Hello, and welcome to another episode of Q&A about History of Science and Technology.
Let's see, I think there are some questions here.
Gosh, lots of questions.
Let's see… HistoryBiffiff asks. They say history…
A history unstudied leads to a repetition of the same mistakes.
What parts of the history of science should we be studying or learning from?
that's an interesting question.
the… So… things that happen in the history of science. People have good ideas.
And the ideas get discarded or ignored for one reason or another, and then eventually they come back, and people are like, we could have figured this out 100 years ago if we hadn't been confused by this or that thing.
That's one type of thing. Another type of thing that happens is people, for some political, cultural, whatever reason.
Decide that something has to be a certain way, and the fact that it was… it is in fact, some other way gets kind of hidden for a long period of time.
I would say, I mean, if I look at…
Look back at some parts of the history of science, you look kind of a snapshot of what people were saying at some point in the past.
A few things, I think, strike one.
So…
Looking in modern times, you say there's a certain amount of good stuff, and there's a fair amount of noise.
And you might say, oh, that noise, that's a feature of modern times, you know, science is big, etc, etc, etc. Some of that is true, but if you go back to, let's say, the 19th century, and you start reading through, you know, science journals and things like this, there's still quite a lot of noise there.
And the thing that is confusing when we see history from the future, so to speak, is that that noise all got forgotten. And 100 years later, people only remember the signal, so to speak.
So, you know, there's… there's always noise, and that's something to recognize.
I think…
that another thing that happens is that there are things that were very famous in their time, and utterly forgotten years later, including people who were very famous in their time as being, you know, that was a great scientist of time X, and, like, nobody's heard of them later.
And usually the reason for that is that a lot of the science they were doing was not really significant for its content as it was significant for the fact that this person was a strong expositor, or this person had a school of people who followed what they were doing, things like this.
I think…
Well, there are other things to say about history of science. I mean, another thing is sometimes people take the point of view that this or that thing was established. It's true that XYZ.
when it in fact, isn't. And people don't go back and rethink those things. I mean, in, I'll give a few examples.
Okay, a very typical issue is…
A field has started. At the beginning, sort of, everything is up for grabs.
But then, certain things get kind of folk-established in that field. It's like everybody knows that blah blah blah.

You know, everybody knows that quantum mechanics is very weird, and you do, you know, quantum measurement this way. You know that, you know, everybody knows that,
some result about, I don't know,
neuroscience or something. Everybody knows that, you know, memory is stored in this way. Everybody knows whatever.
And sometimes.
and then people kind of build these fields on top of that. A good example, direct example, in physics, sort of everybody knows that relativistic invariance is fundamental to the structure of space-time.
And everybody knows that space and time are sort of the same kind of thing, are interconvertible, and we should only talk about space-time and not separately about space and time.
about those two latter things, I think those things are wrong, and they're things which to a good approximation are true, but they're not things that should be thought about as sort of foundational to the structure in that case of spacetime. Yet, for the last hundred and something years, they've been sort of part of the orthodoxy of that area of science, and just assumed to be true.
So, a thing that I've noticed very often is that
you know, in the first generation of people who work in a particular area of science, it's like there are many things where they're sort of up for grabs, and they don't really know how it works, and they're kind of tentative about it. But by the time you're kind of 5 academic generations later, the people who come into those fields are just like, oh, that was established, you know, 50 years ago. We know that's true. We don't have to discuss that anymore.
this, we know it's true and we don't have to discuss it anymore, but when you push people, they say, well, I don't really, you know, you know, we just know it's true, you don't have to talk about it. That's always a sign of a weakness, and that's happened in the history of science over and over again, that these things which were just… things assumed
turned out not to be true. That was also true for absoluteness of space. That was kind of the story of, kind of, the Newtonian version of space, the Galilean version of space, versus Einstein's version of space in relativity, and so on. That for a couple of hundred years, it was like, this is how it… how we know it is. I mean, even going back further, when it was, you know, we know the Earth as the center of the universe.
And we can tell that the Earth is standing still, it's definitely not moving, and that was a thing that people sort of just took as a sort of an axiomatically true thing for a long time before it became clear that wasn't the right way to think about it.
But, so, I mean, I think the… the… I suppose the meta lesson of the history of science is, you know, scientists are… are kind of, they're… they… they… they're herd-like animals.
So to speak. They tend to, you know, once the herd is going in a certain direction, there won't be a lot of stragglers, and people won't take the stragglers seriously, even if they're there, saying, wait a minute, that wasn't the right direction to go in.
And sometimes the herd has it right.
And that is the way that science progresses. But sometimes, particularly when people are so certain about something, and yet, if you ask, well, why is that true? People just sort of say, but it is true. You know, I know as a practical matter, talking to experts in many areas of science over the course of many decades now, that's always a dead giveaway.

When people are like, I… I… that's so obvious, I can't tell you why it's true, type thing. That's always a sign that there's… there's something… there's something fishy there, and often something that leads to very interesting science when you pick it apart.
Often, in what kind of happened is that there was a reasonable assumption to make for the early development of some field, but 100 years later, when it's worth reexamining that assumption, because maybe the assumption was kind of 95% true, and that was good enough for the first 100 years, but the last 5% it isn't really true, and that's what you need to build for the next 100 years, and so on.
Anyway, a few thoughts about that. Let's see…
The question here…
Couple of questions here. Justin asks, when we look back at old science, how much should we judge it by modern standards?
I suppose one of the questions is, why are you judging it? I mean, in other words, if the question is, you know, was Isaac Newton as smart as we thought he was, or not?
you know, was Descartes as smart as we thought he was, or not, based on what we now know? That's one sort of form of judging.
I would say that, another form of judging is, is it worth learning that stuff?
You know, is it worth learning what Aristotle had to say about physics in a modern physics class? Is it worth learning what Newton had to say about physics in a modern physics class, given that we now know lots more?
I think in that case, sort of interesting, because, you know, Aristotle had things which are interesting if you're interested in learning about how to think about things. They're not interesting if you want to know facts about the physical world. I mean, Aristotle's view of gravity, about how things just like to be closer to the center of the Earth, well, they didn't know about that so much, but they like to be sort of closer to the ground.
is…
a reasonable way to think about something that sort of anthropomorphizes the operation of the physical world. It's interesting to untangle why you would think that and why it might not be true, but as a matter of knowing the facts of physics, it's pretty useless.
However, you know, knowing Newton's laws of motion or something is still pretty useful, even though we know that they're not quite right.
So it's a slightly fine line. What's… what things from the history of science are worth knowing? What things that were thought about a long time ago are worth knowing, what are not? I will say that one meta point about that that's been important for me is that
If you want to really understand a field, knowing the history of the field is really, really useful. Partly because if you're just told the field in its current state.
and you're just told, this is true, this has been established, that's true, that's been established, the field has gone in this direction, these definitions have been made, et cetera, et cetera, et cetera, you're often asking yourself, wait a minute, why? You know, and it seems very arbitrary, it's just like, we're just learning, we're just memorizing, this is what was done. But if you can understand something about how it got there.
You both know how much to believe it, and often, it's much easier to kind of remember what's going on, because you kind of can see the path by which it was gotten to, rather than just being told, these 6 facts are the things that came out.
So, I think…
that, sort of seeing, seeing those things is useful. Now, in terms of how kind of…

