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Program Information:

Title: Kevin Kelly: The Next 100 Years of Science

Location: Cowell Theater - San Francisco, CA, The Long Now Foundation

Date: Mar 10 2006

Good evening. I'm Stuart Brand from the Long Now Foundation. If I could do the whole hour on Kevin Kelly, it would be an interesting one to do, actually. He's done a few unusual things. He's biked across America, twice. He's walked the Appalachian Trail, most of it. Says it's pretty boring. He spent ten years instead of being in college, which he dropped out in his freshman year, walking all over Southeast Asia and taking photographs, astonishingly all of which survived, that he put out in a book called Asia Grace, which is just photographs, no captions. But there is a link to the web, and you go to the web, and that's where you find out about what's going on in the pictures. That's normal for Kevin. He is always up to something. Connected but strange. A lot of us who've known, watching him, slogging away on this book, What Technology Wants, for years now. Have been waiting to see pieces of it. And that's what we're seeing tonight, specifically looking at the history and future of science. Kevin Kelly.

Thank you. It's wonderful to be on the other side of this program. What I want to talk about is something that is very important to us, but we don't talk about very much. Which is science. Science produces the only news, but it's rarely in the news itself. I have had a sort of a long interest in science. I began as a kid, I had a nature museum in my basement when I was in junior high school. Then I got a chemistry set, and I think perhaps I was the most unusual chemistry set in America for a boy because I actually did not make a bomb. I never tried to blow anything up. I actually tried to make nylon once, I was trying to do chromatography, I was actually trying to do cool stuff with chemistry. And from there I went on to high school, I took I think every single science and math class that my high school offered. But as Stuart said a little bit maybe too prominently, I dropped out of college. Found it a little too boring as well. And I went to Asia where I basically awarded myself an advanced degree in Asian Studies. And but all that time I kept thinking, well maybe I missed out on science. Maybe I should have really tried science. And so I actually invited myself to a friend who ran a lab who was a professor at the University of Georgia, and he was doing Microbiology Lab, and I went down to Georgia and I worked in his lab, where we were studying lipids.

And I actually made a film with him, and this is-- we made an educational film on digestion, and a note about the white lab coats, scientists do not wear white lab coats, but you're in a film, and the guy who made the film insisted that we wear them. So it turns out that actually I'm a very bad scientist, I'm not-- I don't really have the patience and the dedication that you need to do science. And so while I dropped out, the guy I worked with went onto greater things. He actually was studying lipids and getting proteins across lipids, and then he went onto GenenTech as well, and right now, just last month, the FDA approved his inhaleable insulin. That was his product.

And so now he's changing the lives of many people in the world, but I dropped out and I did the next best thing, which is that I married a scientist. So my wife, who's here,

