RioTinto

Transcript

Things You Can’t Live Without

Episode 10 - Hod Lipson’s Graphics Processing Unit

No. of words	2,555	Time	24 minutes

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Anna Ploszajski [00:00]
Welcome to Things You Can't Live Without, the science podcast where I, material scientist Anna Ploszajski, ask a special guest about the one thing that they can't live without. Despite us living for this stuff, we know that all of it has an impact on our planet. So together we'll find out from experts about the science behind the energy, materials, processes and people power that goes into making our favourite things exist, and what needs to be done so that we can continue making it all sustainable into the future.

Anna Ploszajski [00:00:35]
Joining me today is Dr Hod Lipson, an author, speaker, and researcher at Columbia University who works in the areas of artificial intelligence and robotics. Hod and his students love designing and building robots that do what you'd least expect robots to do. Self-replicate, self-reflect, ask questions, and even be creative.

Anna Ploszajski [00:00:58]
Welcome, Hod, to Things You Can't Live Without.

Hod Lipson [00:01:01]
My pleasure.

Anna Ploszajski [00:01:02]
Really nice to meet you. So, tell us, what is the one thing that you can't live without?

Hod Lipson [00:01:07]
Well, you know, the thing I cannot live without is a GPU. And probably you won't be able to live without one too.

Anna Ploszajski [00:01:14]
So can you describe to us what a GPU looks like and what it does?

Hod Lipson [00:01:18]
Well, a GPU is sort of like a computer, but it's really many, many computers stuck together into this enormous supercomputer, but it's something that's so compact, you can actually carry around, put it in your desktop, you can put it in your phone, but it really underlies all of the AI revolution that we're seeing today.

Anna Ploszajski [00:01:38]
Fantastic. And to take us through what Hod's GPU is made out of, and how it came to be, we're also joined by Rio Tinto's Chief Executive of Minerals Sinead Kaufman. Welcome, Sinead.

Sinead Kaufman [00:01:49]
Hello. Thanks, Anna.

Anna Ploszajski [00:01:51]
Really nice to have you here. Can't wait to talk to you more. But first, Hod, I want to turn to you. Our listeners will likely be listening to us today on some sort of device, probably a smartphone or a laptop. Are GPUs allowing this to happen?

Hod Lipson [00:02:07]
So, behind the scenes, GPUs are sort of, you know, they underlie almost anything that involves AI, involves real time processing. So, there's a lot of history behind it. It all started with gaming and things like that. But right now it's sort of, it's really the, all the horsepower of computing and learning, machine learning, image processing, all of that is happening on GPUs. And the more GPUs, the larger, the faster they are, the more stuff you can do.

Anna Ploszajski [00:02:36]
So we're surrounded by these things. We, we all rely on them, even if we don't realise it. How about you? How are you using them in your research, in your work?

Hod Lipson [00:02:46]
So, the beautiful thing about GPUs, and originally they were sort of intended for gaming. The G is there for graphics, graphics processing units. We use it, uh, for machine learning.

Hod Lipson [00:02:59]
So besides the use at home when I have a TV or a phone, we use it in the lab. All day long, and we beg for these things to be bought. And if you look at what, you know, the bottleneck that's preventing, big companies from becoming even bigger, the open AIs and the Googles, it's access to GPU.

Hod Lipson [00:03:20]
It's also one of the biggest consumer of electricity. It's one of the biggest, you know, there's materials involved that are hard to get.

Anna Ploszajski [00:03:29]
Can you paint us a picture, maybe, of the sorts of applications that you're working on in robotics?

Hod Lipson [00:03:36]
Sort of things that, I would say, in the past, people thought it was impossible for computers to do, like be creative.

Hod Lipson [00:03:43]
It was almost an oxymoron to say that a machine could be creative. But now we're seeing generative design everywhere. And it's growing in capacity and capability. And that's the kind of thing we work on. We work on making machines that can design things, AI that can design and make engineering designs, not just write poems, but, you know, design antennas and, and, robots and things like that.

Hod Lipson [00:04:07]
But we also, in particular, recently work on this big question of self-awareness. Can robots be self aware? Can robots be conscious? Can robots have feelings? And I know it sounds fantastical. I think it's around the corner and underlying all of that is a huge amount of computation.

Anna Ploszajski [00:04:26]
Has that been the limit so far, the computational power?

