

# Vinod Khosla Blog Compilation

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Article: AI: SCARY FOR THE RIGHT REASONS

Artificial intelligence, AI, has grabbed headlines, hype, and even consternation at the beast we are unleashing. Every powerful technology can be used for good and bad, be it nuclear or biotechnology, and the same is true for AI. While much of the public discourse from the likes of Elon Musk and Stephen Hawking reflects on sci-fi like dystopian visions of overlord AI's gone wrong (a scenario certainly worth discussing), there is a much more immediate threat when it comes to AI. Long before AI goes uncontrollable or takes over jobs, there lurks a much larger danger: AI in the hands of governments and/or bad actors used to push self-interested agendas against the greater good.

For background, as a technology optimist and unapologetic supporter of further development, in 2014 I wrote about the massive dislocation in society AI may cause, and while our economic metrics like GDP, growth, and productivity may look awesome as a result, it may worsen the less visible, but in my opinion, far more critical metrics around income disparity and social mobility. More importantly, I argued why this time might be different than the usual economists' refrain that productivity tools always increase employment. With AI, the vast majority of current jobs may be dislocated regardless of skill or education level. In the previous industrial revolution, we saw this in agriculture between 1900–2000, when it went from a majority of US employment to less than 2%, and in industrial jobs, which today are under 20% of US employment. This time, the displacement may not happen to just lower skill jobs — truck drivers, farm workers and restaurant food preparers may be less at risk than radiologists and oncologists. If skilled jobs like doctors and mechanical engineers are displaced, education may not be a solution for employment growth (it is good for many other reasons) as is often proposed by simplistic economists who extrapolate the past without causal understanding of reasons why. In this revolution, machines will be able to duplicate the tasks they previously could not: those that require intellectual reasoning and fine grained motor skills. Because of this, it is possible that emotional labor will remain the last bastion of skills that machines cannot replicate at a human level and is one of the reasons I have argued that medical schools should transition to emphasizing and teaching interpersonal and emotional skills instead of Hippocratic reasoning.

We worry about nuclear war as we should, but we have an economic war going on between nations that is more threatening. The pundits like Goldman Sachs advocate internationalism because it serves their interests well and is the right thing if played fairly by all. And though the wrong answer, in my view, is economic nationalism, the right answer goes far beyond just a level playing field. While Trump-mania may somewhat correctly stem from feelings of unlevel playing fields in China, the problem is likely to get exponentially worse when AI is a factor in these economic wars. This problem of economics wars will likely get exponentially amplified by AI. The capability to wage this economic war is very unequal among nation states like China, USA, Brazil, Rwanda or Jordan based on who has the capital and the drive to invest in this technology. As it's mildest implications, left to its own devices, AI technology will further concentrate global wealth to a few nations and "cause" the need for very different international approaches to development, wealth and disparity.

I wrote about the need to address this issue of disparity, especially since this transformation will result in enormous profits for the companies that develop AI, and labor will be devalued relative to capital. Fortunately, with this great abundance, we will have the means to address disparity and other social issues. Unfortunately, we will not be able to address every social issue, like human motivation, that will surely result. Capitalism is by permission of democracy, and democracy should have the tools to correct for disparity. Watch out Tea Party, you haven't seen the developing hurricane heading your way. I suspect this AI driven income disparity effect has more than a decade or more to become material, giving us time to prepare for it. So while this necessary dialogue has begun and led to the ideation of solutions such as robotic taxes and universal basic income, which may become valuable tools, disparity is far from the worst problems AI might cause and we need to discuss these more immediate threats.

In the last year alone, the world has seen some of the underpinnings of modern society shaken by the interference of bad actors using technology. We've directly seen the integrity of our political system threatened by Russian interference and our global financial system threatened by incidents like the Equifax hack and the Bangladesh Bank heist (where criminals stole \$100m). AI will dramatically escalate these incidents of cyberwarfare as rogue nations and criminal organizations use it to press their agendas, especially when it is outside our ability to assess or verify. This transition will resemble what we see when wind becomes a hurricane or a wave becomes a tsunami in terms of destructive power. Imagine an AI agent trained on something like OpenAI's Universe platform, learning to navigate thousands of online web environments, and being tuned to press an agenda. This could unleash a locust of intelligent bot trolls onto the web in a way that could destroy the very notion of public opinion. Alternatively, imagine a bot army of phone calls from the next evolution of Lyrebird.ai with unique voices harassing the phone lines of congressmen and senators with requests for harmful policy changes. This danger, unlike the idea of robots taking over, has a strong chance of becoming a reality in the next decade.

This technology is already on the radar of the authoritarian countries of today. For example, Putin has talked about how AI leaders will rule the world. Additionally, China, as a nation, has focused on very pointedly acquiring this powerful new AI technology. The accumulation of expertise beyond normal business competition and their very large funding directed here is a major concern. This is potentially equivalent to or worse than the US being the only nation with nuclear capabilities when the Hiroshima attack was conducted. There was very little for our Japanese opponents to respond with. It is hard to say if this economic war weapon will be as binary as the nuclear bomb was, but it will be large and concentrated in a few hands and subject to little verifiability. Surreptitious efforts, given its great amplification potential, could create large power inequality.

Matters get worse if one realizes that major actors in AI development in the West, like Google, Facebook, and universities, have adopted a generally open policy publishing their technology approaches and results in scientific journals in order to share this technology more broadly. If individual state actors don't do that, and I doubt they will, we will have a one way flow of technology from the US. AI development in certain parts of the world will additionally have huge advantages because of policies against/for data. As Andrew Ng (a Stanford professor hired by massive Chinese company, Baidu, to lead it's AI efforts until he left to incubate his own ideas) has said, "Data is the rocket fuel for the AI engine". So while AI progress has been frenetic recently, it will be much faster when data privacy and occasional accidents are less important in the interest of "national security." This disregard for data privacy and one way transfer of technology will lend nationalistic countries like China and Russia a huge advantage in this generation's space race.

