HD **Meet boy wonder: doing revolutionary chemistry before he leaves school!**

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Hungry Science Beast for Radio

The Science of Doctor Who

A new approach to living in the sky

Robyn Williams: Perhaps this is not the best time to ask this question but I will anyway; how thick would a spiderweb have to be to stop a jumbo jet in mid flight? The answer in today's Science Show. I'm Robyn Williams.

And I see that last month jumbo jets turned 45. Well, today we'll meet Doctor Who, Australian style, look at tall cities, those spiderwebs, and bees, how to save them.

Let's though start with proteins. You like proteins, you're made of them, and this is the 100th year of crystallography, so we're looking at new ways to picture proteins and see how they interact. That already strikes you as complicated, confess! So why on earth would this sort of research attract a school kid and make him want to join in, with sensational results?

Meet Professor Rommie Amaro at the University of California, San Diego.

So here you have these very complicated molecules, and the way they work depends on their shape. And you're looking at the way they move around and might take up different aspects. How?

Rommie Amaro: That's right. So it turns out that we get these images of how these machines are and they very often are static images, but these are really dynamic moving machines.

Robyn Williams: You're calling proteins a machine?

Rommie Amaro: I am, yes.

Robyn Williams: That's bold.

Rommie Amaro: They are machines. They are the workhorses of the cell. So the function of these machines is really intimately tied to how they move and their dynamics.

Robyn Williams: How do you study that?

Rommie Amaro: So we are using just very simple physical equations where we can approximate the structure, the atomic structure of the molecule. And then we just integrate Newton's equation of motion over time essentially, and we do this on these supercomputers, these really, really large computers. We integrate these equations of motion millions and billions of times and then we can evolve a dynamic picture of how these proteins are actually moving.

Robyn Williams: So you animate them?

Rommie Amaro: Exactly.

Robyn Williams: And having animated them can you see them doing different things that you hadn't thought of before?

Rommie Amaro: Absolutely, that's the fun part. Discovering how they move and how that motion can be tied to function that either we know about or, for example in a lot of cases of these small molecules that we are now discovering, entirely new sites, new binding sites for drugs can actually reveal themselves in these computational simulations.

Robyn Williams: How long has this kind of work been going on?

Rommie Amaro: Well, the approach that we are doing is very, very new in terms of using the output of molecular simulation in a drug discovery program. There have been a lot of success in rational drug design for other targets, but to date we haven't had one that actually made it into a human yet, just because the timeline is so new, it's so long, and this is such a new technique. But we are pushing ahead on some very promising new cancer therapeutics, and so I'**m** hopeful that in the next 10 to 15 years hopefully we will be there.

Robyn Williams: Ten to 15? I'll come back in 10 to 15 months.

Rommie Amaro: I know, it's not fast enough, right? But it's the process, it's the process of actually getting a drug to market.

Robyn Williams: What happened when a young man knocked on your door?

Rommie Amaro: Oh, Eric, Eric Chen. Yes, so he knocked on my door and told me he was interested to do research. So I said okay, sure, I talked to him a little bit, he was in high school, young…

Robyn Williams: A high school boy.

Rommie Amaro: A high schooler, that's right.

Robyn Williams: A high school boy interested in proteins.

Robyn Williams: Yes, believe it or not! He's a rare one I guess. But he came and he was interested to do research and he seemed pretty determined. So he came to see me and I said okay, sure, send me an email, and he did. I probably didn't reply the first time, but he sent another one, and so I sent him a few papers and then he came back, and that relationship sort of took off.

He went to a summer school that I have here at the university to sort of learn some of the basic techniques, and I actually had assigned him a project. I said okay, you're going to look at this protein and cell signalling, and he did. And then after those eight weeks he came into my office, he said, 'Dr Amaro, I have an idea for a new project.' And I said, all right, I knew things had been going pretty well. So I said, okay. And he said, 'I really want us to come up with a new drug for the flu.' So influenza, obviously we hear about this all the time, and even now there are new strains all the time, so he was really interested in coming up with some drugs for it.

So he had identified a protein called endonuclease which when it's blocked, when its activity is blocked it basically stops viral replication. So it already had early indications of being a very good target. And again, since he is young and he's in high school I said, okay, if you're interested, go for it.

So he went off, and he did talk with people in my **group** and so forth for some technical guidance, but he came up with a set of molecules, small molecule compounds…so what we do is we take these protein structures and we can screen them or develop models of them that we can then use to possibly discover new drugs, and so that's exactly what he did. And he came with a set of compounds. And normally I have to say in my lab it sort of stops there, and at that point I call up a collaborator or I email someone who actually does bench work and I say, okay, we have some compounds, would you like to test them? And they do.

But Eric actually decided he wanted to run the assays too, he wanted to do the experiments. Fearless kid, just fearless. And so he knocked around on different labs and he was able to get into the Department of Pathology and run the assays, validated that these compounds actually worked. And that was kind of the story taking off. And then he also registered for a number of science fairs, and he used this work as a platform to win the Google Science Fair.

Robyn Williams: He won the Google Science Fair?

Rommie Amaro: He did, the grand champion, yes.

Robyn Williams: At the age of what?

Rommie Amaro: I guess he's 17.

Robyn Williams: 17? You're kidding!

Rommie Amaro: 16, 17, yes, he is young. It's amazing. And then a few months later he won the Siemens competition which is one of the most prestigious international science competitions, even bigger money kitty. So he is just sort of sweeping…and, I have to say, as a scientist I especially proud of…he has a first author publication in ACS Medicinal Chemistry Letters. So he has that also…he made it into the literature.

Robyn Williams: Before leaving school.

Rommie Amaro: Yes, in high school, it's really just phenomenal.

Robyn Williams: I find that very interesting because most of the remarkable young people I hear about are young women, and having a young man with the confidence to do that is, may I say, exceptional.