Hod Lipson [00:04:31]
You know, oddly enough, it's a, I, I don't know if it's the limit, it's certainly a, a, necessary ingredient. And without having a lot of computing power, you cannot get, to these, you know, very interesting levels of intelligence, of machine intelligence that are involved in things like creativity and self-awareness.

Hod Lipson [00:04:52]
These are sort of, uh, almost the holy grails of, intelligent, of, of machine learning, if you like. And, they definitely involve a lot of computing power. Now, it doesn't mean that just a lot of computing power and we're done, there's a lot more to it.

Anna Ploszajski [00:05:07]
Can you give us maybe one example of your favourite robot you've developed or kind of interesting story, any surprises?

Hod Lipson [00:05:14]
Yeah, well, you know, we have, we are, just now building a robot that, it's, it's a humanoid face, it's a soft face, and it's learning to make, facial expressions that, are sort of, meaningful to, to people, it's learning, and in particular what I've learned, we, we try to do right now, it's really hard, if we try to get the robot to lip sync, and, in order to try to get the robot to move its lips while it's, while it talks, to smile like you are smiling right now and to nod and to look you, look you in the eyes when it's talking and to sort of make the appropriate faces at the right time.

Hod Lipson [00:05:54]
These are, this turns out to be an incredibly difficult challenge because we have so many muscles in our face. Our face is so expressive. I have to say, I'm a jaded roboticist. I don't get excited by robots, but when this robot smiles at me, I smile back. I mean, it's, it's very powerful.

Anna Ploszajski [00:06:16]
I love that. And so this is what we mean when we talk about machine learning. It's about giving it inputs that it can, as you say, sort of teach itself based on, in this case, visual cues of how to move and how to react.

Hod Lipson [00:06:27]
Exactly, exactly. It's getting a little bit less uncanny, I have to tell you. It's getting real. Pros and cons to this, we can debate, but it's definitely underlying all of that is the ability of this robot.

Hod Lipson [00:06:43]
It's far too complex for anything that we could program. So, we just let this robot watch itself in the mirror, and then it watches YouTube all day long. And as it's watching itself and watching YouTube, it's gradually learning how to make authentic facial expressions, including some bad ones. It's learning to eye roll.

Hod Lipson [00:07:02]
It's learning to do some things that we don't want it to learn, but, you know, it's a lot, better than anything we could program. So that's my surprise of the week, but really, it happens all the time. And of course, the next thing, we'll listen to the conversation and learn. You know, when is appropriate to make a particular gesture based on the context of a conversation, and a lot harder to do, and, and likely will involve even more GPUs.

Hod Lipson [00:07:27]
Behind the scenes, we actually have to put these GPUs inside the robot, because, inside the robot's head, because it has to have all that computation in real time as it moves around because it needs to sort of process it right there and then.

[music interlude]

Anna Ploszajski [00:07:48]
And to take us through what Hod's GPU is made out of and how it came to be, we're also joined by Rio Tinto's Chief Executive of Minerals Sinead Kaufman. Very warm welcome to the podcast, Sinead.

Sinead Kaufman [00:07:58]
Thanks, Anna. Hi, Hod. Nice to meet you both.

Anna Ploszajski [00:08:00]
Lovely to have you here. Of course, none of our computing world would be possible without the physical materials to operate it on. Hod, do you know, or can you make any guesses, of what materials your GPU is actually made out of?

Hod Lipson [00:08:17]
Well, you know, I know it's made of silicon. That's kind of what silicon underlies a lot of the semiconductors, but I have to say beyond that, I am pretty clueless.

Anna Ploszajski [00:08:28]
That's a very good, it's a very good guess. Yeah. Silicon is definitely at the heart of your GPU. The, the stuff of computers are really the integrated circuits or the, the computer chips.

Anna Ploszajski [00:08:38]
These are the, the small objects that contain the billions of electrical components like transistors and resistors and capacitors that do the actual calculations. And the main material of computer chips, as you say, is silicon. Silicon is what we call a semiconductor. The super clever thing about semiconductors and why we use them in electronics is that you can do Clever things about changing their electrical conductivity in useful ways by introducing impurities which allow us to create these tiny, tiny electrical circuits in a process called doping, which is another strange materials word.

Anna Ploszajski [00:09:17]
All of this is to say that you can kind of put these different flavours of silicon in different patterns on a computer chip. Because we can make these patterns of different flavoured silicon on very, very, very tiny scales now, we can fit, as I said, billions of components on one very small chip, and you can do different layers of them, so that in a very small volume, you can create an object that can have a huge amount of computing power.