Germaine, is a scientist at GenenTech, and she's a biochemist, and while I'm at home typing up little reviews of the next best bottle opener, she's trying to cure cancer. And she also makes a very-- she also makes it very clear that my knowledge of molecular biology and genetics is pretty flip flop and...but I still enjoy hanging around with scientists and talking to them. And so while I was at Athens and researching, one of the things that, the reason why I did not become a scientist became much more interested in what scientists were doing. Rather than trying to study what the lipids were, I became really interested in how scientists themselves were processing information. How did they know what to do?
How did they get information themselves? How did they pass it around? I became much more interested in the science process rather than the scientific work. And in fact, I became so interested that I actually wrote up a little article, it was one of the first articles that was published, and it was called Information as Communicable Disease. And not coincidentally, it was published in Stewart Brand's magazine at that time called Collusion Quarterly. And I was really interested in how information is connected, and the connections between scientists and the information that they generate. And this is a citation map from Gene Garfield, which was just trying to make a map of the connections and the references between scientists.
And so what happened was, I became really interested in science from a-- once removed. And I'm not a scientist, and I'm not even really a science journalist, really, and I, because I don't even have enough of in depth knowledge about certain fields to be a science journalist and so it was a long time I tried to figure out what is it that I am. And I finally had decided that I am a science groupie. I like hanging around scientists, I like to hear them talk shop, I like to talk about their science, and most importantly, I like to talk about science itself. And that's an interesting discussion, because you can talk to science and the field work and the kind of result science has, but if you want to talk to scientists about science, they're clueless. They look at you with a big blank. They say, if you ask them about, you know scientific method has changed, it's not going to be the same in the future, it doesn't quite register. The fact that we, and the way we do science, will change.
And so this is what I want to talk about, is how the scientific method itself has changed over time and how it will change into the future. And I'm really interested in sort of those long-term trends about science. Because I think that is the foundation of our culture, it's the foundation of our society, and we really need to look at that. And I'm interested in it for a couple of different reasons. And so I know everyone here likes to know about the next one hundred years of science, but before we can do that,
we have to kind of figure out what science is.
Now a lot of people do a lot of lists out there about the best scientific inventions in the last 2000 years. And that's the kind of common way people think about science. And when the list was asked by John Brockman, and the kind of answers he got was very interesting, because he asked some of the most prominent scientists around the world, what were the most important scientific inventions in the last 2000 years, and you get some very interesting questions. So the future of science, as we think about it, is not this. Okay. That's not what the future of science is really about.
And I'm going to talk about something else.
The kind of example that people will give for the best invention of the past 2000 years will be something like "hay." This was actually Freemon Dyeson's suggestion. Who is

working off of Lynn White and others who said, well you know, "Hay." It was domesticated, it made possible the storage of animals over the winter, it was basically a part of the agricultural revolution. And that in its way it furthered the development of our culture more than other things. Another common reply is well, "Penicillin, or antibiotics." These were obviously things that changed the course of history. Paper. Paper was a great invention, right? It allowed printing and then money.
And that itself of course transformed our economy.
The rudder was another example. It allowed navigation, exploration of the seven seas, it allowed the settlement of Micronesia and Australia, and it was very important in changing the dynamics later on in terms of empires. Or electricity. Of course that changed the world too. But in each one of these cases, this is not what I'm talking about. I'm not talking about the different little things that science throws off. I'm trying to talk about something else, something more profound. And in some sense this is like the ideas the brain throws off. If you're trying to really study the brain, you're not just going to look at the words that people use, or the words that people say, or the ideas that the brain has. You want to study the dynamics of the brain itself rather than the words that are thrown off. And so if you try to think about the categorizations-- if you ask yourself, is there a pattern? To all the scientific inventions of the past?
The common way that we kind of line them up is to say, well we have some idea of stone age, bronze age, iron, steam, we kind of see them in that way, and again, this is not really I think very helpful in trying to understand science I went back to try to find out the first conceptions of science, when science was first used. And around 1000 and maybe around that era, there were seven sciences, and they were basically types of desk work. They were a type of knowledge, they were things that were done at a desk. The very first example I could find, one of the first examples I could find in the word of science was used often interchangeably with another word, called sapience. Science and Sapience. They both meant knowledge. In fact, it's probably only a quirk of the language that when they named us, they named us Homo Science. Could have just as easily, because at that time, before his time, that was what the word meant. It meant knowledge.
And it was not until the 1700s that science came to be seen as a word to indicate a process of how we come to knowledge. And it's that word that has taken on its meaning now that I'm most interested in. So the interesting aspect about what we have when we have a process is that it enables sustainable long-term change. That's what we get from science, over time, is we have change that's sustainable over long terms. And it's not, at first, what we think of as civilization, because the interesting thing about civilization is, is that civilizations come and go. Civilizations disappear. So we have this sense in which a civilization can come up and reign for a while and then they go away. But science is much more of a progressive sensibility.
There is something else going on besides just the fact that we have a civilization, in fact I think the progressive nature we have in civilization comes from the science part of it. Otherwise, in the old days before there was no science, there was the appearance of civilizations being more cyclic. I have a map on my chart on my wall in my home office, and this is a map of the civilizations of the last 5000 years, and there's a range, geographically, you kind of get a sense that there's really not a large pattern there.
So the aspect of science that I find most interesting that I want to kind of take a few