how impressive was it that person X figured out fact Y?
The thing to understand is, Often, things… Well, things at first
Seem very much… how could that… often seem very much… how could that possibly be true?
But then later on.
It can be the case that that sort of… the fact that it's true, the fact that atoms exist, which was something debated for 2,000 years, you know, that becomes something that, sort of, everybody has kind of heard that atoms exist from when they were pretty young, and so it's sort of obvious that atoms exist.
One that is notable for me.
In work that I've done on, sort of, the computational universe and, kind of, the behavior of simple programs and so on. I even wrote in the preface to my big book, A New Kind of Science, that I published in 2002, I basically said there are many things here that at first will seem shocking, and later will seem obvious. And, that's exactly what happened.
2002, people were like, how could this possibly be true?
And, you know, what is the story here? But by now, a bunch of those ideas, like the idea of computational irreducibility, for example, many people are like, well, that's just obvious.
And for me, it's interesting to see, in 25 years, the transition from it's shocking it couldn't possibly be true, to it's obvious.
And the question then is, do you now take the current view, it's obvious, and project that back and say, wait a minute, when I first invented these concepts in the 1980s, it should have been obvious?
I think…
In some cases, maybe, but in more often, the real thing that's going on is that when the concept is first invented, there's a whole context, a whole way of thinking about things that has to be wrapped around it for one to even invent the idea.
And once that sort of context is wrapped around, maybe the idea is fairly straightforward, but the real work is kind of wrapping that context, and building up that context, and breaking away from things that were believed before, and then people kind of absorb that context. It's not the fact so much that they absorb, but they absorb the context, the way of talking about things, and so on, and then the thing kind of becomes obvious. I think
People have, sometimes in talking about mathematical theorems, people ask the question, you know, you want to find this mathematical theorem. It's like, you know, breaking open a nut.
And one way you can do it is with a hammer, and it's, you know, a big, you know, sort of, big effort. Another way is you just soak the thing in some appropriate liquid for a while, and eventually the thing just sort of opens itself up. And that second thing is, for big ideas in science, the much more common thing to have happen. That it's really a question of sort of building up all this context and so on.
And eventually, the sort of the tough nut becomes something that just sort of opens itself up. But the effort to build up that context is quite great, even though, from the future, it won't be obvious, because that context will sort of just be part of the general way that one understands things. I mean, I think the same could be said, you know, you go back and look at
The way people described,
Well, you know, things, I don't know, early history of computing, where people didn't talk about gates and AND gates and OR gates, they talked about organs, because they were thinking about some sort of biological analogy.
And some of that biological analogy was very misleading.

and very wrong. And the idea that the… this kind of what computers in the 1940s and early 50s were doing was sort of directly analogous to what's happening in biology, that wasn't really right. And… but nevertheless, the, and that sort of way of talking about things is sort of confusing for modern ears.
Let's see…
Tech is asking, why do you…
Still think some things get rediscovered
decades after they get published, why is knowledge not more linear? I think it's for kind of reasons I've been talking about, that there are facts, and there's a context for understanding those facts.
I mean, in,
And sometimes when it engages with technology, there's a… and why do we care about that? You know, liquid crystals were discovered maybe nearly 100 years before people started using them for displays. It was a kind of a cool phenomenon, but why did we care?
well, eventually, we had a reason to care. Sort of gets enmeshed with technology. I think
That's, you know, so… so, for example, there are, no doubt, properties of materials that are kind of languishing in the literature, having been discovered in, you know, 1873, and then somebody's going to realize that, gosh, that's a really cool way of kind of, having the right kind of, thing that will be sensitive in some
you know, measurement device and so on that we hadn't thought of before that's measuring some, you know, a smell detector or something like this, that we haven't really examined before, and that weird thing languishing in the physics or chemistry literature from 1874 or something is just what we need. But we didn't care about it until now, because we weren't making an artificial nose until now.
Let's say. So that's a reason why things can languish, is just there's no… there's no attachment point that makes you care.
The same is true, for example, in mathematics. I mean, I remember years ago.
Meeting an old number theorist, who was very proud of the fact that the things he'd done would, would never be applicable to anything. They were just pure thought, they were purely abstract kinds of things that would not have a practical application in the world. So I was very amused a number of years later when I first saw that person's name and his theorem mentioned in the cryptography literature as number theory got used for cryptography. But again, what
He had done Could have languished forever.
And if it hadn't been picked up by an application in number theory, I'm reminded of things… well, lots of examples of that, where a new application or a new way of looking at things kind of unearths things that had been looked at a long time ago in a different context, and where somebody had done good scholarly work and had figured out this or that thing.
But nobody cared. Another example I'm just thinking of is from Hermann Grassman from the 1870s, who was involved in kind of the formalization of algebra and things like this, and invented the idea of non-commuting things where X times Y is not equal to Y times X, and had sort of developed a way of thinking about that.
And…
Sort of nobody cared for a long period of time, until people started studying supersymmetry in physics, where Grassman variables became all the rage.
And that was kind of a 100-year span where sort of nobody cared.

