

Things You Can't Live Without

S2 Episode 1 – Dr Adam Rutherford on bodies, blue-sky projects and blue-blooded crabs

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Dr Anna Ploszajski: [00:00]

Hello and welcome back to Things You Can't Live Without, the podcast where I, material scientist Dr. Anna Ploszajski, ask a special guest to tell us one thing they can't live without. Like last series, we interrogate a host of experts to find out how these items are made, where their components come from, and how the future of those items is being planned for. Joining me today is Dr. Adam Rutherford, a scientist, writer, and broadcaster. Welcome, Adam.

Dr. Adam Rutherford:

Hello, Anna.

Anna: And I'm also joined by Marie-Pierre Paquin, Head of Science and Partnerships at Rio Tinto, who will be taking us through the innovations in sourcing and processing the materials that we need for crucial scientific research. Welcome Marie-Pierre.

Marie-Pierre Paquin:

Hi Anna. Hi Adam.

Anna:

So, Adam, what is the one item that you can't live without?

Adam:

Well, we had a bit of a problem getting to this point, because when you asked me, my initial response was poo poo'd. You banned it, and it was flesh. I mean, it was bodies.

Anna: [01:02]

Yeah.

Adam:

And then my second suggestion was going to be temperature, or low temperatures, in order to preserve the bodies that we work on as geneticists. But apparently, cool is not a material.

Anna: [01:04]

Not a material. Yeah, correct.

Adam:

So, we've gone for fridges.

Anna:

Fridges. And yes, material scientists don't consider anything bleedy or squishy to be a material.

No, thank you. Marie Pierre, what do you think about fridges as an item? Can you live without a fridge?

Marie-Pierre: [01:32]

No, no, I can't. And as like a lot of people I do own a fridge, and I do own a freezer. But I don't put body part, human body part in it. Last summer I went for a weekend, and I didn't close the door properly. So, when I came back nothing in the freezer was proper for safe consumption anymore. And I will leave the details out. It made the freezer like very obvious that's something that we need for health and for general wellbeing and I'm reading this book by Anna Ritchie and she's proposing data on how access to clean water changed the life expectancy health of different communities. And it got me thinking like, how would it affect different regions of the world where they don't necessarily have access to electricity, or a freezer, or a refrigerator to keep their food safe, or even vaccine and certain medicine. How would that affect their life expectancy and the quality of life in general?

Anna:

It's totally something we take for granted, isn't it? So, you thought fridges wasn't an interesting option, Adam, but we've already got into it.

Adam: [02:39]

Well, and the defrosting thing is, I mean, yes, it's incredibly annoying when you leave your fridge or your freezer open and the food goes off. Imagine how bad it is when you do that for a freezer which is a minus 80 and contains literally unique samples of DNA or tissue taken from the ground, from a fossil, that's why minus 80-degree freezers in biology labs have alarms on them.

Anna: [03:00]

That sounds like a very useful feature for sure. We're going to be thinking much more about how important the fridge has been, not only in scientific research, as you've been saying, Adam, but also to our lives. I also really want to get into how research and development is helping innovation and progress in general. But first, Adam, I want to get a bit more stuck into you and your job. So, you're a geneticist and lecturer at University College London and I know some of your books have been related to science, eugenics, race, a brief history of everyone who ever lived and how to argue with a racist. Where did your interest in genetics and the human body first come from?

Adam: [00:03:45]

Well, I went to university in fact to do medicine and I had decided not to be a doctor, and I think the third day, when I just had no particular interest in practicing medicine. I finished a year, and I wanted to pass my exams and then I transferred to genetics. It is the science that underlies all bits of biology, right? You know, it's a young science. It's only 100 years old in any sort of meaningful sense. The word gene was only invented in 1900. But it is also the study of families and inheritance and sex and disease and those are things that have been preoccupying people's minds for well since people have had minds. In the 90s, I started as an undergraduate in the same year the human genome project did so we were about to enter this Golden Age of Discovery just by chance and go through this process, this sort of transformational process in our understanding of genetics, which is ongoing and we're in the thick of it now.

Anna: [04:40]

Okay, well, let's get back to fridges and dead bodies. Fridges and freezers are really important pieces of equipment for laboratories everywhere. Why is that?

Adam:

Because bodies degrade, they need to be maintained at certain temperatures during life, where all of your tissues are being replaced by very active processes to replace molecules and to do the functions of, and that all takes energy. As soon as you turn off the power supply, we start decomposing. Now, the bit that I'm interested in is how bodies get preserved when they die. And

there's a specific reason for that, which is that in the last 15, 20 years, we invented the ability to extract DNA from people and other animals who have been dead for thousands, tens of thousands, and in some cases, hundreds of thousands of years. And that has completely revolutionised our understanding of evolution, particularly human evolution. Now the temperature bit is relevant here. Because DNA is well preserved at cold temperatures, but badly preserved when it gets warm. So, we've got lots of DNA from the Northern Hemisphere, and the further north you go, the better preserved it is. But we've got none, none from Africa. And that's a real shame, because most of our evolution occurred in Africa.

