Hey everyone, it's Ariel Hohwani and I'm Chuck Mendenhall and I'm Pete Caryl and together we are 3Pac.
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Perce!
We're out of here.
This episode is one of my favorites of the year.
Last week I published an article in The Atlantic about the 10 greatest, coolest breakthroughs of 2022.
That is, what were the most interesting and important discoveries or inventions in the last year across any scientific domain, bioscience, clean energy, vaccinology, nanotechnology, AI, what was Apex Mountain for humankind?
I've said before on this show that I think there is a negativity bias in news which results in this list being a surprise for me and for many listeners.
I think it's sneaky weird that this list is a surprise, that the most important breakthroughs of the year typically come as a shock because the news media is significantly more efficient at surfacing and its readers are more efficient at sharing news that makes us afraid or outraged rather than news that makes us curious or even hopeful.
For example, I'm not sure that most people know we are in a golden age of obesity therapies.
Until very, very recently, most reasonable doctors did not prescribe medications or pills or injectables for weight loss, like the term weight loss pill was very rightly a pejorative.
But in just the last two years, there's been an extraordinary revolution in weight loss medication, thanks to a happy accident.
In the 2010s, patients on the diabetes medication semaglutide noticed something interesting.
They were losing a ton of weight.
And so the parent company, Novo Nordus, looked into this and they realized that the side effect of this diabetes medication wasn't a fluke.
The diabetes medication seemed to mimic naturally occurring hormones in the body that regulated the release of insulin and slowed down how fast patients' stomachs emptied.
Last year, the FDA approved injectable semaglutide for weight loss under a new name, Wegovi.
And this is not the only weight loss medication now in the pipeline.
A similar weight loss medication called Terzepotide showed an average 20% reduction in patients' body weight in the latest clinical trial.
There is another medication that Amgen is currently experimenting with.
It's called AMG-133.
And in phase two trials, patients on the highest dose lost more than 14% of their body weight in less than three months.
So this could be the dawn of a new age.
Roughly 40% of Americans are technically obese, and we know that obesity can in many cases increase someone's risk of heart disease, high blood pressure.

And for men, as we just heard on a recent show, it seems correlated with declining sperm count as well.
So this is a breakthrough worth celebrating.
And also, because every discovery can have positive and negative implications, I think it's a breakthrough worth watching as well.
Another revolution that I think will maybe one day become synonymous with the 2020s is the incredible blowout in generative AI tools.
We've got image-generating apps like StableDiffusion, Dali2.
These turn text prompts into lush illustrations.
You can say something like, show me a podcast host on Venus, smoking a cigarette in the style of Van Gogh, and it will produce something astonishingly beautiful, weird, inspiring.
There are also large language models such as ChatGPT, which can answer complex questions, spit out bespoke Wikipedia articles in seconds, write song lyrics, and even conjure many essays.
The results are quite uncanny and quite mind-blowing.
So for example, I was inspired by a few tweets that I saw that got ChatGPT to write poetry and religious verse, and I gave ChatGPT a cheeky little prompt.
I said, write a biblical verse in the style of the King James Bible about a Manhattan finance bro throwing up on his friends after having too many fireball shots.
And in approximately eight seconds, this is what the AI wrote in response.
And it came to pass that the finance bro having imbibed too heavily of the fiery liquid did vomit upon his companions, and great was the displeasure of the friends for they were covered in the sick of their companion, and the finance bro did wail and gnash his teeth for he knew that he had transgressed and brought shame upon himself.
Thus saith the Lord, quote, Let him who is without sin among you be the first to cast a stone at the finance bro.
And with this, the friends did forgive their companion, for they too had known the temptations of the flesh and the perils of excess.
Like that is amazing.
I don't know what this thing is yet.
I don't know if it will ultimately evolve into being a mere toy, if it will replace me, if it will replace Google search, if it will merely be a second mind for the creative class or if it heralds the end of the world, whatever it is, it is a rather extraordinary feat of technology, and I think in time we may consider it the most important breakthrough of the year.
At last today's guest is a return guest, Eli Dorado.
He is an economist and a researcher and a writer who has his pulse on the frontier of invention and sciences, much as anybody else I know, especially across all the different domains that I want to touch on, bioscience, AI, hardware.
He is our guide to the future for the next 45 minutes, and if you have half as much fun listening to Eli as I had talking to him, I think you are in for a treat.
I'm Derek Thompson.
This is plain English.
Hey everybody, Derek here.