Now, there are other things where, there are results, I don't know, in things like set theory from the late 1800s, where… and transfinite numbers and things related to that, where they have been things in themselves that are studied for their own sake, but
many of those things haven't really attached to anything which was a, and now we really, really care about this, because it's connected to some developments in physics, or some technological application, or something like this. So I think that's a… that's a reason why things languish. I think…
as the question of, if something was known, does it have to be rediscovered to be used? That's an interesting question. There are definitely cross-field things that have been rediscovered many times. I mean, people are fond of commenting that feedback control and reinforcement learning are sort of the same kind of thing, and got invented sort of in different domains.
And given different names, even though there are correspondences between them.
And there are many examples of that, where, oh, I don't know, in spatial statistics, I know there are a whole bunch of things, you know, two-point correlation functions, in physics are called, oh, I don't know, maybe the Ripley K function or something in, in spatial statistics.
Exactly the same concept, invented in two different fields, given two different names, that were not really connected to each other.
And now sometimes there will be a set of ideas where they're couched in different words in different fields, and people in those fields are used to those kinds of words, and so they really can't access the exact same concept.
Used in some other field.
I know when I was first studying cellular automata in the beginning of the 1980s, these simple, discrete computational systems, I discovered that that
They'd been reinvented, or invented, oh, at least half a dozen, if not 10 times.
And, they had been given different names, you know, I think one of them was called Forests of Stunted Trees. How would you know that that was the same as a cellular automata? Kind of, automorphisms of the shift.
Again, not obvious, same thing.
But in fact, they're the exact same concept, invented many, many times. It's a very natural concept, so in some sense, not surprising, it was invented many times. I think, you know, I had the good fortune or something to have probably the sort of the cleanest invention of these things, a very simple kind of way of explaining what was going on, but
But nevertheless, the, the, you know, the ideas had been invented that the basic structure had been invented many times. This was, you know, this… I was discovering this back in 1981 or so, when sort of the… there were already, online.
abstract services where you could do searches, keyword searches for things, and there was also the Science Citation Index and so on, and so I spent a long time both in the library dealing with paper, Science Citation Index, books, and, spent a bunch of money in the, the, the, it was called Dialogue, the system that you could use to
To do, online searching of, of scientific abstracts and so on, trying to fit together, trying to understand, kind of, what
all the different threads of people who'd sort of invented the same idea, had come up with. And actually, then I had the fun in 1983, organized a conference at Los Alamos, actually, where I invited, kind of, sort of everybody who'd worked on what turned out to be the same kind of thing, even though almost none of them knew about the other pockets of work that had been done on what was, in fact, the same kind of thing. And it was,

It was really kind of interesting to have those… those people meet for the first time there. But… so that's… that's a type of thing that happens. Also, is…
Things get reinvented in a different context with different words, even though the fundamental idea is the same.
An interesting question for modern times is the extent to which LLMs can sort of notice the thematic similarity and kind of knit these pieces together. And I've certainly tried experiments looking for things which are sort of only thematically searchable for. So far, the experiments haven't been wild successes, but they've had modest successes. And I think that's a thing that we can expect
is… has a bit more potential going forward. And, you know, to… to have less rediscovery and more, you know, if it was… if it was discovered, even if the words used to describe it were different, then it can be known about. Of course, you have to know to ask the question in order for that to be… to be surfaced, so to speak.
Let's see…
Upcycle asks, to what extent does the evolution of scientific ideas constrained by the representational systems available at the time, such as languages, notations, computational frameworks? I think the answer is a lot.
And…
A lot also gets constrained by the words that are used to describe things, even if those end up being… being not the right words. Like, a good example from the 1800s would be caloric fluid, which was the kind of… the thing that was supposed to be heat.
That confused people a lot, because heat is not, in fact, a fluid. My own guess is that dark matter, you know, named, oh, 50 years ago or so now, that people have been confused about that, and have spent billions of dollars doing experiments, because they're looking for matter.
But actually, my guess is dark matter isn't matter at all. Just like caloric fluid isn't a fluid at all, it's a feature of the microscopic structure of matter, my guess is that dark matter is not matter at all, it's a… it's a feature of the microscopic structure of space.
And in fact, it'll be probably the word matter in dark matter might have cost people, I don't know, tens of billions of dollars of experiments that wouldn't have been done if it had been called, you know, spatial distortion or something. That would have been, had people looking in the right direction, so to speak.
And I think, that,
that's, you know, what things get called often is more important than one might imagine. And in terms of, sort of, how things are represented, absolutely, there are things where
It's hard to discover things when you kind of don't have a way to talk about them. One that I suspect is the case
Has to do with algebra.
In…
in antiquity, you know, there were ways of representing numbers, like Roman numerals are a way of representing numbers that uses the letters of the alphabet, you know, arranged, you know, V111 means 8 or whatever, and but those are letters of the alphabet.
Similarly, in the Greek number system, the, the numbers are just as the alphabet, alpha, beta, gamma, and so on. I mean, amusingly, they burnt in letters like Sampi, which were part of the early Greek
kind of alphabet.