Rommie Amaro: It is exceptional. I mean, he is just really an incredibly…just has such initiative, and, like I said, he's just fearless. He will just try new things and knock on people's doors to take it all the way to the end. I think he has a very bright future ahead of him.

Robyn Williams: And he's a swimming champion and he sings like Justin Bieber and…

Rommie Amaro: Probably, probably a virtuoso, yes! I think he does fencing. Yes, a lot of skills.

Robyn Williams: Well, that shows you that an academic at your level should always open the door and always follow up the emails because bright young people may come and make all the difference.

Rommie Amaro: I think so, absolutely, that's part of our job, right?

Robyn Williams: Thank you.

Rommie Amaro: Thank you, this was a lot of fun, thank you.

Robyn Williams: And this is aforementioned Eric. What made you knock on the door of a professor and want to join in?

Eric Chen: I don't know, my love for science started when I was just a little kid actually, and I was really, really curious. And I guess I soon found that science had the answers to the questions that I had. And as I grew older I kind of realised science actually doesn't have all the answers, there is this entire field of research devoted to answering questions we haven't answered before, and that's what really got me interested in research. I thought it would be the coolest thing ever to be able to discover something no one has ever found before, and that's what really got me into it I guess.

Robyn Williams: How did you know you'd be good at it?

Eric Chen: I didn't! I thought it would be something I'd want to try out, and it really took off from there.

Robyn Williams: May I ask you how old you are now?

Eric Chen: Right now I'm 17 years old.

Robyn Williams: You're still 17. How do you deal with the successes you've had, these prizes?

Eric Chen: I don't know, I've been very honoured with what I've been able to accomplish. Of course I've been very surprised whenever I get one of them. But I've been very, very busy I guess, because I'm not at school a lot of the time to go to this outreach event or that talking event, and my teachers and mentors have all been very supportive of me and I'm really grateful for it.

Robyn Williams: What did your fellow high school students say? Where they excited, were they dismissive?

Eric Chen: They were definitely excited. A lot the students…the friends I had before, they were always very supportive, and even after I won these awards it didn't really change the relationship between us and I felt that was nice, and we still help each other out and maybe I'll say, 'Can I present this,' or, 'Can I practice this presentation to you,' and they'll say, 'Of course.'

Robyn Williams: I'm assuming you'll follow it up and go to university and study science and all the rest of it, but, you know, the really crucial question is; when you were so young, as you said just before, what really made all the difference to encourage you? Was it your parents, was it your teacher, was it things you observed, or what?

Eric Chen: Partly it was because of my parents because they are in science, and because of that I got the early influences where I could…I had maybe a toy microscope or this textbook lying around and I'd read through it. But it was also just I guess my observation, as I mentioned before. I found that a lot of these questions, the answers were all scientific. And because of my curiosity, that's what really deepened my interest for science.

Robyn Williams: And what do you plan to do?

Eric Chen: Oh gosh! In the future I guess I'd either like to become a college professor, I actually really love teaching as well and this would let me pursue both my passions for research and teaching. Or I'd like to become an entrepreneur because doing this research, it's really shown me the difference between discovering something in a lab and getting it to the market, to the consumers. And I think it would be really cool to bring these scientific innovations to those who need it.

Robyn Williams: At the age of 17. Congratulations.

Eric Chen: Thank you.

Robyn Williams: Eric Chen, who last week won the $100,000 Intel science grand prize, awarded in Washington DC. He has also won the Google International grand prize and the Siemens Foundation science prize, and I'm told he has been offered a place at Harvard. And, get this; he's considering it.

Before Eric you heard Professor Rommie Amaro at the University of California, San Diego, and she's also a star.

Okay, more chemistry. If Eric's a genius, then so are spiders, making silk that can be the strongest material on Earth nearly. Meet Jeffery Yarger who works at spit central at Arizona State University.

Professor, outside the building it says Comparative Salivary Research. What does that mean?

Jeffery Yarger: Good question because I have nothing involved with that, but in fact it's even worse than that because the signs in the building said Spit Camp last week, so I was really worried about getting spit on lately. But I think these are people who we could all sit here and spit into a cup and they could compare our saliva and tell us I don't know what, but I'm assuming maybe what we had for breakfast or what drugs we'd done or something.

Robyn Williams: Those aren't the glands that spiders use to make silk?

Jeffery Yarger: I don't think they have anything to do with salivary glands, especially given that they are on the other side of the animal from its mouth.

Robyn Williams: How many different sorts of spider do you have here?

Jeffery Yarger: It depends on the time of the year. In winter we come down to four or five species, usually tarantulas and cob weaving spiders like widow spiders that we find in the desert, which is where we live here in Arizona. In the summer months when we get a lot of the tropical spiders from places like Australia, from Latin America, Florida et cetera, we often have up to 20 or 30 species in the lab.

Robyn Williams: And do they all have different kinds of silk?

Jeffery Yarger: Yes, they all have different types of silk, and in fact they get labelled by…some simple spiders like tarantulas or jumping spiders often only produce one type of silk, the dragline silk they drag behind or something that they lined their burrows with, to the other extreme which are orb weaving spiders which are the ones we think of as making webs, they usually produce 6 to 7 different types of silk within a single spider.

Robyn Williams: Why?

Jeffery Yarger: They do it for several reasons, but one is a web requires two or three different types of silk, some high elasticity to be able to absorb the energy when something hits the web, a high tensile strength one so it doesn't break, a sticky glue-like substance to make sure it doesn't come off, and then it uses a completely different almost like Saran-like or sheet-like silk that it wraps its prey in. It uses a different silk to make egg sacs with, et cetera. So they use it for a lot of different components of their life and life cycle.

