Hello everyone, welcome to another episode of Q&A about history of science and technology.
I see a few questions saved up here, though please feel free to ask more.
That's it. There's several actually quite similar ones here. Philo is asking, would you consider Thales of… of…
Miletus, or Isaac Newton, the first physicist.
Well… I think,
You know, we have to ask ourselves, what is physics? What is science? I always view science as being the effort
To take things that happen in the natural world and create narratives about those things that Sort of fit in human minds that we can talk about.
So, you observe something in the natural world, you try and describe it in a way that, for example, lets somebody else understand what it was, lets you perhaps predict something about what will happen to the thing you're looking at, or something else in the future, those kinds of things.
I think Thales, I mean, I don't think any of his actual original works have survived, but the general vibe has been
you know, he was, kind of… I think he was kind of an everything is made of water, ultimately. I mean, I think one of the things that was a very early idea, it's an idea that's cropped up many times in the history of science, is everything is made of one thing.
whether it's, sort of everything is made of spirit, or everything is made of, kind of, the mind of God, you know, elements of the mind of God, everything is made of monads, this has showed up a lot of times in the history of, kind of, philosophy, and that's intersected with, sort of, early history of science.
I would say that the, the idea that, sort of.
The first kind of meta idea that you need to start imagining that you might do physics is some way of taking all the detailed diversity of the natural world and saying, are there general principles that govern all of this?
from, you know, the river, to the rocks, to the trees, to the sky, etc, etc, etc. What
you know, in what sense is there a unified way of thinking about all these kinds of things? And so the idea that, sort of, ultimately everything is…
made of water or something, whatever that means, and you always have to worry about, sort of, the translation of what was said, et cetera, et cetera, et cetera. I mean, I know that's an issue in many philosophers, what they said, if it wasn't written, for example, in English.
Or if it was written with their own way of saying things, often the sort of the meme translation isn't actually really quite what they meant.
But in any case, so I think this idea that, sort of, you can break down all the things in the world and say something, sort of, about them that is unified, that's a key idea in inventing science.
Now.
You know, in terms of physics, for example, the… kind of the…
the idea that you could sort of know what would happen in certain physical circumstances, clearly, people had sort of an intuitive sense of that from a long time ago. You drop a thing, it falls to the ground.
It's, that's a thing for which people had observed that forever, and people kind of knew, well, there's this thing, and I, I, you know, it's something that causes things to fall to the ground. Now, Aristotle, for example.

had the idea that things would fall to the ground because they somehow wanted to be closer to the center of the Earth.
It's a thing where the notion that
there is sort of a force in nature that is of a different kind than kind of the ways that we think about things happening. I think that's an idea that emerged only rather slowly, and really only Fully emerged in the late 1600s with kind of the mathematicization, the abstraction of science.
I think that the idea of… so for Aristotle, for example, there was a question of what causes things to happen.
And Aristotle, who liked, like, making lists of things, had invented, kind of, four causes, four types of causes for things. I think, let's see if I can remember what they are. I think there's the, the…
The material cause, the formal cause.
the final cause, and another cause. Well, but some of them are not what we might usually think of as what causes something to happen. They're things like, what is the thing you're talking about made of?
Or, in the case of final cause, what is the purpose achieved by having this thing happen?
And the, the kind of, I think the formal cause is a bit, again, one of these translation issues, is more about the form of the thing, the shape of the thing, and so on, how that affects what the thing does, so to speak, or how it can be used, so to speak.
And I think the, but this idea that
Things sort of spontaneously happen in the world.
And it is our… in the natural world, and it's sort of our job in science to explain those things, I think this notion that sort of things just happen in the world
was a complicated notion in ancient times. I mean, there was a… there was quite a tendency, at least in the things that were said, or written down, to say, a god did this, a god caused this to happen. You know, it isn't just…
that the wind blows, it's that some, you know, I don't know.
Poseidon or something is… is… or the waves are going this way. Poseidon is making the waves do that. There was a notion that… that sort of the universe couldn't spontaneously do things.
On the other hand, well, and that somehow it had to come from some causa that was sort of a thing a bit like a human, that would be causing things. I think the idea that things
could, sort of, just happen as a result of, kind of, the operation of the universe. However, whatever that… the source of it might be, that was the thing that really became, you know, clear when one started talking about, sort of, the mathematical versions of science.
Late 1600s, Galileo, then Newton, and so on.
talking about, kind of, we can describe what the natural world does in terms of these things like mathematical equations, and that's just… the natural world just does these things, and there's no causer of these things. Now, I have to say, I find it amusing, interesting, that in modern times, as I've talked a lot about computation as kind of the raw material
for understanding how things work in the natural world, that it's a surprisingly common thing that people you might think of as surprisingly sophisticated ask questions like, so if the universe is computational, where's the computer it's running on?
So, that's very much like
the version in antiquity of, you know, Poseidon has to be, sort of moving the ocean, so to speak. It's not just a thing that happens.

It's a… it's a kind of a need to find some kind of sort of causative element, I suppose, rather than just saying the universe does what it does, and we're merely describing it.
I mean, I think, I noticed another question here from Grant. What actually counts as the beginning of science? Was there a moment when it started? Did it gradually emerge from philosophy and craft-type traditions?
I mean… I think the… well.
There's different kinds of science. I mean, let's take the life sciences, for instance.
you know, was it a science when Aristotle was, you know, cataloguing sea creatures?
Did it become a science when Linnaeus gave the, you know, the binomial classification of biological organisms? What made, kind of, the study of natural history become a science, or is it even a science even yet today, so to speak?
what… what counts as a science? As I say, I think my view of, sort of, what science is, is this way of getting a narrative about what happens in the natural world that fits in human minds and so on.
Now, another thing that tends to be the case in what we might call formal sciences, the exact sciences, is this idea that you can kind of build a tower of consequences with the science, that it is somehow formalized to the point where you can build a tower of consequences. In something like physics.
That tower can be built pretty tall. Once you have the rules for quantum electrodynamics, you can go and spend years of computer time working out
to whatever it is, 15 decimal digits of precision or something, lots of, lots of features of how electrons and photons will behave and so on. That's a tall tower of consequences built on this rather formalized kind of science.
If you ask about biology, and you say, for example, natural history, the forms of preachers on the Earth.
How tall a tower can you build from the Linnaean classification of the forms of creatures on the Earth? The answer is not much.
you can say things like, well, if it's a mammal, it's probably, you know, it might have fur and things like this, or it might be warm-blooded, something like that. That's a… that's a small kind of distance you can get from kind of the structuring of that kind of science.
But, you know, the… to get… there are only a few sciences that manage to get a long way. Now, if we define, kind of, the beginning of science to include, sort of, the classification of sea creatures.
That's one kind of beginning. If we say science only begins when you can build a tall, formal tower, that's a very different beginning, where we're still not quite out of the starting gate for the life sciences, for example. And in, I don't know, something, other… there are areas that have been mathematicized, for example, where we have managed to build pretty tall towers, mostly in physics and places like that.
In other places, I think that we are beginning to build those towers using computation as kind of the paradigmatic basis for thinking about, sort of, how we… how we build up chains of consequences and so on. I think that, if we look at, sort of, the history of science.
The, the… the idea
that you could have some shallow, kind of shallow classification of what was going on. For example, you know, the Babylonians would have descriptions of where the planets would move.