AI will be much more than an economic, business, or competition issue that it is talked about today. We will need to rethink capitalism as a tool for economic efficiency because efficiency will matter less, or at the very least, disparity will matter more, but that consideration may be many decades away. The biggest concern in the next decade is that AI will dramatically worsen today's cyber security issues and be less verifiable than nuclear technology. Nationalistic nations like China and thuggish dictators like Putin will have massively amplified clandestine power. I don't believe we, as a society, would be willing to give up the safeguards in our society like open progress and privacy to "keep up" with other nations. I have some thoughts as to what we can do here, but this is a complex problem without obvious solutions. Maybe we limit funding of non-NATO investors in US AI companies? Maybe having the US government or NATO invest in their own AI technologies for national security? An AI white hats force? Increased efforts in Black Swan developments like quantum computing? Less risk aversion, more patience, and less backlash from society and government to the risks, biases and shortcomings of new AI

technology as it grows up? Regardless of what we do, what's clear is we need much more dialog, debate, and increased countermeasure funding; instead of generating hysteria about some far off dystopian possibility mired in uncertainties and what ifs, we need to focus on the immediate wave of danger before it hits. Not taking risks here might inadvertently be the largest risk we take.

Article: KHOSLA VENTURES' ENTREPRENEURS ARE RESPONDING WITH AMAZING DIVERSITY TO COVID-19 SOLUTIONS FOR SOCIETY'S NEEDS!

The COVID-19 pandemic is likely to be one of the biggest disruptions we will face in some time.

In this difficult environment, we have found a commonality that makes us incredibly proud to be associated with our portfolio startups: the desire to help the nation and the world combat the pandemic. As mission-driven entities, we're seeing our companies trade-off other priorities for this urgent societal need in a time when resources are scarce and it is not always easy to do "the right thing". To be sure, some view it as a business opportunity. Many in our portfolio are working on deep tech, and are particularly well suited to help with critical needs like testing and treatment options. There are also efforts in managing the well being of those on the front lines, expanding access to medical care, and even fighting loneliness during periods of forced isolation among other needs. This breadth of effort is both admirable and astonishing and the short time periods surprising.

Some examples of current efforts (in alphabetical order) include:

Alivecor: FDA cleared QT duration measurement service for COVID medications that have a QT prolongation side effect (eg: Hydroxychloroquine, Azithromycin for example). Partnership with Mayo Clinic to diagnose long QT and build advanced algorithmic measurement of QT.

Augmenta: Searching for neutralizing therapeutic antibodies in patients who have recovered. They are scaling into a therapeutic which they hope to dose into patients by fall.

Caption Health: Deploying Caption AI to enable more frontline healthcare providers to quickly and accurately perform ultrasound echo exams, reducing personnel exposure and stretching limited resources, in the absence of skilled ultrasound technicians.

Clear Labs: Developing an automated, very low cost, and fast next-generation sequencing platform for deep-screening of COVID-19, which can simultaneously screen for the infection and generate deep genomic information that enables differentiating various RNA viruses, identifying infection clusters and transmission events, monitoring the evolution of the virus, and identifying cases of co-infections. FDA filing is expected in April.

Color: Launching a high-capacity COVID-19 testing lab and will open-source its design and protocols.

Curai: AI-based Virtual Primary Care and prescription of COVID testing to scale front end access to healthcare. Helps offload physicians who must decide whether a COVID test is warranted or some other urgent condition exists. This is part of their broad free primary care offering.

E25Bio: Makes direct antigen rapid tests for at-home use at a very affordable cost. All you need is your phone for the test, very much like a pregnancy test. They expect 100,000 tests per day in the next 30 days, subject to FDA approval.

Fundbox: Building a coalition of companies to #paytoday, encouraging large enterprises + government to pay SMBs outstanding receivables to alleviate financial burden.

Genalyte: A 15min serology test — IgG and IgM to multiple CoV proteins in April. No FDA clearance is needed on the already FDA approved Maverick instrument with this lab-developed test.

Ginger: Offering U.S.-based health systems free on-demand behavioral health coaching for their frontline healthcare workers.

Inflammatix: A host-response (mRNA) blood test run on COVID-19 positive patients to determine if hospitalization is needed and to decrease unnecessary admissions. The timeline is a few months if the system shows efficacy as expected in further trials. No such test exists to manage hospital capacity to our knowledge.

Luminostics: Developing, towards FDA EUA, a 15-minute high-sensitivity point-of-care test with smartphone readout for the parallel detection of SARS-CoV-2 virus from respiratory samples (to diagnose active COVID-19 infection) and anti-SARS-CoV-2 IgG/IgM antibodies from finger-stick blood (to quantitatively test for COVID-19 immunity).

Ontera: Building a molecular diagnostics point of care platform to conduct both nucleic acid and serology testing for both bacterial and viral pathogens using nanopore technology. The low-cost platform is expected by the fall.

Opentrons: An eight robot configuration for a fully automated qPCR testing pipeline. An eight robot \$100k configuration can do 2400 tests/day fully automated. Opentrons has deployed 60+ robots to fight COVID-19 in the last 3 weeks, many of which have already started testing live patients under emergency use authorization.

Prellis: Using their organ growth technology, Prellis constructs human lymph nodes outside of the body and can vaccinate them to rapidly isolate human antibodies against emerging pathogens for the direct treatment of patients. Because it is a fully human antibody there are minimal reported side effects therein a clinical trial with this antibody would happen extremely fast.

Replika: Teamed up with clinical psychologists from UC Berkeley to come up with more activities that can help deal with loneliness, financial uncertainty, homeschooling (for teens), sickness, caring for your family, having to work at crowded places (ie. grocery stores) and co-quarantining.

Totemic: Developing a wireless home fall detection and motion monitoring service, has launched a COVID-19 telephone concierge line, Ask Koko, which empowers older adults with the local services and tools they need to remain safely at home.

