 'I marvel at the men and women who venture into space. Can they tell us what is the most awesome sight from space?'

Michael Hopkins: Oh, absolutely, there's not a day that doesn't go by when we have a chance to look out the windows down at the Earth that we don't see something just truly incredible. In fact the other night Rick and I just happened to be in the cupola and it was night and we were going down near Antarctica, and the northern lights were just absolutely incredible. It was a scene that we've never seen before. The whole sky was lit up green and you had the blues of the horizon where the Sun was just over the horizon, and then we had Venus come up and the Moon come up. It was just truly amazing.

Josh Zepps: What does that do to your head?

Michael Hopkins: Well, it kind of blows you away. You are just in awe at how beautiful the Earth is, and every day, again, you are just surprised at some of the sights that you see.

Robyn Williams: Mike Hopkins and friends on the International Space Station, talking to Josh Zepps on Huff Post Live. Well done Josh.

So what experiments do they do up there, and why do they go to the bother of launching bugs and apparatus up there into the sky? Who better to ask than Professor Cheryl Nickerson at the Arizona State University Biodesign Institute. First though, the movie.

Have you seen the film Gravity?

Cheryl Nickerson: Oh yes. I thought that the filming imagery was spectacular. There were several liberties taken with reality in terms of what actually happens. There are never two shuttles that are docked with the station in order to leave, but I thought the film itself was magnificent. I think it may have served to help recapture the American public's imagination in a positive way in terms of what can be done up there as opposed to the actual ending of the movie.

Robyn Williams: And you saw the International Space Station. Did you feel any qualms when you saw the space station being beaten up?

Cheryl Nickerson: I did, just as I felt qualms when in the Transformer movies they blew up the shuttle. That's inherently wrong and should not be allowed! But I thought it was incredibly well done, just spectacularly well done.

Robyn Williams: One thing that I always found when I go to the model of the International Space Station, which I have done over the years and walked around, is why anyone would want to have experiments with tissues up there with no gravity. What difference would it make? And you can tell me the answer to that, can't you.

Cheryl Nickerson: Well, that's a great question because that is the response I think that most people have. They say to me, 'Why would you think of doing experiments in microgravity? Why space flight? What advantage does that confer?' And if you think about life as it evolved, it's always evolved under unit gravity. What will it do when you take it away from that?

And by way of an example I like to say, look, it's an extreme environment, and when have we learned more about how biological systems adapt and survive and respond than when we put them under extreme environments of temperature, of pH. When we have watched and studied how organisms respond to that, every single time we have not just generated fundamental new understanding of biological systems, cells and tissues, but we've also been able to take that knowledge and translate that into next-generation breakthroughs that we benefit from every day here on this planet for human health and quality of life. So in that regard it's the next extreme environment whose utility is just beginning to be tapped.

Robyn Williams: But it would make sense for you experimentally if you are looking at ways in which to treat people ultimately if it resembles what's going on in our bodies. It mustn't be that alien that it doesn't count.

Cheryl Nickerson: You're absolutely right. And cells being cultured in microgravity in a liquid container, they experience a very low fluid shear force. That's the force of fluid that cells experience as it passes over their surface. Well, cells in our body are vessels with fluid continually passing over our surfaces all the time, and we know from humans that those forces are important for our tissues to function normally. But no one had really paid much attention in terms of how those forces could affect the virulence or the disease causing potential of bacteria, and yet bacteria experience those forces all the time in our body. So that was my original interest in looking at that problem.

Robyn Williams: So what have you been sending up to the space station experimentally?

Cheryl Nickerson: We have flown three model human pathogens: the major foodborne pathogen, Salmonella typhimurium, which is the leading cause of bacterial foodborne illness worldwide; the opportunistic pathogen Pseudomonas aeruginosa which, unlike Salmonella, doesn't cause disease when you're healthy, it causes disease when you are immunocompromised, it's the leading cause of death of people with cystic fibrosis and burn wounds; and we flew a model human fungal pathogen, Candida albicans.

We chose these pathogens for three reasons. We wanted them all to be sequenced because we wanted to look at their global gene expression profiles, we wanted them all to be very genetically tractable and have good animal models that we could study their disease in. We know that all of these organisms here on Earth are major causes of human morbidity and mortality and we don't have effective treatments for them or vaccines for them.

And we were also interested from NASA's perspective, these are all organisms that either have been isolated from the crew or the space ship in flight and, for example, Salmonella is the leading reason why food that is destined for the International Space Station gets disqualified. Pseudomonas aeruginosa has caused a life-threatening infection in space before. And Candida albicans causes minor skin irritations and respiratory infections there as well.

Robyn Williams: So if you're sending it up into space and you've been monitoring how they behave, are you comparing what they do on Earth, for example?

Cheryl Nickerson: Absolutely. So good science has to have good controls, otherwise we wouldn't know whether or not the microgravity culture environment altered the virulence and gene expression in pathogenesis related characteristics of the organism. So we performed identical synchronous ground controls for all of those organisms at the Kennedy Space Centre. They were loaded at the same time in the same hardware as what flew, half of the hardware flew, half of it stayed in the ground in a special room at the Kennedy Space Centre called the orbital simulator room. So it is linked in real time to the shuttle and also now to the ISS. It maintains the same temperature, humidity et cetera that is on orbit, the only difference is it's not flying, so there's no microgravity.