They were not sort of descriptions based on a theory where you built a tall tower, as Newton and subsequent people did. It was rather more of a, we observe in these two places and we can kind of interpolate between those. It was sort of a shallow theory.
I mean, I suppose we could think about this in analogy to the modern world of LLMs and so on. LLMs are shallow theory kinds of creatures. They are, you know, we've seen a bunch of these things before, we can kind of make a… we can get a certain distance in putting together these pieces that we've seen before, but you can't expect an LLM to go and do the deep calculation in quantum electrodynamics.
It could look up a paper that already did that, but it can't do the long chain of computations. That's a thing that is a creature of, sort of, formalized science and computation.
So…
I think we might be seeing, in some areas, almost a sort of an automatization, if not a formalization, of some of these kinds of more qualitative kind of areas of science.
Let's see… Gosh.
Well, there's a question here from Gregory. Did people in ancient civilizations think about nature differently than we do today?
I think… that…
This idea that there is a spirit that moves things, that there is a causer, a human-like causer of things in nature.
Was pretty common in… in ancient times.
I think… the notion that… I mean, in our everyday speech, We are constantly anthropomorphizing nature.
We're saying things about how, you know, this or that chose to do this or that.
Even though the idea of a conscious choice brain-like choice is something that, when we think about it at the level of knowing science, we know that's not what's happening to the rock, so to speak.
The So, I, I think, these questions about
For example, there's a question, can we expect to understand nature? Can we expect that nature will repeat itself?
Is nature doing things capriciously? Or is nature doing things according to a fixed rulebook that's kind of burnt into nature? You know, in… in…
There are religious traditions, for example, where one talks a lot about miracles. What is a miracle? A miracle is a thing where there are laws of nature that one thinks of as actual, sort of constant features of the natural world, but occasionally there's a glitch, a bug, an exception. And something different happens.
And, sort of, the notion that there could be miracles is an interesting notion that, kind of. doesn't… it doesn't conform with the idea that the universe is something which just operates according to certain rules, and and that's what the universe is. It kind of more has the implication that there is a causer of the universe that, like us, can do capricious things.
I think that, the… the kind of the… the kind of an important watershed in kind of the way that people think about nature is probably Copernicus.
1500s, and, the idea, you know, it had been the case that people said, well, we know the Earth is standing still, because look, we're just standing on it, and, you know, it's not moving. And yet, then, what became clear with… originally with Copernicus, and then pushed by Galileo.

idea that, well, no, actually, your common senses are not right. Actually, the Earth is moving around the Sun, and the fact that it appears to you that it's stationary is just a feature of you as the observer, not a feature of the way the…
the world, in a sense, fundamentally is. It's just a feature of the way that you have sliced off that part of the world. Now, I have to say, in modern times, thinking about the Rulliad and things like this, the notion of a true, sort of, objective reality to the universe, completely independent of the observer, is kind of thrown… is thrown in a different direction.
Because with the Rulliad, we do have, in a sense, an ultimate objective reality, which is the whole Rulliad, the unique, necessary structure of the Rulliad, but that thing is something far beyond what we observe about the universe, far beyond… it contains sort of all possible laws of physics.
Whereas the laws of physics that we actually observe are laws of physics that are specific to observers like us, who are, for example, computationally bounded and so on. Now, the observers of pre-Copernican science were observers who were, in a sense, yet simpler than the observers that we think of ourselves as being today.
But I think in, This, this notion
That, well, there are many…
things that have changed over the course of the last few thousand years. One example is the idea of free will.
The, you know, I think in antiquity, to a lot of people, it was just like, fate is going to make certain things happen. It just is that way. And things will happen to me, things will happen to the world, it's fate. It might be caused by the gods, but in some sense, it's fate, it's an unmodifiable fate.
And then, I think it was actually a rather Christian religious concept that, no, actually, we humans have free will. We can decide and take responsibility for our decision to do this thing rather than that thing.
And I think that… that a lot of that kind of segued into all kinds of discussions about sort of good and evil, and if there's a, you know, if there's a God who's kind of determining what happens in the world, how come there's evil in the world, all these kinds of things. And… and I don't know the full sort of theological plumbing of this, but the end result, I think, is that the idea that sort of, there is free will about what you can do, that you can make a personal decision about something. I think that is a sort of post-Christian kind of concept, and that that wasn't the general prevailing view of how things were in earlier times.
And certainly, that
That then throws science in a different direction. Because, for example, once you have free will, once we humans have free will, we can sort of do things to the world, we can do experiments, we can do different kinds of experiments, and so on. Whereas, if everything is just determined by fate, it's a bit of a different story.
You know, I think this idea of, for example, experimental science, clearly, there were pieces of experimental science from long, long ago. You know, somebody had to invent the Bronze Age. Somebody had to, you know, invent the wheel, and so on. It was, these things where people obviously had to try a bunch of stuff, and eventually something would work.
and then they thought it was going to go on working, it was going to work repeatedly. That is, in a sense, a form of experimental science. The idea that you could make kind of abstract conclusions from doing experiments, and you could deduce things that weren't just, oh, this is

how we make bronze, but was more sort of a conclusion, an abstract, almost philosophical conclusion about the world that came from doing experiments.
That was, I think, a much later kind of concept. I mean, Francis Bacon was much involved in pushing that, though I don't think originated it. I think the thing that is non-trivial, and that kind of goes into this question about causes and miracles and things like this, is
Why would scientific induction work?
In other words, you do a thing once, twice, three times, four times. If you do it 100 times, is it always going to come out the same way?
So, scientific induction is… you need very controlled circumstances for scientific induction to really… for detailed scientific induction to work. Now, certain kinds of things, you know, you let go of a rock and it falls to the ground. Okay, it's not a very elaborate experiment, and you can tell it's always going to happen that way.
By the time you're asking questions about, oh, if we… if we push this thing in this way, exactly how far will it move? You have to control things more carefully and say, well, exactly how fast did we push it? You know, what was it doing? You know, when Galileo was measuring things like a pendulum and trying to figure out things about the period of a pendulum, it was, you know, there was, first of all, there was… there were questions about, sort of, how was the… what was the, how was the pendulum
attached, and did that matter? And then it was like, well, how do you even measure the time? Galileo used his pulse to measure the time delay of the pendulum and so on? It's not… it's kind of this idea that you could have a thing
And you could do the experiment many times, and it would come out the same.
That's a non-trivial thing that requires a pretty controlled set of circumstances to achieve, but that's the foundation of scientific induction, and in a sense, the foundation of sort of the traditional scientific method kind of approach.
Now, you know, when you look at the life sciences, even today, we… it's a difficult thing to have reproducible experiments. Molecular scale, yes, they're reproducible. By the time you're dealing with a whole mouse.
you know, you end up having to just say, statistically, even the purebred mouse did this some fraction of the time and that some other fraction of the time. It's not a deterministic thing. It's not like physics, where you say, if you set up the initial conditions exactly the same, it'll come out exactly the same.
Now, you know, presumably part of the reason for that is no two mice are exactly the same. You know, they grew differently, you know, epigenetically, even if they're genetically identical and so on. They had different life experiences, et cetera, et cetera, et cetera.
So, you know, biology, in a sense, has another level of non-reproducibility built into it by the nature of the kinds of things that you're doing experiments on. If you're doing experiments on some particular molecule, well then, all molecules of that particular kind are at some level identical. But not all mice, even purebred ones, are truly identical.
So, you know, scientific induction, in some sense, you know, still doesn't really quite work in in, for example, biology. You do, you know, this happens for five mice, but the sixth mouse could do something different. Of course, that's a thing that bikes one all the time in clinical trials of medical therapies and drugs and so on. It worked on a thousand people, but the thousand and first person had some nasty, kind of side effect from it.
So…