Anna: [06:14]

Wow, so we need cold temperatures and for that DNA to have been stayed frozen basically for thousands of years.

Adam:

Yeah, I think I'm right in saying that the oldest DNA we have so far recovered, it's about a million years old.

Adam: [06:25]

It's not from human. I think we've got some equine DNA, and we've got some plant DNA from about that time. Animals or plants that were buried in snow and ice and have been compacted. So, they're really, really well preserved.

Anna:

That is incredible, isn't it? So that's why you need these fridges and freezers in your lab is so that you can continue to preserve those tissues and be able to get as much information as possible out of them.

Adam:

Exactly.

Anna: [07:00]

But Marie-Pierre, I'm guessing that Rio don't do a lot of genetics research, similar to what Adam's describing, but could you take us through this sort of research and development that does go on at Rio Tinto?

Marie-Pierre:

We actually do some with some of our partners. So, one of the team we're working with is looking at all kinds of bugs. Bacteria and other organisms that you can find in like a mine site, for example. And they're studying these organisms to see if they could extract some of the valuable material. For example, a bacteria or bug that lives naturally in a copper mine environment, would be able to sustain a high level of copper in its own organism and will survive to that naturally. And understanding those type of organism might help us find ways to extract those material in a very different manner than what we're doing today. So there is some study, and they actually use those, very fancy fridge to keep the sample at the right temperature and be able to do the sequencing, of these samples.

Adam: [08:07]

Well, I was just going to say that caves and mine systems have become an incredibly rich resource, not just for the minerals that you're looking for, but also for novel biology. Because what we've discovered in the last few years is that there's life everywhere and you can go down like seven or eight kilometers and find new bacteria.

As Marie-Pierre is saying, they often have extreme behaviors because they live in these unusual environments. We call them extremophiles. And so we find life that lives at extremely hot temperatures in hot springs or ridiculously cold temperatures, but also things that process, for

example, high levels of copper because the environment is such, that's what they have to feed off or methanogens who process methane rather than oxygen. Looking in caves and looking in mines for extremophiles before unusual biology has turned out to be a very rich potential source for new antibiotics. So, there is a real link between environmental geology and both genetics and subsequently medicine.

Anna: [09:14]

That's so interesting. And it reminds me of, people might remember those headlines from a few years ago, where scientists in Japan discovered that bacteria were munching on plastics in landfill sites. They had evolved to metabolise, digest, I don't know if that's the right word, these polymers as food. And it sounds as if they've also been munching on copper and other minerals that we might mine as well.

Adam:

Yeah. I mean, the cliché, the line from Jurassic Park is 'life will find a way', and it is true. It is mostly bacteria. Most life on earth is bacteria by weight, by number, even on and in you, you are more bacterial cells than you are human cells, but pretty much wherever we look, we find bacteria and similar types of cells that are doing things that we were previously unaware of.

Adam:

So, I think R&D departments should always be talking more to each other about what is in there. Because if you're exploring, it doesn't matter whether it's geology or biology, we're going to find new things which are going to be interesting and potentially of use.

Anna: [10:21]

For sure. So, Marie-Pierre, as well as the genetics research that you mentioned that Rio is working on, what are the other sort of major R&D areas?

Marie-Pierre: [10:29]

There's so much I was thinking about it and it's like picking your favorite child, but I'll try I'll try to share a few with you. There's a team in our iron and titanium business that is working with one of the startups we invested in that are looking at new ways to use biocarbon to replace fossil-based carbon in our process. That would have a tremendous impact on our greenhouse gas emissions.

Anna:

What's biocarbon? What do you mean by that?

Marie-Pierre: [11:00]

So, we call biocarbon carbon that is from biomass. So, whether it's barks, it's like trees or it could be other kind of like biomass residue that can be harvested in a sustainable manner. Other project, we're also investigating carbon mineralisation. So, it's a way that we could potentially store CO₂ in a safe and permanent manner in a rock form. So, no risk of leakage or anything like that. There's also a team called Nuton™ looking at heap leaching of copper. So, heap leaching is a technology where you build some mountains of ore. So, you put it in a big pile, once it's mined, and then you will put a reagent on it. And the reagent will just percolate through the heap and collect the metal as it just percolates it. So, it's kind of a passive way to extract material from the ore and get it into solution. So, it's very low energy and low impact on the environment.

Anna:

Love that, stick it in a big pile.