Robyn Williams: I'm going to ask you a ridiculous question; if you were to take the average web that we see in the garden, how much would that weigh?

Jeffery Yarger: It would weigh about one-tenth of a milligram. So if you take it all the way down and look at it, it would look like just a really small on-the-end-of-your-fingertip little cotton ball that you webbed up, and you would barely be able to weigh it with a kitchen scale.

Robyn Williams: Something so tiny and thin the spider can weave out to be a place to live and a place to catch. So you are studying the tensile strength of these silks, are you?

Jeffery Yarger: A lot of people have looked at the mechanical properties or tensile strength and toughness of hundreds of different silks for the last 20, 30, 50 years maybe. And it's been known for a long time that spiders have had some incredible properties. For example, some of the dragline silks are some of the toughest materials we know of, twice as tough as Kevlar, for example. We are trying to understand at a molecular level why. What about the structures give it that toughness?

Robyn Williams: Aren't people making artificial silk anyway already?

Jeffery Yarger: Yes, in fact that's how we got into this, is that the first people 30, 40 years ago, molecular biologists picked up this problem and realised that silk is a really interesting material, and the problem is that we cannot produce enough of it naturally, so let's produce it synthetically or artificially to be able to use this material. The problem is that they've been doing that and they've made some great strides in actually making these very large complicated proteins to get the primary structure of that protein or the right amino acid sequence and artificially express that. The problem came is that once they artificially expressed mass amounts of this it didn't have the same properties as natural silk. That's when we came in and said why doesn't it? And it's because the ones that they are mass producing, they are not folding in the right molecular three-dimensional shapes that natural silk is able to do.

Robyn Williams: Is it technically possible to imitate the sort of thing that the spider makes?

Jeffery Yarger: We are working with a lot of the molecular biologists that have produced things like transgenic silkworms that produce spider silk as their cocoon instead of their own natural silk worms. So people who are doing it…smaller systems in E. coli bacteria, et cetera, people who are doing it in goats **milk**. A **company** called Nexia, now Randy Lewis at Utah State has transgenic goats that produce spider silk in their goats **milk**.

Robyn Williams: You're kidding!

Jeffery Yarger: No. Not that I'**m** a fan of milking goats. I think if you need some extra goat **cheese**, they have it. But a lot of different places around the world have produced large amounts of these synthetic versions, and we are working with them to show them the molecular structures that natural silk has to show them the way that spiders are actually able to produce that natural silk so that we can reverse engineer that process when we are working…

Robyn Williams: And the payoff to get new materials would be what?

Jeffery Yarger: The payoff would be to have bulk amounts of natural protein-based polymer that has incredibly different properties. For example, if you could reproduce the natural dragline silk out of a spider like a Nephila that you would find in Australia, you would have something that's twice as tough as Kevlar. If you are able to produce the minor ampullate silk from a black widow spider you would have a biomaterial that matches the exact properties of human tendons as a potential artificial tendon replacement, because these are just protein polymers like collagen, like elastin, that you would naturally find in your body anyway.

Robyn Williams: Why not take 100,000 spiders, feed them, make them happy, and just collect what they produce?

Jeffery Yarger: That has been done once that I know of, at Madagascar. In fact it was in the Natural History Museum in New York last year for a while…there was one tapestry produced from about 3 **million** golden orb weaving spiders in Madagascar. But it took three years, it took 3 **million** spiders a lot of effort just to produce this one tapestry. It's a heroic effort.

Robyn Williams: Going around your lab seeing all your different spiders, it's very inspirational. Actually you've also got some silkworms there as well. How far have you reached?

Jeffery Yarger: I would actually say we're about 95% through understanding at a molecular level what secondary structures cause different mechanical properties in silk. The next stage is that almost all of these silks are made up of two or more proteins. And so that requires tertiary or quaternary protein-protein interactions that must be involved as well. And that's what we are getting to next. So I think we understand at a secondary protein structural level what's going on, almost completely at this point, and now we are working on some of the higher order hierarchical structures, and then once we get those down I think in the next five or ten years we'll have a very complete picture from a molecular standpoint of how spiders are able to produce such strong materials from natural protein.

Robyn Williams: What if it turns out to be too complicated to reproduce artificially?

Jeffery Yarger: All indications are…because we've been studying this from an MRI perspective, they're able to take a 30% or 40% completely disordered protein solution, kind of like you would crack open an egg and have a gooey egg white, right? They are able to take that, store it in glands for weeks at a time, just an aqueous solution, it doesn't seem like anything special is in there, no special enzyme or extra lipids or anything, and at will they can pull it through a series of ducts and make this super-strong fibre.

And there are several factors that go into it besides the obvious dehydration as it goes through these ducts. There is a change from sodium potassium pumps, there's a CO2 partial pressure that increases, there's a pH change. Teasing apart all those little mechanisms that happen for them to fibre engineer it is what we are working on now. And it seems fairly straightforward to hopefully reverse engineer this into a fairly green aqueous chemistry fibre pulling technology.

Robyn Williams: So far it looks doable?

Jeffery Yarger: So far.

Robyn Williams: Another absurd question; how much spiderweb would it take to stop a jumbo jet?

Jeffery Yarger: You would have to have a hell of a lot of spiders doing that. But what I always like to say is if you were to scale up the properties of spider silk…so the silk that they naturally make is really, really thin and we're all familiar with this, we don't think of it being that thin because we go out to our garden and we see a web, and the reason we see that is…you're not actually seeing the web, you are seeing the water that's on that web. And we almost always see it on a dewy a day or because of humidity.

But we also have the opposite experience, which we've always walked down a corridor and we've started brushing our head because we run into a spiderweb that we didn't see at all, and that's because they are very, very thin, only a few micrometres, about 100th the size of a human hair is what the diameter of a natural spiderweb is, the fibre that makes that. If you scaled that up a few millimetres to a centimetre and you made the entire web out of something like that and it linearly scaled the toughness properties, you'd be able to stop a jet in flight.

