**ANDREW NG:** With the rise of technology oftencomes greater concentration ofpower in smaller numbers of people's hands,and I think that this createsgreater risk of ever-growing wealthinequality as well.To be really candid, I think that withthe rise of the last few ways of technology,we actually did a great jobcreating wealth in the East and the West Coast,but we actually did leave large partsof the country behind,and I would love for this next oneto bring everyone along with us.

**KEVIN SCOTT:** Hi everyone. Welcome to Behind the Tech.I'm your host, Kevin Scott,Chief Technology Officer for Microsoft.In this podcast, we're going to get behind the tech.We'll talk with some ofthe people who made our modern tech worldpossible and understand whatmotivated them to create what they did.So, join me tomaybe learn a little bit about the history ofcomputing and get a few behind the scenes insightsinto what's happening today.Stick around.Today I'm joined by mycolleague Christina Warren.Christina is a Senior Cloud Developer Advocateat Microsoft. Welcome back Christina.

**CHRISTINA WARREN:** Happy to be here Kevin,and super excited aboutwho you're going to be talking to today.

**KEVIN SCOTT:** Yeah. Today's guest is Andrew Ng.

**CHRISTINA WARREN:** Andrew is, I don't think this is too much to say,he's one of the preeminent mindsin artificial intelligence and machine learning.I've been following his work sincethe Google Brain Project,and he co-founded Coursera,and he's done so many important things andso much important research on AI and that'sa topic that I'm really obsessed with right now.So, I can't wait to hear what you guys talk about.

**KEVIN SCOTT:** Yeah. In addition to his track record asan entrepreneur, so Landing.AI, Coursera,being one of the co-leads ofthe Google Brain Project in its very earliest days,he also has this incredible track recordas academic researcher.He has a hundred plus really fantastically good paperson a whole variety of topics in artificial intelligence,which I'm guessing are onthe many a PHD student's reading listfor the folks who are trying to getdegrees in this area now.

**CHRISTINA WARREN:** I can't wait. I'm reallylooking forward to the conversation.

**KEVIN SCOTT:** Great. Christina, we'llcheck back with you after the interview.Coming up next, Andrew Ng.Andrew is founder and CEO of Landing.AI.Founding lead of the Google Brain Projectand co-founder of Coursera.Andrew is one of the most influential leadersin AI and deep learning.He's also a Stanford UniversityComputer Science adjunct professor.Andrew, thanks for being here.

**ANDREW NG:** Thanks a lot for having me Kevin.

**KEVIN SCOTT:** So, let's go all the way back to the beginning.So, you grew up in Asia?And I'm just sort of curious when was it that yourealized you were reallyinterested in math and computer science?

**ANDREW NG:** I was born in London,but grew up mostly in Hong Kong and Singapore.I think I started coding when I was six-years-old.And my father had a few very old computers.The one I used the most was some old Atari,where I remember there were these bookswhere you would read the code in a book andjust type in a computer and then you hadthese computer games you could playthat you just implemented yourself.So, I thought that was wonderful.

**KEVIN SCOTT:** Yeah, and so that was probably the Atari400 or 800?

**ANDREW NG:** Yeah. Atari 800 sounds right.It was definitely some Atari.

**KEVIN SCOTT:** That's awesome. And what sorts ofgames were you most interested in?

**ANDREW NG:** You know, the one that fascinated methe most was a number guessing game.Where you, the human, would thinkof a number from 1 to 100, then the computer would basically dobinary search but chooses: Is it higher or lower than 50?Is it higher or lower than 75 and so on,until it guesses the right number.

**KEVIN SCOTT:** Well, in a weird way,that's like early statistical Machine Learning, right?

**ANDREW NG:** Yeah, and then, so at six-years-oldit was just fascinating that the computer could guess.

**KEVIN SCOTT:** Yeah. So, fromsix years-did you go toa science and technology high school?Did you take computer science classeswhen you were a kid or...?

**ANDREW NG:** I went to good schools: St. Paul's inHong Kong and then ACPS in the Raffles in Singapore.I was lucky to go to good schools.I was fortunate to have grown up incountries with great educational systems.Great teachers, they made us work really hard but alsogave us lots of opportunities to explore.

And I feel like, computer science is not magic.You and I do this, we know this.While I'm very excited aboutthe work I get to do in computer science and AI,I actually feel like anyone could do what I'd do if theyput in a bit of time to learn to do these things as well.Having good teachers helps a lot.

**KEVIN SCOTT:** We chatted in our last episode with Alice Steinglass,who's the president of Code.org,and they are spendingthe sum total of their energy trying toget K-12students interested incomputer science and pursuing careers in STEM.You're also an educator.You are a tenured professor at Stanford andspent a good chunk of your life in academia.What things would you encourage students to thinkabout if they are considering a career in computing?

**ANDREW NG:** I'm a huge admirer of Code.org.I think what they're doing is great.Once upon a time, society used towonder if everyone needed to be literate.Maybe all we needed was fora few monks to read the Bible to us and we didn'tneed to learn to read and write ourselves becausewe'd just go and listen to the priest or the monks.But we found that when a lot of us learned to read andwrite that really improved human-to-human communication.