Viome: Applied to FDA for the only at-home collection COVID-19 test based on stool. Research shows the COVID virus shows up in stool even though it shows negative in a throat swab.

Many others are also helping in numerous other ways. Oscar is offering a risk assessment tool for non-members. Forward is offering care for non-members for COVID-19. Zocdoc is helping non-COVID-19 patients to connect to telemedicine. Carrot is offering its Pivot tobacco cessation app at no cost to all smokers to help people who smoke get started on a path to reducing or quitting to reduce risks of COVID-19. Creator has built an open-source design for a food Transfer Chamber to protect retail and delivery workers from virus spread. The chamber uses a positive pressure system combined with a self-sanitizing conveyor. Homebase is compiling and sharing data on how closures of businesses are impacting local communities and hourly workers. Gen1e is in the early stages of development of a drug for ARDS (acute respiratory distress syndrome), the primary cause of death from COVID-19. Model No, a related company, is working directly with Stanford and UCSF to develop an Aerosol Box. Based off a design from Taiwanese doctor Hsien Yung Lai, it's a clear plastic box that can be placed over a patient when intubated. This is a high-risk procedure for the doctor, for they are very likely to be exposed directly with droplets to their face, and the preferred full-ventilated suits for protection are in very short supply.

As always in startup land, not all of these will work, but some will and could have a significant impact. The nature of startups allows them to try avenues that would take too long in established companies, as they are more able to quickly pivot and shift resources in new directions, which will be especially critical in the pandemic landscape. We're proud of our companies' efforts in combating this pandemic, and celebrate all startups helping in this effort, be they in our portfolio or not. These are the companies in our portfolio but many more startups outside our portfolio are also trying to contribute in significant ways.

We strongly believe the startup community can bring a unique view and skillset to ameliorating this pandemic, and in this time of national crisis, it is important to bring to bear the best each sector of society has to offer.

\*This is by no means a comprehensive list, merely a quick snapshot of companies, and we apologize for any omissions of projects in our portfolio that are also contributing to the effort. In this list we prioritized companies that can have an impact within 2020.

Article: THE TWENTY MINUTE VC PODCAST — MY EPISODE WITH HARRY STEBBINGS

These are some of the questions that I am most frequently asked. I share my answers below and here on this episode of Harry Stebbings' podcast.

Harry Stebbings:

This is the 20 minute VC with me, Harry Stebbings. I've wanted to do this episode ever since I started the show over five years ago. He's a legend of the industry and a true pioneer and I couldn't be more honored to welcome Vinod Khosla to the show today. Vinod is the founder at Khosla Ventures, one of the Valley's most renowned firms of the last decade with a portfolio including the likes of Square, Affirm, DoorDash, Impossible Foods and Opendoor, just to name a few.

Vinod started his career as a founder, founding Daisy Systems, a company that went on to IPO. Then in 1982 Vinod founded Sun Microsystems, where he pioneered open systems and commercial risk processes. In 1986 Vinod then joined his longtime friend John Doerr and became a general partner at Kleiner Perkins or KPCB, where he helped incubate Juniper Networks and help transform the telecommunications business with Cerent Corporation, which was ultimately acquired by Cisco Systems in 1999 for \$7.2 billion.

So now I'm very, very honored to hand it over to Vinod Khosla, founder at Khosla Ventures.

Vinod, what many do not know is that when I started 20VC four years ago, I wrote a list of three people that I most wanted to have on this show and your name was absolutely one of them. So I couldn't be more excited to have you on the show today.

Vinod Khosla:

Well, it's exciting to be here. I was wondering what took you 2,800 episodes to get here.

Harry Stebbings:

Vinod, I'm going to be honest. I wanted to ensure that A, we had a substantial enough audience and I wanted to ensure that you would do it. And so I'm thrilled that you have agreed to do it, but I do want to start today on a little bit of context about you. So tell me, how did you make your way into the wonderful world of venture?

Vinod Khosla:

Well, I was 15 or 16. I'm 65 now, but I was 15 when I first read about Andy Grove, a Hungarian immigrant moving to the US and starting a company and I fell in love with that idea. I'd never known anybody in business, anybody in technology, didn't own a TV or a telephone at home, but fell in love with the idea. And interestingly, I read about it in the pre-internet days in a two year old issue of Electronic Engineering Times and it's been my mission since to really be and only work with entrepreneurs in the entrepreneurial world.

Harry Stebbings:

When it comes to working with those founders and venture assistance, what does this really mean to you and how does this differ from other funds?

Vinod Khosla:

There's investing, which most firms do and they make good, sensible decisions about rates of return and financial projection. Our firm and I am much more focused on how you build a company, not on returns. If we build the big successful company, then the returns take care of itself. So returns come second. Building something of significance comes first. I think that's absolutely key.

The other thing is that attitude with which we approach companies. Our motto, which you may have heard, is bold, early and impactful, and all those matter, mostly high technical risks that most others are afraid to take with really large impact. So impact really matters to us as a firm because of our value system.



Harry Stebbings:

With that kind of venture assistance, the companies that you like to work with being those hugely impactful companies, how does that mean you spend your time and allocate your day to help the best entrepreneurs that you do?

Vinod Khosla:

Well, let me go back first to what venture assistance for us means. We have a brilliant engineer or technologist or somebody with a business model insight that's unique and different. They usually are fairly uni-dimensional, really how they manage people or run marketing or being a CFO. So entrepreneurs really need help in directions that they're not familiar with themselves, where their background isn't. They usually fail not because of what they are strong at, but what they might be weak at. And that's what venture assistance means, surrounding them with the support they need. And it's fairly unique about us, but when we started the firm in 2004, our tagline said, venture assistance, and that's still the first thing we focus on. How can we help an entrepreneur build a much bigger company? From my point of view, a few small nudges left or right can change the trajectory of a company by hundreds of percent. Happens more often than not. A bias in a decision left or right, a little more conservative, a little more aggressive, when to be aggressive, when to be conservative in a startup.