The conversation you're about to listen to is about the most exciting and important scientific and technological breakthroughs of 2022, and it was recorded just days before US government scientists made a breakthrough in nuclear fusion.
Fusion reactions are different from fission.
That's what typical nuclear power has been.
It emits no carbon, produces no long-lived radioactive waste.
It's an extraordinary technology that could give us limitless zero-carbon power if we can scale it, if we can get it cheaper, if we can get it widely available.
It's a thrilling, thrilling breakthrough that clearly would have made this podcast if the news had broken a week earlier, six months earlier, 11 months earlier.
Trust me, we're going to have many more episodes about this awesome breakthrough in nuclear fusion, just not this one.
Okay, please enjoy.
Eli Dorado, welcome back to the podcast.
Thanks for having me on, Derek.
I am more excited to do this episode than I've been in a long time.
I honestly find a lot of bad news interesting, and so I write about it a lot, and I podcast about it a lot.
A long time is up, sperm counts are down, bad news, bad news, but we're getting close to the holiday season, and I really wanted to do an episode that doesn't make me want to self-eject from the planet, and I made a promise myself this year that I would take time in December to research and break down what I considered the most interesting and important science and technological breakthroughs of the year.
I just published this big piece in The Atlantic, breaking down my top 10.
In the open, just before welcoming you on, I talked a little bit about my fascination with large language models like chat, GPT.
I want to save that for the end.
What I want to talk about with you, because last time we had you on the show, you gave us this incredible tour of the scientific and technological frontier.
I want you to walk with me through some of these incredible science and tech breakthroughs of 2022.
Let's start with science.
Let's start with the cosmos.
In July, NASA's James Webb Telescope sent back its first images of light from across the universe, and with just extraordinary clarity.
This showed off these nebula that looked like neon soap bubbles and craggly red mountaintops.
One of them looked like a little luminescent shrimp that was floating in a black soup.
I mean, just amazing, amazing images that go back as far as 13 billion years ago.
Okay, so they're clearly cool.
Why are they important beyond just being cool?
Well, there's so many reasons.
I think that you can do it in radio astronomy is a bunch of different things.
You can learn more about physics.

The really high energy, large scale stuff in the universe, you can't do it in a lab on Earth.
It can't be contained like that.
The James Webb Space Telescope is going to be doing all kinds of experiments that take advantage of the cosmos as a physics laboratory.
And the other thing that it's going to do a lot of is looking more locally at a lot of stuff we haven't really looked at before.
So I'm really interested in actually looking at planets that are close by.
So yes, the space that James Webb can look very deep into the cosmos, but it can also look more closely to stuff that's only like 10 light years away or something like that.
And you can actually start to study the atmospheres of these planets that are nearby.
And that could potentially tell us, is life common or is it not common in the cosmos?
I'm really curious about that question.
Radio astronomy has already told us that interstellar space has organic molecules, hundreds of organic molecules, including amino acids, including amino acids that we have in our bodies.
That exists in interstellar space.
And we know that because we've had past measurements from radio telescopes.
Every time we get a new instrument, either a step change in resolution or a new frequency that we get access to, we discover something new about the universe.
I am most fascinated by the possibility of seeing into the moments, relatively the moments, the million years after the Big Bang, to learn more about the ultimate existential question.
How did it all begin?
Where did time and space and matter begin?
What were the conditions of the universe 13 billion years ago?
How are they different than the conditions now?
Is the universe ruled by a different set of laws?
Can we learn maybe what those laws were by looking really, really closely at these different snapshots of 13 billion years ago?
That's the most interesting me.
Just tell me a little bit more about what we could learn from these exoplanets that you're describing.
So we use our telescope to stare five, ten light years away from Earth.
You call this a shortest distance, but to me it seems relatively long, neither you nor I are likely to ever go there.
But we're looking into these atmospheres, maybe we're getting the view of these planets that, in my mind, I think that it's a little bit similar to in like a Star Wars or Star Trek movie.
When they show the planet coming up, you start to see its color and the state of its atmosphere.
What could we learn about these planets?
Different molecules in the atmosphere are going to emit different spectra.
You could conceivably learn that there are molecules in the atmosphere that are on Earth or at least in Earth-like environments are telltale signatures of life.