Anna Ploszajski [00:09:44]
To summarise then, we've got, yes, silicon definitely, lots of different other elements from the periodic table though, that we rely on for computing power as well, like phosphorus, antimony, arsenic, aluminium, gallium, indium, and boron. And it's the last of these, it's boron that I want to talk to you two about today.

Anna Ploszajski [00:10:03]
I'd love to bring you in at this point, Sinead, to tell us more about boron. It's a very, very common material element in our lives, but most of us haven't really thought much about it. So, can you tell us first, what actually is boron?

Sinead Kaufman [00:10:19]
Yeah, certainly. It is a really interesting material. And when you ask people about what's mined, even within our own business, a lot of people don't really understand what boron is for.

Sinead Kaufman [00:10:30]
But I've got to say, boron is anything but boring. It's in absolutely everything. And the geology you need to create boron is a combination of an inland lake or a river where, where material can get deposited. So, you need volcanics, you need faults, and you need a body of water. So, not that common to have in one location.

Sinead Kaufman [00:10:53]
So, if you think about where boron deposits occur in Turkey, in, in, in zones where there's mountains at the San Andreas Fault in, in California, in Tibet, and also in Chile. When we look at research and development, where else can it be used? It is in everything. It's in everything from micronutrients and soil to help grow plants, to GPUs, to help stability of a GPU, to the hardened glass on your iPhone or your iPad, and even that, that glass that bends on Samsung phones.

Sinead Kaufman [00:11:28]
It's one of the key components that helps that flexibility. But it's also in surfboards. It's in ceramics. It's in an incredible amount of things. We all carry it in our bodies. Most humans need about two milligrams a day of boron to help absorb vitamin D, to help manage hormone regulation in the body.

Sinead Kaufman [00:11:48]
And also we have it in things like our kitchens where it's in Pyrex or so the heat resistant glass, it'll be in the oven glass if you're looking inside your oven when you're cooking something, when it is used in, in pyrotechnics, it produces the bright green colour in fireworks, but if it's absorbed into carbon in diamonds, it makes blue, blue diamonds, which are the rarest diamonds in the world. And, so, it really does exist around us in lots of different, different ways. So, it's a, it's a, it's one of the most versatile minerals that I think we've, we've ever seen in a, in industrial use. I always refer to it as the WD-40 of the world.

Sinead Kaufman [00:12:26]
It's kind of really useful. And one piece that I found really interesting is it's also a neutron absorber. In things like the Chernobyl nuclear disaster, one of the things they did to slow the reaction down was to actually dump large amounts of boron into the reactor from the air.

Anna Ploszajski [00:12:44]
That's incredible. I had no idea that it was used in so many different applications, but never really on its own. It sounds like it's often tied up inside other materials like glasses and ceramics.

Sinead Kaufman [00:12:54]
Yeah, that's correct. And I was thinking, Hod, as you're speaking about how many GPUs I have, even in the room I'm in, let alone in my house. It suddenly makes me think.

Dr Anna Ploszajski [00:13:03]
Can you take us a little bit more through that history?

Sinead Kaufman [00:13:06]
The original mining that was done of boron going back to sort of 4,000 years ago was actually in Tibet when it was mined out of a, out of a lake and at that point it was used as a material to help with goldsmiths and silversmiths and so its first uses were very much around being, it's got quite a high melting point so it's used in things that where you need to have a material that can help to, to be a medium. And it's, it's used in applications where high heat and differences in temperature are critical, like the space shuttle tiles that are used for re-entry, or for putting something in a, in an oven, whether it's a domestic oven or an industrial oven.

Hod Lipson [00:13:48]
So, so I'm wondering, you know, It's interesting that you say that it's been used for a long time. In what form does it show up? Is it like a salt, like I'm imagining, sort of granular material? Is it, is it a liquid? How do you isolate it? And how much does it cost? Is this like gold? Is this something that you can carry around or is it always tied into something else?

Sinead Kaufman [00:14:14]
In its own right, it's, it looks like a really boring brown.

Sinead Kaufman [00:14:19]
Sort of powder once it's processed, but essentially it, it, it appears in rock or in salt and essentially what we do is we dissolve the rocks around it to be able to extract it as a, in an acid form. Typically, as technology improves, then we can start to see, well, what other uses does it have? We've identified in the last sort of modern history that it, it's also one of the key components you can use to make ceramic, Kevlar type materials to, to protect equipment and people.