I think that in the future,every person needs to be computerliterate at the level of being able towrite these simple programs.Because computers are becoming soimportant in our world and codingis the deepest way forpeople and machines to communicate.There's such a scarcity ofcomputer programmers today thatmost computer programmers end up writingsoftware for thousands of millions of people.

But in the future if everyone knows how to code,I would love for the proprietors ofa small mom and pop store at a corner togo program an LCD displayto better advertise their weekly sales.So, I think just as literacy,we found it having everyone being able toread and right, improved human-to-human communication.I actually think everyone in the futureshould learn to code because that'show we get people andthe computers to communicate at the deepest levels.

**KEVIN SCOTT:** I think that's a really great segueinto the main topicthat I wanted to chat about today, AI,because I think even you have usedthis anecdote that AI is going to be like electricity.

**ANDREW NG:** I think I came up with that.

**KEVIN SCOTT:** Yeah. I know this is your brilliant quoteand it's spot on.The push to literacy in many ways isa byproduct ofthe second and third industrial revolution.We had this transformed societywhere you actually had to be literate inorder to function in this quickly industrializing world.So, I wonder how many analogues yousee between the last industrial revolutionand what's happening with AI right now.

**ANDREW NG:** Yeah.The last industrial revolutionchanged so much human labor.I think one of the biggest differencesbetween the last one and this oneis that this one will happen faster,because the world is so much more connected today.So, wherever you are in the world, listening to this,there's a good chance that there's a AI algorithmthat's not yet even been invented as of today,but that will probablyaffect your life five years from now.

A research university inSingapore could come up with something next week,and then it will make its way tothe United States in a month.And another year after that,it'll in be in products that affect our lives.So, the world is connected in a way thatjust wasn't true at the last industrial revolution.And I think the pace and speed will bring challengesto individuals and companies and corporations.But our ability to drivetremendous value for AI, for the new ideas,the tremendous driver for global GDP growthI think is also maybeeven faster and greater than before.

**KEVIN SCOTT:** Yeah. So, let's dig in to that a little bit more.So, you've been doingAI Machine Learning for a really long time now.When did you decide that that'sthe thing you were going to specializeon as a computer scientist?

**ANDREW NG:** So, when I was in high school in Singapore,my father who isa doctor was trying to implement AI systems.Back then, he was actually using XP systems,which turned out not to be that good a technology.He was implementing AI systems ofhis day to try to diagnose, I think lymphoma.

**KEVIN SCOTT:** This is in the late'80s.

**ANDREW NG:** I think I was 15years old at that time.So, yeah, late'80s.So, I was very fortunate to learn frommy father about XP Systemsand also about neural networks,because they had day in the sun back then.That later became an internship atthe National University of Singaporewhere I wrote my first research paper actually,and I found a copy of it recently.When I read it back now,I think it was a very embarrassing research paper.But we didn't know any better back then.And I've actually been doing AI,computer science and AI pretty much since then.

**KEVIN SCOTT:** Well, I look at your CV andthe papers that you'vewritten over the course of your career.It's like you really had your handsin a little bit of everything.There was this inversereinforcement learning work that youdid and published the first paper in2000. Then, you were doing some work on what looks like information retrieval, document representations, and what not.By 2007, you were doingthis interesting stuff on self-taught learning.So, transfer learning from unlabeled data.

Then, you wrote the paper in 2009onthis large-scale unsupervised learningusing graphical processing.So, just in this 10-year period in your own research,you covered so many things.In 2009, we hadn't even reallyhit the curve yet on deep learning,the ImageNet result from Hinton hadn't happened yet.How do you, as one of the principles,you help create the feel,what does the rate of progress feel like to you?Because I think this is one of the things that peopleget perhaps a little bit over excited about sometimes.

**ANDREW NG:** One of the things I've learned in my careeris that youhave to do things before they're obvious to everyone,if you want to make a differenceand get the best results.So, I think I was fortunate back in maybe 2007or so,to see the early signsthat deep learning was going to take off.So, with that conviction,decided to go on and do it,and that turned out to work well.

Even when I went to Google tostart the Google Brain project, at that time,neural networks was a bad word tomany people and there was a lot of initial skepticism.But, fortunately,Larry Page was supportive and then started Google Brain.And I think when we started Coursera,online education was not an obvious thing to do.There were other previous efforts,massive efforts that failed.But because we saw signs that we could make itwork with the conviction to go in.

When I took on the role at Baidu at that time,a lot people in the US were asking me, "Hey,Andrew, why on earth would you want to do AI in China.What AI is there in China?"I think, again, I was fortunatethat I was part of something big.Even today, I think landing.aiwhere I'm spending a lot of my time,people initially ask me, "AI formanufacturing? Or AI foragriculture? Or try to transfer calls using AI?that's a weird thing to do."I do find people actually catch on faster.So, I find that as I get older,the speed at which people go from being reallyskeptical about what I doversus to saying, "Oh, maybe that's a good idea."That window is becoming much shorter.

**KEVIN SCOTT:** Is that because the community is maturing orbecause you've got such an incredible track record that...

**ANDREW NG:** I don't know. I think everyone's gettingsmarter all around the world. So, yeah.

**KEVIN SCOTT:** As you look at how machine learning haschanged over the past just 20 years,what's the most remarkable thing from your perspective?