Robyn Williams: So there you are, a centimetre-thick spiderweb could stop a jet. Jeffery Yarger is a professor of chemistry and much else at the Arizona State University.

And this is The Science Show on RN, where we've long been worried about bees. They too are getting chemical attention in New Zealand. Their bees have been fighting an attack on two sides, from mites and from insecticides. Professor Peter Dearden at Otago University in Dunedin may have an answer.

Peter Dearden: New Zealand bees have a number of problems that are kind of unique and some which are imported. So the biggest problem we're having at the moment is varroa mite, which is a parasitic mite which eats bees. Australia at the moment doesn't have it, which I think you should be very proud of and actively try to keep out. The mite is problematic because it causes wild bees (or bees that aren't managed) to die. So in New Zealand since about 2003 and the introduction of the mite we've seen feral populations of bees collapse. So the bees have gone from a wild species we managed to a domestic species.

They are controlled with a bunch of chemicals which allow us to kill the mites but not the bees. Those chemicals are reasonably good but we have resistance to almost all of those chemicals in the rest of the world and that resistance is appearing in New Zealand as well. So the mites stress the bees. We've got reduced populations of bees. And on top of that we are starting to understand that many of the agricultural chemicals that are used have effects on bees. I'm sure you'll have heard that in Europe and America people are interested in particular classes of insecticides called neonicotinoids which affect bees at a sublethal dose.

So what you would generally say if you were interested in insecticide is at what dose of this insecticide does this animal die? And of course bees being a species that we like, people have tried to work out how much of these neonicotinoids they can use without affecting the bees. And that's a decent thing to do, and the neonicotinoids themselves are really great insecticides, they are wonderful for controlling pests.

The problem comes about because we've forgotten that bees don't just die, they live in a society, and the interactions in that society and their ability to remember things is really key to everything they do. So these neonicotinoids seem to affect the way that bees remember things or are able to forage, and that causes the bee colonies to collapse to some extent, to get smaller and to start dying.

So in New Zealand we have the problem of verroa mite which is killing our bees, we have probably very narrow genetics of our bees because they've been imported in very small numbers, and now we have agricultural chemicals which also seem to be affecting them. So it's a bit of a perfect storm for bees, and we need to understand ways to try and help the species.

Robyn Williams: It has to be done quickly presumably to look after them.

Peter Dearden: Yes, I think there are short and there are long-term solutions. Surprisingly I think genetics is the short-term solution, trying to breed of bees which are more tolerant of the verroa mite. But the long-term solutions are much more difficult. We have an enormous trade-off here between the use of insecticides and their effect on beneficial species. Insecticides are very important for agricultural productivity, and they say that a third of the food we eat requires pollination, and about a third of our stored food is eaten by insects. So there's a balance here. If we use insecticides then we protect our food better. If we don't use them then we get better pollination. So we need to be able to break that trade-off, we can't just keep manipulating it, we need to find some way to kill insects without affecting our beneficial species.

Robyn Williams: Do you have any clues as to what might work?

Peter Dearden: Well, one of the things that has been happening around the world for the last 10 years or so is the sequencing of insect genomes. So a lot of people around the world have been interested in how insects work and how they develop and how they evolve. And so we are starting to have genome sequences from lots of different species, and with the advent of the new sequencing technologies we've now got a flood of insect species genomes.

By looking through those genomes what we can do is try and find things which are specific to particular groups. And some time ago when the bee genome was sequenced we first identified that there were a lot of genes that control early development in flies that are missing in the honeybee genome. As we've sequenced more and more species we've discovered that actually those genes are patchy, that they are in some species and not in others, and that they are probably evolving rapidly but there's a huge diversity in the way that insects control their early development. But we've also started to find genes which seem to be missing from the bee genome but are present in other species.

Robyn Williams: So you can put them in?

Peter Dearden: Well, no, at this point what we're looking at is parts of the brain talk to other parts of the brain to control moulting in an insect. So insects in their larval stages go through a series of critical moults which allow them to grow, because they have an exoskeleton. If they don't moult their exoskeleton they can't grow any bigger. It turns out that some of the genes which control those sorts of processes are absent in the honeybee.

Now, honeybees moult, so they must have some work-around in their genome to deal with this, and we are trying to understand how they deal with these missing genes. But also it gives us the opportunity, if we can find a chemical which blocks the interaction between those genes than we might find something which affects insects other than bees and causes defects in their moulting.

Robyn Williams: I see, so you go for the other insects, and the bees will be fine.

Peter Dearden: That's right, yes, we wish to kill the other insects, the bees will be fine. That's the idea. Some of the things we found are extracellular, so ways that cells are talking to each other, and those are critical drug targets if you think about the pharmaceutical industry. So it gives us the opportunity to use that great power of medical genetics to find chemicals which block those interactions.

Robyn Williams: And presumably you're talking about one or two species of bees, because there are so many. We've got I don't know how many wild ones in Australia. So you've got a fairly fine focus, have you?

Peter Dearden: It's kind of interesting. We've just recently helped sequence the genomes of two bumblebees, which are probably the closest bees to the honeybee itself. We find these genes missing in those bumblebees as well. We don't know how far out we can go. We've looked in some wasps where the genomes have been sequenced and found the genes are present there. So something is odd about the evolution of this clade of bees. And it may be that that happened very early in their evolution and therefore all the bees will be missing these genes, or it may be that it's quite a late thing and just the honey bees and their closely related friends are missing it. We need to understand that more, but it's very difficult in genetics to look for things that aren't there. When you think about a genome it's a very, very big thing, and you're looking for a needle in a haystack, and it's hard sometimes to tell whether something is missing because it's really not there or something is missing because of a technical error.