So we could sort of maybe form hypotheses that some planets may have at least bacterial life on them from looking at these atmospheres.
I think the other question is about sort of the interaction of magnetospheres and stellar winds and so on.
So Earth is fortunate to have a magnetosphere that keeps our atmosphere from having been blown away over the last billion years or so.
Without that sort of the polarity of the Earth, the North Pole, the South Pole, the magnetic fields that arise from them, our atmosphere would have been blown away by the solar wind.
And so if you study exoplanets, we could sort of get an idea of how common is that?
How common is it for an atmosphere to build up on a rocky planet?
And if you ever did find a star system that had a bunch of magnetic fields, a bunch of planets with magnetic fields, and all of them had atmospheres in them, and what they might have interesting signatures and so on, that could be a sign of a terraforming civilization.
If I found improbably that one star, infer some base rate from your other observations, if you found improbably that one star system had a bunch of planets that had atmospheres and magnetospheres, that would be a sign of something interesting that we would want to go check out.
I would say so.
Yeah, that sounds pretty thrilling.
All right.
Let's move to the next breakthrough that I want to talk about, which is a breakthrough around the disease Multiple Sclerosis.
There was a study done by a team of scientists that looked at a large group of military service members, and it concluded that there was very strong evidence that the Epstein-Barr virus EBV, which is best known for causing mononucleosis, might be a leading cause of MS, Multiple Sclerosis.
Infection with EBV raised the odds of developing MS by a factor of 30.
Now, many, many people get EBV.
Many people contract this virus.
Only a tiny minority of them seem to develop Multiple Sclerosis later in life, but it suggests that Multiple Sclerosis is like long EBV, maybe, the same way that we understand there to be COVID, which lots of people get, and then a small minority of them get long COVID, the long virus.
Eli, what do you think are the most significant implications of this discovery?
For a long time, Multiple Sclerosis is a autoimmune disease.
There are a lot of autoimmune disease, and we kind of don't understand how they work.
That sort of the autoimmune, I would even say it's an autoimmune hypothesis, that it's our body just sort of fighting itself.
If Multiple Sclerosis is caused by EBV, it raises the possibility that maybe a lot of the diseases that we think of as autoimmune, maybe they are, maybe the etiology actually is pathological, they're pathogenic diseases.
Which just to clarify, pathogenic disease means it's a disease that comes from a bacteria or virus.

Exactly.
It lingers in our system for a while, the same way that we're familiar with the concept of long COVID.
People get COVID, it lingers for a while, and then it causes a range of things like brain fog or some kind of muscle weakness that we don't necessarily, it might be a little bit different from the immediate effects of COVID, but we consider it a part of long COVID.
Maybe there's a bunch of diseases that have specific names like Multiple Sclerosis, but they're actually just long viruses or long bacteria.
Exactly.
Or maybe even not long, maybe it's just, we don't know, we just have never found a pathogen.
It could be just, it could be the non-long version of some virus as well.
And so, yeah, I think a promising avenue would be for anybody that has a mystery disease or a disease where we don't know the cause.
We should be screening their blood and their other bodily fluids, and just genetic sequence everything you find.
If we could genetic sequence everything we find in all of these patients, that might lead us to some more discoveries of, well, actually, this thing that we thought was autoimmune was, it's becoming clear, there's another pathogen that causes it.
So I think we're not at the end of sort of figuring out the role of pathogens.
To me, it's like, all right, there's lots of research on treating MS, dealing with MS, which results in nerve damage, which disrupts sort of communication between the brain and the body.
There's certain ways that you can think about treating a disease like that, whether it's the treatments work on the immune system or the treatments do something about nerve communication.
But with this knowledge, it might be the case that the clearest thing to do is to get vaccinologists to work on a vaccine against Epstein-Barr virus, which up to now was kind of important to do.
Mononucleosis is a nuisance, but multiple sclerosis is much more of a problem than mono.
So this has clarified the cost of EBV on the human population, such that it might profitably redirect a lot of investment toward eradicating EBV from the human population.
Is that right?
Yeah, that's 100% right.
But it's interesting, with MS, there's all kinds of ideas of how you could treat it.
People are saying, oh, I had MS and I ate a bunch of vegetables and changed my diet in some way, and that helped to get better.
That may or may not be true.
We don't have a good way of evaluating that because we don't fully understand the causes.
But if it is a virus, and of course what you eat affects your immune system, some of these stories start to make sense in a way that could be made consistent with scientific observation as well.
I want to move on to another discovery that has a little bit of tie-in with the pandemic, and that is that we are very clearly in a golden age of vaccine research and maybe also

vaccine production.
There were a range of breakthroughs in the world of vaccines in the last year.
There was a record, one of the most successful trials for any vaccine in malaria came out this year in September.
Oxford University scientists developed this malaria vaccine, small trial, 450 children in Burkina Faso, but it found that three doses of the vaccine plus a booster shot was up to 80% effective at preventing infection.
That is remarkable because malaria kills around 40,000 people every year, many of them children.
It's not caused by a virus.
It's caused by a plasmodium, which has so far been very difficult to vaccinate.
But these scientists from Oxford seem to have some success in coming up with a successful vaccine candidate.
Another really interesting breakthrough in vaccines this year came against the flu.
There was an experimental flu vaccine that was found to be protective against all known types of flu in animals.
Now, I think every year we get a flu shot, and that flu shot is bespoke to the kind of flu that is circulating, and the influenza virus family has 20 lineages and a bunch of strains under all those lineages, so we have to change the flu recipe every single year.
If this vaccine worked, it would essentially lower the mortality ceiling of every kind of flu that we could possibly get in all the years to come, which would make a Spanish flu epidemic extremely unlikely.
Those are some of the vaccine breakthroughs that we had this year.
Eli, which of them do you consider most interesting, most important?
Well, I think malaria is just such a huge killer in all of the tropics that it's incredibly important that we've made that advance.
I think one thing that we're learning is that not all antibodies are the same.
You can have two different people who are exposed to the same disease, and their bodies might make slightly different antibodies in response to that virus or the bacterium or whatever it is.
One of the things we're learning is you can target better and worse antibodies.
Being able to design a vaccine that generates an immune response, an antibody, that attacks like a conserved part of the virus, a part of the virus that doesn't mutate very much.
That's a playbook that we can do over and over again.
There's not that many families of viruses in the world that infect humans, and we could do it potentially on all of them.
We're getting to the point where viral infection might not be a thing that we have to live with in the next, say, two decades.
People are talking about, we could get rid of the common cold.
I think there's all kinds of questions about, do we need occasional viral insults to our immune system to keep our immune system active?
I think that's the kind of question that we're going to be facing because we have so many tools being developed that make us able to make more effective vaccines.
That's great.