minutes to talk about right now is the way in which science makes connections. And I think it's the connections and relationships between ideas, and between facts, and between knowledge, that actually give science its character and its strength. Now, I think the fact that things are connected is very very important. Because there is, it's sort of politically incorrect to say that Columbus discovered America, or that Oscar von Gringe discovered the gorilla in say 1902, because those were things that obviously other humans knew about. But in fact I think there is a way which is true within science, that those were discoveries. Because what was happening was they were taking some knowledge that was very isolated before, and we were connecting it to all of the things that were known. Those acts brought in some information and it was being tied into and related to everything else that was known. It was no longer isolated. So the information about the gorillas was kept very local, was not tied in, was not referenced, was not checked, was not in any way proved by the rest of the knowledge that the world knew, and that's what science is doing. So what these things create is basically a structure of sustainable changes, and what these connections do is they allow change to happen in a sustainable way.

And as I explore this idea of different ways and different connections within science, there's one idea, one necessary connection that I think I have to make clear, one kind of technical idea. And that is this. This is basically a picture of recursion. This is a recursive thing where it can go, right now it has a sense that it's going smaller and smaller, but you can go the other way, you can think of something that's bigger inside something that's getting bigger and bigger. And there are many ways to do recursion. This is another way. This is more interesting because you can't really see the bubble, there's, it kind of flows from one level flows into the other and you're not really sure what's going on.

Of course, Escher made this very famous in his lithographs. And of course now we're into the territory of Douglas Hofftetter, who spent an entire book kind of reflecting on the ways in which there's self-reference. This is...which is the classical simple thing, is that eating itself, is it inside the mouth or outside the mouth. And there's other ways you can have self-reference, which is like a fractal where the larger whole references the smaller parts. That they're identical in all different scales.

But here's another way even language has a way that's self-reference. This is, "This sentence is false." And so there's a sense in which the sentence points back to itself. And I think that pointing back to itself is very very profound, and it's very profound in science, because what's happening is that in that pointing back to itself, it's referencing an implicit other level that did not exist before. Right, so when the sentence goes back and points to itself, you suddenly, you're taken out of it, and it's moved to another level of meaning. And that's happening in every emergent system that I can really think of, is what really happens is that the circle creates a new level of outside experience or outside level that did not exist before. And we have the same thing happening in computer programming. Recursion is a very common pattern, and it gives a robustness and a power to computer programs, is the fact that they can do this. This is a map of the genetic-- excuse me, the metabolic pathways in a cell, and it's nothing but recursion. As well as most genomes, where they have genes turning on other genes, that turn on other genes.

And so you have this sense in which things point back to themselves, and this pointing back creates another level of existence or reference that did not exist before. This is citation, this is science where you have authors citing other authors who are citing other authors, you have this sort of web of citations and interconnection of facts, and that is what science generates. Is it generates paradox, for one thing. These are paradoxical systems because you don't know what's at the bottom, things are kind of turning around to themselves, there's a sense of emergence. A new reference coming out. They're sustainable in the sense that they keep things going, they keep going things around and around, and they're also, it's about changeability.

Here is a wonderful sense of, a wonderful instance of recursion which is the US Constitution. Article 5 talks about how you amend the Constitution. So, within itself, there's something that points back to the document itself, and so you have a mechanism for how this is going to change, and that is actually, I think, the power of this document, is that it allows sustainable change over time because it has some rules for how it changes itself. So it's pointing back to itself. That changeability, that pointing back to itself, is, it's a little game, it's kind of sounds fun, it sounds trivial, but in fact, I think it's actually the engine for making this infinite game, because it can keep going. As long as you're going back to it, you can kind of, as long as you're changing the rules that change the change, you can keep the system going forever.

So this recursive game can be read in many different ways. You can say, well science is the evolution of evolution itself. How evolution evolves over time. It's exploring the ways to explore. It favors opportunities which create other new opportunities. Or it's how you play the game of playing all games. That's the infinite game. And what's interesting to me is that when you think about the two large systems that play infinite games, there's two of them. One's science and the other is religion. And I'll come back to that later. But I think that that's the background of why I want to go into the history of how science has changed over time.