Sinead Kaufman [00:14:49]
And so the question is what next? And when I hear you, Hod, talk about how you can actually generate not just a, an emotional computer or one that understands and can generate its own feelings, but one that can generate feelings in humans. As well and have that, that connection and I'm thinking about our, our, our iconic mine in California thinking I don't think anyone on site is thinking that this material is going to help us to connect with machines better.

Sinead Kaufman [00:15:17]
It's sort of takes us from the realm of what we used to think of as science fiction into science and how materials can do that is, is actually quite a, quite a humbling thought.

Hod Lipson [00:15:28]
You know, what I'm thinking when you talk is about how, how difficult it is to understand how to use materials. I mean, it's so unintuitive, you know, I think this is something that I'm seeing a lot when we talk about AI and creativity.

Hod Lipson [00:15:44]
Most people think, when they think about generative AI that's everywhere these days. They think about AI that can write poems and generate movies and generate art, but where creativity is really needed is actually in areas like material science. This is where we, we humans, don't have a lot of intuition.

Hod Lipson [00:16:05]
You know, it's so hard to, to, it's very few people, very few material scientists that can sort of anticipate all these uses of, of boron, for example. It's not something that you can just, dream up. You really have to do a lot of experimentation to, to start getting real deep intuition. And yet you, show these kinds of things to AI and for AI understanding, how do you generate new materials.

Hod Lipson [00:16:32]
In fact, it's easier for AI to write, to generate new materials than to write Shakespeare, because Shakespeare involves all kinds of human quirks, but materials are very functional and well defined.

Sinead Kaufman [00:16:44]
Yeah, super exciting. Maybe one, one example to give on that is one of our challenges in mining is always to make sure that we can sustainably find materials that we will need for the future.

Sinead Kaufman [00:16:55]
And, what's a little, little bit terrifying as a geologist is that,I think that AI might be better at this than, than we are. We had an example in the last few years where we found a copper deposit in a part of Western Australia, which had been explored before and was viewed as being, essentially, there is nothing there.

Sinead Kaufman [00:17:15]
It's got really deep sand. And we used computer-based technologies to actually identify the patterns around what could be there. In our first drill hole, we found a copper deposit. So, I think as we, as we think as a society, how do you generate these new ses of technology, technology in itself is helping us find the raw materials that we need to be able to, to do the, the technology development.

[music interlude]

Anna Ploszajski [00:17:43]
So, Hod, on this podcast, I often like to transport my guests to a nightmarish future in which their objects, can no longer be sustainably made, the materials can't be sustainably mined or sourced or we've simply run out of them. And in that case, let's say that we don't have a future with boron in it. What are we going to do? What would your world look like?

Hod Lipson [00:18:04]
The bad news is we'll go back to sort of where we were with computers in the 90s or, or, you know, when we, we had, we thought we had fast computers, but we didn't know what fast really meant. So I think, I think that's the sort of one scenario, but.

Hod Lipson [00:18:19]
What's really going to happen is we're going to power up the GPUs that we have, still have with boron, and we're going to run the new AI to find some alternative. And I'm sure there's a, some alternative, you know, many, many times these, materials, these minerals are replaceable. There are just, so they're found by accident and it seems to work and we build a whole industry around them, but there's actually alternatives that might be better.

Hod Lipson [00:18:43]
And we, again, it boils down frequently to just the range of possibility when it comes to combinations of materials is so vast that it's just hard to understand what's out there and what's possible.

Anna Ploszajski [00:18:57]
You're an optimist. I love this about you, Hod. That's a really nice answer. Sinead, we've already touched on this already, but would you call boron a particularly finite resource? You know, what are the risks that we're actually going to run out of there?

Sinead Kaufman [00:19:10]
So, so being an exploration geologist by nature, I'm an optimist as well. And, and I, I think as you were asking that question to Hod, my thought was, well, we might need AI actually to, to think about how you can not just find more uses, but also explore for more.

Sinead Kaufman [00:19:25]
And I think I often, when we look at minerals that we use today versus materials that were critical in the, in the past, you know, an example would be tin was a, was a mineral that was, you know, so important when it came to industrialisation in the early days. And yet now it's something, when you look at tin tantalum deposits, that's where lithium is often found as well.