Even if we don't fully eradicate viruses, I think what's interesting about this particular flu vaccine is that all the articles that I read were very careful to point this out.
This does not make it so that you cannot catch the 2023 flu or the 2024 flu or the 2025 flu, which by the way are almost certainly going to be different strains.
Whether it makes all of those strains significantly less lethal.
Something like the Spanish flu pandemic would be basically impossible if we could do something like this for the influenza family, for Plasmodia like malaria, for coronavirus as a family, not just this novel coronavirus, but for the family.
It would mean with these family level mortality lowering pan vaccines that, yes, people might, in this future that I'm sketching out, they might still get sick, but we would turn everything into the common cold or something like it.
No coronavirus would kill 10% of people over 80.
No influenza would kill 100,000, 200,000 people a year, or in the cases of 1920, millions of people throughout the world, everything would be a little bit more moderate.
Is that future also something that could come into focus?
Yeah, it's very plausible, but I think it would be shocking to me if people didn't go after even the common cold.
Think about how much during sort of cold and flu season people just missing work and stuff like the economic cost of that.
I would be surprised if nobody goes after it.
People are going to want protection, I think, well, I don't know.
People didn't want protection from COVID in the vaccine, so maybe they won't want vaccines for everything.
Half of the adults over 45 of particular, yeah, political ideology in this country weren't particularly eager, but yeah, the rest of the country was relatively eager and people around the world were decently eager.
Can you help me understand, because before I go way out over my skis and get way too excited about the future of ending all the viruses, obviously there's all sorts of scenarios in which we might be in a kind of, they talk about AI summers and AI winters, there's periods where the technology sprints forward and the period where the technology doesn't.
It's possible that right now we're in a bit of a vaccinology summer, and in a few years we might be in a vaccinology winter and realize, wow, it's actually really, really difficult to invent all of these pancoronaviruses and paninfluenza viruses.
What would you say we learned in the pandemic that is responsible for this summer that we're experiencing in antiviral vaccinology?
I think it's mainly that we can go faster than the state of the art was before.
I wrote a piece at the beginning of the pandemic on what we could do to accelerate vaccine approvals and I thought we should just, once somebody, a credible company had a candidate, we should let people try it.
You need data one way or the other, you need to have guinea pigs.
If people want to do informed consent and get a jab of an mRNA vaccine that's unproven, they should have been allowed to.
That was my argument, because I was worried that it was going to take years, it was very

common before COVID to have a vaccine take 25 years to be fully developed, go through all the trials and so on.
25 years might have been on the high side, but it was never, never under a year.
I thought we needed to just accelerate the whole process.
We kept the clinical trial requirement, but somehow we made it through a lot faster.
It helps that a lot of the people who got the vaccine were exposed naturally.
We didn't have challenged trials for the most part, but we just had an epidemic raging, a pandemic raging, and that enabled us to go faster.
Even without that, I think there's a lot of time that we can cut off the development cycle.
Anyway, I don't think it is like a summer, winter kind of thing.
I think it's here to stay that we're going to have a lot of progress.
There's just so many tools coming down the pike in biology, like the labs are getting so advanced, they're able to do so many interesting things that it would be surprising if there was a slowdown.
The big obstacle is what can you get approved and what can make it all the way through the clinical trials and to consumers.
The scientists in the labs, they're like wizards, man.
They're doing so much exciting stuff.
I'm glad you ended on that.
The fact that the science is moving very, very quickly, we need to find a way for policy to move quickly too.
I have a piece in the magazine that comes out, I think the day this podcast comes out called the Eureka Theory of Progress is Wrong.
I tell a story of Operation Warp Speed and exactly how it worked.
I say, what would it mean to have an Operation Warp Speed for some other biological crisis that we recognize?
Let's say Operation Warp Speed for cancer.
What would that mean?
Well, on the one hand, it would mean spending more money on research, Operation Warp Speed said, here's a bunch of money you're willing to spend on any of the pharmaceutical companies that come out with a vaccine in mRNA or attenuated, et cetera, we're going to spend money directly on the production of the material.
But also it turned what you described as this 10 to 30 year obstacle course for new vaccines into a glide path.
It's like, we're going to make this possible in six months, so what would it mean to do that for cancer?
I talked to Heidi Williams at Stanford and the Institute for Progress about this amazing paper she coauthored about how since the war on cancer was declared in 1971, Richard Nixon, the US has way more late stage cancer treatment pills and almost no cancer prevention medicine.
So a ton of pills you can take when you're on stage three, stage four, but not a lot of cancer prevention.
Why?