They burnt them in in the order they appeared in the early Greek alphabet, and when they kind of went out of circulation, they were sort of stuck in the number system, because you could sort of move up the next number, so to speak, to fill in the gap. But in any case, the main point was, in antiquity, kind of numbers were represented by letters.
And so, when it came to, let's try to have an unknown
thing to make an equation, for example, it's like, how are we going to represent the unknown thing? We've already used, you know, we might use a letter to represent it, a shortening for a word, or something like this, but wait a minute, we've already… that's very confusing, we've already got the, letters that are being used for numbers.
And my guess is that algebra didn't develop until after the introduction of Hindu-Arabic numerals, partly because it was just not obvious how you could have a notation that separated the unknown from just a number.
I mean…
in general, the kind of use of words to represent mathematics, which was what was done in antiquity for people like Archimedes and Diophantus and so on, all math was written in words. And a lot of things that became much more streamlined with mathematical notation were really, really clunky in those days. And I suspect that that, you know, the taking off of mathematics in the 1500s, 1600s, and so on was in no small part associated with the fact that notation got invented for mathematics at that time.
I mean, in my own life and work.
I've spent a lot of effort trying to invent a notation for computational ideas. That's what Wolfram language is. It's a… it's a language that provides kind of a notation for computation, and that, for my own work.
kind of the fact that I've had that kind of computational notation has allowed me to kind of reason about and build
a lot of kinds of computational structures that I don't think I would possibly have been able to do if I didn't have that underlying computational language as my notation for thinking about things computationally. So my guess is that that's a… it's really a very important thing. You know, in linguistics.
people argue a lot about whether the words that are in languages affect the ways people think about things. And there is a sort of a comment about human language that, to a fair approximation, you can kind of translate any kind of thing you want to say into any human language.
Of course, as people who know multiple languages are always saying, that's not really true. There's a whole complicated cultural entrainment of some particular word in some language, and it isn't really translatable in the same sense, because the culture doesn't exist on the other side. But there's a certain universality to most kinds of language, human language, that you can more or less say the same kinds of things in different languages. Of course, there are specialized languages and specialized jargon for different fields that may or may not exist. It may or may not have been translated into some other language, and so on.
But the question is, to what extent… so it's the Sapier-Worf hypothesis, there's this whole story about the idea that the language you have to describe things affects the way you think about things. To some extent, that is sort of obviously true. To some extent, it's probably… you can avoid it being true, and you can translate things into other languages, and you can say, well, it doesn't really matter, I could describe it this way.

that, and it's also, and I think… but I think the place where I've seen that really, sort of really be significant
Is in more formal areas, formalized things, like mathematics, like computation, where notations for things are really critical to understand what's going on in that thing.
And the kind of… the presence of a notation lets one start talking about things. The absence of a notation makes it really pretty close to impossible to talk about things. I'll give you an example. Consider networks, graphs. You can draw a network of, you know, these nodes, and they're connected by these edges. You can see them in a picture, you can get some idea of what that network is. Imagine that you had to describe that network in ways
words.
Well, it would be…
really quite incomprehensible. I mean, when you read patents, for example, many things that one might just draw a diagram to represent end up, for reasons of how the legal system works, you have to kind of describe it in words. Thing A is connected to thing B, which is connected to thing C, and connected to et cetera, et cetera, et cetera. It's written in words.
Maybe people who deal with patents all the time can understand these things. I certainly can't. But yet, if you show me a picture, I'll readily be able to understand it. And I think the,
this… for these more formal areas, and particularly for computation, I think it is the case that the language you have to describe things really can affect what you can understand and what you cannot. I mean, I know for Wolfram language that there are concepts that I introduced, you know, 35 years ago or something now that have become pretty commonplace to anybody who uses the language.
And those are things that one can readily think in terms of. Something like the fold list operation. is something that you realize, oh, that's a fold list, I know what that is, I can think in those terms, which you just… I mean, I know in that particular case, I know, because I kind of… that was a hard-won piece of language design, one didn't think in those terms before and had that kind of well-crystallized concept. It was much muddier.
So…
Let's see… Gosh, many, many questions here.
There's a question here…
Well, I'm going to say that if you look at different… on this question about representations of things, some fields almost got defined by the time when
sort of notation got invented that sort of systematized knowledge in a particular area. And whether that was the Linnaean binomial nomenclature for biological species, whether that's some kind of crystallographic, sort of representation of things, etc. These things, that's what sort of made them start on the journey to being more formalized sciences.
was when there was kind of a systematic notation for things. So I think that's pretty important.
For, and I think in the… that's why I've spent a good part of my life
kind of trying to invent, sort of, the notation for thinking about things computationally, because I think that's really important to, sort of, having it be the case that there's sort of a computational X for all X made possible by this kind of computational notation for thinking about things.
Let's see…
Justin asks, what's a discovery that almost didn't happen because nobody believed the person who found it? Oh, there are so many of these things, whether it's the existence of germs, whether it's,

things about… Things in neuroscience, things in… I mean, they're just… they're just tons of these things.
the… You know, why do things not get believed?
Usually, it's cause… There's a… a whole… So, there's a self-consistent paradigm
that doesn't have the thing in it. So, for example, why did the Copernican idea of the Earth going around the Sun not get believed? Well, because there was… it seemed like it was obvious that that wasn't true, but also there was a whole structure that had been built up of, this is how the planets move on crystal spheres, and this is what happens, and so on. Whole structure that one had to kind of overturn
To get to that new way of that new idea.
Sometimes, I mean, I think, they're just… all sorts of… Things where people…
say, you know, that's just not possible. It's usually… Hey.
It's usually a kind of dead giveaway, when people say, it's impossible to clone a mammal, for example. Why? Oh, it's too complicated a system, and the DNA is too long, and the this, and the that, and the other. Well, of course, mammalian cloning got done.
oh, you know, it's impossible to do cryomics, let's say. You know, eventually that will seem weird that anybody thought it was impossible, because it, you know, it will eventually just get done.
I think. And, you know, these things where, you know, what…
Where it's just impossible, and kind of everybody knows it's impossible, and so you can kind of just, you know, anybody who says it isn't that way, it's kind of, you know, there's a herd belief that it's impossible, and so it's just not even worth thinking about the thing.
I must say that my own defense against that is
To really ask the question, how do we know that?
Do we actually know that? You know, can I explain to myself
from very first principles, why that's true. Not because it's in every textbook, that's not an answer.
It's like, can I really understand why that's true? And… or… or if it's an experimental result, how we could know that that's true?
Or is it something where, like, well, yes, people have done experiments, they've written textbooks about it, but if we really start drilling down, do we actually know it's true? That is a good defense against, kind of, the thing where the herd went off in one direction, but it's not doing that on the basis of something that's really correct.
And, I mean, the history of science
Okay, so when people come up with outlandish ideas, there's a question of what is the… how do you guess whether those ideas are right or not?
And, you know, I know for myself, I get sent every day many different, sort of, theories of fundamental physics, for example. Unfortunately, these days, usually written mostly by LLMs.
And, where I'd be really curious what some of the prompts were for these things, because that's the real, sort of, spark
And the question is, you know, if it's like, I'm gonna throw a thousand theories of physics at the wall and see which one sticks, you know, what is the prior? How do you guess which ones might even have a chance of sticking, so to speak?
And I think the, a lot of that has to do with, kind of, the problem… how… how it… how that theory came to be, and what that theory is connected to, and what…