We are also linked in real time with the crew, so they would call down to us. When they started the experiment we were linked in with them in the room. We started the experiment at the same time. When they terminated it, we terminated it. Everything was kept identical, with the exception of things flying.

Robyn Williams: What did you find?

Cheryl Nickerson: It was very exciting what we found. We found that spaceflight increased the virulence of Salmonella. I should say we did this in two independent shuttle flights, and what's a very exciting is that usually you don't get a chance to independently validate, we have to do that at the bench because spaceflight is such a unique opportunity to fly, but on two independent shuttle flights we showed that culturing Salmonella in the space flight low fluid shear microgravity environment increased its virulence significantly, which means it was a more robust pathogen.

It globally altered its gene expression. But what was very interesting is the genes that were being turned on and off weren't being turned on and off in a manner that was consistent with the organism being more virulent when we culture it down here on Earth. So we were able to identify a master global regulator or

master switch that was responsible for the vast majority of regulating the genes Salmonella was turning on and off. We identified all the genes that were differentially regulated, and interestingly not one virulence gene was increased, they were all either not changed in expression or decreased in expression, which provides new insight in terms of how these pathogens actually causing disease in the body. We are finding differences as to how these pathogens can cause disease that we don't see when we culture them normally.

Robyn Williams: So the live creatures behave differently up there. You can find things are not visible on Earth. And you can then change the pathogens to make them safe, and even, according to Professor Nickerson, use those safe germs to carry vaccines. Here's how:

Cheryl Nickerson: Those differences are happening in our body down here, this is not unique to spaceflight. But the force of gravity down here can mask some of those responses. So when we grow these cells, these pathogenic cells, in microgravity and greatly remove that force of gravity, other forces can come into play and genes are expressed differently then.

So we have been able to since show that this master response regulator that Salmonella uses to regulate its genes in these low fluid shear environments, other very different pathogens use that same master response regulator. It's evolutionarily conserved all the way up through into your cells.

We've been able to show that we can actually turn off that increased virulence up there and make the bug not cause disease. We have also translated that to an approach for a vaccine initiative. So with the understanding that space flight could uniquely alter the disease causing potential, the virulence, and the gene expression of Salmonella, these are important properties for a live attenuated vaccine strain.

And so we wanted to then ask can space flight to do the third thing that would be important for developing an effective vaccine? Can it alter the immunogenicity, the protective properties of a vaccine strain? So we paired with Roy Curtiss who is the world's leader in turning what I like to say Salmonella from a foe into a friend. So he has spent decades masterfully engineering Salmonella to not cause disease in the body but serve as a vector, a vehicle into which we can put immunogenic genes from other pathogens into Salmonella and then deliver that to the patient. And those immunogenetic genes confer protection against other deadly diseases.

So he had constructed a strain that is actually in phase 1 clinical trials. It was a Salmonella strain that was designed to protect against streptococcal pneumonia. It was doing okay in clinical trials, but its immunogenicity needed to be better, it needed to be more protective. And we reasoned, can we fly that vaccine strain, study it, see if it's more protective, and then if it is more protective identify all the genes whose expression changed to make it more protective, go back in here on Earth, re-engineer that strain to give it those same protective properties that we hope to have observed from flight, and then translate that back into the clinical trials. So that's just one of the many lines of study we are pursuing.

Robyn Williams: It's quite amazing, isn't it. Were people surprised to find that what you do here in the lab on Earth in a flat dish can be misleading?

Cheryl Nickerson: I think that most scientists know that everything is a model system that we use and there is no model that's perfect, and we know that no one way to study things will give us 100% of all the answers. I think what surprised them was that the actual microgravity environment would be useful for that, and I think it's simply because since all cells, all life has evolved under unit gravity, no one really envisions if you take that away from it what will happen. And when you take that away from it amazing things happen.

And I would like to stress, because I think it's very important, this isn't just for infectious disease research. The leading causes of human morbidity and mortality—infectious disease, immunological disorders, including cancer, bone and muscle wasting loss diseases, neurovestibular disorders, and muscle degenerative diseases—all of these disciplines have been studied in the microgravity environment. And each one of these studies has provided very intriguing insights, but there's no magic pillar box. I'm not suggesting we have (and I don't like to use the word 'cure') the answer to these things.

But every single one of these disciplines has provided very intriguing and novel insight in terms of how these diseases may actually be developing, how cells behave from going normally to transiting to disease phenotypes that we don't see when we do that research down here. That also includes advances in tissue engineering that my team has been working on to develop more human-like models of cell-based tissues and organs that are in your body that we can study how they respond to pathogen infection and get a better understanding of how the disease is occurring in the body.

So I think the potential for breakthrough using this innovative platform, and now it's a US national laboratory up there as well. And so we need to use it like a US national laboratory. It's fully built, it is ready to roll. In the past science has been conducted on the fringes of building the ISS up there but now it's open, and so I

just hope since they've extended it for four years, the lifespan, that we can make effective utilisation of that globally for human health and quality of life.