**ANDREW NG:** I think a lot of recent progresswas driven by computational scale,scale of data, and then also by algorithmic innovation.But, I think it's really interesting when somethinggrows exponentially, people, the insiders,every year you say, "Oh yeah,it works 50 percent betterthan the year before." And every year it's like,"Hey, another 50 percent year-on-year progress."So, to a lot of machine learning insiders,it doesn't feel that magical.It's, "Yeah, you just get up andyou work on it, and it works better."

To people that didn't grow up in machine learning,exponential growth often feelslike it came out of nowhere.So, I've seen this inmultiple industries with the rise of the movement,with the rise of machine learning and deep learning.I feel like a lot of the insiders feel like, "Yeah,we're at 50 percent or some percent better than lastyear," but it's reallythe people that weren't insiders that feel like,"Wow, this came out of nowhere.Where did this come from?"So, that's been interesting to observe.

But one thing you and I have chatted about before,there's a lot of hype about AI.And I think that what happened with the earlier AI winters isthat there was a lot of hype about AI thatturned out not to be that useful or valuable.But one thing that's really different today isthat large companies like Microsoft,Baidu, Google, Facebook, and so on,are driving tremendous amounts of revenue as well asuser value through modern machine learning tools.And that very strong economic support,I think machine learning is making a difference to GDP.That strong economic supportmeans we're not in for another AI winter.

Having said that, there is a lot of hype aboutAGI, Artificial General Intelligence.This really over hyped fear of evil killer robots,AI can do everything a human can do.I would actually welcome a resetof expectations around that.Hopefully we can resetexpectations around AGI to be more realistic,without throwing out baby with the bath water.

If you look at today's world,there are a lot more people working onvaluable deep learning projectstoday than six months ago,and six months ago, there were a lot more peopledoing this than six months before that.So, if you look at it in terms of the numberof people, number of projects,amount of value being created,it's all going up.It's just that some of the hype andunrealistic expectations about, "Hey,maybe we'll have evil killer robotsin two years or 10 years,and we should defend against it."I think that expectation should be reset.

**KEVIN SCOTT:** Yeah. I think you're spot onabout the inside versus outside perspective.The first machine learning stuff that I did was 15years-ish ago whenI was building classifiers forcontent for Google's Ad systems.Eventually, my teams worked on some ofthe CTR predictions stuff for the ads auction.It was always amazing to me how simple an algorithm youcould get by with if you hadlots of compute and lots of data.You had these trends that were driving things.

So, Moore's Law and things that we weredoing in cloud computing was makingexponentially more compute availablefor solving machine learning problemslike the stuff that you did,leveraging the embarrassingly parallelismin some of these problems and solving them on GPUs,which are really great atdoing the idiosyncratic type of compute.So, that computer is one exponential trend,and then the amount of available data fortraining is this other thing,where it's just coming in at this crushing rate.

You were at the MicrosoftCEO Summit this year and you gavethis beautiful explanation where you said,"Supervised Machine Learning isbasically learning from data,a black box that takes one setof inputs and produces another set of outputs.And the inputs might be an image and the outputsmight be text labels for the objects in the image.It might be a waveform coming in that hashuman speech in it and the output might be the speech."But really, that's sort of at the core ofthis gigantic explosion ofwork and energy that we've got right now,and AGI is a little bit different from that.

**ANDREW NG:** Yes, in fact to give credit where it's due.You know actually many years ago,I did an internship atMicrosoft Research back when I was still in school.Even back then, I think it wasEric Brill and Michele Vankoat Microsoft way back had already published a paperusing simple algorithms, that basicallyit wasn't who has the best algorithm that wins,it was who has the most data forthe application they were looking at at NLP.And so I think that the continuation of that trend,that people like Eric and Michelle hadspotted a long time ago,that's driving a lot of the progressin modern machine learning still.

**KEVIN SCOTT:** Yeah. Sometimes, with AI Researchyou get these really unexpected results.One of those I remember it wasthe famous Google CAT result from the Google Brain Team.

**ANDREW NG:** Yes, actually, those are interesting projects,while still a full time at Stanford,my students at the time Adam Coates and others,started to spot trends that,basically the bigger you build inyour neural networks, the better they work.So that was a rough conclusion.

So I started to look around Silicon Valley to seewhere can I get a lot ofcomputers to train really really big neural networks.And I think in hindsight,back then a lot of us leaders ofdeep learning hada much stronger emphasis on unsupervised learning,so learning without label data, suchas getting computers to look a lot of pictures,or watch a lot YouTube videos without tellingit what every frame or what every object is.

So I had friends at Google so I wound up pitching to Googleto start a project whichwe later called the Google Brain Project,to really scale up neural networks.We started off using Google's Cloud,the CPU's and in hindsight,I wish we had tried to build upGPU capabilities like Google sooner,but for complicated reasons,that took a long time to do which is why I woundup doing that at Stanford rather than at Google first.And I was really fortunate to haverecruited a great team to workwith me on the Google Brain Project.