Well, one answer she said is that cancer prevention clinical trials take forever, because if you take a lung cancer prevention pill at 20, you might not know until you're 60 if it's actually prevented, your lung cancer is 70, 80, and she said, we have a solution for heart disease.
We have surrogate endpoints, which is a wonky term for short term proxies.
You take a pill, we say, is your cholesterol going down, is your blood pressure going down, and we're going to infer that if it is, this will prevent a heart disease later.
If we could find a way to develop these short term proxies for cancer prevention in clinical trials, we could have short clinical trials for multi-decade cancer prevention medicines, which would mean an explosion of cancer prevention therapies.
You wouldn't even need any kind of revolution on the invention side.
Scientists could keep doing exactly what they're doing, and we could like 10x the number of cancer prevention pills that Americans can take.
And so going through that little bit of research made me really optimistic that the scientists are doing incredible work, and we need to learn from Operation Warp Speed how to get little innovations on the policy side to make this world abundant in anti-cancer therapies.
Let's move on to clean energy.
You have taught me a lot about geothermal energy, which basically means drilling deep into the ground to use the Earth's heat.
Pretty much it's geothermally heated water for power.
And geothermal is such a cool energy source because it's more consistent than wind or solar.
The middle of the Earth is always hot in a way that the wind isn't always blowing.
And it doesn't have the waste concerns of nuclear, but the problem is that there's some parts of the world that are fantastic for geothermal, like Iceland, and there's other parts of the world that are not good for geothermal because it takes so long and so hard to dig to that part of the Earth's crust that has the geothermally heated water.
You told me about a solution to this problem.
Tell me about that solution.
Yeah, of course.
So in my day job, I spent a lot of time looking at technologies and diving deep into them.
And geothermal is one of those.
And I got so excited about this particular solution that I actually ended up investing personally.
So this is a company called Quaze.
They're a spin out of MIT.
And they took something out of the fusion lab.
So to sort of feed the fusion reaction, scientists have this tool called a gyrotron that produces millimeter wave energy.
And what Quaze is doing is they say, OK.
Can you just, like I'm in sixth grade, what is millimeter wave energy?
Millimeter wave energy is like radio energy.
So light is radioelectric energy.

It's photons.
So visible light is in the 400 to 700 nanometer wavelength range.
And so imagine photons, instead of being in that spectrum, they're just moving in the millimeter sort of range of a spectrum.
So that's really it.
It's light that's been, the wavelength has been, is longer than light.
It's photons, though.
It's exactly the same as same particle.
And so what they've figured out is that you can drill mechanically very well through the sedimentary rock and so on.
But at some point, you hit basement rock.
And if you take a gyrotron at the surface and point it down into the ground and have sort of a corrugated steel tube that sort of guides the waves down, what you can do is produce a concentration of millimeter wave energy at the bottom of the hole that vaporizes the granite and just completely destroys it.
The ashes like sort of, you have to think about like, how do you circulate a gas there to pull the ash out, but you vaporize granite, you melt the side of the hole so that it becomes like a liner.
So it becomes 10 times stronger than the surrounding rock.
That helps with, normally when you drill, you have to do some sort of casing to preserve well integrity, make sure there's no leaks and so on.
So this liner is like automatically formed and you can just go and go and go deeper and deeper.
Is this kind of like, and this is just because I finished Andorra a couple of days ago, it's kind of like a tiny Death Star, but used for good, right?
It like it uses, you know, right?
Like the Death Star just like- It's directed energy, yeah.
It's just directed energy.
It destroys a town, destroys a planet.
In this case, we're not trying to destroy a town, thankfully.
We're trying to destroy a very concentrated bit of granite that is deep in the ground and it is really, really hard and is otherwise very difficult to drill through, given the temperatures and the pressure of being that far underground.
You shoot it with this sort of super fancy special laser.
It totally obliterates it and gets us clean access to actual geothermal power.
That's right.
So technically, it's not a laser, but it's an energy, it's a concentrated like energy ray, right?
That you create using this wave guide.
And yes, it vaporize, it basically makes it much cheaper to, you know, when it comes to fruition, right?
It's going to be much cheaper to drill very, very deep, right?
I mean, Quaze is talking about we could drill like up to 20 kilometers of depth with this