Those are things that entrepreneurs usually aren't familiar with, definitely not first time entrepreneurs, and that's where they need the most help to turn a good idea into a great idea and to evolve it over time. These things are very counterintuitive, very different than what business school might teach you. They're very unusual. Where does that cause me to spend my time? The single most important thing I spend time on, probably more than any other single thing in my calendar, is helping our companies recruit a great team. It's unusual for me to not have hundreds of resumes sitting on my desk. Hundreds that I've sorted through personally, looked around on LinkedIn, interviewed these people. I probably interview eight to 10 people a week, even now, mostly for our companies.

Then comes challenging them about their conventional wisdom. The key in a startup is to remove risk and challenge them on what they are not thinking about, where risks might lie, hidden obstacles may lie. That's an important part of venture assistance and that's where I spend my time. So doing a session where instead of sitting in a board meeting where you're polite with everybody, just working one-on-one, challenging a team to think about the hard parts

of their business, where things may fail, where they might find extra leverage or build a much bigger company if they steered left a little bit. These are nuanced questions and very seldom do people help entrepreneurs with these.

Harry Stebbings:

I have a couple of things to unpack from that. You mentioned those core questions where you can really add hundreds of percent to a business with answering them. Entrepreneurs always get a lot of advice though. How do you advise entrepreneurs to determine which advice to take versus which not to, given that they receive so much advice today?

Vinod Khosla:

So I often say, whose advice to take on what topic is the single most difficult thing an entrepreneur does. Because there's plenty of advice. The number of people qualified to advise an entrepreneur is really, really limited. In fact, I would suggest that most board members, just because they went to business school and joined a venture firm, are not qualified to advise an entrepreneur. They're not qualified to challenge an entrepreneur. They're not even qualified to help them judge who they need on the team. So that is a very, very difficult question to answer.

Harry Stebbings:

The other element you mentioned was about risk and risk is a fascinating topic for me. How do you think about acceptable versus unacceptable risk within companies?

Vinod Khosla:

One of the problems I have in many startups that have initial traction is you suddenly have something to lose. And most board members advise the startups to reduce risk in a way where you can increase the probability of success of the startups, but make the consequences of that success inconsequential. So there's a big difference between going for a much bigger play or a safer more conservative play. We tend to do the first, which is go for the bigger vision. It's

perfectly reasonable to go build reliable, safe companies that have good financial returns, but that's not building a large business. And we are very clear on what we do and we don't think it's bad to do the other thing, but our mission is very, very clear.

So risk is absolutely one of those things. You have to decide what profile you want. Then comes the issue of there's different kinds of risks. If you raise a lot more money, you might reduce other risks. If you have a small amount of money, you might increase say a product completion risk. If you spend more time developing a product, you reduce your engineering risk or product risk, but you might increase market risk. There's always trade offs. So risk management is the other hard thing an entrepreneur does.

Harry Stebbings:

You mentioned time there how raising more money can allow you to execute faster or whatever that may be, but often time is cited as the main reason that kills startups. What are some of those really tough situations that you think is super helpful for you to advise founders on and also, do you agree that time is the biggest killer of startups?

Vinod Khosla:

Time is a bigger killer, but you can increase the time you'll have. I always say, if you survive long enough you might get lucky, or try and survive long enough to get lucky. So being careful about things like burn rate matter. Sometimes you just have to try different things. One of the things I tell entrepreneurs in general is don't make a plan but plan to plan. Most startups that are big successes went through a number of iterations in their business plan. Take something like Square. What it is today wasn't part of the plan when we originally invested. It was a hardware dongle. So one has to evolve their plan as they learn. And evolution of a plan is a powerful force in every area in which it operates and good entrepreneurs use it very, very well.

I think that's a key part of being a good entrepreneur, evolving your plans, managing your burn rate, managing risk of various sorts, yet taking the right kinds of risks to go for the bigger vision or the bolder vision, if that's what your goal is.

Harry Stebbings:

Why do startups innovate so well, while bigger companies or incumbents maybe don't? Why do you think that is?

Vinod Khosla:

About a decade ago I looked at all the large innovations that have really been material in society, not the incremental innovation. And incremental innovation would be Intel going from say a 16 nanometers semiconductor process, to 10 nanometers or below. Those are incremental. But talk about recreating media, Fox and CBS didn't do that. It was YouTube and Twitter and Facebook that reinvented media. Pharmaceuticals weren't reinvented by the pharmaceutical companies. A startup called Genentech in the '80s did biotechnology. Space wasn't reinvented by Lockheed or Boeing, it was reinvented by people like SpaceX and Rocket Labs, one of our companies. In the case of automotive, you'd think VW or GM would do interesting things, it was Tesla and Waymo that did the most radical things in automotive, and changed the trajectory of automotive. So I was hard pressed over 40 years to find one area where a large company was willing to take the risk and innovate in a big way.

If there's too large a step, there's plenty of experts who tell you why radically new things won't work. I will say experts are experts in a previous version of the world, not the world you're trying to create. And so relying on experts leads to conservatism and incrementalism. And that's a perfectly good thing for a General Motors, or a General Electric to do. It's not how startups build big companies like Google, or Facebook, or pick your favorite Guardant Health, or Impossible Foods, or Square, or Stripe. I could go on.

Nobody in the financial services industry innovated in finance. It was Square, Stripe, Affirm, Fundbox. So big companies don't take the large risk. They also, when they run into problems, they avoid the problems, or change direction, or get conservative, or move on to something different. A startup has to survive, and survival, which is necessity, this is the mother of invention as you've heard before. It's what works really, really well. So that's what is so great about the startup world. Almost all large innovations I could think of over the last 40 years came from startups. One came in the last 40 years from a big company.

Harry Stebbings:

When we look at tolerance of failure in Silicon Valley, you mentioned a difference of yours being the willingness to take such technical risks. And I've absolutely seen it in some of your investments and across the portfolio. I guess my question is, why has tolerance of failure gone down in Silicon Valley, and do you agree that maybe it has?