Robyn Williams: Do you think the work you are doing here will be of any use to the beekeepers in America where they really have got a huge problem?

Peter Dearden: I think it has to be. In America there are lots of…again, there are even worse things happening to bees and it's not terribly clear what those are. Insecticides certainly are a key issue, and while New Zealand has probably had less effect of insecticides on bees, in America and in Europe in particular it's much more problematic. So we hope that if we can develop new chemicals which are effective against other pests but don't affect bees, then maybe they'll be used widely in America and Europe.

Robyn Williams: Peter Dearden is professor of genetics at the University of Otago in Dunedin, and let's hope he's right. We need bees, and now they need us.

Our PhD this week is already doctored, and not like the usual contribution we've had on this program. This one, from the ANU, saw Hungry Beast on ABC television way back and wondered why there's no Hungry Science Beast. So they've made one. Here it is.

Niraj Lal and Hamish Clarke: Hungry Science Beast. Light bulbs with opera, and the brown note.

20 years ago the light bulbs in our homes used to be incandescent. And if they were playing sound instead of light they'd sound a little bit like this:

[discordant musical chord]

A whole bunch of mish-mashed notes. The light that we can see is made up of lots of different colours, and these different colours can be thought of as notes. What incandescent globes do is play all of the notes, including some of the ones that we can't see, kind of like the optical equivalent of the brown note in music.

We've since found out a way of doing it better and playing chords with our light bulbs instead. And if they were playing music, this is what they'd sound like:

[musical chord]

This is what fluorescent bulbs do, and you can see the light that they give from the reflection of a fluorescent bulb from the back of a CD grating. And we've since found out a way of doing even better and playing just a single note with our light bulbs, sounding a little bit like this:

[sings one note]

The pure note of an opera singer. By putting all of our energy into just one colour, one note, we can make the light brighter and save on the energy that we use to make it.

So there you have it, light bulbs with opera and the brown note.

Robyn Williams: Well, I don't know what a brown note is, it sounds dubious. How better to get light from lamps. Hungry Science Beast at the ANU. More in a minute.

[Doctor Who theme music]

And you're listening to The Science Show on ABC Radio National, RN. And you can hear a bit of thumping in the background, which is in fact WOMADelaide. So you've got a mixture of science, of chat, and music. With me I've got Ben from the RiAus who is involved in producing Doctor Who. How long is Doctor Who and the science thereof going to be on the road?

Ben Lewis: Well, The Science of Doctor Who, the first dates we have are in Perth on April 26, then we go to Sydney, Adelaide, Brisbane and Melbourne, and we finish in Melbourne on June 13, 14, 15.

Robyn Williams: And is there any science in Doctor Who?

Ben Lewis: There's a surprising amount of science in Doctor Who actually. You know, it is science fiction, they take some liberties, but at the end of the day there is some reality in what we see, and that's what this show is all about. It's all about having fun with Doctor Who but exhibiting some of the science that is influencing that.

Robyn Williams: Have you been able to work out what he's a doctor of?

Ben Lewis: No.

Robyn Williams: Well, there laughing along with us is Martin. Martin, are you the Doctor?

Martin White: No. Many students have said this in the past because of my accent but I have definitely never travelled through time and I've never killed any alien races.

Robyn Williams: I see, but you are a theoretical physicist at the University of Adelaide.

Martin White: Yes, and an experimentalist on the Large Hadron Collider. So one of the things we talk about in the Doctor Who show is the extra-dimensional element. So the TARDIS is famously much bigger on the inside than it is on the outside, that's accomplished using extra space dimensions, which we are hunting for in the collider. We should be able to see them if they are there.

Robyn Williams: How would you recognise them?

Martin White: Well, when you smack protons together they could make particles which literally disappear into the extra dimensional and you can plot a graph on your computer which would have a series of bumps in it that tell you how many dimensions there are and how big they are.

Robyn Williams: And Ben, do you have a cosmic or sonic screwdriver?

Ben Lewis: Yes, I do. My collection is nowhere near as big as our host of the show, Rob Lloyd, who has every one ever made and probably multiple copies of each. He's absolutely obsessed with Doctor Who, so his collection does put mine somewhat to shame.

Robyn Williams: Martin, does the sonic screwdriver kind of work scientifically?

Martin White: Well, I think it certainly works as a plot device, although whether it's an elegant one the audience can decide. You could technically do everything that that thing does with sonar, but I think it would be difficult to miniaturise the device. A dolphin would actually be a very effective sonic screwdriver.

Robyn Williams: A dolphin?

Martin White: Yes, dolphins take their young to the bottom of the sea and talk to them with sonic booms. That's a little known fact about dolphins.

Robyn Williams: Are you serious?

Martin White: I'm absolutely serious, one might say deadly serious.

Robyn Williams: And what happens when they do that?

Martin White: I imagine the young ones get very annoyed.

Robyn Williams: Or leave home.

Martin White: Yes. It's a big home if you're a dolphin, right?

Robyn Williams: So far you've got the Hadron Collider that is large and small inside and out, and you've got the sonic screwdriver. What else? Are you scratching the barrel to find some real science with Doctor Who?

Martin White: Well, the biggest thing is of course time travel. So we actually early in the show introduce people to Einstein's relativity and whether time travel is physically possible. There are lots of other nice bits of science in Doctor Who like cloning. You know, human cloning has probably happened somewhere or is about to happen, so we kind of explore the ethics and the philosophy of that.

Robyn Williams: Well, it's not a very long show in that case.

Ben Lewis: We go through star formation and black holes, time travel, extra dimensions, as Martin has already talked about as well, parallel universes, life on other planets, cloning, teleportation. So we go through about ten of the most common scientific theories that you come across when you watch Doctor Who. So in total we're looking at a roundabout 75 or 80-minute show, really good fun. We race through it all and it pumps along, it's really punchy, so it pumps along at a good speed and we have a lot of fun with it. It's a show written by fans. We're fans of Doctor Who.