You know, the emergence of scientific induction as a methodology, not obvious. I think it required some degree of, kind of, control of systems. And, you know, for Isaac Newton, for example, his first law of motion that
Things set in motion will stay going, you know, in the… will stay moving the way they have been moving, unless acted on by an external force.
That wasn't a trivial thing for him to come up with. You know, he didn't have air tables where you can have a puck, and you just push it, and it keeps going in that direction. In his time, most things had lots of friction.
You know, if you rolled a ball, it didn't keep going in the same direction, it would come to rest, because it had friction. So, it wasn't an obvious idealization for him to say that the first law of motion should be the way things really work.
My guess is that that… I don't know this history, but my guess is that that was… he was thinking a lot about the heavenly bodies, about things… about planets and things like that, where, certainly from what Copernicus had done, what Galileo had done, and so on.
The idea that things sort of just keep moving
Out in space was a more reasonable thing, even though, terrestrially, you know, that wasn't an obvious phenomenon because of things like friction.
the, let's see, there are all sorts of questions here, but Gregory asks again.
Did earlier scientists feel like they were figuring something, exploring something mysterious, or did they feel confident that they were figuring everything out?
Well, it's an interesting question. For example, the question of whether there can be a fundamental theory of physics has bounced up and down over the years.
to the Greek philosophers, the Democritus and Heraclituses and things like that of this world, they were like, we've almost got it. It's all atoms, it's all things that flow. You know, we nailed it. We figured out how the world works.
Well, of course, they hadn't. They just, you know, they'd said something very kind of qualitative about what might be the way it is.
By the time one gets to Descartes in the early 1600s, Descartes had some statement that, you know, within 100 years, we will be able to understand a tree as we understand a clock today. In his time, there was technology, like clocks, where you could look at the cogs and you could see how it worked.
He thought that that would be true, sort of, throughout the natural world, that there would be a limited time before we could understand the operation of the natural world as he understood the operation of clocks that had been made by human engineers.
And didn't work out that way. And I think the, there was a…
a certain tendency, well, coming into the 1800s, for example, there was a whole movement of natural theology
which was kind of a reflection where one looked at particularly biological organisms and so on, and one said, these are the reflections of the work of God, so to speak, and that
what one was studying was kind of, when one studied biology, natural history, whatever else, or for that matter, science, one was, in effect, studying the creations of God.
And in a sense, one could have the sort of the rhetoric that one was sort of getting closer to God by studying his creation, so to speak, at least in the Judeo-Christian tradition.
So, the, I think, so there was definitely a strand of that.

I think the idea that there was sort of a… a… a godless, kind of hard, clockwork universe that one was figuring out, that was an idea that I think emerged quite gradually, and it probably emerged as kind of the…
the world and the ways to… and the way that intellectual, academic-type people tended to operate. I mean, it's worth remembering that back in the day, sort of all of academia was deeply wound up with the church.
Or with monasteries, or whatever else. It was all kind of the, the, the doing learning, well.
That wasn't true in ancient Greek times, but in, by the Middle Ages, certainly, sort of, the activity of intellectual work was all bound up with, with kind of these religious pursuits.
And I think that sort of unraveled
sometime, probably, well, 1700s, 1800s, and then more firmly by the 1900s. And I think that's, I mean, I think you would have, if you'd polled physicists in the mid-1800s, you would have found that
I don't know, in a country… well, I… certainly in a country like England, I think they would have mostly identified as Christian, for example.
I, I'm not… I think that's true everywhere, and, I mean, in, you know, in the appropriate, sort of cultural
foundation, but as they would have identified as… as sort of religiously oriented. And so, you know, in a sense, this… from that vantage point.
One is studying, kind of, the mysterious works of God.
and not studying the kind of… the clockwork operation of the universe, so to speak. Clearly, Copernicus and Galileo were the beginning of that strand of we're just studying the clockwork operation of the universe. The question of whether you'd be able to get to the end and eventually say, this is really how the universe works.
Not… there's still mystery down there. It's, but this is ultimately how the universe works.
I have to say, that's been a thing where, in my lifetime, people in, let's say, physics have gone sort of up and down, and we're almost there, or it's still very mysterious, and all we can find is an approximation. And it's kind of almost humorous to imagine
that we would actually be able to nail physics, as opposed to always be only working with the Newtonian approximation, the this approximation, the approximation that ignores quantum gravity, the this whatever.
I must say that I feel like we're in the unique position now, from all this effort with our physics project and so on, that we actually can potentially see to the bottom.
We actually can see, right down to the lowest level machine code of the universe, we actually can finally nail it.
we can do what Descartes thought in the 1600s would happen in the next 100 years. Maybe it took 300 or 400 years to happen, but I think we really have reached the end there, which is a different situation than we've ever been in before. Now, having reached the end, having said we know what the machine code of the universe is, you can say, well, does that mean I'm going to eat a piece of chocolate in the next hour?
Obviously, there is a great distance between knowing the fundamental rules and knowing the actual details of what happens in the universe. This is this whole phenomenon of computational irreducibility that I talk about a lot, that even though you know the underlying rules, to know their consequences, the only way you may be able to do that is just follow the rules step by step. You may not be able to jump ahead and look from the outside and say what the consequences are.

Let's see. Alright, some very different questions here.
Well, let's do, Jameson asks, were famous scientists considered celebrities in their own time?
I think that's been very variable.
I think in… You know, in antiquity, like…
Archimedes was something of a celebrity.
I think, I think most of the… most of the philosophers and mathematicians that we've ever heard of today probably were celebrities in their time.
you know, I know Euclid is reported to have been a very minimalist kind of character. I don't know whether, you know, I don't know whether Euclid was known far and wide in his day. You know, somebody like Pythagoras,
was, you know, he operated this sect in southern Italy in the end, after he got ejected from one place and ejected from another place, and, you know, it had a few hundred people in it, and I don't know whether the… whether, sort of in… if you ask people elsewhere, you know, have you heard of that Pythagoras dude, whether they would say, yeah, or whether they would, you know, it's like, we'll wait 100 or 200 years, and then people will have heard of him.
I think if we go to more modern times, it's been… it's been very variable.
I mean, for example.
Well, Galileo made himself a celebrity in his times, I mean, but he did a lot of
kind of marketing. I mean, he went around giving speeches and things, and he was quite an activist, and then, you know, his run-in with the church kind of continued that sort of, you know, the gossip columns of the day were surely filled with information about Galileo.
So, you know, that's an example along those lines. I think…
If we look at somebody like Isaac Newton, he was…
I, you know, I think… first of all, you have to realize that, sort of, everything was smaller. The set of people who might have cared about Newton was a lot smaller than the, sort of, the general public today, so to speak. And, you know, when Newton's Principia was published.
I think maybe 1,500 copies altogether, is that right? Maybe less than that, were produced. And they sort of went to all the… all the people and libraries they might have gone to. Now, with somebody like Newton, the,
You know, the circle that sort of cared about these things will surely have known all about him.
The general public?
I don't think so. I mean, later in his life, Newton became controller of the Mint, and was responsible for chasing down forgers and all kinds of, all kinds of other things like this. I would suspect that more people knew about him in that connection than knew about him as a scientist among the general public.
So I don't think that, in that sense, he was a celebrity. Now, you know, I think he got buried in Westminster Abbey and so on, which is sort of the fancy place for British folk to get buried, and that's a sign of some celebrityhood in his time.
I think, you know, among British scientists, for example, sort of Darwin was another person who was a celebrity in his time, but I think
for a couple of reasons that weren't necessarily so obvious. I mean, first of all, Darwin wrote general interest books. He basically wrote travel books about, you know, his trip around the world on HMS Beagle and all the funky things he ran into.
he also… his, kind of, bulldog, Huxley, was responsible for a bunch of, kind of, PR stunts and so on, like the big, sort of debate with, Bishop…
Wilberforce? No, I'm not… I forget the name of the… it was a debate held in Oxford with,