Robyn Williams: Do you know, the Astronomer Royal, Martin Rees, has said that he could not see any scientific benefit of the International Space Station lab. I think you are in the process of proving him wrong?

Cheryl Nickerson: It's not me who is in the process of proving them wrong. People are going to believe what people want to believe. Some of the smartest people that you know of can amazingly have on blinders. And science done inside a box is not the kind of paradigm-changing vision we need if we wanted to continue to advance the way we need to advance in biological sciences, biotechnology. You've got to think outside the box. Sometimes your way isn't the only way. We all just need to be more open-minded and make effective utilisation of these novel environmental platforms for research that we have.

For example, for infectious diseases we are not doing a good job of outpacing them here on Earth at all, and so anything that gives us an advantage to do that, to reduce the time of 10 to 15 years to get a drug to market, to reduce the cost of $1 **billion** to do it, and to fundamentally understand these novel insights into cells as to whether they are behaving normally or transitioning to disease, it's absolutely worth it to use it.

Robyn Williams: When's the next flight?

Cheryl Nickerson: We are flying on SpaceX 5 which has currently just been pushed out, I found, to the end of November, so it looks like Thanksgiving we'll be back at the Kennedy Space Centre with our friends, so we'll have turkey there.

Robyn Williams: Thank you.

Cheryl Nickerson: Thank you.

Robyn Williams: The irrepressible Professor Cheryl Nickerson at the Biodesign Institute, Arizona State University, waiting for the next space shot. One way to gain new insights, microgravity.

Another way being explored by Australian physicist John Spence is micro-time. Watch reactions in femtosecond slices to find out what's really happening. And they've just scored $50 **million** to do the work.

John Spence: A couple of decades ago the X-ray laser was invented, and we were lucky enough to be there around 2003 when the Department of **Energy** in the United States decided to build this thing for about $600 **million**. Of course they were looking for things to use it for, and we suggested uses in biology. There was a possibility of getting snapshots of molecular machines at work, and this would cover everything from the molecular machines that do photosynthesis in the green plants that make the oxygen that we breathe, to new drugs. You want to know how the atoms are moving and what they are doing.

Robyn Williams: Why not just use a synchrotron?

John Spence: A big problem is…if you imagine having a chest X-ray and you want to see finer and finer detail, then you would turn up the intensity of the X-rays. But there comes a point where the illumination of X-rays is so intense that it destroys the thing you are trying to look at, and particularly if you want to see finer and finer detail.

In 1986 a scientist by the name of Solem wrote a theory paper where he suggested that if you did it with the shutter speed, the pulse of X-rays were brief enough, you could get a picture before the sample, as it were, knew what had happened to it, before it was blown up, because the radiation damage occurs later, and the elastic scattering that you make the image with is instantaneous. So that was the whole idea of this diffract-and-destroy mode, which is the main discovery this is based on.

But the experiment that showed that it actually worked was by Henry Chapman who comes, like me, from Melbourne University, and Henry did his PhD there a few years after me.

Robyn Williams: So you can actually learn something by examining the reaction as it's happening, something that you didn't know before.

John Spence: Yes, and the way we do it is like a stroboscope. Photosynthesis is a beautiful example because it's driven by sunlight, and so you can have a system where we use flashes of simulated sunlight from a laser to start the molecule, the molecular machine doing its thing. And then a little later we hit it with the X-ray pulse and take a snapshot of that at a particular stage of the motion. And then we repeat that thousands of times for every different stage in the cycle and then put them all together to make a 3-D movie.

Robyn Williams: And that will tell you what's going on that you didn't know before?

John Spence: Well, it's chemistry really. There's a lot of effort now with alternative **energy** on artificial photosynthesis. So if we can understand the mechanism in plants then we can make inorganic systems that mimic that.

Robyn Williams: You mentioned a few names of people who have been involved in something similar, and one name that occurred to me is Ahmed Zewail who actually got the Nobel Prize for taking snapshots of chemical reactions in femtoseconds, which is a **million millionth** of a second or something. The timespan you are operating in, how different are your plans from what he has done?

John Spence: Well, Ahmed at Caltech did spectroscopy, and we're doing imaging, making pictures and then movies. The timescale is about the same, 50 femtoseconds is fast enough to outrun radiation damage. We use these brief snapshots to avoid damage, but of course it also gives you wonderful time resolution. Ahmed has more recently changed his field into fast electron diffraction which is actually my old field. I came here to work with John Cowley, another very famous Australian who left Melbourne University again in about 1970 to found the group here.

Robyn Williams: All these Australians we're losing, what are we doing wrong?

John Spence: Well, you might get them back because, you know, the success rate in grants here is about 10% at NIH/NSF. This is a very serious problem, a 90% rejection rate, you would really think twice about sending your kid to do university research. So my friends tell me that it's just as bad in Australia, but there's a chance you'll get it back. Actually Robyn, I have brought with me a piece of this X-ray laser, and I should say it's built in a tunnel a couple of miles long near Stanford, it runs under the freeway, and it cost, as I said, $600 **million**. It's like a laser pointer but it spits out X-rays and it's much bigger. And I'**m** sure that if I just hold this a little bit closer to your microphone then your viewers will see it in much more detail, so here it is up close.