I think one of the best things I did wasconvince Jeff Dean to come and work.And in fact,I remember the early days,we were actually nervous about whetherJeff Dean would remain interested in the project.So a bunch of us actuallyhad conversations to strategize,"Boy, can we make sure to keep Jeff Dean engagedso that he doesn't lose interest and go do something else?"So thankfully he stayed.The Google CAT thing was led by my,at the time PhD student Quoc Leput together with Jiquan Ngiam,were the first two sort ofmachine learning interns thatI brought into the Google Brain Team.

And I still remember whenQuoc had trained us on unsupervised learning algorithms,it was almost a joke, you know I was like, "Hey!there are a lot of cats on YouTube,let's see this learning cat detector."And I still remember when Quoctold me to walk over and say,"Hey Andrew, look at this." And I said, "Oh wow!You had unsupervised learning algorithmwatch YouTube videos and learnthe concept of 'cat.' That's amazing."So that winds up being an influential piece of work,because it was unsupervised learning,learning from tons of data foran algorithm to discover concepts by itself.

I think a lot of us actuallyoverestimated the early impact of unsupervised learning.But again, when I was leading Google Brain Team,one of our first partners wasthe speech team workingwith Vincent Vanhoucke, a great guy,and I was really working with Vincent and his team,and seeing some of the other thingshappening at Google and outside that caused a lotof us to realize that there wasmuch greater short term impact tobe had with supervised learning.

And then for better or worse,when lot of deep learning communities saw this,so many of us shifted so muchof our efforts to supervised learning,that maybe we're under resourcingthe basic research we stillneed unsupervised learning these dayswhich maybe, you know,I think unsupervised learning issuper important that there'sso much value to be made with supervised learning.So much of the attention is there right now. And I think,really what happened withthe Google Brain Projectwas-were the first couple of successes,one being the Speech Projectthat we worked with the speech team on.

What happened was other teams sawthe great results thatthe speech team was getting with deep learning with our help.And so, more and moreof the speech team's peers ranging fromGoogle Maps to other teamsstarted to become friends andallies of the Google Brain Team.We started doing more and more projects.

And then the other story is after,you know, the team had tons of momentum,thank god, we managed toconvince Jeff Dean to stick with the project,because one of the things that gaveme a lot of comfort when I wantedto step away from a day-to-dayrole to spend more time in Coursera was,I was able to hand overleadership of the team to Jeff Dean.And that gave me a lot of comfort that Iwas leaving the team in great hands.

**KEVIN SCOTT:** I sort of wonder, if there'sa sort of a message or a takeawayfor AI researchers inboth academia and industry about the Jeff Dean example.So for those who don't know,Jeff Dean might be the best engineer in the world.

**ANDREW NG:** It might be true. Yes.

**KEVIN SCOTT:** But I've certainly never workedwith anyone quite as good as him.I mean, I remember there was this-

**ANDREW NG:** He's in a league of his own. Jeff Dean is definitely-

**KEVIN SCOTT:** I remember back in long,long ago at Google.This must have been 2005or 2005,right after we'd gone public,Alan Eustace who was running all ofthe engineering team at the time would,once a year, send a note out to everyone in engineering atperformance review time to get your Google resumepolished up so that youcould nominate yourself for a promotion.

First thing that you were supposed to dowas get your Google resume,which is sort of this internal version ofa resume that showed all of your Google specific work.And the example resume that he would send out was Jeff's,and even in 2004,like he'd been there long enoughwhere he'd just done everything.

And, you know I was an engineer at the time.I would look at this and I'm like,"Oh my god, my resume looks nothing like this."And so I remember sending a note Alan Eustace saying,"You have got to find someone else's resume.You're depressing a thousand engineersevery time you send this out."Because Jeff is so great.

**ANDREW NG:** We're just huge fans really of Jeff.So me, you know, fans of Jeff among them and just,not just a great scientist butalso just an incredibly nice guy.

**KEVIN SCOTT:** Yeah. But this whole notion of couplingworld-class engineering andworld class-systems engineering with AI problem solving,I think that is something that we don'treally fully understand enough.

You can be the smartest AI guyin the world and you know just have this sort ofincredible theoretical breakthrough, butif you can't get that idea implemented,not that it has no impact it just sort ofdiminishes the potential impact that the idea can have.That partnership I think you have withJeff is something really special.

**ANDREW NG:** I think I was really fortunate thateven when I started the Google Brain TeamI feel I brought a lot ofmachine learning expertise and Jeff,and other Google engineersearly team members like Rajat Monga,Greg Corrado, just thought apercent project forhim. But there are other Google engineers--really first and foremost Jeff--they brought a lot ofsystems abilities to the team.

And the other convenient thing was that,we were able to get a thousand computers to run this.And having Larry Page's backing and Jeff's ability tomarshal those types of computationalresources turns out to be really helpful.

**KEVIN SCOTT:** Well, let's switch gears just a little bit.I think it was really apt that youpointed out that AI andmachine learning in particular are starting tohave GDP scale impact on the world.Certainly, if you look at the productsthat we're all using everyday,there's many levels of machine learning involvedin everything from search to social networks to-

I mean,basically everything you use has gotjust a little kiss of machine learning in it.So, with that impact andgiven how pervasive these technologies are,there's a huge amount ofresponsibility that comes along with it.I know that you've been thinking a lotabout ethical development of AIand what our responsibilities areas scientists and engineersas we build these technologies.