kind of thing, which is deep enough to get to the temperatures you need to produce geothermal literally anywhere on the planet.
So let's get excited about this and then let's come back down to earth on this.
In the excitement category, it's like, okay, we're used to energy being geographically specific.
Like, windy places are good for wind power and sunny places are good for solar power.
And there's parts of the world that are kind of hard to see just from walking around like Texas and Saudi Arabia that underground, it turns out they're incredible for their oil resources and so they're energy rich.
But all of the planet is over the core of the planet, like by definition, that's how a sphere works.
And so if we had some technology for drilling really, really deeply into the planet, it could turn any patch of land into a piece, a territory that is as valuable for geothermal as like the Texas or Saudi Arabia lands are for oil.
Like that's, that's incredible to think about.
Like you wave the magic wand over the world and it's all Saudi Arabia for oil, except the oil is an oil and it has no carbon emissions.
Like anybody, anybody can be Iceland, right?
Like anybody can.
And so in Iceland is like the world leader in energy production per capita.
And they have, you know, they have aluminum production on the island, like way out of proportion to their population size.
They're like, I think the top per capita producer of aluminum.
I mean, it's just because that's an energy, electricity intensive industry and they have such cheap energy availability.
So, so yes, anybody can be Iceland.
So anyways, we're making the entire planet Iceland, everyone's Iceland.
There's abundant energy.
There's abundant electricity.
It opens up all these incredible venues for new things we can do that take a lot of energy, whether it's desalination of water or just, you know, running a perfectly electric economy.
All right, that's the vision.
That's all very cool.
Back to reality.
What are the bottlenecks?
Right?
Like everywhere, like technically it's, it's almost nowhere right now.
It's very nascent.
So what are the clear bottlenecks to making something like this cheap and available and scaled?
So, so with quite specifically, like they're still developing this tool that will allow them to drill very deep, right?
So they are, they're doing lab tests.

They're doing field tests, but it's still under development with the industry more generally.
I think that the biggest challenge is that sort of for near term deployment, the best resources overlap significantly with federal land.
So it's, so it's just most of the, in the US, most of the, the sort of the shallowest geothermal resources happen to be in the western half of the United States, of which the federal government owns a huge chunk of.
And so to, if you want to sort of get started, and I believe that this is an industry that will be characterized by, very much by learning by doing, right?
You're going to have to, you're going to, the more we deploy geothermal energy, the more the cost is going to come down.
And so you got to start somewhere in that somewhere ideally would be, would happen to be on federal land, but it's just such a challenge to get, you know, these, these wells permitted on, on federal land, which is kind of crazy because it's the same equipment, you know, for the mechanical drilling.
It's the same equipment as you're using in oil and gas, right?
It's, so it's, it's in same workforce, same, same techniques, et cetera.
And you can get an oil and gas well approved in about two weeks on federal land.
And it takes like two years to do geothermal.
So there are scientific bottlenecks here, we need to figure out how to get this super fancy laser that isn't actually a laser to work.
And there's also policy bottlenecks.
We need better laws in this country that allow us to innovate in places where geothermal is, where the, the, the fruit is lowest hanging when it comes to figuring out exactly how to get this technology off the ground.
And that requires regulatory changes.
Exactly.
Yeah.
And I, and I do, I am optimistic that like the administration hears us on this and, and that, you know, they, they want to do something about it.
We'll see.
We've saved the best for last, at least according to me.
I am really, really excited about chat GPT.
I have loved playing around with this toy, uh, the economist Larry Summers when about as far as one can possibly go when it comes to the potential of this technology, when he said the chat GPT is a breakthrough on par with electricity.
I am prepared to defend why I think this technology is so cool and with continued exponential growth could be so revolutionary.
Tell me what, tell me one thing that impresses you about chat GPT and what leaves you cold about this technology?
Um, yeah.
So I was using it last night to just write, you know, collaboratively write bedtime stories with my kids.
Right.

So I was like, sit down with my kids, be like, okay, let's prompt chat GPT.
What, what do you want a story about, you know, uh, you know, one of them wants to be a princess, one of them wants to be a knight.
They really like Minecraft.
We can say, okay, they're in Minecraft, uh, in the Minecraft world, and we can just like get a story written for us on the spot.
Right.
It's like, it's like sort of like unlimited content production.
Right.
It's just, you know, on demand.
Um, so, so I think it is really exciting.
Technically, it's a huge breakthrough.
By the way, chat GPT is not yet GPT for, which is on the verge of release and it's just another step forward.
So, so it's just, it's just going to get even, even better, uh, you know, in the, in the coming, uh, months, I think, um, yeah, the, the thing that it doesn't leave me cold.
But the place where I think a lot of people are, are overstating the importance is that some of the, you know, some of the content can be a little bland, right?
It is taking sort of the entire English language corpus that it's using for training and it's sort of like averaging over it, right?
Unless you're sort of like a prompting wizard, right?
It's hard to get it to say anything interesting.
And so it is not a replacement for, uh, you know, the writers that we read online at the Atlantic, uh, such as Derek Thompson, uh, who say something, you know, interesting and unexpected
in every article, right?
Whereas, you know, like, I think, I think it, so chat GPT as far as I can tell, like can't do that.
Like I, you know, I try to prompt it for like, you know, give me a shocking twist at the end of the story, but also make sure that there's foreshadowed kind of earlier in a non-obvious way.
And it just doesn't have a concept of, of a lot of that.
Um, so, so yeah, I think it will be, I think it will do amazing things.
And I think, I think on the, on the imaging side as well, it's like incredible, uh, incredible capabilities, uh, being developed.
And by the way, I mean, the thing that I think is going to shock people in the next, uh, in the coming like, uh, you know, weeks or months on the imaging side is people are going to learn about model distillation, right?
You can, you can distill these imaging models into, you start, you start with a big model and then use that to train a smaller model that can generate an image in like under a second on your laptop without needing to use a server.
Step back.
What, what, what, what, yeah, give me, tell me the full story of that.