Robyn Williams: Kaboom, yes, well. You say the grants are difficult, but you've scored with your colleagues $50 **million** with which to do this. That was a tremendous triumph.

John Spence: Well, NSF does have this program of science and technology centers. So in our competition, which we started a couple of years ago, there was multiple levels of refereeing, so they made three awards, so a 1% chance of success. And one of them was MIT, one was at Harvard, and the other was us, so we were incredibly lucky. They run usually for 10 years, and over the 10 years it would be $50 **million**, yes.

And so there are six or seven campuses involved. ASU here is the biggest group in the scientific research, we have six professors here, and there's a big outreach program run out of Buffalo where they have education and technology transfer and patents and so forth. And just last week the NSF had us all here together to teach us how to collaborate. That was a lot of fun, teaching professors, these prima donnas, how to work together. They hired a professional **company** to do this, so we had a few days learning to do the same thing which of course professors are trained not to do.

Robyn Williams: And you all did hugs in the afternoon and played soccer or something?

John Spence: Well, I kept saying, you know, breakthroughs are meant to surprise and surprise cannot be planned. But institutions have to…if they are giving you money, they have to know what's going to happen or think they do. So it will be a flexible plan.

Robyn Williams: You mentioned photosynthesis. What other examples, if things go well, do you think you might produce knowledge about?

John Spence: Yes, well, another big field at the moment is called GPCRs, this is a class of proteins involved in drug delivery. The problem with them is you can't grow big crystals of them. All our knowledge of how proteins work is mainly based on knowing the structure of them, and to get the structure you have to grow a big crystal. And that's the whole bottleneck in structural biology because it's so difficult and it's largely a matter of chance as to whether the crystal grows or not. What we find with this method is we can determine the atomic arrangement in proteins which only grow very tiny crystals, some micron in dimensions. And that's opened up a whole new field of proteins which we can address.

Robyn Williams: Amazing apparatus, as you say, very, very long, and you are zapping big molecules and you are finding out something which, to the general public seems quite astounding, but is it a game-change that will make a huge difference?

John Spence: You have to understand how important radiation damage has been in the history of microscopy. Since Van Leeuwenhoek in the 18th century people have been turning up the brightness so they can see finer detail better…

Robyn Williams: That was 1674.

John Spence: Right, absolutely. And as they turn up the intensity of the illumination they fry their samples and they can't see anything. This has been a real roadblock until…so to have a breakthrough where you suddenly understand that you can scatter as many photons as you like without damaging the sample if you do it quickly enough is really important. Then is it a game-changer? Well, the fact that we can study proteins which don't grow big crystals the biologists tell me is very important, yes.

Robyn Williams: And now they've got $50 **million** to prove it's important. The new science, really taking off. John Spence is professor of physics at the Arizona State University, formerly of Melbourne.

This is The Science Show on ABC Radio National, and I'**m** at one of the great zoos of the world which does research with its animals, which has huge crowds coming, as today, to look at some of the exhibits and some of the ways in which they are being looked after, the animals. And with me is Ron Swaisgood who is the head of ecology. And we are standing next to where the pandas are actually having lunch under the bright sun in the middle of winter. And you can hear in the background lots of people queuing up to see them. And you've got a baby there, have you? How old is the baby?

Ron Swaisgood: Our baby is a year and a half.

Robyn Williams: So it's a toddler.

Ron Swaisgood: Yes, so this one, she is about ready to be weaned from the mother.

Robyn Williams: What happens when it's weaned?

Ron Swaisgood: Well, pandas are solitary in nature, and so mother and offspring, they go their separate ways as they would do naturally in the wild. And so they will be kept separately in the enclosures here as well.

Robyn Williams: So you gradually separate them and they get used to being alone.

Ron Swaisgood: Yes, exactly. And eventually all the offspring born here will go back to **China** and enter the breeding program there. We've actually had several go back, and we've got quite a few grandkids in **China** now that have come from our pandas here at the zoo.

Robyn Williams: Talking about breeding, the pandas are famously not very good at it. What really stops them being so enthusiastic about sex?

Ron Swaisgood: Actually I think that's a bit of a misnomer. It's not that the pandas don't do what comes naturally, they actually do what comes naturally quite well if given the appropriate environment and circumstances, that's what some of our research here at San Diego Zoo has been about over the last 15, 20 years. We've been flying back and forth across the Pacific Ocean and we've been working with the **Chinese**. Most pandas will mate naturally given the appropriate circumstances.

Robyn Williams: And what are the circumstances? Flowers, chocolate, or what?

Ron Swaisgood: Well, in pandas it's really about the perfume. And so pandas do have a special gland that they use to mark their environment, and you remember now they are solitary, so they don't have opportunity for face-to-face interactions that often in the wild, in fact they avoid one another. But they keep tabs on one another through scent marking. And so what we found is that if you provide them with the right opportunities to communicate with one another through scent marking at the right time, that actually the aggression levels go down and the sexual motivation, libido, goes up. And you place them together at the right time and all will usually go well.

Robyn Williams: Clearly, with that success rate. And I think his mother next door is chomping away at her leaves, undistracted by the crowds, she doesn't seem to bother about the crowds looking.