And whether it's just a… and it came into existence out of hold cloth from this one idea, or was it something that really is entangled with lots of other things and makes things fit together?
I mean, in, you know, I, I think… That's,
You know, kind of the… the lone, funky idea, for…
I will say that for most people, most of the time, these very outlandish ideas mostly won't work out.
Occasionally they do, but if you look at, kind of, the story of the person or the environment in which the idea was created, it kind of becomes less surprising that an outlandish idea coming from that person or that environment had a chance.
And…
the, you know, this is, again, something I've learned from, sort of, history of science, these things where the storybook version is, and then this idea just arrived to this, you know, person who wasn't connected to anything. That's almost never the case.
there's almost always some kind of chain of provenance that leads you there. That doesn't diminish the… the sort of personal achievement of actually getting there, but it means it's not as incomprehensible how… how that could have been achieved. And I think that's a, kind of the… the…
The picture, even, you know, the picture, the lone scientist, the lone inventor, and so on, it… That doesn't usually work out.
the lone scientist, who, by the way, happens to have, you know, studied science for many, many years, and at places where there are lots of great science going on, and so on, and then decides to go off and hang out by themselves on a little island somewhere or something, that's a very different story from the person who never got exposed to these kinds of ideas.
Now, you know, the thing that surprises me sometimes is that
it is possible in modern times to get exposed to ideas, you know, you're… wherever you are, on the web, through, you know, through livestreams, through whatever else, you can get exposed to ideas. It is still the case, though, my impression is, that
An awful large fraction of the time that when, sort of, big ideas emerge, they are from
in situations where people really had, sort of, personal connection, in a sense, to some of the sources of some of the precursors of those ideas. I mean, something which sort of surprised me for myself is I've worked in a bunch of different fields, and I was…
thinking at some time, you know, how do people end up getting involved in different fields? And I realize it usually is through this kind of chain of personal interaction. But I've worked in fields where I had no direct personal interaction. Well, at least no
no interaction that was kind of in a kind of a structured interaction. I might have run into people who were in that field, but I haven't kind of, in a structured way, engaged with that field.
And yet, I've ended up doing things in those fields, sometimes to the kind of almost horror of people already in those fields. Who is this person who just sort of dropped in and did something in our field? And I hadn't really realized until very recently, and my own embarrassment for not realizing this, that that's quite unusual. And in a sense, if I've been able to do that, the main reason is because I've kind of learnt
meta things about having worked in, you know, various numbers of tens of fields or whatever, that I know a certain amount about how to get into some new area, and the kinds of things you need to know to fit your way of thinking with that area. And so, in a sense, even if I don't know that particular field, I know kind of the meta thing about entering new fields, and that's what makes that possible for me.

And in a sense, if you looked at the chain of how did I get to this or that thing, it's, well, because I've done things in other fields that were sort of vaguely similar, even though they were not really about quite the same subject matter.
Let's see…
Gosh.
There's a question here I'm thinking. It's a fun, different one, from Jace. What's the ancient history version of, this meeting could have been an email?
Ancient history.
And I'm… I'm thinking in, the,
You know, did you send the messenger with the dispatch that said, with the, with the message to the, to the king of the neighboring country or something, saying, hey, we should both be worried about this, you know, river that's overflowing, or whatever else? Or did you have to, did you have to go in person as a delegation to, to, to deliver that message?
I would say that, the, I have to admit, that…
I, myself, in my sort of business life.
do not encounter very much, and maybe that's because of the way I've structured things, a… this meeting could have been an email, type of situation. Possibly that's because I'm so drowning in email that so much gets sent in email. That's the default, in a sense, and meetings tend to be the result of aggregating things from email, rather than things which got set for the sake of, for the sake of having a meeting.
But I'm not, I'm not immediately coming up, but I'm sure there's a, there's a… there's probably a,
An entertaining example of, you know,
where somebody showed up for some piece of diplomacy, and they could just have sent a… sent a message, and it would have been just the same thing. I'm not sure.
Well… That's,
There's a question from Preston here. If old inventions had product reviews, which ones would have the most one-star complaints? Oh, I mean, there are a zillions of, you know, patent medicine cures.
From particularly the 1800s and so on, where people would do all sorts of crazy things, and that… and the confusing thing about that is that because
Medicine, because we're all different.
and sort of medicine has, sort of, footnotes all the way down. That thing, which somebody said is the most wonderful patent medicine, and it's going to cure your… whatever it is, you know, acne, or your… or your cancer, or whatever it is, the… that,
You know, and then people say afterwards, but it didn't work.
Well, the thing that's probably super confusing is that maybe it did work one time out of a thousand.
And in the modern way that medicines are tested and approved, it did work one time out of a thousand, just won't cut it. It'll just, like, it won't make it.
unless the people who invented the medicine are clever enough about the way they design their study that they only give it to people who have the characteristics that are the one in a thousand characteristics. But in general, most of the time, it's just going to fail. And so.
things that… I'm sure there are things which sort of worked one time out of a lot, and, then get kind of, and most people would say that that's a total lose. I mean, I would say, oh, I'm thinking of other kinds of products. I mean, radium dials on watches.