a person promoting, kind of, the idea of creationism rather than evolution and so on. But, so, you know, Darwin had kind of a PR agent in the form of Huxley. People like Leibniz, for example, no PR agent. I don't think
widely known outside of the kind of court circles in his time. Now, later on, you go to later scientists, for example, Kelvin, William Thompson, later Lord Kelvin, he was pretty well known in his time.
I think he was well known because of things like the fact that he was the guy who helped make the transatlantic cable not break when it was laid. And, you know, he had a company based on that and made some money from it, and I think that
He became kind of a public celebrity, much more on the basis of those kind of technological achievements than the basis of his basic science.
For example, James Clerk Maxwell, in many ways, in my opinion, a greater scientist than Kelvin, although Maxwell died young, so didn't have as many years to produce science. Maxwell was not well known in his time. I mean, Maxwell was, you know, he was a professor in Cambridge in the end, but I don't think he was… he was not a sort of publicly known person.
Now, again, people like Michael Faraday, a little bit more publicly known, because Michael Faraday, part of his job at the Royal Institution, was to do public presentations of science, so people were coming in and sort of seeing his presentations.
Now, you know, there are scientists that were celebrities in their time, but one has never heard of as scientists today. There were, particularly in the Victorian period, there were plenty of scientists who were very much into the kind of science meets spiritualism type thing, where they were known for that.
And when that went away, so to speak, they weren't known again.
There are other scientists in the 20th century. I would say one of the big, sort of celebrity scientists was Einstein,
the, I think Einstein became a celebrity through, sort of, U.S. forces.
I think in his, sort of, life in Switzerland and Germany and so on, I think Einstein was known in, sort of, scientific circles, but I think his real, kind of, celebrityhood and ticker tape parades and things like this, that happened after he came to America. And I think what happened, my impression is.
that…
you know, America was sort of an emerging intellectual power in the 1920s, 1930s, and so on, and I think that the, sort of the, you know, bring in
the, the famous German professor type thing, was, was something that kind of resonated with the, with the emerging kind of enthusiasm for sort of intellectual development in… in the U.S. I mean, I know that, in…
in earlier days, sort of, well, there were… I mean, you go through the various scientists of the 1800s, late 1800s, 1900s, there was not a lot of celebrityhood among most of those. I mean, even the ones who… I know Boltzmann, for example, who was
a, boltzmann became somewhat more known later in his life, probably because he kind of switched from being a scientist, a physicist, to being more of a philosopher and somebody who gave public talks and things like this. But I don't think he was ever terribly well known.
And he came to the U.S, he visited Berkeley, it was a very young university at the time, and
He has some wonderful quotes. He has a… he wrote a little book about, a German professor visits America, and it was… it was clear that, at least for him, America was a very, very

Hicksville place at the time. I think he has a nice quote about how, you know, these Americans do stand a chance. They might go somewhere.
Although I've seen them at their worst doing things like calculus.
But, but, you know, that wasn't a celebrity thing. I think…
you know, an example of, kind of, celebrity in science. When the Institute for Advanced Study was created at the beginning of the 1930s.
There was, was like, let's hire all sorts of, you know, distinguished scientists and so on, but really, the one who was the big, sort of, celebrity person was Einstein, and I think that those forces that drove that were… were different from, sort of, the mainstream science. Now, it also, again, I have to say that
there were people, and I might not even be able to name them, well, I maybe can name a few of them. There were people who were very well known as, in the science circle in their time, but were not
directly scientists that one knows about. So, for example, Mary Somerville in the 1800s was very well known for her popularization of science, which was quite good, but she didn't view herself and wasn't a primary science producer.
But, you know, it would be like people saying, you know, name a scientist, and people would say, Carl Sagan. I never met Carl Sagan.
But, you know, Carl Sagan had done some decent science, but he was vastly better known as a popularizer of science than he was as a primary doer of science. So, you know, this question about celebrityhood in science, there's kind of the celebrities who also happen to be a bit scientists, or more seriously scientists. There's the,
You know, there are people who are, you know, and then there are people who are scientists who kind of, you know, typically, people are not
people are rarely known for their science alone, at least for a long time. And I think, you know, typically there's some other sort of hook that kind of introduces them to the world. I mean, I'm trying to think of,
Am I thinking of counterexamples for that?
You know, there are occasionally moments when, sort of, science hits
the celebrity button. So, for example, when Andrew Wiles proved Fermat's Last Theorem in the 1990s, there was a brief moment, in fact, I talked to Andrew Wiles at that time about… about how to handle the PR, so to speak. He didn't take my advice, but that's… which is a shame for many reasons. But in any case, the,
about,
kind of, you know, that was a moment when, sort of, the media caught on to, oh, something happened in science. I mean, I think, you know, the question of what makes
You know, what… what should the public care about? What does the public care about?
what… how does that relate to the raw science that's being done? I think those are complicated questions, and anyway, that's a somewhat fragmented answer to the question about scientists who were or not celebrities in their own time. I mean, there… there are
Scientists, where they kind of died believing their theories were utterly forgotten.
And, there are scientists where they knew perfectly well in their lifetime that their theories were going places. Sometimes they knew their theories were dramatically going places, sometimes, just that, yeah, well, people at least had understood what they'd said.
And sometimes it was a curse for some scientists that very early in their lives, they had theories that were successful.