Ron Swaisgood: No, you know, they are actually quite docile animals, and they do very well in a zoo environment, quite happy to eat bamboo about 14 hours a day and not be bothered at all by their admirers.

Robyn Williams: It's an exciting life, isn't it.

Ron Swaisgood: Yes, and the other 10 hours is mostly spent sleeping. Every once in a while they get up and move to a different bamboo patch.

Robyn Williams: They don't do anything else?

Ron Swaisgood: Well, then comes the mating season, and that's when everything changes. It's very difficult to find a panda in the wild, because they do live in a very dense bamboo habitat, but come mating season they are actually quite noisy. And what we'll do is we'll up on ridges and listen for the panda vocalisations. The males are fighting…the female, when she comes into heat, several males will aggregate around her, follow her for several days or a couple of weeks. A female will often climb a tree and wait for the males to duke it out down below. So yes, it's a time of a great deal of activity. There is often even a little bit of bloodshed when the males fight, so they are not always docile. Then the female will come down and they'll mate, and a few months later she will give birth to a cub, usually in a cave or a tree den, and raise the cub.

Robyn Williams: Does the cub play at all?

Ron Swaisgood: Of course the cubs are very playful, they play with the mother, and then they'll play with anything in their environment. They'll break off a piece of bamboo and roll around with it. They are very playful animals.

Robyn Williams: I suppose y ou're not allowed to interfere and to make physical contact much?

Ron Swaisgood: Yes, we have a hands-off policy in terms of direct contact, and they are not pets. But when they are in a zoo environment we want them to have a relationship with their keepers because it's not about having no relationship because then it actually can be stressful if they are having to do things that a keeper is asking them to do. So our keepers actually have very strong **bonds** with the pandas.

Robyn Williams: You gave the example then of the return of the cubs to **China**, and for some years you've been returning animals to their native wilderness, if you like. Some examples of your successes?

Ron Swaisgood: Yes, so often when people think of zoos and reintroduction programs, which is what we are talking about, returning animals to the wild, we think of them as coming from the zoo and back to the wild, and actually we have done that on some occasions, but really what we do often now is a bit more strategic. We have what I call demand driven re-introductions or translocations. So we are working on the landscape, and where the animal is missing, perhaps it's extinct in the wild, perhaps it's locally extinct, we try to bring them back, back to that ecosystem. So we're trying to play a role in the recovery of the whole ecosystem, not just individuals. And so we have programs designed to do that. In some cases we'll breed up dozens or hundreds of individuals and release them back. In other cases we'll do what's called translocation and we will capture individuals from one location where there is a surplus and relocate them and release them to establish a new population. And we've done that with black rhinos in Southern Africa, we've done it with kangaroo rats here in southern California, and a number of other species. The California condor being of course one of the classic examples.

Robyn Williams: That was down to very few numbers, wasn't it.

Ron Swaisgood: Yes, the California condor was down to 22 individuals, and all of them were brought into zoos for breeding, and now we are up well above 400 individuals with about half of those in the wild. And so we've been releasing them in California and out of the Grand Canyon. And then the zoo runs a project down in Baja, Mexico, where we have over 20 condors flying free in Mexico for the first time in many decades.

Robyn Williams: What depleted their numbers in the wild?

Ron Swaisgood: Well, a number of things led to the decline of the condor. One of the big ones was **lead** poisoning. So when hunters shoot an animal, the bullet that is left in the environment the condors would end up consuming, and that would kill them. And of course there's been a lot of other habitat changes in California. What used to be an area that had lots of large animals roaming free now pretty much has one large animal roaming free. And when we die we tend to bury them, so there is not much condor food.

Robyn Williams: And so what was the secret of being able to breed from, well, a couple of dozen to 400? How did you manage that?

Ron Swaisgood: This was done by several zoos, with San Diego being one of the **lead** organisations doing this. And yes, it's call ed aviculture, and it was a lot of learning and trial and error to learn the correct techniques. One of the key things that was developed early on was puppet rearing for in cases when the parents did not rear the chicks. We don't want them to imprint on humans because then they're going to think they are human and they're not going to be very good breeders back in the wild. And so they are reared with puppets and they are fed with a puppet that looks like the condor, and that was one of the keys to success as well.

Robyn Williams: I see, isn't that clever! They are huge animals, aren't they, with a really vast wingspan.

Ron Swaisgood: There's nothing more amazing than seeing a condor soar over your head in the wild. I've been down to our field site here in Baja, Mexico, and yes, a nine-foot wingspan. And first thing in the morning they are all roosting on the edge of these cliffs, and these are desert cliffs, and when the hot air starts to rise they'll get enough lift and they'll start soaring. And if you sit up on top of the ridge in the morning and wait for that thermal lift and then wait for them they'll just circle up and come right over your head. And there's nothing more amazing than that feeling.

Robyn Williams: They're not killers, they're scavengers, aren't they?

Ron Swaisgood: Yes, they are scavengers, so they find something that has already died and they are nature's cleaner-uppers.

Robyn Williams: Yes, hence having to avoid the **lead**. Well, those success stories are really indicative of a new era for zoos because they used to be places where you kept animals and you can still look at them…I must say I'**m** astounded by the hundreds, thousands of people you have here. I know it's a sunny day, but what a turn-out. Is the public aware of the scientific part of what you do?