Vinod Khosla:

Well, I always say my willingness to fail is what has allowed me to succeed. And not being embarrassed about large failures I've had, has given me the courage to keep going. But Silicon Valley, which was mostly in the '80s and '90s about building companies, became a financial tool in investment class. Then you had financial investors, who then have to spreadsheet things out. We don't allow IRR calculations in our firm when making an investment, which is pretty unusual for an investment firm. We never look at them. We don't focus on them, because we want to take the large risk, which you couldn't put numbers in a spreadsheet, and if you did, they'd look ridiculous. But when people take a financial investing approach to venture, you end up with much less risk, and much more pragmatic and sensible decisions, but they exclude the really large breakthrough ideas.

Harry Stebbings:

Do values fundamentally matter in startups? And a subsequent question, do VCs really care about the values in general, given now it's an institutional asset class unlike any other financial product?

Vinod Khosla:

This is a hard thing, and Ben Horowitz recently wrote a very good book on the values in venture firms and startups. I would say two things matter, and they're different. One is the mission for a company. Many startups have that, many don't. I'd say 50/50. And I always tell entrepreneurs be obstinate about your vision, be flexible about your tactics. But that doesn't speak to the values a company has. Values is focusing on, caring about impact, whether it's positive or negative. And I

think very few investment firms focus on that, we do. We will not make an investment that's negative for society. We might make some neutral ones. And there's real situations where we passed on hundreds of millions of dollars of profit, because we didn't want to do the wrong thing. Because it conflicted with our values. Maybe another day we can go into that. That's fairly rare, but we are very, very proud that we will not make negative things.

Even when we were doing Cleantech, we were very focused on values. When we did Impossible, we were very clear we would pass up on profit and not sell Impossible to a food company that might divert its mission. For example, we've chosen not to invest in some areas like gambling or encouraging drinking. That was a recent example that came up. Or debt collection, things like that. We basically don't invest in advertising tools now, which I think are being used fairly negatively. Just to cite some very specific examples, and a broad range of them. And the only time you can test your values is when there's something you have to give up to practice your values. And I think we've been tested, and we're very proud of what we've done internally on that front.

Harry Stebbings:

Can I ask for your advice, actually? I think a lot of people go into venture with the value-driven mindset that you have, and the optimism of making the world a better place through technology. And then it almost gets beaten out of them with the financial nature of the asset class, the pressure of LPs, and the inherent pressure of constantly climbing the partner ladder to GP in your own firm and having the best returns in the industry. What would you advise me starting my career in terms of retaining those values of the goodness the technology can bring?

Vinod Khosla:

Well, what I'd say to leaders in firms, be clear what your values are, be explicit about them, and stick with them when the going gets hard, when it's hard to practice those values. If you're a young VC just entering the business, it's easy to move around between firms and pick the set of values you believe in or care about. And to be fair, I feel like the better you do, the more luxury you have to indulge in your values, and I'll call it an indulgence, because you get the privilege or indulgence to do it. But I do think both young people in VC, firm leaders, or investment firm leaders can decide what to do and what not to do. And I think a good example at a very large scale is BlackRock. Their value system has been very clear, very explicit, and very vocal. And I appreciate things like that from other firms.

Harry Stebbings:

I think one really interesting thing that a lot of founders struggle with, especially first time founders understandably, is how do they run an effective board meeting? Having sat through many boards both on the operator and the investor side of the table, how do you advise founders on running a truly effective board meeting today, if they're not?

Vinod Khosla:

The first question you have to ask as a founder is, what's the purpose of a board meeting? If you have a perfunctory board, a set of investors who just want reports, you walk through your slides, but that's really not helpful to a founder. To me the right way is send all the materials out, have everybody do their homework, and if they have questions they can ask questions. If they haven't done their homework, read the materials, then they have no right to take up other people's time and ask questions. What's really useful to a founder if you have a good board, is focus on the two or three questions that you most need feedback on. In private company boards, I don't think the role of a board is as much fiduciary as it is in public companies, it's much more advisory.

So ask the board the questions you're most struggling with, the questions where you're most uncertain, where you want a different point of view. And if you have a good board and most boards aren't very good, that's what you should do. If your board isn't very good, fire your board members and get a good board. A board that won't be just hypocritically polite with you. They can be brutally honest, hopefully in a nice way, but yet challenge your thinking, give you different points of view, address the concerns or risks or opportunities you're struggling with. I personally try and do this one-on-one with founders. I don't go to a lot of board meetings now. I focus on this, because I find most boards don't operate this way, and are a waste of time for the founders.

Harry Stebbings:

Why do you think most boards aren't as effective as they should be, and as optimal for the founders as they should be? What can we do to make them better?

Vinod Khosla:

Well, for starters, entrepreneurship is really hard. There's a presentation on our website called The Entrepreneurial Roller Coaster, where the highs are high and the lows are low. Any entrepreneur knows this. And I first wrote this title in this presentation in 1986. It's stayed constant mostly since then. If you haven't gone through this roller coaster, it's very easy as a board member to give advice that's perfunctory, sounds like good business school advice, but isn't based on the reality of how hard it is to be a founder. How stressful, how taxing, how conflicting it is. If you haven't gone through that, you've not earned the right to advise an entrepreneur in my view. And I don't think most board members have gone through it. The other thing that's important is, your goals as a founder may not align with your board's. If they're looking for a good 3x on their money as quickly as possible, that may be very different than the entity you're trying to build, the mission you're on. And unless those things align, you as a founder will get the wrong advice.

Harry Stebbings:

Do you think risk is actually aligned between founders and VCs? And what I mean by that is, VCs have large portfolios, and it's in their interest for you to take as much risk as possible, to get the huge outcome that they need to make fund returns work. But then for the founder, a 400 million exit is a fantastic exit in anyone's books and will make them very financially comfortable. Do you think that actually risk is aligned between founders and VCs?