**ANDREW NG:** I'd love to chat about that for a few minutes.Yeah. There's potential to promulgatethings like discrimination and bias.I think that with the rise of technology oftencomes greater concentration ofpower in smaller numbers of people's hands.And I think that this creates greater riskof ever-growing wealth inequality as well.

So, we're recording this here in California,and to be really candid,I think that with the riseof the last few waves to technology,we actually did a great jobcreating wealth in the East and the West Coast,but we actually did leave large partsof the country behind,and I would love for this next oneto bring everyone along with us.

**KEVIN SCOTT:** Yeah. One of the things that I've spent a bunchof time thinking aboutis, from Microsoft's perspective,when we think about how we build our AI technology,we're thinking about platforms that wecan put in the hands of developers.It's just sort of our wiring as a company.

So, the example you gaveearlier and the talk where you want someone in a momand pop shop to be able to programtheir own LCD signto do whatever and everybody becomes a programmer,we actually think that AI can play a big role indelivering this future. And we wanteverybody to be an AI developer.I've been spending much of my time lately talking withfolks in agriculture and in healthcare,which again you're thinking aboutthe problems that society hasto solve.

In the United States.the cost of healthcare is growingfaster than GDP which isnot sustainable over long periods of time.Basically, the only way that I seethat you break that curve is with technology.Now, it might not be AI. I think it is.But something is going to have to sort ofintercede that pulls cost outof the system while still givingpeople very high-quality healthcare outcomes.

And I just see a lot of companies almost every week,there's some new result where AI can read andEKG chart with cardiologists' level of accuracy,which isn't about taking all of the cardiology jobs away.It's about making this diagnostic capabilityavailable to everyone because the cost is freeand then letting the cardiologist dowhat's difficult and unique that humans should be doing.I don't know if you see that patternin other domains as well.

**ANDREW NG:** I think there'll be a lot ofpartnerships with the AI teams anddoctors that will be very valuable.You know, one thing that excites me these days withthe theme of things like healthcare, agriculture,and manufacturing is helpinggreat companies become great AI companies.

I was fortunate really, to have led the Google Brain teamwhich became I would say probably the leading forcein turning Google fromwhat was already a great companyinto today great AI company.Then, at Baidu, I was responsiblefor the company's AI technology and strategy and team,and I think that helped transform Baidu fromwhat was already a great company into a great AI company.

I think it really Satyadid a great job also transformingMicrosoft from a great company to a great AI company.But for AI to reach its full potential,we can'tjust transform tech companies,we need to pull other industriesalong for it to create this GDP growth,for it to help people in healthcare delivera safer and more accessible food to people.

So, one thing I'm excited about,building on my experience, helping withreally Google and Baidu's transformationis to look at other industries as well to seeif either by providing AI solutions orby engaging deeply in AI transmission programs,whether my team at Landing.AI,whether Landing.AI can helpother industries also become great at AI.

**KEVIN SCOTT:** Well talk a little bit more aboutwhat Landing.AI's mission is.

**ANDREW NG:** We want to empower businesses with AI.There is so much need forAI to enter other industries than technology,everything ranging from manufacturing toagriculture to healthcare, and so many more.For example, in manufacturing,there are today in factoriessometimes hundreds of thousands of people usingtheir eyes to inspect parts as they come off asthe assembly line to check forscratches and things and so on.

We find that we can, for the most part,automate that with deep learningand often do it at a levelof reliability and consistencythat's greater than the people are.People squinting at somethingcentimeters away your whole day,that's actually not great for your eyesight it turns out,and I would love for computersrather than often these young employees to do it.

So, Landing.AI is working witha few different industries toprovide solutions like that.We also engage companieswith broader transformation programs.So, for both Google and Baidu,it was not one thing,it's not that implementneural networks for ads and so it's a great AI company.

For a company becomea great AI company is much more than that.And then having sort of helped two great companies do that,we are trying to help other companies as well,especially ones outside tech becomeleading AI entities in their industry vertical.So, I find that work very meaningfuland very exciting.Several days ago, I tweeted out that on Monday,I literally wake up At 5:00AMso excited about one ofthe Landing.AI projects, I couldn't go back to sleep.I started getting and scribbling on my notebook.So, I find these are really, really meaningful.

**KEVIN SCOTT:** That's awesome. One thing I wantto sort of press on a little bitis this manufacturing qualitycontrol example that you just gave.I think the thing that a lot of folksdon't understand is it'snot necessarily about the jobs going away,it's about these companies being able to do more.

So, I worked in a small manufacturing company whileI was in college and we had exactly the same thing.So, we operated a infrared reflow soldering machinethere which sort of melts,surface mount components onto circuit boards.So, you have to visually inspectthe board before it goes on to make surethe components are seated and the solderhas been screened and all the right parts.When it comes out,you have to visually inspect it to make surethat none of the parts have tombstoned.There are a variety of like little thingsthat can happen in the process.So, we have people doing that.

If there was some way for them not to do it,they would go do something elsethat was more valuable or wecould run more boards so actually, in a way,you could create more jobs becausethe more work that this company could do economically,the more jobs in general that it can create.