Robyn Williams: Have you done it…in other words, trial runs, previews here in Adelaide?

Ben Lewis: Yes, in 2012 we did it for Adelaide Fringe, and we did a couple of shows and they were **sold** out, a huge success. And from that we've now developed a relationship with BBC Worldwide, Australia and New Zealand, who are helping us out with this tour as well. So really that partnership stemming from those earlier shows allowed us to really take this up to a whole **brand** new level.

Robyn Williams: One of the problems, Martin, is that Doctor Who fans and Trekkies are notoriously picky. Are you worried about being found out getting something wrong?

Martin White: Well, we used to have a question and answer section in the show, and we expected obviously the public to ask us science questions because we spent years training in science, and all you ever get is, 'Well, in episode seven of Remembrance of the Daleks, is it true that this happens and this happens,' and we just had to refer them to our host who is such a Doctor Who fanatic. I think he knows more than Steven Moffat knows about Doctor Who. Steven Moffat, for those who don't know, essentially writes the show nowadays or leads the writing. He should be the top Who but he isn't, it's Rob Lloyd.

Ben Lewis: He wows us every single day with his encyclopaedic knowledge of Doctor Who. There's only ever been one question which I've asked him about Doctor Who which he hasn't been able to answer, and I won't reveal what that question is because I like to torture Rob with it. But he has an unbelievable knowledge of Doctor Who, he really does live Doctor Who, and he even looks suspiciously like David Tennant as well, which is a bit of a bonus I think.

Robyn Williams: So do you actually, if you had a shave. But talking about Steven Moffat, who wrote many of the Doctor Whos, he of course writes and is behind Sherlock. Now, Sherlock, there you have some science because that's based on a doctor in Scotland who had the kind of Dr House, you know, another Sherlock type, the duo is famous in literature. Were you temped perhaps to follow it up with a Science of Sherlock?

Ben Lewis: You never know what might happen in the future or the past anyway, talking about Doctor Who. But you're right, there is a lot of science in a Sherlock and there's a lot of ideas that can possibly be produced out of that.

Robyn Williams: You're going on the road, remind us, you're going to Sydney, Perth…what dates?

Ben Lewis: Perth we are April 26, then we head up to Brisbane on May 10, Sydney on May 23, 24 and 25, Adelaide May 31, and we finish up in Melbourne June 13, 14, 15.

Robyn Williams: And people can get tickets from the usual place?

Ben Lewis: The best place to go to for tickets is RiAus, that's riaus.org.au/doctorwho. And it's got some information about the show and booking links for all the cities.

Robyn Williams: It's the Royal Institution Australia, based in Adelaide, is it not?

Martin White: It is indeed, in the Science Exchange Building.

Robyn Williams: And one last question; you're doing work on the Hadron Collider, have you got anything yet?

Martin White: Well, of course we saw the Higgs boson which was dramatic. It's currently resting because we are upgrading it to run at higher energy. It will start again probably next April, and we will be looking for extra dimensions and supersymmetry, for fans of those.

Robyn Williams: Good luck on the road.

Martin White: Thank you very much.

Robyn Williams: Dr Martin White from the University of Adelaide, and Ben Lewis from RiAus, taking Doctor Who on the road. And another word from Hungry Science Beast, now having a shower:

Niraj Lal and Hamish Clarke: Hungry Science Beast. Why shower curtains are evil.

There's nothing like coming home at the end of a long day and jumping in to a nice, hot shower. Until [screams] the shower curtain starts to creep eerily inwards towards you, wanting to stick to you like a long lost lover.

What's going on here? Well, the air particles on the outside the shower curtain are constantly pinging on it, pushing it inwards. The same with the air particles on the inside of the shower curtain, constantly pinging on it, pushing it outwards.

Everything is usually nicely in balance, until you turn the shower on and the water droplets start moving the air particles around and the air particles start heating up, becoming less dense and moving upwards. And all of this means that there are less air particles on the inside of the shower curtain pinging on it, pushing it outwards, allowing it to creep eerily inwards towards you.

If you have the misfortune of the shower curtain actually touching your skin, and in my mouldy share house this is definitely a misfortune, then the shower curtain seems to want to be able to stick all across to your skin.

So what's going on here? Well, the water droplets on the shower curtain get in touch with the water droplets on your skin, and they'd much rather touch their water droplet friends than be in contact with the air on the outside. So this is why the shower curtain wants to stick to your skin.

So there you have it. Nothing evil, but enough of a reason to get my housemates to help clean the shower.

Robyn Williams: Well, Hungry Science Beast is at the Australian National University in Canberra. Niraj Lal is a post-doc fellow making better solar panels. His mate Hamish Clarke studies the impact of climate change.

And both these ingredients, by the way, it's clear, affect the growth of cities. We can either make cities 21st-century style and apply the best of high-tech, even using down-to-earth approaches like the barefoot architects featured in By Design this week. Or we could let it all just happen as we are, with possibly dire results.

Here are the choice is put by Professor Saskia Sassen from Columbia University in New York.

Saskia Sassen: So the future of cities, let me just give you a framing thought. I think that on the one hand we have technologies, capabilities, discoveries, powers of money literally, to develop perfect cities, but of course there is no such thing as a perfect city. On the other hand, we have masses of people who are being literally expelled from the land because the land is being bought up by foreign farms, by foreign governments, who of course have to go to the city. So besides the natural growth of the population in cities, we have people who are expelled from rural areas.