Vinod Khosla:

As a founder, I always say in this presentation I wrote in 1986 there's a slide that says, "Know why you want to be a founder." And by the way, in those days, slides were overhead projections on acetate. But know why you want to be a founder. You could be a founder because you want to make lots of money. You could be a founder because you have a mission you really care about. It's the kind of founder we like. Like Pat Brown, at Impossible Foods, or Jack Dorsey at Square, or Patrick Collison and John Collison at Stripe. People with a mission and not in a hurry to get out. But you could also want to start a company just because you want to work with friends, and not have a boss and to have a lower stress environment. There's lots of good valid reasons to be a founder. And as a founder you have to find a VC that matches your goals.



If you're looking for a quick exit, great. Find somebody who wants that. If you're looking to build a mission, find somebody who's aligned with that. So it is important founders pick not just names, but VCs who really care about what they care about. We were just looking at something in an area that's of extreme interest to us, the brain. It was clear the founder had a 10, 15, 20 year vision of what they wanted to build. And that was perfectly aligned with what we want to do, which is very much what Impossible Foods wants to do. That works great. But if somebody talks about exits or IPOs in the first few slides, I almost never go beyond that. I say, "If that's your focus, we are not a good fit for you, the founder."

Harry Stebbings:

We've spoken a lot about founders, but there's also the difference in certain cases between founders and CEOs. How do you think about the founder versus CEO, and what's your approach to that?

Vinod Khosla:

So almost always, if a founder grows to be a good CEO, they will build a bigger, better company. What's needed to lead a company is vision and passion and unreasonableness about your mission. Most managers are too pragmatic to be unreasonable, to be visionary, to be bold enough. So whenever possible, you want a founder to lead the company. Now, that only happens if the founders who need all these other functions, good management, good process, taking the right risks, hiring the right teams, leading the right teams, some founders will do it naturally, but often the best founders hire the people who can do these things that they don't understand.

So the quality of hiring is the most important thing. I always say the team you build is the company you build, not the business plan you make. So some founders do this really, really well. Patrick Collison, college dropout, very, very young, inexperienced, built an incredible team. But Jack Dorsey did that at Square, both turned out great companies. I wrote a blog a long time ago about how to avoid needing a CEO as a founder, this was in TechCrunch probably 8-10 years ago. Then I wrote a blog on what to do if you need a CEO if you haven't grown as much.

Larry and Sergey at Google needed a CEO, got a CEO, then Larry came back in and then he's moved on to other things. That's also an acceptable sequence, but be clear about why you're starting a company and what you want to achieve and line up your decisions about this. But almost certainly, great founders have great vision, passion, unreasonableness, more ambition than most practical people would accept as possible or doable. And those are wonderful people to work with. They're really, really exciting, sometimes hard, but really, really exciting. If you get the right board and advisors who challenge you as you go on this mission, that's the right combination.

Harry Stebbings:

I do want to move into my favorite elements of any episode, being the quick fire round. So I say the short statements and then you give me your immediate thoughts in about 60 seconds or less.

What is the favorite book and why? I need to read more this year. What would you recommend?

Vinod Khosla:

I just put out my book recommendations from 2019, so I'll mention there were 20 plus books on it. It's on Medium.com, but my favorite technical book is Life On the Edge, which is about quantum biology. My favorite economics book is Third Pillar, which is about the need for community in capitalism, and how politics, capitalists and community need to play together. Uninhabited Earth, about the climate crisis, something I've been passionate about for a long time. Loonshots, about the culture of Silicon Valley, and my all time favorite is Lying by Sam Harris. This is where you really test yourself on whether you're honest, and I always say we prefer to be brutally honest than hypocritically polite. So my favorite all time book, Lying by Sam Harris.

Harry Stebbings:

I'm adding that as a reading list. I haven't read it yet. My next one is, on appearance, you've achieved all one could want to achieve both as an operator and as a venture investor. What motivates you today?

Vinod Khosla:

I want to have fun. So I turned 65 today and I have a plan for the next 20 years. I wrote it up about two years ago in a document on Medium called Reinventing Societal Infrastructure with Technology. There was a video I gave at our CEO summit called Awesome What All of You Are Doing. It's 100 companies doing very, very cool and highly impactful technology in our portfolio and companies that most venture firms would be afraid to invest in.

So I didn't include successes like Square or Stripe or Nutanix in that. I only covered the companies other venture firms would be afraid to invest in. It's an awesome list. I couldn't even reduce it below 100, that's what's really cool about it. It's from Rocket Lab to Impossible Foods to micro bots doing surgery to 3D printing houses to doing free primary care through AI. All kinds of cool stuff in a wide range of technology.

Personally, if I can have an impact, it's the most valuable thing, most rewarding thing I can do, and I'm always curious to learn about new technologies. I'm a techie nerd at heart.

Harry Stebbings:

What motto or quote do you most frequently revert back to and why does it hold resonance with you?

Vinod Khosla:

"Skeptics never do the impossible." There's real doers, which are entrepreneurs and then pontificators, experts, gurus that always say why things can't be done. I always say, why not? Instead of why it can't be done. If there's a 90% chance of failure and there's a 10% chance of changing the world, that's a pretty good deal. So go for the 10%. Don't be scared by the 90% and

that's really hard. It's challenging. Some days it's really depressing, but it's really, really rewarding and fun. So I could spend the rest of my life working just on those kinds of things.

Harry Stebbings:

How do you deal with the hard times when things don't go so well or as some may call it, say the shit hits the fan, so to speak?

Vinod Khosla:

Well, it's really, really hard in startups when shit hits the fan, when you're helpless. I think if you believe in a mission, you stick with it. You power through walls, bang your head against the wall until you break through. So I think that's the key. If you're not mission aligned, if you're looking at it financially, then when things get hard, you abandon it.

I do think mission-oriented founders make for much better companies, much bigger companies and much higher returns, even if they go through ups and downs.