So first I'd like to talk about the origins of science, then I'd like to talk about the future, and then most important to me, I'd like to talk about the meaning of science. So how does science change over time? Well, the first thing is there were observations, facts, and then people began to do this recursive thing. You had a bibliography. You have a document, a book. That basically references other books. And when the first indexes to other books are actually very old. The first collections, very early, have indexes to them. Then you had catalogues, where the actual listed, the book itself is listed in the book of other books. Libraries with an index is another kind of same theme. We're actually, this is the imagination, a virtual rendering of what the library of Alexandria looked like, there were scrolls. So what's happening is we're starting to structure this information more, collaborative encyclopedia. Where you have more than one person, more than one source coming in to write a book, collectively. Kind of like Open Source.

Controlled experiment came along and of course Roger Bacon was very instrumental in that, in suggesting the fact that you want to have an experiment that you can change the variable, so here is, in another structuring of the information, laboratories became common when people decided to actually do things in a controlled setting. Again, to structure the information coming out of it. Telescopes, other things that were invented to allow more data to come in, to generate new data in new ways. By having new tools you can see new things, having questions. This was another important advance in the history of science. The society of experts, where again, you collect it, people would try and work on similar kinds of questions and problems and exchange the information between them. So we have a further structuring of that information.

Then Boyle was the first to propose that the necessity of having a repeatable experiment in his work with a coal pump, and heating coal. He said you have to be able to repeat the experiment in order to make it valid, so they were adding another level of information and structure. Scholarly journals came out along the way, and they started to pass this information, and put it into documents, and peer review, which started off as letters being passed between each other where they were actually starting to evaluate, to check, and comment on the work of others in a more organized fashion. And then the hyposthesis and projection, which came with Newton trying to suggest, well if this is true then we should expect this. Again, a further structuring of this.

So all these kinds of things I want to show in a diagrammatical way, these notions have no real meaning, but we have the facts, we have lots of facts, we start to add a bibliography around them, which takes the same thing, so one of the items is itself referring to others, that's a bibliography, we have a library that does the same thing, we begin to add other facts outside, we start to have new ways of seeing, new inputs, scopes, telescopes, which bring in more information, which is then connected with hypothesis and predictions, which evaluate. We have another one, it's repeatability, we try it again over here. We add a society of experts which are cross-referencing. All these things are to show you that what we have with science is information that's being further and further structured and organized.

More into this century, or last century, we have the invention of the falsifiable testability, saying that something really cannot be declared-- you can't really judge something unless there's some way to falsify it. That was Popper. And then the randomized design, which is that one of the ways that you wanted to verify and add depth to the kind of information you're doing is you-- ah, this was Fisher, who said you have to have a, you have to have a, you have to be careful of, and be mindful of, probability and statistics. That this is an important component. In fact, you can actually do things where you take random or statistical approaches to information.

And then the control placebo. The idea of, that you would actually have, basically a null set. You would have zero in an experiment, and that would be the control that was a way again of adding structure to it. Computer simulations came along, this was a very big thing, and then the double blind refinement of an experiment, where you actually do the experimenter and the patient also both would be ignorant of-- again, different ways in which this information is being structured.

And finally, science itself. Not that late, but this was a representation of a famous book of structure of scientific revolutions, suggesting that science itself was a subject of study, and that looks like this. Okay, here's recursion. Where you're taking the whole mass of things and then you're looking at it itself. Okay. So my conclusion about all this is that science is a way, is a process of changing how we know. It's about knowledge, it's about sapience and it's about knowing, and it's a process for changing how we know things.

Okay, so what-- that's really interesting, but I think what most everybody really wants to know is, what's the next thousand years of science, okay? I mean, that's.... So one easy general answer is, well it's this. Okay, it's more structuring of information, more connections between things that we've made and know, more ways of knowing, deeper, more complex things. But what you really want to know is, you know, well, when are we going to have flying cars. Right? Or robots? That talk? Or maybe virtual reality.