And I'm sort of seeing AI inseveral different places likein manufacturing automation as helping to bringback jobs from overseasthat were lost because it was just sort ofcheaper to do them withlow cost labor in some other part of the world.They're coming back now because likeautomation has gotten so good that youcan start doing them withfewer more expert people but here,in the United States,locally in these communities wherewhatever it is that they're manufacturing is needed.It's like these really interesting phenomena.

**ANDREW NG:** There was one part of your careerI did not know about it.I followed a lot of your work atGoogle and Microsoft, and even today,people still speak glowingly of their privacy practicesyou put in place when you're at Google.I did not know you were intothis soldering business way back.

**KEVIN SCOTT/ANDREW NG:** Yeah, I had put myself through collegesome way or another. It was interesting though.I remember one of my first jobs,I had to put brass rivets into 5,000circuit boards.Circuit boards were controllersfor commercial washing machines and there weresix little brass tabs that you would putelectrical connectors onto andeach one of them had to be riveted.

So, it was 30,000rivets that had to be doneand we had a manual rivet press andmy job at this company inits first three months of existence rightafter I graduated high school was to press,rivet press 30,000times, and that's awful.Automation is not a bad thing.

**ANDREW NG:** In a lot countries wework with we're seeing,for example Japan, the country isactually very different than the United States,because it has an aging population.

**KEVIN SCOTT:** Yeah.

**ANDREW NG:** And there just aren't enough people to do the work.

**KEVIN SCOTT:** Correct.

**ANDREW NG:** So, they welcome automationbecause the options are either automate or well,just shut down the whole plant because it is impossible tohire with the aging population.

**KEVIN SCOTT:** Yeah. In Japan, it actually is going to becomea crucial social issuesometime in the next 100 years or sobecause their fertility rates are suchthat they're in major population decline.So, you should hope for really good AI there,because we're going to needincredibly sophisticated things to takecare of the aging population there,especially in healthcare and elder care and whatnot.

**ANDREW NG:** You know, I think when we automated elevators.Right? Once elevators hadto have a person operating them,a lot of elevator operators did losetheir jobs because we switched to automatic elevators.I think one challenge that AI offers isthat there will be as connected as it is today,I think this change will happen very quickly,or the potential for jobs todisappear is faster this time around.

So, I think when we work with customers,we actually have a stanceon wanting to make sure that everyone is treated well,and to the extent, we're able to step in and tryto encourage or even assistdirectly with retraining to help them findbetter options, we're truly going to do that.That actually hasn't been needed so far forus because we're actually not displacing any jobs.But if it ever happens, that is our stance.But I think this actually speaks tothe important role of government with the rise of AI.

So, I think the world is notabout to run out of jobs anytime soon,but as LinkedIn has said throughthe LinkedIn data and many organizations,and Coursera has seen and Coursera's data as well,our population in the United States and globallyis not well-matched to the jobs that are being created.And we can't find enough people for-we can't find enough nurses,we can't find enough wind turbine technicians,a lot of cities,the highest paid person might bethe auto mechanic and we can't find enough of those.

So, I think a lot of the challenge andalso the responsibility for nations orfor governments of a society isto provide a safety net so that everyone hasa shot at learning new skills they need in order toenter these other tradesthat we just can't find enoughpeople to work in right now.

**KEVIN SCOTT:** I could not agree more.I think this is one ofthe most important balances thatwe're going to have to strike as a society,and it's not just the United States,it's a worldwide thing.We don't want to under investin AI in this technology because we'refrightened about the negative consequencesit's going to have on jobs that might be disrupted.On the other hand, we don't wantto be inhumane, incompassionate,unethical about how we providesupport for folks who are goingto be disrupted potentially.

**ANDREW NG:** Yeah.

**KEVIN SCOTT:** I think Coursera playsan incredibly important role inmanaging this sea change in that we haveto make reskilling andeducation much cheaper and much more accessible to folks.Because one of the things that we're doing is,we're entering this new worldwhere the work of the mind is going to be far,far, far more valuable even than italready is than the work of the body.So, that's the muscle that hasto get worked out and we've just gotto get people intothat habit and make it cheap and accessible.

**ANDREW NG:** Yeah. It is actually really interesting.When you look at the careers of athletes,you can't just train them ingreat shape at ageand then stop working out.The human body doesn't work likethat. Human mind is the same.You can't just train, work on your brain until you'reand then stop working out your brain.Your brain you go flabby if you do that.

**KEVIN SCOTT:** Yes.

**ANDREW NG:** So, I think one of the ways I want the world to bedifferent is I want us tobuild a lifelong learning society.We need this because the pace of change is faster.There's going to be technology invented next year andthat will affect your job five years after that.So, all of us had better keep on learning new things.

I think this is a cultural sea changethat needs to happen across society,because for us to all contributemeaningfully to the worldand make other people's lives better,the skills you need five years from now maybe very different than the skills you have today.If you are no longer in college, well,we still need you to go and acquire those skills.So, I think we just need to acknowledgealso that learning and studying is hard work.I want people if they have the capacity.

Sometimes your life circumstances prevent you fromworking in certain ways, and everyone deservesa lot of support throughout all phases of life.But if someone has the capacity to spendmore time studying rather thanspend that equal amount of time watching TV,I would rather they spendthat time studying so that they canbetter contribute to their own livesand to the broader society.