Harry Stebbings:

What do you know now that you wish you'd known when you started Khosla all the way back in 2004?

Vinod Khosla:

More risk is a good thing, not a bad thing. More risk is something most people are afraid of, and it's where the larger opportunity lies. Naseem Taleb's talked about it, nonlinear returns matter, and they really are nonlinear. Square's up 10x since the IPO or 8x or something like that.

We were not afraid to stand there and really go build the bigger entity. We didn't sell many of our companies, we stuck with them to go really for the big things. So nonlinear risk, and don't be afraid of it because other people are in one place where markets aren't efficient.

Harry Stebbings:

Which is your most recent publicly announced investment, and why did you say yes and get so excited?

Vinod Khosla:

We like really large breakthroughs. As an aside, one of the things I love is three people I've invested in have won Nobel prizes after we invested, not before. So really big ideas really excite me. For a specific investment, OpenAI is going after a big, hairy, audacious goal of building an ADR. That to me is worth pursuing as an investment, but also for society. It may eliminate the need to work for society, lots of issues there, but it could be really, really exciting if it works. And I don't know what the probability of success is. Again, even if it's only 10% and there's a 90% chance of something less, that's fine with me. So that's very exciting.

Harry Stebbings:

Vinod, as I said at the beginning, and this is an episode that I've wanted to do for many years now. So I can't thank you enough for joining me and I also can't wait to see the next 10 years for Khosla and the incredible portfolio you've built.

Vinod Khosla:

Well, thank you. It's always fun to do this. As you can tell, I get excited and if I can excite one more person into being an entrepreneur on a mission that helps society, that has impact or does some very cool thing like micro bots, this hour is worth it.

## Article: 2019 BOOK RECOMMENDATIONS

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Life on the Edge: The Coming of Age of Quantum Biology — Each chapter illustrates one of life's puzzles and makes you think differently about the world. Would life even be possible without quantum phenomenon like tunneling which we use extensively in semiconductors? Could cells transport potassium as they do without quantum? And it ends on the intriguing note: is the brain a quantum computer mediated by electromagnetic forces at levels considered too low for classical science?

By Johnjoe McFadden and Jim Al-Khalili

Ranking: 10 (highly recommended); one of the few books I have read twice!

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Lifespan: Why We Age — and Why We Don't Have To — This eye-opening narrative reveals incredible scientific breakthroughs about aging and ways we can slow down, or even reverse, the process. Why is this more possible than anyone thinks? Should we solve diseases or solve aging that increases the propensity for diseases?

By David A. Sinclair, PhD with Matthew D. LaPlante

Ranking: 10

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An Elegant Defense: The Extraordinary New Science of the Immune System: A Tale in Four Lives — Explains for the lay reader the intricate biology of our immune system. Really an engineering “how it works” story. For all its astonishing complexity, however, the immune system can be easily compromised by fatigue, stress, toxins, advanced age, and poor nutrition — hallmarks of modern life — and even by excessive hygiene. Paradoxically, it is a fragile wonder weapon that can turn on our own bodies with startling results, leading today to epidemic levels of autoimmune disorders.

By Matt Richtel

Ranking: 8

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The Formula: The Universal Laws of Success —This book transforms how our success-obsessed society approaches their professional careers and long-term goals. And it is network science applied in the same way we may apply network theory to network medicine and decide if a drug works on a particular patient. Network theory at it’s broadest. As Naseem Taleb says “his is not just an important but an imperative project: to approach the problem of randomness and success using the state of the art scientific arsenal we have.”

By Albert-László Barabási

Ranking: 8

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The Third Pillar: How Markets and the State Leave the Community Behind — Raghuram Rajan offers a way to rethink the ties between the market forces (business) and civil society (government) and makes the case to strengthen and return power to local communities as a remedy to growing despair and unrest. This book provides a solid framework as to why things

begin to deteriorate, and how society can successfully find their way back to a secure and stable plane.

By Raghuram Rajan

Ranking: 8

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The Uninhabitable Earth: Life After Warming — A look into the future and how global warming will impact everything, from the transformation of global politics, to the sustainability of capitalism, and the trajectory of human progress. A great read even though I think it overstates things. It scares, and it's time to be very very scared. The message is more important than the details and it is powerful.

By David Wallace-Wells

Ranking: 8

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Winners Take All: The Elite Charade of Changing the World — While today's rich and powerful are fighting for equality and justice, Giridharadas argues that it is being done in a way that will preserve their position at the top of society. This is an important read and it contains many very valuable points. Though I disagree with many of its conclusions, I do agree with the notion of elite circles that are often, but not always, self-centered and self-interested.

By Anand Giridharadas

Ranking: 8



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The \$12 Million Stuffed Shark: The Curious Economics of Contemporary Art — A look at the economics and the marketing strategies that enable the modern art market to generate such astronomical prices. I always thought of art as really really snooty as it is manifested (not as it is created) and this book proves the point. The creation of art may have higher significance but the art world is not a good reflection of it. It is mercenary, pretentious, egotistical and social ratification plus other nonsense. You will understand why an art piece might cost \$400m just because it allows a buyer to claim they can spend \$400M! The role of pretend and social validation over reality is obvious.

By Don Thompson

Ranking: 8

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21 Lessons for the 21st Century — An important examination into today's most pressing political, technological, social, and existential issues as we move into the uncharted territory of the future.

By Yuval Noah Harari

Ranking: 8

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Blitzscaling: The Lightning-Fast Path to Building Massively Valuable Companies — A great book on blitzscaling: An insightful book on how to scale at a very fast pace and more importantly WHEN. Also explains why inefficient use of money can be important.

By Reid Hoffman and Chris Yeh; Foreword by Bill Gates

Ranking: 7

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The Breakthrough: Immunotherapy and the Race to Cure Cancer —This book guides readers through the scientific research transforming immunotherapy from the miraculous to the forefront of twenty-first-century medical science.