So let me tell you about what some of my speculations are in the next hundred years of science. So first, I would say, is that science is going to change more in the next 50 years than it has in the past 400 years. As different as the scientific method is now from how it was 400 years ago, and Bacon and Boyle and Newton, it's going to be even more different in the next 50 years, hundred years. Okay? Because we're going to continue to restructure how we know about things. And that process of how we change things.

Okay, so the second thing I would say is that it's going to be a bio-century. And that's not just because Germaine's a biologist. It's because biology even this year already is the biggest science that we have. It gets-- there's-- biology gets the most funding, has the most scientists working in it, it has the most results being published, it has the most economic value, it's the most ethically, and it's culturally important, and I think it has the most to learn from.

Okay, I think there's actually more information in biology for us to extract out of than there is in physics. Okay. So the difference is that while physics is very deep, it hasn't been changing over 4 billion years. It's exactly the same since it was from the beginning of time to now. Whereas biology has had 4 billion years of investing huge amounts of energy to making very very complex and full of information. It's full of information. It's informationally dense. And so it's a huge treasure trove of things that we don't know.

The third thing I would say is that computers are going to lead to a third way of science. And let me take a few minutes to explain what that means. Traditionally there was two ways, two pillars of science, were measurement in a hypothesis, so you take data, and you have ideas about it, and you would, and the two would sort of feed and test each other. And the measurement field, we're going to see more and more data. Okay, right now there's nothing growing faster on this planet than information. Okay? There was a study that Halvarian and Lineman did at Berkeley where they measured the growth of information, the total amount of information in the world, and the information's growing at 66% a year. Okay, that dwarfs, that dwarfs every other thing that we can measure in terms of its growth over a very long term, over decades. IPod sales may go up 200,000 or something, or 200% in a year, but that's just very short term. But over decades, decades, the only thing we can measure in this graph growing that fast is the intangibles of information. Now what's interesting about 66%, which I don't have a good explanation for, is that basically is More's law.

So right now information is the fastest growing thing, and so we have data coming off, and if we take the history of data, the different thresholds, is that the first thing that came along was precision. More and more precise ways to measure. Then we had new spectrums, new varieties to measure, then there was the new sources, like cameras and other kinds of tools, and we also have a more duration so we can get data all the time and run these longer and longer.

Okay, and so in some sense right now we're filling out the entire globe with sensors. It's getting a body in terms of having ears, sound, and all this data is flowing in and that's what we're headed towards is humongous flow of data. I just threw up a couple of instances of the growth in data, and I call it zillionics, because there's zillions of bits, there's zillions of everything, and dealing with zillions of things is actually difficult. We