Marie-Pierre:

Which would remove the need for a very expensive smelter being built and reduce the footprint in general of copper mining. So, these are all super exciting projects. They all have one thing in common. They have a reduced impact, whether it's less water use, whether it's less land

disturbance, whether it's less energy consumption or greenhouse gas emission. And environmental impact in general and societal impact in general, they all aim at reducing that.

Anna: [12:35]

Awesome. As I said earlier, most material scientists like me won't go near anything squishy or anything that is liable to bleed on them. There's that funny kind of separation in my mind between kind of biological materials and my materials, the material scientist materials. But of course there are massive crossovers in both. Do either of you have any guesses on how many elements of the periodic table are contained within a human body? Do you know the answer already?

Adam:

Ooh, that's a great question.

Anna:

There's 118 elements.

Adam:

I would guess it's fewer than 20.

Marie-Pierre: [13:15]

I would guess it's more than 50.

Anna:

Okay. The answer is surprisingly low. It's actually 21.

Adam:

Hey, not bad. I reckon I could rank them.

Anna: [13:30]

Go on then.

Adam:

So carbon, oxygen, hydrogen, obviously. That's going to be most of them. Yeah. Then there's quite a lot of phosphates because that's one of the key elements of DNA. Then there's going to be plenty of iron, magnesium, calcium. And then lots of other much more tracey metals. Not very good.

Anna:

Yeah, you're doing really well. There's a big one that you haven't mentioned. If you think about like hydration.

Adam:

Oh, sodium.

Anna:

Yes, sodium, exactly.

Marie-Pierre:

I guess you would need magnesium and potassium.

Adam: [13:58]

That is an excellent pub quiz question. I wonder how many of my biology colleagues could do 21 of them.

Anna:

Yeah, that's so true. Yeah. So we've been talking about mining and minerals, but also minerals in the human body. One of the kind of the big metals in mining is of course iron. And we know that this is important to the human body. What does it actually do, Adam?

Adam:

It's so fundamental to human biology because it's the oxygen carrying molecule in red blood cells.

Adam: [14:25]

And the reason they're red. is because they have iron in the centre of them. Hemoglobin are protein molecules. The oxygen is transferred in the lungs to the centre and carried by iron in the body. And that's why our blood is red. I mean, interestingly, not all organisms use iron as the oxygen carrying molecule. So for example, crabs and other crustaceans use copper. And so that is why the blood of crustaceans is blue and not red because copper is in their oxygen carrying molecules instead of iron.

Anna: [15:00]

What? That is a great fact. Marie-Pierre, I want to ask you about mining copper. How fundamental is it to Rio's operation?

Marie-Pierre:

We do have like quite a few operations in copper. We have this huge mine in Utah near Salt Lake City, Kennecott Copper. We have our operation in Mongolia and a couple of a joint venture and a lot of our resources around exploration are turning towards copper. And the reason for that is that the amount of copper that will be required for the energy transition is tremendous. There's estimated around in the public domain that we'll need as much copper between now and 2050 as ever been produced by humans ever. Like, since the beginning of time, since we started to use copper.

Anna:

And that includes the Bronze Age, which was really, like, big on copper.

Marie-Pierre:

Yeah. So, we need more copper between now and 2050 than whatever we've produced before. So, obviously, recycling is a big part of it, but we don't have enough copper in circulation even to sustain our needs for the energy transition. So obviously copper is going to be critical moving forward. Think about AI, all these data centre and everything. This will all require copper to be implemented. So that's why copper is such an important metal for Rio Tinto.

Anna: So what are you doing about it? How are you meeting that need?

Marie-Pierre: [16:27]

We are dedicating a lot of our resource towards exploration of copper, but we're also looking at different resources where we can find copper. We launched, last year, the Centre for Future Material in collaboration with five different universities. We have a university of California, Berkeley, that is working with us, UBC in British Columbia, Canada, we have WITS in South Africa, ANU in Australia, and the centre is managed by Imperial College of London. We put the challenge to ourselves to look at the material required for the energy transition. This was launched to celebrate the 150th anniversary of Rio Tinto. So looking at what are the material required for the energy transition - copper is obviously one of them but there's many others. Where can we find those materials? So is there different sources than the one we've been exploiting for a long time? And then how can we extract those material in the most efficient and sustainable way? And there's a big social component to the centre where we look at how can we make those operations socially acceptable for the very nearby community, the first owner, or the traditional owners, the government, and the society in general. Because the time between a copper deposit discovery and actually moving it to a mine in operation and getting copper out of the ground, the average time is

about 20 years. So, 20 years is a long time when you think about the energy transition and meeting all of those requirements in the coming decades. So, we cannot wait 20 years to have more copper available. So how can we do differently? How can we do with different type of resources? Can we extract copper from waste? We usually extract copper from copper sulfide, but is there other source like copper oxide that can be unlocked with different process?