And then it was like, well, what do I do next, type thing. And I think those are… so it's a complicated thing. I mean, for… I think sometimes that the best trajectory is that, sort of, theories are gradually absorbed over the course of one's lifetime, so to speak. And that's kind of a fun ride, rather than, you know, you're 25 years old, everybody gets your theory immediately. And then it's like, well, what do I do next, type thing.
So, while sometimes one feels, I certainly feel that it will be good for the world, and it will be nice to see the things one's done absorb more quickly, in some sense, maybe it's not such a bad deal to have them, sort of, a slow burn, so to speak, of the absorption of things.
Let's see…
Boy, other questions about,
Okay, there are all kinds of interesting questions here. Well, let me, let me, take one from Zach. What was the work ethic of scientists now and in the past? Were they working harder? Has the way of thinking and doing science improved?
Well, the amount of science that I can do per unit time today is so ridiculously larger than even I could do in the past, or than people could do in past ages. There's no comparison. The automation of science has had dramatic consequences for the rate at which science can be done. I mean, I've spent a lot of my life building tools, like Wolfram Language, for going from idea to implementation, using computation as a tool. That's a… that's a huge multiplier for what one can do in science.
Even the better connectivity of the scientific literature
the web, the fact, you know, I can go find, you know, what is known so far about this or that thing. LLMs, another level of this where I can just ask some question, and the LLM will sort of pull together things which effectively came from grinding up 50 different scientific articles and produce to me the thing that I actually want to know. That's super useful.
And, you know, I think these are huge multipliers for the… for the sort of effectiveness of science. Also, the communication of science… well, the communication of science is a mess. I mean, the communication of science back in the day was people writing books.
In the 1600s, scientific journals came into existence. I think for a long time, it was sort of, I'm going to send it to my friend who's the editor of that journal, and then later on, particularly post-World War II, kind of, I'm afraid this was one of the legacies of Robert Maxwell, a kind of publishing baron, who kind of had this idea of buying up obscure journals and then making, it's kind of a racket.
of selling, you know, getting university libraries that were trying to sort of advance themselves in the 1950s and 1960s. If you're going to be a respectable library, you have to subscribe to this set of 200 obscure journals, and by the way, they're going to be very expensive.
But that dynamic of pushing, kind of, the giant expansion of the scientific publishing enterprise made the whole thing kind of a mess.
And then, you know, things like peer review became popular, and the sort of… the dynamics, the publish or perish dynamic of academia, has, in my view, largely ruined kind of the sort of the actual… the publishing part of science. Now, for people like me, I haven't published a paper in an academic journal, or at least I haven't… I haven't sent a paper to an academic journal since 1986, some journals have republished things of mine, so I can't say they've never appeared there. But my primary means of communication is I just have a website, and I post things on it. You could call it a blog, but I think it's a little bit of an extreme version of a blog, because there tend to be 100-page documents and things there. But, you know, that's a thing where, you know, when I finish

working on something, I press the button, and it's out in the world. And that's a thing that's… that's a good dynamic.
that's a thing that sort of also existed in the 1600s, if you were, you know, publishing in the Proceedings of the Royal Society, and you'd send it in one week, and, you know, the printer would print it, and out it would be in a week or two.
The, you know, that got all sort of ground to a halt in the, in the giant expansion and, and, and mess of, sort of, academic publishing.
So, you know, the workflow of the… the workflow of scientists has… is affected a bit by how scientists make a living.
So, you know, back in the day.
many scientists were independent, you know, of independent means. They weren't making a living doing science. A few people, like Isaac Newton, made a living doing science.
you know, he had a professorship, the Lucasian professorship, endowed by a chap called Lucas, I think, not long before Newton had it. And that was kind of the deal, was you are there to do science and teach science and so on, or officially mathematics in that case.
But that was… that was fairly unusual. I think for… For Newton.
For example, well, for, you know, Newton didn't get to use Wolfram language to do his calculations, nor did Maxwell, or Kelvin, or any of these people.
You know, and that means they spent a lot of time, you know, I've seen in their archives of some of these folk, you see their actual, you know, calculations, their pages and pages covered with, you know, things being calculated and so on, and it's like, now you just type it in and it gets done. And but I think that
And, you know, when I started doing science, it was, you know, there weren't word processors yet.
And so, you know, you were handwriting things, you were putting sticky labels on things to make corrections and so on. There was a certain amount of extra, kind of, time waste associated with those types of things.
I think, but… but I would say that for… so there's been a strand of scientists who either were a rare set.
They got paid to do science.
Or people who had independent means and were able to do science.
And in modern times, that's pretty rare. I mean, it exists in some, some places, and there are a small number of people, like myself, who just…
Do science, you know, have a day job doing something quite different, in my case, running a tech company, and, you know, have the means to just… and the… and the kind of motivation to just do a bunch of science, so to speak, independent of those constraints.
That's a very…
that's… you can do a lot of science that way. I think I've… I'd like to think I've demonstrated that, particularly in the last 5 or 6 years, that with the tools and the freedom, you can get a lot of science done.
My situation is not common. The common situation is
You're an academic, you're working at a university, you're teaching a bunch of classes, you're on a bunch of university committees, you are, you are writing proposals, most of which get rejected, you are trying to kind of toe the line to,
to make sure that people support the stuff you're doing, so you'll get funded, so you'll get promoted, all those kinds of things. I think…

that the effort of writing proposals, for example, and sort of fighting with journals and things like that to get your papers published, I think that's a high load.
on typical scientists today. I think a lot of times, people are doing as much on the procedural side of science, of write the proposal, respond to the reviewers, do these kinds of things as they are doing actual, sort of, scientific research.
In its own right. I mean, I hear that complaint from many people. Not my situation. My situation is I get to carve out time, sort of, you know, in addition to my day job, I sort of carve out a bunch of time to do… to do science, and then I just do it.
And, you know, I've built a lot of tools and so on, and have some folks who work with me who help me, and that helps a lot. But, you know, it's a… and I think…
Well, another thing that's changed in science in modern times, not so much for me, but for other people, is this, you know, it's all done in teams.
I have to say, while it's great to have people help me do stuff, and often they go off and do other things with the things we've done and so on, and that's wonderful, you know, I think, sort of, highly creative science is pretty…
You know, it has to be driven
with sort of a single leader mechanism. I don't think this, let's have a great big team that sort of committee figures out these things. That seems like a very slow way to do things to me, but that has become much more common in science. Maybe I'm wrong about that. Maybe it's an effective way to do science, but it feels like much more of a proceduralization of science.
I mean, you know, in a company or, you know, when you're doing product development, sure, you have a big team, but that's a… there's many aspects of product development that are quite proceduralized. There's, you know, there's the UX design, there's the quality assurance, there's the, you know, this and that and the other thing.
I think, it's, so, so, I mean, the, yeah, so I think, and to the question of whether scientists work harder now than they did in the past, I mean, they are, you know, they're, they're a…
My guess is that different scientists have worked more and less hard at different times in history, and it's been more of a sort of, it hasn't been something that's changed through history, except for some of the proceduralization of science. You know, if you look at some areas of science, particularly math.
You'll find people who work very, very hard, and are doing, you know, doing math 14 hours a day, and you'll find people who say, yeah, you know, I go to the cafe in the morning, and I spend 2 hours thinking, and that's the time I do my great math, and the rest of the day I'm goofing off.
And those people sometimes are as
in a sense, productive, maybe not in writing as many pages and so on, but they're as productive in terms of their contribution, let's say, to mathematics, as the people who say, I'm working 14 hours a day, 16 hours a day, doing this kind of thing. It's something where when there are procedural aspects of science, then you kind of have to put in the time. When it's more the idea side of science.
you, it's more a question of having the ideas. I have to say, for myself, I work very hard, and, you know, part of what I have
managed to do is I have, kind of, ways to grind forward with science that involve doing computer experiments, writing things, and so on, which are things that take time. And it…
isn't the case. If I were, sort of, if I were just saying, let me just take all the things I've done in science and just have the ideas of those things, I'm sure the raw ideas, in principle, could be had