Ron Swaisgood: Yes, absolutely. What we are trying to do at the San Diego Zoo is bring people in for them to enjoy the animals that we have here but we want them also to walk away with messages about what actions they can take to conserve and protect our resources. And part of that is learning about our programs, our conservation and science that we do, and how they can help to facilitate those efforts as well.

Robyn Williams: Well, thanks very much, and good luck with the separation of these pandas. When are you breeding next, do you know?

Ron Swaisgood: Well, the female will come into oestrus in the spring, typically April. And two years ago when she last produced a cub, if she had just waited to have that cub for two more days she would have set the world record for the oldest female to give birth. So she may be at the end of her reproductive life but she is in very good health, and so we're going to see how it goes this year, and if she mates then we may get one last cub from her. She has been a wonderful female for us and, as you know, she has brought six cubs into this world here at San Diego Zoo.

Robyn Williams: Ron Swaisgood is director of applied animal ecology at the zoo.

And this is The Science Show on RN, where Natasha Mitchell of course presents Life Matters. She was also an editor last year of the book Best Australian Science Writing, which we featured on this program. In 2014 the new editor is Ashley Hay, based in Brisbane, and here she is with a last-minute reminder should you wish to send her an article.

Ashley Hay: As a writer for hire, I'**m** used to shuffling between a range of different projects, but my two main jobs at the moment are editor of this year's Best Australian Science Writing anthology, to be published by New South this November, and owner/operator of a five-year-old child. It's interesting how the two occupations intersect.

My five-year-old is a walking embodiment of curiosity. He asks questions, he wonders about things, he wants to know the how and why of what happens and where. He loves jigsaws too, turning the pieces face up and beginning to assemble the image. He loves the moment when the cars or dinosaurs come into focus. He loves the moment when the last piece clicks in, complete.

His combination of curiosity and jigsaws provides a strangely apt model for editing an anthology; the curiosity of opening a submission for the first time, the rush of a first read that shows off its ideas and contours, the flickers of connection or recognition between one piece and another, and the process of unravelling whether these complement or cancel each other. In this way the parts of the whole can combine.

Best Australian Science Writing provides a kind of snapshot of some stories that made it in science in the past year, new and wonderful dispatches from the cutting edge of somewhere, cataclysmic reports from different parts of our world that can take your sleep away, particularly if you are someone with an eye to the future.

This, the anthology's fourth annual edition, gives us the chance to celebrate not only scientific research but also the best ways we've found of talking about the discoveries and disappointments, the characters and the metaphors. This will be the last edition to be supported by three years funding from the Copyright Agency Cultural Fund. From 2015, Best Australian Science Writing will be on the lookout for new patrons.

As a novelist (another of my titles), I'll always argue that telling the stories matters, but stories about science matter in a different kind of way. They are an integral part of the work science does in expanding and explaining everything from the microcosmic to the macro.

When I first started wondering what shape this collection might take when submissions opened last December, I conjured the American writer Joan Didion. She might not be someone usually associated with hypothesis, experiment and analysis, but one of her most quoted lines seems suddenly to make a different sense; 'We tell ourselves stories in order to live, she wrote in The White Album, and I saw this in terms of the invention and the explanation that is vital to the work of science, and vital to the way we talk about it.

Perhaps this is giving the book a more literary purpose than you might expect, but it has helped draw the first pieces together, and the overall picture of the anthology is starting to emerge. If you have contributions you'd like to suggest might be part of it, you've got until 31st March to send them in.

Robyn Williams: And we'll have a link on the Science Show website to help you do just that. Ashley Hay in Brisbane.

Last week our PhD graduate was Hungry Science Beast Niraj Lal. His hungry mate is equally ravenous, Hamish Clarke, who does research on climate at the University of New South Wales.

Hamish Clarke: Although we feel weather at local scales, it's driven by forces which are really global in nature. To illustrate this I'd like you to think of a sausage sizzling away on a hotplate. If you're like me you regularly turn the sausage, making sure it gets cooked evenly. But no matter how often we turn it, the ends of a sausage don't get cooked as well because they are not touching the hotplate.

Okay, the Earth is a bit like that sausage, rotating once every day, getting evenly warmed by the Sun, and the north and south poles of the Earth are like the ends of the sausage, never really getting the full force of the Sun. Unlike the sausage, Earth has an atmosphere and oceans which are perfect ways for moving this extra heat around. And so a lot of what we know about the global climate system comes from following the Sun's heat as it moves through water and air, outward from the Equator to the rest of the world.

Robyn Williams: And of course when the temperature goes up, especially here, the risk of fire soars, so Hamish is also keen to know, being a Hungry Science Beast, what really sets fires going.

Hamish Clarke: When it comes to bushfire risk, what really matters? Ross Bradstock at the University of Wollongong has come up with a model he calls the four switches of bushfire. These are: one, the amount of fuel; two, the dryness of the fuel; three, the weather conditions; and four, a source of ignition. Each of these factors is a switch, but, unlike most appliances, just having one switch isn't enough, you need all four. If even one of the four switches is off, you won't get a fire.