don't, I mean, it requires kind of a new set of parameters and perspectives to deal with zillions of stuff. And that's what we're talking about.
Also, this is getting eclipsed very fast, because I noticed there was one terrabyte. Well I just brought a one terrabyte hard disk two weeks ago and I've already filled it up. It's with videos, digitizing videos from home movies. So terrabytes, you know, we're going very fast. We're headed into another realm with this.
The second pillar of classical science with hypothesis: learning. Where you were going to try and make a theory, you were going to try and structure something, not just measure it. And that will always work off, in tandem, with observation. Well, some of the things that are coming along that are in the new science coming down is dealing with matrices of multiple hypotheses. So instead of having a cereal one where you have a hypothesis, you try it out, you go along, is you entertain multiple ones at the same time. And you actually try and navagate through, and so things can be kind of partially true, and partially incorrect. And you kind of go through all of the possibilities at once.
Another way to do it, another way, is you actually kind of, what we call common material sweep, is you go through the possibility space. You explore the all possible arrangements. Before computers this was impossible, but now you can kind of do this on a mass scale, and this is an example of Stephen Wolfrums going through CA space and looking at all possible CAs as a way to try and understand what the general behavior of CAs were, rather than going one experiment or one at a time. And we use combinatorial search in lots of things. You're going, you're making huge libraries of possibilities, and chemistries, or chemicals, new ceramics are found that way, rare earths, formocology of large molecules, synthesis, multiple hypothesis, operating all at once.
Now the third variety that we haven't had is simulations, that was not until 1946, and this is a big thing. We do huge, again, huge simulations, and what's interesting about the huge simulations is that they generate huge amounts of data. And the bigger and more complex and the realer and more sophisticated they are, the more data that this simulation itself is generating, not the observation. So we have a move now to, where I think, most of the data that we're going to be generating is probably going to be coming from, simulations. And not from observation. That the simulation data will actually dwarf the real data. Not real data, but the observation data.
So these three things, these three things. We had two, now we have a tripod of three different kinds of science, and they're feeding off each other in kind of a new way. So this three, where you have simulation, which will in some cases inspire measurement, and other times the measurements will inspire a simulation, or you have a hypothesis, and a simulation, the two of them working against each other, where you have a hypothesis and you try it out in simulation, and simulation forms hypothes... So now there's sort of a triangle of three different ways, three different pillars. And this intersection of the three, I call that deep science. Because it is a different way of doing science. Where what you imagine plays as important point as what you measure.
So I can kind of show you how there's three little patterns where maybe in say you take real time measurement, vast amounts of quantity, it can inform, a really deep simulation, which can then go out and inform hypotheses and those three can be working together.
You can do the same thing in the health sciences. Again, where you continue this real time measurement of body functions, could process an assimilation of the body itself,

which can then go and work with different computer aided theorems about what's happening. And in the environmental science, it's the same thing. You see the same triad of deep science. So this third way of science, which is really being propelled by computers, well maybe you can think of it this way, maybe this is the third way of science, I'm not sure. Where we have hell there. But it's a way in which computers are changing.
The fourth way that I think science is going to change in the next hundred years is science will again create new ways of knowing, and an example of that will be Wiki Science.
Large scale numbers of people involved in an experiment. I talking to an editor of a science journal recently and they were saying they were expecting the first one thousand author paper to come in this year. Okay, it was at the Hadron Palighter in Europe, one thousand authors. Well, there's nothing-- that's just the beginning of very very large experiments that can be done, and maybe even experiments that aren't finished, they're sort of like Wikipedia where you continually are adding onto it over time, there is no beginning or end, it's like one of those encyclopedia articles done by many many people all at once.
Another interesting thing is compiled negative results. Negative results are what happens when you try to experiment and it doesn't work. Normally that information's thrown away. There's no reason why it should be thrown away. There's no reason why it should be thrown away, because the fact is, it's very very important. But who's going to read it all? Well, if you have algorithmic and you have ways in which you can automate the processing of the negative results, it can become very very valuable.
And two things have happened, one is I discovered that actually is a journal that's publishing negative results, the important ones, they feel are more important, and secondly, the new journals in the medical field where negative results are often very critical, have decided not to accept papers who did not register and therefore show that they basically, excuse me, let me say that differently, there's clinical trials, and often the negative results will happen very early on, and a pharmacological company has no reason to report them, but now a medical journal will not allow their final results to be published unless they register and let them know the early results. So this is a way to basically enforce the large scale habitual recording and processing of negative results.
AI computer proofs, this is Keppler's Conjecture which was around 1590 I think, about how to pack oranges, it was only recently proved with the aid of a, what was proved with the aid of a computer and also the proof of it required a computer. To prove it. So no human really understands this sufficiently to be able to prove it or to verify the proof.
And I think we'll see more of that as well. Triple blind emergent trials is the idea that if you take enough data all the time and it's non evasive enough, and you statistically have enough people involved, you can actually go back and extract out your controls. You can actually do it statistically, to say that-- so in this sense, neither the person involved nor the experimenters were aware at the time of the experiment, that the experiment was going on.
So distributive experiments, and this is another idea, again, this is Paul Allen's distributed telescope, which is a fast, cheap, and out of control idea, which is that lots of little things hooked together, lots of small experiments hooked together, lots of small pieces of equipment, lots of small sensors together, can in aggregate become very powerful. And in the past these ideas never made sense because the transactional costs were so steep that it really didn't make sense, but now, and again we have example after example proving how these mob crowd hive mind distributed bits can actually total up to be something