A lot of these people, the first stop is a shantytown. If they are lucky it's a working shanty, a slum, right, you know the language that I'm using. So if I look at the future I see two urban settings, they will be…those two urban settings can happen in New York, in Shanghai, in Nairobi, in many places. And one of them is really advanced urban spaces with extraordinary technologies and capabilities. But the other one is a degraded space. Some of those people may be very creative, generate little businesses, have start-ups, because we see that in the slums, but it is a life of hardship where getting water will be tough, getting electricity will be tough.

So the challenge is can we create more of a balance, not put so many resources in building the ultimate luxury urban settings, and redistribute a bit so that we really have a reasonable mode of urban living. Sure there will be always inequality, always elite spaces, but that most of the people have access to water, have access to food et cetera, and that cities can in fact generate part of their own food, part of their own energy et cetera. And I've been very interested in understanding how the capabilities of the biosphere in the form of bacteria, algae, capturing the energy that movement produces, a whole range of things, how can we deploy those inside cities?

Robyn Williams: Well that's a sociologist's view. Professor Saskia Sassen from Columbia University in New York. She was at the AAAS.

And this week Australia played host to Green Cities, a conference in Melbourne. Our own Janne Ryan of By Design was there. Back at the AAAS though, Antony Wood from the Council on Tall Buildings and Urban Habitat, a Brit who spent useful time at Deakin University in Geelong, shocked quite a few by citing Singapore as an ideal model.

People are often quite rude about Singapore, for chewing gum reasons. Why do you think it's a wonderful place?

Antony Wood: You know, in the early '90s, actually after I was in Australia I went and lived and worked in Bangkok, Kuala Lumpur, Jakarta, and Singapore was a place that I would avoid like the plague because then I was in my 20s and I found it a very restrictive environment. Now with a wife and several children I think that if there was one place in Asia that I would be comfortable living back there, it would be Singapore. I think Singapore has had a bad rap in terms of its political system and some of the perceived restrictions on its people, but I think actually if you go and ask most Singaporeans—most, not all—they're pretty happy with life. And really I think a part of their success has been the kind of benign dictator political situation.

I mean, you look at the alternative politically. Let's look…I mean, is America functioning very well at the minute? Is your country functioning? It is my country functioning very well? So it's all right for us to sit in glass houses and throw stones saying, well, Singapore, they don't have freedom. Well, look what freedom has given us; we are a broken system in many ways.

Robyn Williams: Glass houses! What about tall houses? What is so special about their architecture you think is an example?

Antony Wood: Well, I think that 95% of tall buildings around the world are actually pretty bad pieces of design. Tall buildings are essential for the future, against this backdrop of 180,000 people urbanising on the planet every day, us needing to build a new city of a **million** people every week, we've got to densify our cities. The horizontal city is no longer sustainable. Tall buildings are one way to get that density, not the only way but one way against this backdrop of what's happening in **China**, India, Brazil, Indonesia.

So I believe tall buildings are a hugely important part of the future for our continued existence on this planet. What concerns me and what inspires my statement that 95% of them are terrible is that we've kind of seemed to have subscribed to a global architecture which is homogenising cities around the world, often denying thousands of years of vernacular architecture in these places. You look at **China**, look at India, look anywhere and you will see vernacular traditions in architecture. I'**m** not talking about, hey, these buildings look different. The thing with vernacular architecture is that it was a product of its locale. You didn't have energy to blast in air-conditioning around the space, so if you wanted ventilation you opened a window. And we've thrown all that out 60, 70 years ago with the modern movement, and we've created a homogenised architecture, and the tall building is the worst culprit.

Look at Sydney, look at Melbourne, or Moscow or London or New York or Chicago, and the cities are becoming homogenised. Now, it upsets me in two ways. One is an aesthetic way, because I travel around the world because I'**m** interested in the difference between places. But whether you accept that or not, it upsets me more because in doing this we are denying the opportunity for the building to coexist in its environment.

Robyn Williams: How could it look good so as not to disgust you?

Antony Wood: Well, that's why we could come back again to Singapore. Singapore has 60-storey green walls. I have these 10 design principles of which future tall buildings should be based, and one of them is we need to embrace vegetation into the material palate. So, you know, somewhere like Singapore is pretty blessed in terms of a relatively static climate that you can rely on the whole year round. But if you look at your average tall building, the architecture, the expression has not progressed much in the last 70 years, it's just a glass extruded box, like Mies van der Rohe created in the 1950s. It's ridiculous. It's 70 years later, we live in a different challenge. The challenge is how do we continue living on this planet? Therefore the buildings should be permeable, they should be built out of vegetation largely, they should have a mix of uses, they should be naturally ventilated, they should generate energy, they should generate water, they should maximise the capture of water. There are hundreds of things that they should be doing and are not.

Robyn Williams: Is anyone applying any of those 10 principles?

Antony Wood: Yes, there are. So I come back again to Singapore. If you look at the Pinnacle housing scheme in Singapore, that is government-built high-rise housing…just put those words together in most Western countries, 'government-built high-rise housing'…

Robyn Williams: And people run.

Antony Wood: It spells disaster. But 80% of people in Singapore live in government-built high-rise housing. And this Pinnacle housing scheme is seven or eight social housing towers linked at three levels with significant urban habitat. So you've got parks and running tracks and all manner of stuff at 40 and 60 storeys up in the sky, it might be 20 and 40, it doesn't really matter.

But it's not just Singapore, it's happening in other places. I mean, Europe…you look at the Commerzbank in Frankfurt, 1997, Norman Foster architect, Commerzbank, still largely unsurpassed in terms of an ecological tower because every single level of that building has at least a visual, if not a direct physical connection with a significant sky garden. They have access to natural light and natural ventilation and physical communal space. Now, that is a model for a residential tower. It's a commercial tower, it's an office tower, but that's a model for a residential tower, because that is what is disappointing about residential towers, is they don't put in the infrastructure for community to develop; space, preferably green space.