Sinead Kaufman [00:19:49]
And previously, a lot of old mines in, say, Western Australia are now lithium mines. And what was the primary product of tin has become the byproduct, whereas lithium, which didn't have any value, has become the main product. And I think for, for boron, we're actually finding now that boron is also a material that occurs in nature, often associated with lithium, partly because it's, it's generated in the same sort of processes with volcanic processes, use of brines, and two examples I'd give. One is that, we discovered a lithium deposit in Serbia about 20 years ago in Rio Tinto, and it took us years to figure out what it actually was because we were looking for boron, and we found lithium, but we found material that the world had never seen before.

Sinead Kaufman [00:20:40]
And so that's called Jadarite. I'm a firm believer that even though exploration geologists have explored most of the world many, many times through different means, they always find something new when they go back and look at different patterns using AI, when they look at different technologies to be able to see what is beneath the earth.

Sinead Kaufman [00:20:58]
So, I don't think we've run out just yet, but I think as we find more uses, we've got to keep pace and in helping some of that technology to actually find more materials as well.

[music interlude]

Anna Ploszajski [00:21:11]
Hod, what happens to your computer components after you're done with them? Do you have a sort of robot graveyard in the corner of the lab?

Hod Lipson [00:21:20]
Oh wow, this is a, it's a great question. So, we actually have a project which we call Robot Metabolism, which is all about robots that eat other robots. Alright, so okay, what does that, what does that mean? So, this is a big name, but what it really means is imagine a robot that walks up to another robot and can take it apart and use its parts to make itself bigger or more capable or to repair itself and so forth, so forth.

Hod Lipson [00:21:46]
So we, we humans, we do this all the time. We eat, chicken, and we eat plants, and, the plants eventually eat us, and we all consume each other, and in nature, we're all recycling all the time. It's because we're made of the same, relatively small set of amino acids, from which all of life is made. is, is made and, and that, that modularity, if you like, allows us to keep on reusing the same material over and over again for, for, for billions of, of years, literally.

Hod Lipson [00:22:15]
So I know it sounds nightmarish, it's the beginning of a horror movie, but really it's about creating a sustainable ecology of robotics.

Anna Ploszajski [00:22:24]
That is a really fascinating vision for the future. For you, Sinead, what are the biggest challenges that you're facing to make sure that we can continue filling our digital world and otherwise with boron?

Sinead Kaufman [00:22:36]
So I think there's probably two and the mining industry is not a particularly well regarded or, or, or popular industry and, and a lot of concerns that we share with society is around how do we mine things with an environmental and, and social risk component to it and make sure that we can do that in a sustainable way.

Sinead Kaufman [00:22:56]
And there's a legacy that's not that positive sometimes of mining. And how do we turn that into something that we can use in a, in a way that, that creates a mining in the future that is sustainable?

Hod Lipson [00:23:07]
Well, you know, just this discussion makes me wonder what other secret materials, secret ingredients are, are sort of underlying a lot of the things we take for granted, especially in the, in this computing world. So, boron is clearly one of them. What's the next in line?

Anna Ploszajski [00:23:24]
It's a good question. I'm not sure.

Sinead Kaufman [00:23:25]
I was working as a as a mine operator and I spent, spent, some time doing a really basic course on computer science. I don't think I'd ever imagined that the difference today is computer scientists or governments or, or, manufacturers of cars or computers are coming back to the mining industry saying, what exactly is in these components?

Sinead Kaufman [00:23:49]
Where are they found? And nobody was asking the question about supply chains or sustainability of material. So, I do think it's a really great question to ask, Hod. What else is in there or what was mined and why? And one of the materials we don't think have any use today. And has anyone actually asked the question of what could they do?

Sinead Kaufman [00:24:08]
So what is the next boron that's out there?

Anna Ploszajski [00:24:11]
Yeah, super interesting. Thank you. So, boron, as we've heard, certainly has a place in our future and hopefully a sustainable future at that. Thank you both so much for taking us through the boron in your lives, Sinead Kaufman and Hod Lipson. Thanks for coming on.

Hod Lipson [00:24:27]
Thank you.

Sinead Kaufman [00:24:28]
Thank you.

Anna Ploszajski [00:24:29]
You can listen to more episodes of Things You Can't Live Without wherever you get your podcasts. And don't forget to follow, rate and review us to make sure that you don't miss an episode.