very very important, and I think the same thing will happen with science.
And again, the last thing, is the return of the subjective. This recursive coming around, which says that science is for all time been trying to push out the subjective and remain objective, to distance itself from the subjective experience, but when you get down to the very bottoms of things in the very largest of things, when things get really weird, it's actually necessary to come back to a subjective, and I think that we'll see a return of the subjective in some of the most basic things like quantum effects. That it's almost inescapable not to bring in that recursive root back into the equation. We don't have very good tools of how to do that scientifically, but I think that's what we'll involve.
So the fifth and last way I think science will change in the next hundred years is that we'll create a new level of meaning. And what do I mean by that. Only this, that we take this citation map which I showed before, this is a much deeper one showing in the chemical journals all the authors who are referencing other authors, it's their map of influences and how facts are related and tested against each other that is a very recursive net. And this is actually a map of the internet. This is, I'm showing the major trunk lines, and this is I think, Asia is red and North America is blue. It's a pretty current image of the full interconnection and recursive nature of the internet.
And I think what's happening is that this is becoming one machine. And I wanted to-- and I really treated this seriously as if it was a machine. If we had all the computers in the world hooked up through the internet, and you actually totaled, summed up, their specs, what would you have? Well, you can read that here. One billion PC chips. One million emails per second. One million IM messages per second. Eight terrabytes. Blah blah blah blah blah. So that's a very interesting computer. I mean, that's a pretty big computer. And actually I did some other things and I figured out, here's, if we were selling this on Amazon, it would be a trillion dollars, one megahertz email...okay, so that's interesting. It's-- and what's interesting about this one computer that we're making is that it's actually approaching the complexity of a brain.
So here, this is again, this is other, if you take all the transistors and all the PCs in the whole world connected together, there's a katrillion of them. If you take all the webpages there are, all the ones of the deep webpages, on average they have about fifteen links on each page, there's a trillion links, which you can see as a synapse, as in the brain. There's twenty petahertz of synapse firings. That's the speed at which the thing fires. And there's twenty exabyte of memory. That's a very big machine. That's approaching the complexity of the human brain. It's about a hundred-- it's about two orders off. But the thing about the internet, it's doubling every year and the brain's not doing that. Okay.
So I think-- and if you add our own brains at the other end of it, we have a very large machine. And this machine is actually what's doing science now. This new structuring of information and knowledge is the thing that is now doing science. And a lot of people are kind of worried about that, because you've heard Ray Curzwell's suggestion, that this, once this happens, it will just take off and the technology will accelerate into a singularity. I think the singularity is actually an illusion. I think that it doesn't happen from-- I mean, I think that the technology of acceleration is true, is valid, but I think the idea that we're going to go through something that will change and be a discontinuity is not.
This is one of my favorite New Yorker cartoons. For those who can't see in the back, it's, the guy's coming in from lunch, after a long lunch, and he's coming in and his very perky