Robyn Williams: So you're actually picturing something that is not only a tall building but it's horizontal on various levels as well, so it's spreading out sideways.

Antony Wood: Absolutely. You look at almost any science fiction cinematography, city of the future. From 1929 Metropolis onwards, through Blade Runner, through Star Wars, through Sixth Sense, whatever, almost every city that's ever been created in the future is a multilevel city, and some of these are based on dystopias, not utopias, you know, social dystopias where you see social stratification, and the rich are up in the clouds and the poor are down at scum level down on the ground. I'**m** not necessarily advocating that. But the reason that all these cities of the future are multilevel cities is because it is totally nonsensical that we are going to 200, 300, 400 storeys without connecting these buildings. So is that ridiculous, or is going travelling down 200 storeys for a cigarette on your cigarette break ridiculous?

Robyn Williams: Well, is it affordable? Here's a world where you've got the **Chinese** and others showing how you can stick one of these towers up, having modular bits and do it very, very quickly and presumably cheaply. Can you afford to have the kind of vision that you've just outlined?

Antony Wood: Well, you just hit on the number one thing there. Is it affordable? The answer is yes. And it's affordable but it needs a completely new socio-political, economic way of thinking of our cities. So let me ask you this. In cities nowadays, whose responsibility are the parks, the sidewalks, the sewage infrastructure, the power networks, the roads, all those things? It's the city government. Whose responsibility are the buildings? It's the private developer. What I'**m** saying is that we need to take that two-dimensional interface of this infrastructure plus building and we need to flip it vertically so that any building is a public-private partnership. And the public element invests in the infrastructure in the building, together with the private.

It's not without a challenge but it's pretty obvious that if you've got a city and you're not going to go horizontal because the horizontal model is unsustainable, but over the next 10 years you are going to go from 1 **million** to 10 **million**, which is what we are looking at in places in **China** and elsewhere, then we need to recreate aspects of the ground floor to support those extra 9 **million** people that are going to be living in the sky. And to do that we need to get the government and private industry to work together so that financially these buildings become a shared concern.

Robyn Williams: Well, there are two buildings that I've seen which are green, and one of the most famous ones in North America is actually in Vancouver on the campus of the University of British Columbia, another one in Brisbane at the University of Queensland, the Global Change Institute, just opened. And they've got many of the elements that you describe, and they have said that they cost maybe 25% more than the standard building, but having explored ways of doing it, it will become cheaper and cheaper as other people follow their example. Does that make sense to you?

Antony Wood: Absolutely, it's very simple, its economies of scale. I mean, the first time you do anything it's going to cost a hell of a lot more money, and history is littered with examples of great ideas that didn't work, perhaps because of their implementation or marketing that were brought back. You know, it wasn't that long ago, maybe 20 years ago someone actually created a tablet computer that totally flopped, and it took Steve Jobs to bring the development of the iPad. So it's the same with the building technology. It might be 25% more expensive to have created that particular building in Brisbane, but once you create the second and the third and the fourth, and actually really the real question becomes can you afford not to.

You know, at the minute, and this is going to sound melodramatic, but at the minute we are still in a period of choice with sustainability, a period of choice. That means we can still choose whether to turn up or down our air conditioning, get in our car or not, use recycled bags. We are still in an element of choice, and everybody is making that choice. We are rapidly moving towards a plane of survival. You've seen it in Brisbane, you've seen it in Christchurch, you've seen it in London now. I checked the news the other day, three things; bushfires in Australia, flooding in the south of England, unprecedented storms on the east coast of America. One morning. We are rapidly getting to where it's no longer going to be down to choice but survival. Then the economics change fundamentally.

Robyn Williams: In the investigations you're doing, do you include how people can live in these new surroundings, up in the sky, going horizontally and so on? Would it be a drastic change for us to be up there?

Antony Wood: I think it would be a drastic change. And by the way, we are not suggesting here that Sydney has got to pack in its suburbs all the way to the Blue Mountains and everyone has got to load up their car for a one-time journey into a dense city. In America we are projected at 0.9% per annum population growth, these people that are moving to America, partly through immigration, partly through population rate, they don't want to live in Detroit, they want to live in the sunbelt cities. So what we are seeing is…you know, Dallas is projected for a 52,000 people per year population growth for the next few years, that's a significant number. It ain't quite what's happening in **China** but it's a significant number.

And so we do need to densify those cities, and in doing so I think there is a fear; oh well, we've got to pack up our single family home and we've got to find a whole new way of living. Well, look at Seoul, **Hong Kong**, Singapore, and many other cities in Asia where they've been living that way for 30, 40 years. And actually, if you look at it statistically, Singaporeans enjoy a higher standard of life than most Western nations. And if you meet a Singaporean, somehow they've managed to make this transition. And I think that's the thing, it's no longer going to be an element of choice it's going to be an element of survival, and we don't yet know what we need to do. If it's a matter of our continued existence on this planet, more people need to start living on smaller plots of land, I think we got away with it lightly.

Robyn Williams: Getting away with it now, maybe not much longer without applying some real vision. Antony Wood is executive director at the Council on Tall Buildings and Urban Habitat. And he's also associate professor at the Illinois Institute of Technology. He was at the AAAS. And there's much more on some of these ideas like vertical gardens and agriculture coming up in Off Track. That's on Saturdays after this program at 1 o'clock, and on Sundays at 6:30am on RN. Off Track is presented by Ann Jones.

Next week on The Science Show we go into space and do some experiments on that space station. Why is zero gravity important? You'll be surprised. And also visit San Diego Zoo to feed some pandas. Meanwhile, don't forget Gold and the Incas still astounding visitors to the National Gallery in Canberra. It's on until 21 April.

Production today by David Fisher and Leila Shunnar. I'**m** Robyn Williams.

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