Just like create a full example of what you're talking about.
Yeah.
So, so right now you can download like the stable diffusion model on your laptop and use it to generate an image.
Stable diffusion for people listening rate is one of these texts to image generators.
So you enter a text like Derek talking to Eli on an exoplanet using cups and strings in the style of Dalí and it will like weirdly enough do this in like a matter of seconds.
It'll be like pretty good.
It'll be, it'll, you know, so for, for stable diffusion, at least on my laptop, it's like 30 seconds or more to generate, uh, one image, right?
And then, then, okay, then I have to fix the prompt, right?
And I, and I, um, I, so I adjust the prompt based on, on the results and then, uh, maybe I want to adjust it again.
So it, so it is like, oh, feels like very laggy and back and forth, uh, that you have to do this.
Um, so with a distilled model, you can get on the same hardware, you can get a result in like under a second.
So I can enter a prompt, press enter, immediately see the image that I want or that I thought I wanted, adjust the prompt, hit enter, another second goes by, like I see the image again.
And so just for like going back and forth with this model and then, and then maybe at the end, once I find the prompt, I want, I go back to the full model and do the bigger, uh, the, the bigger model for the final render or whatever.
But like, I think this is, is going to be a tool that right now, uh, for, for like, for chat and GPT, for instance, you're doing this on open AI servers, right?
And I think that model distillation is going to allow us to do a lot of these generative stuff on local hardware, on our, uh, on our just like consumer grade laptops.
So I think it's going to be really exciting.
Larry Semmer has called it like a caddy for creative work, which I thought was actually a pretty good metaphor.
Like the caddy is not considered the talent, right?
But still it can be essential not only to have someone carry the clubs, but to advise on which club to use, to think about exactly how do I hit this?
What do we think is the pitch?
I actually don't even play golf.
I don't know why I'm elaborating on this metaphor, but I assume that's what people use caddies to do.
I've seen enough movies of golf.
Um, I see that's already how I use chat GPT.
Um, you know, Noah Smith, uh, had the metaphor of sandwiching.
You have an idea for a prompt.
I prompt chat GPT.
It sends me back an answer.
I edit the answer.

That's actually what I put in my article.
And so much of writing are these little micro questions that occur to me as I'm writing a longer piece.
Like if I'm writing something about, you know, generative pre-trained transformers, and I say, wait, what exactly is that?
And I ask GPT, what is this technology?
How, give me a metaphor to explain GPT to a ninth grader.
It will do that.
Now it might not be A plus, it might be C plus, but then I get the prompt and I can edit it back into something that I consider, I consider appropriate.
Um, you said there was another breakthrough in AI that makes you even more excited about this AI summer that we're in.
And I think it's important to be clear that this year was all about generative AI, but last year, two years ago, it was about, uh, uh, was it Alpha fold?
Yeah, Alpha fold, the AI, protein folding, protein folding, right?
The ability to anticipate the precise structure of any protein in the world and the incredible frontiers that that opened up in the future of protein, uh, proteomics.
So it's every year AI is showing like a little different part of its body to say like, you know, this is, this is what I'm capable of.
Tell me why you're so interested in this other frontier inside of the AI family called precise Adam manipulation.
What the hell is that?
Yeah, sure.
So I think to, to give you a little background, I think about AI and sort of a two by two matrix, right?
Or two, two dimensions.
Um, and, and so one of them is, is it super human performance or is it sub human performance?
Right?
Uh, so, so, uh, so like protein folding, like it's definitely super human performance.
We can't do that at all.
Right?
Whereas like GPT chat or chat GPT, like it's, it's sub human performance in the sense it's like it's not as good as Derek Thompson at writing.
Um, but, and then, and then also like the dimension, the other dimension is like economically useful or not.
Right?
Um, so like we, so we have chess AIs that are, uh, super human performance, but not economically useful, uh, not, not in a significant way, whereas, you know, something like writing or art potentially could be useful even if it's sub human performance, because like you said, it's like a caddy.
So I'm really interested in, in sort of like the, uh, the, the economically useful and, and super human performance, uh, quadrant of, of that.
And I think protein folding is one of them, um, and I think, you know, maybe this sort