quite quickly. You know, probably everything I've done in science, the ideas could be had in a few months.
If it was just the raw ideas. But it turns out you just can't do that. You know, you don't have those ideas until you've done all of the actual work around that to get to the point where you've developed the intuition, you would develop the understanding to then, okay, now I have an idea type thing.
Let's see…
Okay, so Ann… Annieel asks, are there historical ideas or proposals that…
That, okay, that you're waiting for science and technology to catch up on so that these ideas can be materialized. For example, that machine learning required GPUs and lots of training data.
Well, I thought I was going to ask about history, because there were things that people knew, like the idea of artificial satellites, things orbiting the Earth.
Newton knew that was a possibility, but clearly, in his time, the technology of launching a rocket was, well, sort of far away. I mean, it's an interesting question. I mean, the Chinese, you know, folk definitely had, you know, they had gunpowder, they had, they had, fireworks and things. I… it would be an interesting question whether Isaac Newton ever… whether it ever occurred to him that you could take a firework and shoot it up and eventually have it go into orbit. I don't know. I mean, my impression is that that idea only really emerged seriously by
well, certainly by the 1920s, and people like Goddard,
I don't know whether that idea, when it was a question of, you know, H.G. Wells and Jules Verne and people like this, I guess that they had the idea that you could shoot something up and it would go into orbit, but I'm not sure that that idea was clearly understood. I mean, certainly previous ideas, even from antiquity, I think Lucien had an idea that you could take a trip to the moon by having a bunch of geese
pull your, you know, pull your chariot, sort of, up into the sky,
But, so, you know, that, that, the idea that you could, like, go to the moon was an early idea, but, you know, the technology didn't exist for quite a while.
I think that there's always this complicated leapfrogging of what becomes sort of…
the tools, the technological tools that exist that allow you to understand and do something to the point where you can develop the intuition to see what it is you might want to do. I know in my own life that it's been a sort of continual story of building a tower in which there's a layer of technology that provides tools, that let one do a bunch of experiments or get a bunch of intuition, and that then leads to kind of a new piece of science
that then keeps going and leads to more technology and such like. I mean, I think for my own life, there are definitely things where I kind of wonder, could one do this? Like, one very, very big one probably centers around nanotechnology and the extent to which you can sort of control individual molecules and have them compute things. I mean, I think one of the visions one can have
is that just as 100 years ago, artificial materials like plastics were invented, which are sort of things that don't occur in nature, but they're made up from molecules, but they're still very static things. Could one eventually make everything out of computers, in the sense that every molecule is sort of computing things? A little bit like happens in biology, but could we do that in an engineering kind of way?
That's something which, for me, I've been sort of waiting for that to come over the horizon.
for decades now, that one could sort of have an engineered nanotechnology that's kind of molecular-scale computing and so on. I mean, I think there are,

There are plenty of other things where one sort of knew one could do them, but one had to wait for the technology. I don't know, gravitational wave detection is another one, where one sort of knew one could do it, but, you know, where's the technology? Now, for example, for me right now, understanding the discreteness of space.
You know, we have a model of how things work, we don't know the scale of discreteness, and the question is, could we possibly detect it? You know, or is that so far out of range technologically? I mean, it's always worth remembering, when you see some new physical phenomenon, for example, people start talking about, you can immediately ask, when's that going to turn into technology?
So, some things, like, I don't know, the blue LED,
That turned into technology really quickly. You know, there'd been red and green LEDs. As soon as the blue LED was invented, it was just some… what was something… some…
Oops.
Rare earth.
metal nitride, I forgot what it is. But, you know, once the material was known, the doping procedure, I think it involves electron beam, firing an electron beam at the material and things. So once that had been invented, there's blue LEDs everywhere.
which make up, you know, the white light LEDs from red, green, and blue.
But so that was very fast, to go from the sort of… that wasn't so much a scientific theory, that was more just this particular material does this.
Then, there are things where kind of going from the scientific idea
to… well, first of all, knowing that there was any point in doing something with it. Like, liquid crystals were discovered in the late 1800s, I think, but the idea of using them for displays was a… was an idea of the 1970s, or maybe, yeah, 1970s.
And
So, you know, that was a big span from the fundamental physics being discovered to something being done. Now, you know, when it's, sort of, the physics is known, but you can't actualize it, Well, light gravitational waves were an example of that, where from basically 1915, it was known that there should be gravitational waves, but whether that would even be conceivable to detect those. I mean, I remember that I knew the folks who were first working on this in the late 1970s. It was very, very unclear that there would be strong enough sources of gravitational waves, that you'd be able to build the device well enough, that this was a thing of our century, or one century after that time, so to speak, rather than, or that the next century, but, you know, 50 years later or something.
Rather than a thing of 500 years from now, so to speak.
I mean, there are many things that, for example, in biology, in theoretical ideas about biology, and actually a lot of things that have to do with, kind of, molecular scale computation, where, you know, they're probably not yet of our time. I think that the thing that's always worth remembering is
sort of…
the shocking… shockingly big numbers that show up in everything to do with molecules. It's, you know, we are beginning to get to the point with computers where there are shockingly many, you know, bits of memory in our computer, or pixels on our screens, so many that we certainly couldn't count them. But
Those numbers pale in comparison with the numbers of molecules in a, you know, in a piece of gas this size, or something like this.

And those, yet again, pale in comparison with, kind of, the number of atoms of space in the universe, which yet again pales in terms of the number of, kind of, atoms of existence in the Rulliad.
There are these huge changes of scale, and I think we, you know, there's a whole class of kind of scientific thinking kinds of things that involve each different level of that sort of hierarchy of scales. So, really being able to have, you know, we're able to do a lot of experiments today, and a lot of measurements and things today, because we have computers that have gigabytes of memory.
But, you know, when we have materials that have molecular-scale things, that have, you know, instead of billions of bits of memory, they have,
Oh, let's see, trillion, trillions of bits of memory, effectively. That leads us to a different place, and I don't think we yet have intuition for how that all works.
Let's see…
Well, IC, or Elsie asks, does the modern world and its distractions get in the way of sustained deep thinking or work behind, sort of, breakthrough advances of the past, or is this now obsoleted by collaboration, technology, and so on?
you know, as I said before, I think we have huge multipliers as a result of technology, automation, communication, and so on. Yeah, we have more distr… I think people had distractions at all times. I mean, you know, back in the day,
you know, people would have to grow, you know, everybody would have to grow their own food. You know, I don't know whether
you know, Archimedes had to worry about whether, you know, the chickens in his chicken coop were ready to be eaten and things. Maybe, I don't know, his living circumstances, so to speak. But, you know, there were… there were plenty of things that wasted people's time, in some sense, before modern times. I mean, modern times, we have it really easy in terms of a lot of things that people had to spend a lot of time on. I mean, like, for example, modern transportation. is, you know, vastly quicker. Of course, people end up going further, but it's vastly faster than it was, you know, back in the time when people were riding horses or taking horse-drawn carriages, things like this.
Similarly, even, you know, do you have to make your own paper?
Do you have to, you know, make your own quill pen by taking a feather and slicing pieces off? you know, those are things which were sort of things you had to do back in the day, which you now don't have to do. And the, instead, you have things that could distract you. I think there have always been things that could distract people. I mean, it's… I'm sure there have always been, kind of, you know, you could, I mean, I know,
Well, like Isaac Newton, for example. He went down to the pub and, you know, met the locals and so on. By the way, to the point about celebrityhood, I know that when he was down at the pub meeting the locals, they didn't think he was a celebrity.
He was just, you know, a funny chap type thing. Not, was not perceived as a celebrity, at least, And I think,
you know, there have always been distractions. I think the question of the single-mindedness and tenacity to do science is something that is, you know, happens with people who get motivated or who have the… who are built that way, and I doubt that that… I would doubt that that's changed all that much in the course of time. I mean, you know, for somebody like me, I don't watch television, I don't scroll through social media.