secretery is waving a little memo sheet, it says, "Sir, the following paradigm shifts have occurred while you were out." I think that what happens is that we've already been through several of these large scale lifting up of new levels of meaning. This emergent thing where things come back and they come up, but we didn't even notice it.
Here's another cartoon. Two guys in a cave, saying, "Hey did anyone notice that we're using language?" We never did that because-- language was a singularity, we went through it without noticing it. Just as we'll go through this one machine, this large corpus of new thing that's doing science. It's an infinite game. You raise up to the new level, the new level connects and restructures in such a way that it is up to another level.
So one of the things that I think science does not do, which is a very common idea, is that it seeks after truth. That's what people say. The other day a famous scientist said that's what science, it's always seeking after truth. And actually I don't think that's true. I think there is a true course in mathematics that doesn't change, but there are lots of things that we know about science, or we think we know, that is not true over time. Even the idea that the world is round, well we find out that the world is not really perfectly round, it's off. And then maybe in another dimension it's not round.
So even facts like that will change over time.
So I don't think it's actually what truth is. That what science is really after. There's an interesting thing about discovery and invention, which is that when you have enough choices, when the field is big enough, when there's enough variables, when the degrees of freedom are sufficient, that the distinction between discovery and invention are nil. That they're basically equivalent. It's the same act. You can kind of see that, here's a picture of some biological forms, and we can say well evolution, or nature, did they invent those or discover those? But we understand that they're equivalent ideas.
So we can say in the same way that Edison discovered the light bulb. He didn't really invent it, he discovered it. Or that Benjamin Franklin invented electricity. We could say that Pythagoras invented the Pythagorean theory. Okay. So in the same way, I think the difference between knowing and creating is also equivalent. There is an equivalency in-- knowing is not passive, as I'm suggesting it. It's a constructive thing. We're constructing knowledge, and knowing is a constructive, creative act. And in that way, the process of changing how we know provides us with possibilities. And I think this is actually what science is about. Science is about possibilities. It's about differences, options, choices, freedoms, diversity, that's what science generates in us.
If you go back to this handy model of the internet and we see all of these things-- imagine if all of those-- this is a space of possibilities of different organisms. All the species on earth. And this was the possibility space, and of course this is what science is trying to do, is we're trying to explore and reach all of those possibilities.
So in some ways, it's infinite ways to play the infinite game. You can go back to the same map of these things, and we can say, imagine if these things were actually the different ways in which you could be a person. Imagine if this was a map of all the possibility space of all the ways that a person can be born, various-- you know, introverts are over here, extroverts are kind of, you know, there's a very complex high dimension way in which the gifts and talents of different people were mapped. And so what I think, what science is in part about is trying to uncover and reach and have us arrive at those places that would provide the knowledge and tools for every person to fulfill their full potential.

So I like to imagine what it would be like if Mozart had been born before the piano was invented. What a loss that would be. Or if we imagine Van Gogh having been born before oil paint was invented. The option of oil paints. Or Hitchcock before film. And so I think right now, today, this is my son, I think there are children today who are born whose "thing," whose science, whose technology, does not exist yet. They're going to live and die without us having provided, collectively, the thing for them. And I think that's a great shame, and I think in some way we have a moral obligation to actually go out and discover and seek and make all those possibilities. And that's-- so that people can play this infinite game.

While I was searching around for the origins of science, I found a very interesting quote. The very very very first use of the word science I could find in the English language was in 1340. And it was called, "For God of science is Lord." I'm not sure what it means, but it's interesting that it was being there. Because I think I want to come back to the fact that the two entities that generate infinite games are science and religion. And I find it interesting that at the bottom of most religions, and most beliefs in God or the universe, is basically this recursive loop. I mean, you can't get out of it. Beginning of the universe, who made the universe. Well, the universe always was, or God-- who made God? So you have this sense in which it kind of connecting to itself is the origin of everything, there is a paradox at the very base of it.

And I think what science does for myself, is science is the way we surprise God. That's what we're here for. That's what science is. It's a way for us to surprise God. Now you may think that's kind of strange, but think about like second life. Now, what's cooler-- is it to have a game where you make everything in there, or to have a game where-- sufficiently deep enough where the players themselves, these entities, not with people there, but the robots, are actually going to surprise you as the creator. I mean, which programmer is superior? It's the program where the creation actually completes the creation. And I think that's part of what we have with this idea, that we're taking all the possibilities, and I think it goes even further than that, imagine that this is a possibility space of all the possible ways to know. Okay. All the possible ways to know. All the possible ways to be smart, all the possible ways to find out things, all the possible ways to think. So I think we'll take all the possible species of intelligence in order for the universe to understand itself. Okay. So the universe cannot understand itself until we have all the possible minds, all the possible ways, to structure knowledge. Another way of saying it, the way I would say it, is that it will take all possible minds in the universe to know the mind of God. And so for that reason, I think science is holy. I think it's a holy act, I think it's a holy work. And I think that the long term future of science is actually a divine trip. Thank you. I welcome questions.