of Adam manipulation is another one.
So, um, so one of the, one of the technologies that could be the most revolutionary for humanity is the productive nanotechnology, the ability to actually start designing things by placing atoms, uh, exactly where we want them to be right in, in, in molecules and creating, um, creating things, designing things from the ground up at the atomic scale.
We could basically create, you know, the, the, the theorists behind this say like almost mad stuff with almost magical properties, give me an example, uh, like you could have a room filled with nanobots that when you kind of make a motion to sit down, a couch forms under you, right?
So like, I mean, like that is just, it's just wild, right?
Uh, you could have, um, uh, I did a calculation that some of the motors that people have designed, um, that you could take like the Tesla model S plaid motor and you could do that amount of power output in the size of 12 grains of sand, right?
Like this is what you can do.
I mean, it's, it's, it's like hearing about these possibilities is almost like hearing about like, um, like the size of the universe or hearing about like string theory is just like, it's so incomprehensible.
It's like, I guess.
Wow.
Yeah.
Yeah.
So, so, so this is like, you know, I think it is like kind of magical, like some of the theorists are hand wavy at times, right, and, and I, and I would always say like, you know, like, okay, like take it, take it with some grain of salt, but it does seem to follow from like totally standard chemistry and physics that this is possible.
And so what this team did with AI is, is it's not quite that, but they're, they're working on sort of being able to manipulate individual atoms and, and sort of the, if you think about like moving an atom like with like, with like tiny tweezers or like a little stylus, right?
That you're like poking it, right?
There's going to be all kinds of quantum effects if you're on the tip, because you're, you're operating at such a small scale that it's, it's very hard to predict all the forces and the, the movements that are going to happen.
And so what they are doing in this is they develop an AI that like shows them how to move the tip and, and how to poke atoms around and move them around.
So this is not yet creating molecules with atoms.
So these are to anybody who knows, like, they're not covalent bonds.
So you're not making molecules.
You're moving individual atoms around on top of a crystal, which is something that we have done before, but just, it was very hard.
So you have, there's, there's a famous historical example of a team at IBM that had some, I believe it was Xenon Adams, and they, they spelled out the word IBM with just like Xenon Adams on, on a, on a, on a crystal surface, right?
And so, so that's more like what, what they're doing in this example, but hey, you got to

start somewhere.
And I think, you know, being able to actually design stuff and, and, and make it an engineer stuff at the atomic level with that level of precision, that, that it could be the biggest game changer of all for humanity.
What's sort of saying about that is it sounds like AI and machine learning is being used in this case as a tool that unlocks the key to an entire new kingdom that is nanotechnology.
Like we do not have in our own mammalian corporeal bodies the ability to enter this world.
This world is only accessible by developing machine learning technologies that allow us to do extremely precise quasi-magical things with atoms.
But once we unlock that door with AI, the, what's beyond that door is un, is unimaginably awesome and it's not like disappearing into the metaverse.
It's new things that we could build in the physical world that are totally mind-blowing.
As you were talking, I will say at this point, chat GBT seems like pathetic.
It's like, this seems like, like, it feels like, compared to this, it's like some 1600s technology.
And this is one of the reasons why I find chat GBT so thrilling for my work.
I just asked chat GBT, I just typed in precise atom manipulation and it gave me a little definition.
And then I entered the abstract of the paper that you sent me about this and it did a pretty good job summarizing the abstract.
And then I said, what are some of the coolest and most interesting implications of atomic scale manipulation for the future of technology?
And it says precise atom manipulation could enable the creation of ultra-efficient energy storage materials, more powerful computer processors, and highly sensitive medical diagnostic tools.
So I said, what kind of highly sensitive medical diagnostic tools, what could highly sensitive medical diagnostic tools made with this technology, atomic scale manufacturing, do for people?
And it says, detect very low levels of various biomarkers in a person's blood or bodily fluids.
Allow for early detection of diseases such as cancer, et cetera, et cetera, right?
So now I'm thinking, oh, right, another aspect of this precise atom manipulation you're talking about might be not just to create new products in the physical world around us, but to create new products within us that teach us about what's going on in our bodies.
So I would like to make a plug both for your technology and for my love affair for chat GBT.
This is a little bit, Astro Teller calls it, a dumb genie, right?
It's not that creative.
It's not that interesting.
But there's a lot of questions that we dumb people have that also aren't that interesting.
And it's really nice to have this sort of bespoke Wikipedia genie at our fingertips that can just explain these kind of questions to us.
So I find your example magical, and I also found this lesser capability of chat GBT magical in this case.
And it's still getting better, right?

That's the thing to remember is that it's just going to keep improving.
So yeah, I do agree that it's like a significant breakthrough.
Eli Dorado, thank you very, very much.
I think we'll just have you on every single year to walk us through the most interesting things happening in science and tech, because this is always one of my favorite pods to do.
Thank you very much, man.
Happy holidays.
And I'll see you soon.
Yeah, you too.
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