which glow in the dark, because radium is radioactive, and it's, it's sending out high-energy alpha particles, which are causing… which can make something fluoresce, and so you can have a watch that glows in the dark. When I was a kid, radium watches were still being sold.
They were… it was only later that people realized that that exposure to low-level radioactivity was a super bad idea. Actually, another thing of the same kind, when I was a kid, also, you'd go into a shoe store, and there was a little x-ray machine that would x-ray your feet to figure out, I don't know what size of shoe you should have, or whatever else. That became clear that that was a pretty bad idea.
And those are things where it sort of seemed like a good idea at the time, so to speak, but then didn't pan out. Another one that I'm thinking of is people had sort of the idea of, sort of very geometrical forms of
Houses, buildings, etc. And it's like, let's make a hexagonal room, let's make a circular room. Those seemed like a good idea at the time, and for a while there was sort of enthusiasm for those things, but it just turns out, well, like, fitting furniture against the walls of a circular room is a challenging thing, and plus, people just didn't like it very much. Somehow, there are things that are natural to us humans, but are kind of uncomfortable if they're not that way.
I mean, this is something that has been seen plenty in architecture, from particularly 100 years ago or so now, kind of the… the now science governs everything, and science says you don't actually need all that, all those moldings and all that, ornament on a building. You don't need the fancy columns and so on. You could just have a box, and a box is the sort of scientific version Of, the building that you need, so to speak.
Well, then it turns out, actually, that's not really true. People do find it sort of, I don't know, perhaps comforting, perhaps there's a certain familiarity to having this kind of, this kind of structure that is reminiscent of the natural world. The natural world is full of ornament.
you don't… I say ornament in a different sense from humans creating it, but, you know, you look at the typical tree, it's got all these funky leaves on the… on… at the end of its branches. It isn't just the sort of the pure trunk and nothing else. Or it's got, you know, even if it's a palm tree, it's got all those leaf scars on its, that, all that distressing, so to speak, in the… in the language of, sort of interior design.
on the trunk of the tree, not just the pure, sort of, pure smooth trunk, so to speak. And I think these kinds of things are sort of intrinsically familiar to people from the natural world, and so when you remove them in architecture, for example, it makes people sort of feel uncomfortable, and that's sort of a thing that wasn't obvious at the time.
But, became clear. I mean, I think there are… I'm trying to think about other, other examples where,
things… you know, there are an awful lot of examples in software and computers and so on of, sort of seemed like a good idea at the time, but, sort of…
didn't…
didn't quite pan out, and actually that relates to something that was being asked about earlier. One of the things that happened in the computer industry a lot, and particularly in computer science, in the academic version of, sort of, computing, is the following thing. People say about some idea, people said, oh, that was tried, and it didn't work.
Okay, I… I heard that… have heard that many times in things that I've built. People sort of… and I was talking about building them, and people said, well, that was tried, and it didn't work. Therefore, it's impossible.

That's happened, that happened way too often in the history of software, and that always struck me as a terrible argument. Like, people, oh, I don't know, tried building question-answering systems, and it didn't work.
And so, therefore, question answering systems are impossible. That's one that we kind of exploded with Wolfram Alpha in, in 2009. But that had been long believed in sort of the area of early AI and, and so computer science. Question, general question answering just sort of isn't possible, it's been tried and it doesn't work.
The same…
you know, and slightly more technically, I've heard that a zillion times about different kinds of algorithms and different kinds of computer language methodologies and so on. And it usually is, well, yes, the first way of thinking about doing it didn't work.
But, you know, you ran into a problem that,
that you weren't thinking about in a clear way, and so you just sort of, you just sort of, flamed out on that problem. I'll give you an example. In,
in Wolfram language and Mathematica, and my earlier system, SMP, has the feature that, you can…
you can…
Well, it's a system where when you type in, if you say X equals Y, Y equals Z, you type in X, it'll go through all of those definitions. It'll know that X is Y, okay, great, Y is Z, okay, you type in X, you get Z.
It's what's called an infinite evaluation system. It sort of runs down all the different things you've said to figure out, kind of, the end of what you get.
Okay, people told me endlessly, infinite evaluation systems are impossible. What was their evidence? If you type X equals X plus 1, what does it do? It has to sort of loop around and it kind of blows up.
The thing people didn't realize is that
there's a vast ocean of things you can do where X equals X plus 1 never comes up, and X equals X plus 1 is basically an error.
And it just is a corner that just doesn't arise very often. And so you can build this giant system that people use millions of times every day, where that's just something you don't do because it doesn't make any sense. But this was something that, because it was sort of the wrong framework for thinking about these things, people had gotten obsessed on a particular issue, a particular technical issue, maybe not worth describing.
That made them convinced that that was just going to blow up any system that had these properties. But it just wasn't the case when you thought about it at a broader level.
I mean, I would say that in my life building technology, there are very often situations where I'll say, we should build this thing. People will say, that's just not possible. And I'll sort of say, well, but… but, you know, okay, you've run into this one obstruction.
But actually, you can walk around that obstruction. I said, but that isn't exactly the definition of what you wanted to have happen. And it's like, well, yes, you have to… you have to sort of microscopically change the definition, or what you interpreted the definition to be.
in order to be able to actually succeed in getting around that obstruction. But that's the thing that, as I say, people, for some reason, just didn't have the intuition. They were like, this is a thing that's been described, so-and-so tried to do it and it didn't work, therefore it's impossible.

And computer science particularly victim to that particular idea. I mean, I think the same is a little bit true in medicine, that there are things where people say, I don't know, something like immunotherapy. Oh, it was tried 100 years ago and it didn't work.
Or some other, and then you realize that, well.
you know, it… it appeared not to work in that particular case, but you don't really know, you know, how it was tested, etc, etc, etc. I mean, there are… there are other examples, and for example, cold fusion. Cold fusion was, like, it… it didn't work, therefore it's impossible. I don't think that follows at all.
the fact that one particular set of experiments didn't seem to be reproducible, given what was known about what was important about what was happening and should be reproduced, I completely does not establish that it's impossible. Even though the way the sort of herd mentality of science works
For most people, the fact that those cold fusion experiments didn't pan out or didn't end up getting reproduced in the same form, is sort of evidence that, oh, nothing like that could be true.
So… I think, you know, that's not an uncommon thing to have happen.
Let's see… Oh, people are asking about bad idea inventions. I'm, I'm,
I mean, I don't know, I've, I've seen, Like, I have,
somewhere up at my house as a kind of a, just a… an amusing, set of pictures, I have the covers from Scientific American from the beginning of the 20th century, around 1900.
And, the, it was… South African was then a sort of tabloid-type thing, very different from the way it is today. But I remember there's one that,
has steam-powered skates. Steam-powered… it's steam-powered boots. And it says it has some line about how it's the,
I don't know, the Thousand League…
I forget the terminology, something… but anyway, it's the… this is the coming thing, so to speak, and it's, you know, the steam-powered,
steam-powered skates or something. Of course, that didn't happen at that time. However, today, you know, you go to some college campus or something like that, and there are people, going around on, on electrically-powered
You know, sort of things like that.
All the time. It just took an awfully long time for that to be a thing. And, you know, back in those days, people had that invention, but it was sort of a bad idea. Another… another example is quadricopters.
things, you know, there were helicopters, but it's like, well, why don't we just have something which has four rotors, and it's nice and stable, and so on? Well, back in, you know, in the 1940s and things like that, when people tried to do that, it just didn't work.
it was… it was a big splat, probably. It just, you know, nobody could… it just, you know, crashed every time. And what was wrong with that was that humans just don't have the ability to do, sort of, the control to keep stable a system like that.
electronics with modern flight controllers can perfectly well keep a drone with four rotors and so on stable, and… but that was something that required the… just in the physics of the whole thing, required the sort of faster feedback, faster control system that electronics can provide, and humans just couldn't do it. So that's a… an example of, I mean, one… one can look at, sort of, the configurations of lots
of kinds of things, whether it's bicycles and, you know, penny farthing-type big wheel, little wheel type systems, and so on. One can see lots of evolution of things that turned out to be not