You know, probably I miss a lot in the world from that, maybe, maybe not. But, perhaps if I just took the time I could be spending doing those things, you know, that may be the time I'm using to do science, I'm not sure.
Yeah, Peter is asking, what would celebrityhood look like back then, with no media, no books for the most part, sort of pre-Gutenberg? Well, my impression is that there were people, you know, if you went to ancient Athens, wasn't a terribly big place, but, you know, people would be like, oh yeah, that guy Socrates, I've heard of him.
Now, you might have seen him in the Agora or something, so it might be a small enough place, but I think there were… there was plenty of, kind of, word-of-mouth celebrityhood
long before, kind of, you know, any kind of… you didn't need to be on TV to be famous. You know, word of mouth was quite sufficient, and probably word of mouth is an important driver today. You know, it's not broadcast. It's, oh, did you see that thing somebody says, rather than, you know, everybody simultaneously seeing it on television. I mean, maybe at some point, a few decades ago, when television was sort of in the ascender.
that then kind of, like, everybody watched the evening news, and they all saw it at the same time. Now that there's much more fragmented media, I don't think even that will be the case.
At this point.
Let's see…
Sailing is awesome. Historically, many of our greatest technological leaps emerged from military conflict. Is it possible for humanity to achieve the same rate of innovation through peaceful challenges?
I mean, my impression is there have been many times when, when sort of military needs have caused things to jump forwards. I think commercial in…
you know, commerce is not a terrible driver either. Commerce…
tends to have a little bit of, you know, if you're in a military situation, you're in some country, sort of everybody in that country, presumably, is pushing in the same direction, you're trying to make something work. There's kind of a bigger…
a bigger collection of people, sort of all pushing in the same direction. In commerce, I think it's much more there are going to be, you know, five companies that are all trying to do the thing, and it's a little bit less, you know, you're a little bit less, let's put everything into this to do it. But it's certainly something of a driver, and that certainly led to plenty of technological innovation.
I think this question of aspiration as a driver of technological innovation is an important one, and I… and that's a complicated one, because sometimes there's, you know, there have been times in history where there has been… there's been an aspiration, there's been an aspiration forced upon one by… by war, for example, and there's aspirations that are… that are developed
Not in that way. So, for example, let's say, let's go to the moon.
You know, that was an aspiration that was a very easy-to-understand aspiration that led to a bunch of technology being developed. In the end, in raw terms, that aspiration maybe isn't that important.
It's, you know, we, in the 50 years since we've been on the moon, with humans who've been on the moon, it's, you know, we haven't missed that much, I think. You know, not a lot of advances in geology that could have been made, weren't, and so on, probably, I don't know for sure.
But, you know, the kind of, let's make science go forward, I don't think has been critically affected by that. You know, I think that… but the aspiration, the idea, let's go to the moon.
That was a big driver of a lot of technology development, and so on.

I think in modern times, there's a question of what should the aspirations be? I mean, the AGI aspiration is an amusing one. I mean, I think it's kind of a sort of philosophically and technologically doomed aspiration as such, but it is an interesting one as kind of a driver of effort and investment.
I think it is not helped by the fact that it has… it has quite a lot of, wait a minute, that doesn't make sense going around it. You know, let's go to the moon, it's like…
well, maybe it isn't the best way to spend all the tax dollars type thing, but at least it's a… it's a thing. Nobody's going to kind of argue, well, not much, at least, about whether you did it or not. Things like this.
So, you know, I think that in modern times, there are some of these aspirations, there are medical aspirations, longevity ones, you know, cure cancer, things like this. Those tend to be slower burn aspirations, that it's less obvious. I mean, there are a few that are very immediate, like clone a mammal.
Boom, it got done.
or, learn how to do genetic reprogramming. Boom, it got done. I mean, they have many tales of how those things get used, but fundamentally, those are sort of moment-of-time kind of breakthroughs. I think,
And those particular ones, well, certainly those were not driven by military objectives. I think in the case of,
you know, in the life sciences, perhaps fortunately, I don't think we've seen as much
driven by military purposes. I mean, maybe the development of antibiotics, to some extent, although the existence was not related to, you know, to wars, but their deployment was.
you know, x-rays, also not invented for a war, but saw deployment in the First World War and so on. And maybe that deployment helped, sort of, push, kind of, the consumerization of X-rays. I'm not sure of that. I think,
In, yeah, and, I mean…
the idea of developing aspirations and then sort of driving science with aspirations is a good idea, particularly if the aspirations make sense. And it's a lot easier to have an aspiration, like, let's not lose this war, than to have an aspiration that's like, let's make a quantum computer or something. And, you know, it's a…
It's a more, and sometimes, also, in some sense, The, the military objectives
Might seem less, sort of, science…
immediately science-aligned, but I think it's usually the case when you build a big enough tower, intellectual tower, anywhere, you achieve something useful. Let's take radar as an example. You know, there wasn't… it didn't seem like there was a bunch of basic science associated with radar. It, you know, it was… it had a bunch of good ideas and things, and you needed to understand radio, and you needed to understand signals, and signal processing, and so on, but…
Once radar had been developed, well, not only did you get microwave ovens, you also got particle accelerators, and you got the whole possibility of particle physics that came out of, kind of, microwave engineering and things like this.
And I think that's, you know, so that's a… that's kind of a way that… that things get driven from the technological push
we've got to get radar working that had kind of the spin-off of these other kinds of things. Just like the space program, you know, part of its spin-off was kind of the microprocessors, Silicon Valley, that's not the only source of microprocessors, but that was… that was an important driver for that.