Anna: [18:39]

Do you have anyone voicing the crab community so that to protect them from copper mining of their blood?

Adam:

I think that it would be such small quantities that you'd need a lot of crabs.

Anna:

Good, okay. The crab community are safe.

Marie-Pierre:

It has not been proposed yet.

Anna: [19:00]

Good, okay. No, but seriously, that does sound amazing and looking at it being a sort of necessary for modern life, but making sure that it is being done responsibly and from lots of different angles as well.

Anna:

Adam, what in your research is exciting you at the moment?

Adam:

I don't actually do any wet work anymore. And so even coming in and saying the fridge is essential. It is essential for my work as a field, but it's not essential for me. The fridge in our lab is for keeping milk and beer cold. So, all of our work is now computational and we get huge data sets. And process them, look for patterns. We're looking for patterns in DNA. So, our genomes are the most complex data sets that exist in the world. So as Marie-Pierre was saying, we need more data storage. We need more internet capabilities. And all of those things are going to be reliant on the extraction of rare minerals. I mean, lithium is going to be a big problem for battery storage going forward. And so it just shows the interconnectedness of disparate fields, right? We need fridges to do our work and we need chemicals that make those fridges and we need copper wires to do things like this.

Anna:

Yeah, exactly. And thinking about research and development and, how some of it can be, I suppose, quite fundamental, do either of you have a kind of a way that you sell that sort of fundamental research to funders who would be needing to invest in it?

Adam: [20:31]

What you're referring to is we sometimes call blue skies projects. So things that don't have direct applied or translational economic value. So, curiosity driven research is more lucrative to society than directed research. If you can show the numbers on that and do the economics and show that to governments who tend to have shorter lifespans than research projects. But if you look at the economics of the Apollo missions, the most conservative estimates are that the return on investment was seven to one. For every dollar spent, seven was returned to the economy, and that is what long-term planning in blue skies research and science can do, and that's what governments should be listening to.

Marie-Pierre: [21:17]

I really like your comment here, Adam, and that's very similar to the approach we're taking with the Centre for Future Materials. For us, it's a new way of working. It's a new way of working for the university also because often they are used to being told, like, work on this specific issue with the industry, but now we're telling them, tell us what are the key breakthrough that needs to happen.

Anna: [21:40]

For sure. I want to do a brief beat on thinking about the future before we wrap up. And Marie-Pierre, maybe I can come to you first. In thinking about our understanding of the planet and how the research and development going on at Rio is teaching us about that. What key discoveries are you looking forward to? What's on the horizon that will really change that understanding.

Marie-Pierre:

I might talk about two things I'm very passionate about. One is understanding biodiversity. So, we pledge to protect biodiversity, but how is it that we're going to measure biodiversity? What's a good level at which we need to restore biodiversity? The other one, it's the ability to drill deep wells at a much reduced cost. So, drilling in exploration is very expensive. Drilling in mining is expensive drilling for geothermal is extremely expensive and it's a big hurdle for the development of a lot of project. So, if we were to develop a drilling technology that allow us to go very deep in the earth crust at a very low cost, that would unlock so much potential around like brine mining, potential around geothermal power generation, carbon mineralisation, resource exploration, and even things that are emerging like geological hydrogen would be accelerated quite a bit by the ability to drill at a lower cost.

Anna:

Thank you. And same question for you, Adam. What are the key things that would represent breakthroughs that would really teach us about how genetics work?

Adam: [23:15]

I think that the key thing for us is we need more genomes. Right, so this is now a field which is dominated by large data sets, and the only true way we can understand life on earth, human life, human disease, human evolution, but also the evolution of all species, is to get more DNA. It's a data driven issue. Geneticists have become bioinformaticians, but we've also become historians as well. And so really understanding the way that evolution has progressed can only be revealed if we just get more data. So, we're just data hungry right now.

Anna:

And all of that's going to need copper. Well, that brings us to the end of our discussion today. I think from my perspective, maybe before I accept any dinner invites from either of you, I might just check the fridge for dead bodies or dead crabs we've got onto now. Yeah, I've certainly found a new appreciation for copper for sure. You know, a material that is primarily thought of as being one for electronics and for heat applications, fridges, bodies, the planet, all of it has copper in it, and that's something that I never tire of with material science is that there's always new things to find out about these familiar friends of materials. A huge thank you to my guests this episode, geneticist Dr. Adam Rutherford and Rio Tinto's Head of Science and Partnerships Marie-Pierre Paquin. Thank you both so much.

Adam:

Thank you.

Marie-Pierre:

Thank you, Anna.

Anna: [24:41]

And now it's time for me to responsibly store away the first episode of this series at minus 80 degrees celsius for optimum freshness. You can listen to more episodes of Things You Can't Live

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