**KEVIN SCOTT:** Yeah, and speaking again about the role of government,one of the things that I think the governmentcould do to help with this transitionis AI has this enormous potentialto lower the costs of subsistence.So, through precision agricultureand artificial intelligence and healthcare,there are probably things that we can do to affecthousing costs with AI and automation.

So, looking at Maslow's Hierarchy of Needs,the bottom two levelswhere you've got food, clothing, shelter,and your personal safety and security,I think the more that we can beinvesting in those sorts of things,like technologies that addressthose needs and addressthem across the board for everyone,it does nothing but lift all boats basically.

I wish I had a magic wand that I couldwave over more young entrepreneurs andencourage them to create startups that aretaking this really interesting,increasingly valuable AI toolboxthat they have and apply it to these problems.They really could changethe world in this incredible way.

**ANDREW NG:** You make such a good point.

**KEVIN SCOTT:** So, the last tech thing that I wanted to ask you is,there is sort of just an incredible rate of innovationright now on AI in general,and some of the stuff is what I call "stunt AI"not in the sense that it's not valuable but it's-

**ANDREW NG:** No go ahead. Name some names. I want to hear.

**KEVIN SCOTT:** No, so I'll name our own name.So, we, at Microsoft didthis really interesting AI stunt wherewe had this hierarchical reinforcement learning systemthat beat Ms. Pac-Man.So, that's the flavor of what I would call "stunt AI."I think they're usefulin a way because a lot of what we do isvery difficult for layfolks to understand.

So, the value of the stunt is holy crap,you can actually have a piece of AI do this?I'm a big classical piano fan and one ofthe things I've always lamented aboutbeing a computer scientist is,there's no performance of computer science in general,where a normal person can listen toit or if you're talking aboutan athlete like Steph Curry,who has done an incredible amount oftechnical preparation and becoming asgood as he is at basketball,there's a performance at the end where you canappreciate his skill and ability.

And these "stunt AI" thingsin a way area way for folks to appreciate what's happening.Those are the exciting AI things for the layfolks.What are the exciting things asa specialists that you see on the horizon?Like new things and reinforcement learning, coming,people are doing some interesting stuff with transferlearning now where I'm starting tosee some promise thatnot every machine learning problem issomething where you're solving it in isolation.What's interesting to you?

**ANDREW NG:** So, in the short term,one thing I'm excited about is turning machine learning froma bit of a black art into more ofa systematic engineering discipline.I think, today, too much of machine learningamong a few wise people who happen to say,"Oh, change the activation function in layer five."And if for some reason it works,then that can turn into a systematicengineering process that woulddemystify a lot of it and helpa lot more people access these tools.

**KEVIN SCOTT:** Do you think that that's going tocome from there becominga real engineering practiceof deep neural network architector is that going to get solved withthis learning to learn stuff orauto ML stuff that folks are working on, or maybe both?

**ANDREW NG:** I think auto ML is a very nice piece of work,and is a small piece of the puzzle,maybe surrounding, optimizing[inaudible] preferences, things like that.But I think there are even bigger questions like,when should you collect more data,or is this data set good enough,or should you synthesize more data,or should you switchalgorithms from this type of algorithm to that type of algorithm,and do you have two neural networksor one neural network offering a pipeline?

I think those bigger architectural questions gobeyond what the current automatic algorithm is able to do.I've been working on this book,"Machine Learning Yearning"mlyearning.org, that I've beenemailing out to people on the mailing list for freethat's trying to conceptualize my own ideas, I guess,to turn machine learning intomore of the engineering disciplineto make it more systematic.

But I think there's a lot more thatthe community needs to do beyond what I,as one individual, could do as well.But that will be really exciting when we cantake the powerful tools ofsupervised learning and help a lot more people areable to use them systematically.

With the rise of software engineeringcame the rise of ideas like,"Oh, maybe we should have a PM."I think those are Microsoft invention, right?The PM, product manager, and then program manager,project manager types of roles way back.Then eventually came ideas likethe waterfall planning models or the scrum agile models.I think we need new software engineering practices.How do you get people to worktogether in a machine learning world?So all sorting it out to Landing.AI askour product managers do things differently,then I think I seeany other company tell their product managers to do.So we're still figure out these workflows and practices.

Beyond that, I think on a more pure technology side[inaudible] again as I dotransform entertainment and art.It'll be interesting to see how it goes beyond that.I think the value of reinforcementlearning in games is very overhyped,but I'm seeing some real attraction inusing reinforced learning to control robots.So early signs from my friendsworking on projects that are notyet public for the most part,but there are signs of meaningful progressin the reinforced learning applied to robotics.Then, I think transfer learning is vastly underrated.

The ability to learn from-so there was a paper out of Facebook wherethey trained on an unprecedented 3.5billion images which is very, very big 3.5 images is very large,even by today's standards,and found that it turns outtraining from 3.5 billion, in their case,Instagram images, is actually better thantraining on only one billion images.So this is a good sign forthe microprocessor companies, I think,because it means that, "Hey,keep building these faster processes.We'll find a way to suck up their processing power."