You know, I think there was a question earlier about,
things that… science… science that waits for things to sort of develop in the world to be able to be materialized, and I would say that one of the things that I'm sort of reminded of there is particle physics. Particle physics, I think it's really cool, you know, all the muons and kaons and all that kind of thing, but in the
80 years or so, well, more than that, it's nearly 100 years now, that we've known about a bunch of those particles and things. It's like, technological applications, a little bit lacking. I mean, there are a few of those things that are useful for radiation therapy.
Because those particles happen to have, to be absorbed in a more, more in a kind of lump, rather than over a distance, and so on.
And, you know, for muons, there's a little bit of, sort of muon tomography of the Earth, finding, you know, underground mineral deposits or tunnels or whatever else. But certainly particle physics is not, sort of, big time applied in the world as it is, and part of the reason for that, probably, is things like, oh, muons live 2.2 microseconds, you know, on
On average, for example, that's a short time. If you have them go really fast, you can have time dilation, and they can live much longer, but it's like, not so much happens in 2.2 microseconds. Of course, people have often talked about things like muon-catalyzed fusion. If something like that had come to pass, then immediately that piece of particle physics would have had a big effect on, kind of, what, what happens.
I mean, this… and coming back again to aspirations, I mean, fusion is obviously another one of these aspirational ideas that's been around for 80 years or so now, and it's kind of at different times. It's been like, oh, it's a big driver, we really should push to do it, and it's like, look, guys, this isn't going to work, let's give up on it. You know, the look, guys, this isn't going to work, let's give up on it, happened a lot in machine learning over the years.
And you know, that was so… so, you know, sometimes when… when things… when things seem like they'll eventually work.
you know, eventually they'll probably work. Like fusion, for example, controlled fusion. But, you know, exactly how long the technology path is to get there is very, very hard to predict.
Maybe one or two more… oops, I think I'm running out of time here.
I'll take one more question here, I think.
From ACC.
Ahmed?
Do you know about the history of the different possible logics? Rather more technical thing, but I'll just try and talk about that for a few minutes. I mean, logic…
originated in antiquity.
With kind of an attempt to kind of idealize, formalize, and classify the structure of arguments. That had happened a bunch before Aristotle, but Aristotle is most famous for having, sort of, catalogued the forms of syllogism that represented, kind of.
possible valid arguments. You know, all men are mortal, Socrates is a man, therefore Socrates is mortal.
That's… again, that had precursors in the pre-Socratics and so on, but Aristotle was the one who usually gets, kind of, the credit for having catalogued and launched that. That idea of logic carried through, through the Middle Ages, syllogistic logic was people would memorize the forms of these arguments, these syllogisms, and so on. Then.
sort of the next big jump was George Boole in the 18… 30s, 40s, 30s.

I should know, 40s, I think. 1840s. The, in his, sort of, mathematicization of logic and Boolean algebra.
So, Boole…
was kind of roughly saying, let's, you know, we know about arithmetic, plus and times and so on. Times is a little bit like OR, you know, 1… true is a little bit like 1, 0 is… false is a little bit like 0. Sort of, you know, AND is a little bit like you multiply
things X and Y together. If, sort of, if they're both true, if they're both ones, you get one. If either of them is 0, you get zero, okay. Multiplication is like AND. What's… what's, OR like? Well. you know, 1 plus 0 is equal to 1, that's all good, 0 plus 0 is equal to 0, that's all good, but 1 plus 1 equals, oops, 2. It should be equal to 1 if it's just, true or true is true.
So Boole kind of tried to squiggle that around to make an algebra that was kind of like ordinary algebra, but was an algebra where 1 plus 1 equals 1.
And he succeeded in doing that in Boolean algebra. It was a little messy at the beginning, and that kind of led to that sort of formalization of logic.
Well… Then… the, the other… Well, okay.
There are… different forms of logic that we can… different branches from there. There are so-called modal logics where
In addition to saying such and such is true, or such and such is not true, you could say things like, such and such is possibly true, or such and such is not conceivably true, or such and such is true now, but may not be true in the future, or such and such is,
Is true in all possible worlds, or such and such is true only with et cetera, et cetera, et cetera. Those modal logics had, sort of, syllogistic origins in antiquity.
They were not formalized in the same way that Boole formalized ordinary logic. They were not formalized until maybe the 1920s, 1930s, as, but that was one kind of branch, was these logics which have extra stuff, temporal logic.
maybe spatial logic, which is less well formalized even today, but temporal logic of, you know, this happens forever into the future, or this will start happening in the future and then will go on forever, type thing. And there's obviously a structure and logic to how those things combine.
And that's the thing, temporal logic
was, I think invented certainly by the 1930s. It had been, but…
Temporal logic, as an industrial scale thing, came in in probably the 70s and the 80s, when people were doing a lot of systems engineering and verification of systems engineering, like, we have this thing. Will it be the case that the, you know, the wheels of the aeroplane will always stay down when it's on the ground type thing? There's sort of a temporal logic aspect to forever, once it's on the ground, the wheels will stay down type thing, and there's different logic for, you know, the wheels will go up at some point here, et cetera, et cetera, et cetera. So that was a… temporal logic sounded more industrialized at that point. The other branch of logic… well, there's several other branches of logic. Another branch of logic is multi-valued logic.
Where you have, you know, no, yes, and maybe type thing, and there's kind of a mathematical theory of multivalued logic. Lukasevich, in the 1920s and 1930s, was big on that. There's kind of an axiomatic formulation of multi-valued logic.
That you can come up with. That's a thing that I don't know whether that had precursors, it certainly was a thing. Mathematically, it was… it's never been the biggest thing in the world, but it's been a thing that's sort of a sideshow to logic.
Then there's Fuzzy Logic.

Where it's sort of a little bit more segues into kind of probabilistic statements about things.
Again, that's had a certain life, not quite, I think, probably peaked sometime in the 1980s.
And, well, let's see, other forms of logic. I mean, the, Kind of… Well…
You know, people have thought logic is very magic.
I don't really know why, because logic in the form imagined by Aristotle and Boole and so on is very specific.
It's an axiomatic system, it's a rule-based system, it has a particular set of rules. You could pick other rules. Some of these other logics pick other rules. But yet, some people have felt that, you know, logic
well, you know, it has the… it has the kind of the weight of the authority of history, so to speak, but it's been around for 2,000 years. People have felt, you know, then everything must be based on logic. Logic is the foundation of everything. So, for example, between Frager and Russell and so on, it's kind of like, well, let's base math on logic.
Let's start from just…
things that are logical statements, invent the integers based on some sort of logical statement, the number of sets that are not members of themselves, and things like this. The,
and, you know, as a way to start counting, that you can do that sort of quotes purely from logic, and build up everything on this… on this kind of foundation of logic. I've always thought this was a bit silly, because logic, as such, is just a very specific rule system that happens to be a good summarization of certain kinds of human arguments. I don't think it's where you get to build everything.
thing. You, you can do it.
Because there's enough sort of universality at a computational level, you can build everything from that foundation, and certainly for the practicality of computers, that's important, but from a theoretical point of view, that's sort of not where you have to start.
So, that, that's, And I think… When it comes to… Well…
Yeah, I mean, there's a whole separate branch
of thinking about logic as a kind of a way of kind of making inferences in mathematics, kind of laws of inference, and logical laws, and, modus ponens.
as a driver of building more in mathematics, I don't think it's a great direction. I think that this sort of very constructive, very structural approach
you've got two theorems in mathematics. You can kind of intersperse them by having one variable refer to something in the other theorem, and so on. That's the way to sort of build up mathematics. It's much more, what can you construct
then what do you deem to be true? I think the notions of truth and falsity in mathematics are quite muddled, and you get yourself quite confused by thinking in terms of those constructs.
Anyway, I think that's, probably all I have time for.
today, but I see all sorts of fun and interesting other questions that got asked here, and I look forward to addressing them another time. I should say that I am,
I've said a couple of times, we haven't actually done it. We're shaking it up a bit as far as how these live streams are set up, and I will be starting some philosophy discussion livestreams, fairly soon. I also really want to do some slightly more technical, let-me-show-you-code type livestreams also coming soon.
But for now, thanks for joining me. See you another time. Bye for now.