very good ideas, that evolved into other things. Or sometimes there were things which were kind of, you know, way before their time, and you could only do it in a very funky way, and it only became kind of a smooth thing to do, much like
I mean, the same is true with electric cars. People had talked about electric cars a hundred years ago. They just weren't practical at that time, because battery technology wasn't good enough, and probably a bunch of other things about friction were not as well controlled as they needed to be, and so on.
And it just wasn't realistic at the time, and became so only many, many years later. So those things would probably get really lousy reviews if somebody had, yes, we've got this thing with a giant collection of lead-acid batteries, or something like this. I mean, also, in,
you know, other kinds of things, like steam trains, for example. It's,
you know, yes, there's lots of, kind of, you know, soot and so on from the coal being burnt in the steam train, and lots of… lots of things like that, which people might have said was, at the time, people were just really happy that there were trains. I mean, I have to say, when I was a kid, I think I… I got to see the last steam train, kind of, that was in service in England.
kind of, puffing away, and, when I was probably 5 years old or something, and then it was gone, and, you know, it's, it's, it's gasoline-powered and then electric-powered ones, from, from then on. But, you know, so a lot of these things, sometimes they're,
kind of inventions which in their time seemed like a good idea, but it's only a lot later that we discovered that actually, you know, that was a really bad thing to do, because it, you know, it gives us… gives us lots of trouble in one way or another. So I think, you know, sometimes in its time, the invention might have been a good idea, just, you know, not… not subsequently. I mean, they're probably also ones
That just seemed like
they should work, but they didn't work. Like, for example, early mechanical calculators from the, you know, 1600s and so on, I'm sure they didn't work very well. I'm sure that if you, in practice, tried to use them, they were super frustrating, and they got jammed all the time, and so on, and you're like, why don't I just do this calculation by hand after a while?
Alright, maybe one more, question here…
Let's see…
Henrik asks, do LLMs have the potential to make people lazy and kill the human spark that makes scientific discoveries possible?
You know, it's worth realizing that scientific discovery has happened only in, you know, large-scale scientific discovery has been restricted to a modest set of cultures in the history of the world.
I mean, there are, you know, we know about Babylonian mathematics.
we… don't know about, sort of great
you know, we know about Greek philosophy. We don't know about Babylonian philosophy. I don't think the Babylonians were… were that into, kind of, philosophical, you know, conceptual argument.
You know, there's… there's a lot of, you know, the… the development of, kind of.
Science, as we're proud of it today, and as it's led to a lot of the technology we have today, is a construct, is something that has emerged
particularly in Western culture, with some small amounts of input from other cultures, but the main, kind of, you know, a good fraction of it comes from this one particular culture. And I think

there… so there have been long periods of history and long, sort of, parts of the world where there wasn't a lot of science progress.
And… or technological progress.
And… and so I think it's a… it's a… it's a thing which… there does need to be the right kind of cultural ambience for that to happen, and the right…
And sometimes, you know, the things that drive it are things that one might think were undesirable for other reasons, like, you know, war is a good… and conflict of various kinds is a good… is a thing which historically has driven lots of kinds of scientific and technological progress.
And sometimes, you know, out of, all sorts of adversity come inventions that are valuable, and if you're just kind of sitting back, relaxing, not a lot happens.
So then the question is, well, you know, if it's possible to automate more things, does that mean that we humans do less stuff?
In my own life, I've spent a huge amount of effort automating things that I do, and for me, it's been just more exciting to do things as a result of all the automation. You know, I have built our… well, from language technology stack and so on, so that it's possible to go from ideas I have to kind of the working out of those ideas as efficiently as possible. And so that means it's kind of a longer lever arm. I have a small idea, I can have a long arm that kind of reaches out and does a lot with that idea.
And actually, that automation has made it, if anything, much more exciting for me to have ideas. If it was an idea, and to do anything with that idea was like, oh my gosh, I gotta spend months of work to kind of crawl up a little ways with that idea, versus I have that idea, I type something in, and 5 minutes later, I'm seeing, you know, big consequences of that idea.
That's, to me, much more satisfying and exciting. So the presence of automation, if one chooses to use it, is something which, in a sense, gives one much more leverage.
Now, the question is, do you, you know, are you forced to use it? Can you just… are you forced to actually invent new things to do with it, or can you just say, do what I've done before? Do, you know,
keep things simple, so to speak. I know in my own life, there are plenty of things where I keep them simple. I eat the same thing for breakfast every day. I don't think about it very much. You know, I do lots of things in a very habitual kind of way. I,
you know, it's… well, nowadays, you just, sort of tell your car where to go, and it starts driving there. And, you know, and not, you know, in the words, you know, you use GPS so that you at least can know where you're driving. But all these things are, it's, it's kind of,
Does that, sort of, Reduce the,
the fact that so many things are automated, what consequence does that have for how one… what one chooses to do? I think…
as I say, this question of could one just relax and not do anything, and still lead one's life without going hungry or something like this, without really doing anything, you know, I would say that that,
that's possible, and that has been possible in lots of places and lots of times in history. For lots of types of people, that's been possible. And yeah, quite a few people do do that. They don't,
They don't put much effort in unless they have to.
Is that will more people be in the situation where they, sort of don't have to put in so much effort? Maybe a few more, but I think