For example, in the Blue Mountains west of Sydney where I live there is plenty of fuel, several very high fire danger days a year, and a reasonable supply of lightning, hazard reduction burns and arson. But we don't get many long stretches without rain to dry the abundant fuel out. As we've seen, three switches are not enough to make a bushfire, and a so-called limiting switch here is fuel dryness.

Let's compare this with Australia's inland; it gets very hot, it's very dry, there's plenty of lightning, the fuel dries out quickly, but there just isn't a lot of fuel to burn in the first place, partly because it's so dry. The limiting switch here is fuel amount. The key insight of the four switches is not in the discovery of any new factors in bushfire but in the way we look at them. So often in science it's these changes in perspective that can **lead** to new ideas.

Let's think about climate change. If it leads to longer dry spells, then the four-switch model tells us that this matters most in places where fuel dryness is the limiting switch, like my home town. Hmm.

Robyn Williams: Hmm indeed. Hamish Clarke, living in a four-point risk own. He does research with the New South Wales Department of Environment, and a PhD at the University of New South Wales. Another PhD on The Science Show next week.

[Music: Ave Maria from Vespers by Rachmaninoff]

How sublime. Uplifting. But perhaps also analgesic. Miguel Farias lectures in psychology at the University of Oxford and does some wonderfully unexpected experiments on belief, experiments you'd expect to be illegal, like giving pain to his subjects.

How can you do an experiment that tries to find out whether those who believe in God have a different experience of pain from, say, atheists? How does that work?

Miguel Farias: Yes, so what we did was to give electric shocks to participants. You just have a continuous painful electrical stimulus on the back of your hand, and you put them in an MRI scanner while this is happening and it gives subjective ratings of how painful it is. And they are either looking at an image of the Virgin Mary or a secular image. So you've got these subjective reports of how intense the pain is and you look at what's happening in their brains.

Robyn Williams: And you're allowed to do that are you?

Miguel Farias: You know, actually we had a problem with the ethics committee.

Robyn Williams: I'm not surprised!

Miguel Farias: Not because of the pain aspect of it but because of the religious part. We were being challenged on the fact that we are using an image of the Virgin Mary, so the ethics committee challenged us on that, they said why aren't you using an image of Christ? So we had to methodologically explain why we wanted to use Catholics rather than every kind of Christian.

Robyn Williams: What did you find? Who could put up with the pain more? Those with a Jewish association or a Catholic association or what?

Miguel Farias: So unfortunately we only tested Catholics and atheists, and there was a lowering of pain perception for Catholics only when looking at the image of the Virgin Mary.

Robyn Williams: So you felt less pain if you were looking at the Virgin Mary?

Miguel Farias: Yes, for Catholics. But we interviewed them afterwards to try to understand what was going on, and the kind of reports we got had to do with what psychologists call a reappraisal process. They were focusing on aspects of their faith, the role of Mary in the Gospels or praying or thinking of religious experiences they'd had before. So it was this which allowed to down-regulate the experience of pain.

Robyn Williams: And so are you suggesting that if you do have this religious belief you are somehow physiologically protected.

Miguel Farias: Let's say that we had a decrease of 14% in terms of pain perception, and this we think is a subjective reinterpretation of the pain, because when we look at the pain matrix in the brain we get exactly the same level of activation.

Robyn Williams: I see, so the body might have felt the pain but the mind felt it was less.

Miguel Farias: Yes, exactly, and there comes the whole subjective psychological and effective component of pain.

Robyn Williams: So you had these atheists on your hands and you were inspired to take an experiment further. In what way?

Miguel Farias: Yes. Just to give you an example, more recently we've been looking at scientists and we've asked them specifically…this is an experiment in which we put them in a situation where they have to give a speech, an impromptu speech on something which raises their levels of stress. Before that we get them to think about how science has been meaningful, to write about an event where you thought that science was meaningful in your life and tell me how you thought and felt about it.

And often we got these beautiful narratives of how science has helped them to deal with stress. One particular scientist gave the example of how whenever he was stressed he just looked at BBC environmental videos, especially about animals, how are looking at animal and plant life made him feel much more relaxed. Another one gave the example of going through principles of physics whenever he was stressed, how it just suddenly made everything come into place.

Robyn Williams: So it's a personal tool.

Miguel Farias: Yes, exactly.

Robyn Williams: It's the first time I've heard that science can be therapeutic in the same way maybe that going to church could be.

Miguel Farias: Well, there is a twist to my interest in this because there is this huge literature, mostly coming from American doctors looking at these correlations between health variables and religion and saying that religious people have healthier lives, live longer and are happier and that sort of stuff. And I thought actually can we replicate this with a different sort of belief system? And when I started thinking about this with my colleagues, there was a team of Dutch psychologists that had been looking at John

Gray's…you know, the guy who's at the London School of Economics who wrote Straw Dogs, the myth of progress, so they were looking at the myth of progress…

Robyn Williams: Yes, he was a professor of European thought.

Miguel Farias: Yes, exactly. He's a wonderful nihilistic atheist, very different from the Dawkins kind, almost Nietzschean kind of existentialist, and he's very critical of the idea of progress, that we actually believe that we are morally progressing, not just in terms of technology but in terms of actual moral progress. So they devised a series of social and psychological experiments where they show that if you put people in situations of uncertainty and anxiety, they believe more in moral progress.