But with the ability to train on really,really massive data sets to dotransfer learning or pre-trainingor some set of ideas around there,I think that is veryunderrated today still. And then super long term-We used the term unsupervised learning to describe a really,really complicated set ofideas that we don't even fully understand.But I think that also will bevery important in the longer term.

**KEVIN SCOTT:** So tell us something that people wouldn't know about you.

**ANDREW NG:** Sometimes, I just look at those bookstoreand deliberately buy a magazinein some totally strange area that Iwould otherwise never have bought a magazine in.So whatever, five dollars,you end up with a magazine in some area that youjust previously knew absolutely nothing about.

**KEVIN SCOTT:** I think that's awesome.

**ANDREW NG:** One thing that not many people know about me,is I actually really love stationery.So my wife knows, when we travel to foreign countries,sometimes I'll spend way toolong looking at pens and pencils and paper.I think part of me feels like, "Boy,if only I had the perfect pen and the perfect paper,I could come up with better ideas."It has not worked out so far,but that dream lives on and on.

**KEVIN SCOTT:** That's awesome. All right.Well, thank you so much,Andrew, for coming in today.

**ANDREW NG:** Thanks a lot for having me here, Kevin.

**[MUSIC]**

**CHRISTINA WARREN:** That was a really terrific conversation.

**KEVIN SCOTT:** Yes, it was a ton of fun.It was like all of my best conversations,I felt like it wasn'tlong at all and was glancing now at my phone andI'm like, "Oh, my god. We've just spent 48 minutes."

**CHRISTINA WARREN:** One of the questions that you asked Andrew was,what technology is hemost impressed by and excited bythis coming down the pike with AI?I wanted to turn that back on youbecause you've been working withAI for a really long time at Google,and at LinkedIn, and now at Microsoft.So what have you seen that really excites you?

**KEVIN SCOTT:** Several things. I'm excited thatthis trend that started a whole bunch of years ago,more data plus more compute equalsmore practical AI and machine learning solutions.It's been surprising to me thatthat trend continues to have legs.So, when I look forward intothe future and I see more data coming online,particularly with IoT and the intelligent edge aswe get more things connected to the Cloud thatare sensing either through cameras orfar field microphone arrays ortemperature sensors or whatever it is that they are,we will increasingly be digitizing the world.

Honestly, my prediction is thatthe volumes of data that we're gathering now willseem trivial by comparison to the volumes thatwill be produced sometime in the next-years.I think you take that with all ofthe super exciting stuff that's happening with AI siliconright now and just thenumber of startups that are workingon brand new architecturesfor a training machine learning models,it really is an exciting time,and I think that combo of more compute,more data is going to continueto surprise and delight us withinteresting new results and also deliverthis real world GDPimpacting value that folks are seeing.So that's super cool.

But I tell you, the things that really move me,that I have been seeing lately are the applicationsinto which people are putting this technology inprecision agriculture and healthcare.Just recently, we went out to one of our farm partners.The Microsoft Research has been workingwith the things that they're doing withAI machine learning and edge computing inthis small organic farm inrural Washington state is absolutely incredible.

They're doing all of this stuff with a mind towards"How do you take a small independent farmerand help them optimize yields, reduce the amount ofchemicals that they have to use on their crop,how much water they have to use so you're minimizingenvironmental impacts and raisingmore food and doing it in this local way?"In the developing world,that means that more people are going to get fed.In the developed world,it means that we all get to be a little more healthybecause the quality ofthe food that we're eating is going to increase.

There's just this trend, I think,right now where people are juststarting to apply this technology tothese things that are parts of human subsistence.Here's the food, clothing, shelter,the things that all of us need in order tolive a good quality life.I think as I see these things andI see the potential that AI hasto help everyone have access to a high quality of life,the more excited I get.I think in some cases, it may bethe only way that you're able to deliver these things atscale to all of societybecause some of them are just really expensive right now.No matter how you redistribute the world's wealth,you're not going to be able to tend to the needs ofa growing population withoutsome sort of technological intervention.

**CHRISTINA WARREN:** See, I thought you weregoing to say something like, "Oh,we're going to be able to live in the world ofTron Legacy or the Matrix or whatever."Instead, you get all serious on me andtalk about all the great things that inthe world changing awesome thingsthat are going to happen.I'm going to live in my fantasy but Ilike that there are very cool things happening.

**KEVIN SCOTT:** I didover my vacation read "Ready Player One" anddespite its mild dystopian overtones.

**CHRISTINA WARREN:** It's a great book. I like the book.

**KEVIN SCOTT:** That's a damn good book.I was like, "I want some of this."

**CHRISTINA WARREN:** I'm with you. I'm with you.I was a little disappointed inthe movie but I loved the book.Yeah. We can talk about this offline butwe'll end this now.

**KEVIN SCOTT:** Yeah. Well, awesome Christina.I look forward to chatting withyou again on the next episode.

**CHRISTINA WARREN:** Me too. I can't wait.

**[MUSIC]**

**KEVIN SCOTT:** Next time on Behind the Tech,we're going to talk with Judy Estrinwho is a former CTO Cisco,serial entrepreneur, and as a Ph.D. student,a member of the lab that created the Internet protocols.Hope you will join us. Be sure totell your friends about our new podcast,Behind the Tech, and to subscribe. See you next time.