The choice to put in more effort is one that you can make or not make, sort of independent of whether there is more automation around the possibility of, you know, being able to get at least a decent amount for putting a very little in.
I think… I don't know…
you know, as people sort of say, oh, all college courses are dead because everybody can just do them with AI nowadays, it's kind of interesting to see people say that. It's happened quite suddenly. When we first introduced Mathematica.
Back in 1988, when we first introduced Wolf Malfa in 2009, these were both moments where things that people had thought were lots of human effort suddenly got to be automated.
And you just didn't have to do it. And those things, particularly Wolf and Alpha, did, in some sense, blow up a certain set of exercises of, oh, go off and do this exercise. Well, now you can just do it by computer. Actually, that had much less
It had very positive effects, and it had many fewer negative effects than I would have expected. I was…
concerned about some of the potential negative effects, but they really didn't happen. And I think instead, kind of the set of things that… that even at sort of an educational level, that one could expect to be able to do and rely on kind of expanded, and so it was possible to do more things.
Now, has that really been absorbed in education? Not very well. I mean, what is computationally possible now
and the kinds of, sort of, leverage that one gets from computation, has that been… has that turned into, well, we should teach different kinds of things, not as much as it should have done. It's been very slow moving.
But I think the,
you know, will the scientists all sort of give up and just say, oh, I'm just gonna… going to, you know, stop writing papers, I'm just gonna have LLMs submit my papers for me? Yeah, some people will do that. But then the kind of the expectations for what becomes possible get raised, and, you know, people…
Like me, who like using tools when they exist, will just end up
being able to kind of walk on taller stilts, so to speak, and do more stuff. I mean, that's been certainly the story of my life so far in the last 50 years or so of building technology to be able to do things in science. There are things where, yes, I could have spent a bunch of effort doing that in the past, now that's completely automated, but yet then I can do more stuff.
I mean, I think,
the question of sort of the spark of motivation for doing science is, you know, where does that come from? You know, it's sort of in the… there's a certain cultural ambience that's useful there.
I think the realization that that spark can have more leverage
is potentially very encouraging, and something that's made possible by, kind of, the world of LLMs, as it has been made possible by other pieces of automation technology in the past.
Well… Alright, we should probably… I'm… I'm…
In kind to just look at one more question here.
There's one from Serena.
Why did people first start doing math? Was it for counting money, measuring land, building things, or something else?
I think…

the records that we have of serious math mostly come from ancient Babylon, maybe from 4,000 years ago or something in some cases, and you know, even writing and the things that we have recorded
were mostly associated with commerce and law and so on, kind of the organization of human affairs. And so, yes, a lot of things about math
Had to do with, well, not necessarily specifically money, but goods and so on, and,
sort of being able to systematize, I've got, 22 pieces of barley, and if I use up this number, I have such and such a number left, and so on. And I think,
that was one thing, land surveying was another thing, of just how much land do I have? And and then…
There were kind of things that, involved, sort of, Can you predict the future?
And…
sort of the entrainment of predicting the motion of planets and other things, and the astrologers, ancient astrologers, I think one can guess that they were like, let me show you
you know, I can predict where this moving star will be in the sky, therefore you should believe me when I tell you that this battle will be won or lost. I suspect that was part of that story, and I think
The, the idea of using something math-like to predict where will that moving star, aka planet, be, you know, next week or something, is something that has the need for a certain kind of math.
I mean, the,
The kind of things you see in the kind of exercise books from, 3,000 years ago, a little bit less than that, are…
Very shockingly similar to the exercises you see today, except that sometimes the subject matter is a bit different.
about people, oh, I don't know, digging ditches in this way and that way. I mean, you know, in much of the world, those ditches would now be dug by a machine, and it wouldn't be a team of people doing it, and such like. But the kind of the general sort of math word problems of 2,500 years ago are very similar to the ones of today.
And those problems led to certain kinds of math being useful, like, for example, some rudimentary forms of equations. If you know it took such and such a number of days for this to happen then, etc. So that was, I think.
by the… there were… Well, lots of different…
motivations for being able to predict things, like, for example, the motion of projectiles. You know, you are… you have a catapult, and you organize it this way. Will the catapult, you know, throw something up in the air so it will clear the city wall and land on the inside, or something like this? Those are things where it was a question of, let's do math to work that out.
Although, I guess in the rudimentary forms of that done by folks like Archimedes, they didn't know about the things that Galileo and so on figured out about parabolic trajectories and such like, so I'm not actually quite sure how they… how they did those calculations.
Anyway, so I think the, yes, the early… early math was driven by practical kinds of things, but then, in Greek philosophy, kind of.
that…
that was the real moment. Folks like Euclid and Plato and so on were the ones who kind of abstracted, said, yes, but this thing that originated in a very practical discussion about numbers that were used for, you know, barrels of barley or something like this, those things we can abstract

The kind of pure thing involving numbers, the pure thing involving geometry.
And it isn't about a field, it's about just this generic
trapezoid shape, let's say, that that was a thing that could be abstracted, and you can talk about that at that formal level. That was a thing that I think really came in in kind of Greek times, and maybe 400… 400 BC, or something like that, and doesn't seem to have appeared much before.
The things that were in sort of the Babylonian exercises were always couched
in very practical terms, you know, this set of people are digging a ditch, how many days is it going to take them? Rather than abstractly, here are some abstract circles and abstract lines, what can you conclude about those? That was a thing that I think originated in
Kind of the attempt to think philosophically about the world, the attempt to think about the world as a matter of pure thought, rather than as something which
Came about by sort of looking at practical things that were going on.
All right, well, I should wrap up there. So, thanks for a bunch of interesting questions today, and I look forward to being able to address more of those and others another time.
So, thanks for joining me, and bye for now.