Robyn Williams: It makes sense.

Miguel Farias: Yes, well…

Robyn Williams: Let me take you to prison now and another example of the kind of experiments that you were doing, taking yoga to prisoners. How did that come to be?

Miguel Farias: So I met the person who runs this small charity based in Oxford called the Prison Phoenix Trust who has as one of the patrons Jeremy Irons.

Robyn Williams: The actor?

Miguel Farias: The actor, yes. And I learned about this wonderful history of two women who had dedicated part of their lives to taking yoga and meditation into prisons. And it was one of those moments that as a psychologist I thought, wow, if this works it would be wonderful to test it and to show that actually using a proper experimental design it works. And I would be in a unique position because as a research psychologist my stuff doesn't have a practical edge or application to it. And I thought, wow, perhaps this would be a way of giving back something to people who are in a rather deprived and unfortunate situation, being in prison.

So that was really what sparked the interest, in a kind of subtle ideology of the people who run this organisation, which is mostly run by volunteers, and it's a very hippie, new-ageish idea. Remember Timothy Leary in the '60s. So if you put people in the right frame of consciousness it will change them, so he was trying to go around giving LSD to politicians. The idea with transcendental meditation was very similar in the '70s, that if you just put people in the right frame of mind it will change, crime will go down. So the idea of most of the volunteers who run this isn't very unlike that, they believe that if you get prisoners to realise their true spiritual nature they will just be enlightened and don't feel the need to be criminals.

Robyn Williams: Endure being locked up a bit better.

Miguel Farias: Ah, I would think of that as potentially the negative side of meditation and yoga, all of these eastern spiritual practices, that it can actually **lead** you to be more passive rather than reactive.

Robyn Williams: So you went in, and did the prisons allow you to do this work with no problem?

Miguel Farias: Oh goodness no, no, it's a real headache getting into prisons, it took us one year to get ethics permission. We wanted to use cortisol and they said if you get saliva samples you could run genetic analyses on the prisoners that would be unethical. But I said, but we're not, we don't have the means, we don't have the money to do it. And then because we were being sponsored by a foundation which money comes from a pharmaceutical **company**, they said we would want to sell the data. I mean, complete nonsense. Anyway, they very subtly told us that we can't give you permission, however if you were to go to a regional governor and seek permission there, we would be fine with that, which is what we ended up doing.

Robyn Williams: So you went to which prison?

Miguel Farias: We went to the Midlands prisons.

Robyn Williams: And the prisoners were welcoming to you, or did they briskly tell you to bugger off?

Miguel Farias: We had two female research assistants, one of whom used to be a model, so that was rather successful with the male prisoners. Most of them were quite happy to try to do something. We randomised them into a control group or a yoga group. There's some kind of ongoing prejudice about yoga being a girlie activity, but most of them were happy to engage with it.

Robyn Williams: And the results?

Miguel Farias: So we got some interesting results. We had prisoners doing a ten-week yoga course, and we saw significant reductions in tress, increases in positive effects in general psychological well-being, and we also used an impulsivity task, a very simple computer task—go, no-go—where we saw that they were better at impulsivity, so at withholding their behavioural response, which is potentially the most promising thing since most of criminal behaviour has to do with an inability to withhold your impulses. So that's promising. I'd like to do some more research on that.

Robyn Williams: When you went away, did they continue the yoga?

Miguel Farias: It's rather problematic to track what happens to these prisoners because for some reason, which I'**m** not entirely clear, they get moved around prison very, very often. So we actually had to negotiate with the prison governors not to move these participants for 10 weeks. I don't know whether the purpose is not to create social **bonds**, I think it's a deeply alienating experience.

Robyn Williams: Well, they're not supposed to have fun when they go there, are they.

Miguel Farias: No, I don't think they have much fun.

Robyn Williams: The overall impression one gets from your work is that you are willing to look at these really exciting attitudes that people have about life, how you get on with life, how you manage to keep yourself stable, how you enjoy, how you even resist pain. It's most unusual really in a psychologist to get such a wonderfully broad approach, is it not?

Miguel Farias: Yes, my head of Department has told me that my research interests do not fit those of the Department. I just do what I enjoy, and yes, I think that most of my work is interesting for people outside of academic psychology. I'**m** trying to write a sort of popular psychology book on the yoga side of things. We have as a provisional title From Monster to Buddha.

Robyn Williams: From Monster to Buddha, right.

Miguel Farias: Well, the problem we've had so far is that the feedback we've got from publishers is because we are introducing a critical edge to it, it's not just 'oh yes, yoga and meditation can do all these wonderful things and can promote personal change', we are actually looking also at the critical aspect of it.

Robyn Williams: From Monster to Buddha, a critical look at yoga. Sounds fun, doesn't it, especially if he can keep the crims out of jail and into 1960s tie-dyes instead. Miguel Farias is Portuguese and lectures in experimental psychology at Oxford.

Next week The Science Show investigates how terrorists use the internet, how an Australian marine scientist is helping to green the port of LA, and how Marcus Chown went swimming with Stephen Hawking. Production by David Fisher and Mark Don. I'**m** Robyn Williams.

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