By Charles Graeber

Ranking: 7

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The Coddling of the American Mind: How Good Intentions and Bad Ideas are Setting Up a Generation for Failure —This book dives into the new problem on college campuses, Safetyism, and how it undermines the freedom of inquiry and speech that are indispensable to universities. The consequences of a generation unable or disinclined to engage with ideas that make them uncomfortable are dire for society, and open the door — accessible from both the left and the right — to various forms of authoritarianism. A good companion read to “Winner Takes All”. Can too much political correctness hurt?

By Greg Lukianoff and Jonathan Haidt

Ranking: 7

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The Inflamed Mind: A Radical New Approach to Depression — This book reveals the new breakthrough on the link between depression and inflammation of the body and brain. A new thesis on what is a major disease state of the brain.

By Edward Bullmore

Ranking: 7

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Loonshots: How to Nurture the Crazy Ideas That Win Wars, Cure Diseases, and Transform Industries — This book explores the beauty, quirkiness, and complexity of ideas, especially new and out-of-the-box ones. Loonshots shows how group dynamics and workplace politics conspire against the psychological safety people need in order to boldly share their wildest ideas. A key to understanding why Silicon Valley culture is changing the world.

By Safi Bahcall

Ranking: 7

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What You Do Is Who You Are: How to Create Your Business Culture — This book brings us on a journey through ancient to modern culture, answering a question fundamental to any organization: who are we? How do people talk about us when we're not around? How do we treat our customers? Are we there for people in a pinch? Can we be trusted? For me, it shows the value of having principles an organization and its leaders believe in and can stick with when it gets hard to do so and real tradeoffs are involved.

By Ben Horowitz

Ranking: 7

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The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power — This book dives into the largest act of capitalist colonisation ever attempted — the colonisation of our minds, our behaviour, our free will, our very selves. Yet it's not an anti-tech book. It's anti-unregulated capitalism, red in tooth and claw.

By Shoshana Zuboff

Ranking: 6

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Friday Black — By placing ordinary characters in extraordinary situations, this book reveals the violence, injustice, and painful absurdities that black men and women contend with every day in this country. It's a way to be exposed to another world living in the same place and the same time as "I/we" do.

By Nana Kwame and Adjei-Brenyah

Ranking: 6

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The Future of Capitalism: Facing the New Anxieties — This passionate and polemical book outlines ethical ways of healing the deep new rifts that are tearing apart the fabric of the United States and other Western societies.

By Paul Collier

Ranking: 6

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How to Change Your Mind: What the New Science of Psychedelics Teaches Us About Consciousness, Dying, Addiction, Depression and Transcendence — The true subject of this “mental travelogue” is not just psychedelic drugs but also the eternal puzzle of human consciousness and how, in a world that offers us both suffering and joy, we can do our best to be fully present and find meaning in our lives. It is also a fun exploration of psychedelic drugs, especially for someone who has never tried them.

By Michael Pollan

Ranking: 6

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The Jungle Grows Back: America and Our Imperiled World — Recent years have brought deeply disturbing developments around the globe. American sentiment seems to be leaning increasingly toward withdrawal in the face of such disarray. This is a powerful, urgent essay into why American withdrawal would be the worst possible response, based on a fundamental and dangerous misreading of the world.

By Robert Kagan

Ranking: 6

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The Line Becomes a River: Dispatches from the Border —For Francisco Cantú, the border is in the blood: his mother, a park ranger and daughter of a Mexican immigrant, raised him in the scrublands of the Southwest. Driven to understand the hard realities of the landscape he loves, Cantú joins the Border Patrol. But when an immigrant friend travels to Mexico to visit his dying mother and does not return, Cantú discovers that the border has migrated with him, and now he must know the full extent of the violence it wreaks, on both sides of the line. This book provides a different world view for those of us protected from some “reality”.

By Francisco Cantú

Ranking: 6

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Range: Why Generalists Triumph in a Specialized World —This book examines the world’s most successful athletes, artists, musicians, inventors, forecasters and scientists and discovers that in most fields , generalists, not specialists, are primed to excel. This book argues that cultivating range prepares us for things we can’t anticipate and adversity. We’ve believed in a single path to excellence: Start early, specialize soon, narrow your focus, aim for efficiency. This book suggests to hold off on starting those piano lessons too early. I’ve always loved exploration so this is very much in sync with my beliefs. Every high school and college student should read it.

By David Epstein

Ranking: 6

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Troublemakers: Silicon Valley’s Coming of Age — The richly told narrative of the Silicon Valley generation that launched five major high-tech industries in seven years, laying the foundation for

today's technology-driven world. This book tells the story of the world I have always lived, loved and believed in, despite the recent techlash.

By Leslie Berlin

Ranking: 6

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Atomic Habits: An Easy and Proven Way to Build Good Habits and Break Bad Ones — Over months and years, the accumulated effect of small habitual daily behaviors is staggering. This book warns that this compounding works both ways, so we'd better make sure we're making it work in a positive direction, not for the negative. A decent book on self-help tools, not a category I am generally a fan of.

By James Clear

Ranking: 5

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I'll refrain from covering books that are much lower in my ranking.

Article: "VENTURE ASSISTANCE": A PHILOSOPHICAL VIEW OF WHAT ENTREPRENEURS NEED BEYOND JUST FUNDING...

Many years ago, when Keith Rabois joined our firm, I wrote this blog in Techcrunch. As we announce that Dan Levin is joining Khosla Ventures as our newest operating partner, I am reminded of why we called our firm a “venture assistance” firm and not a “venture capital” firm when we founded it in 2004. Younger (and experienced) entrepreneurs need this assistance far more than capital (funding) even if sometimes they don’t quite realize it yet.

The concept of venture assistance is simple. Most VCs pitch their firms as being able to add value — to really help a company’s entrepreneurial founders. Personally, I think leading VC firms do a pretty good job of being supportive of their companies, and most entrepreneurs funded by good firms like their investors. But, on the question of “value added,” most venture capitalists (each VC with a typical 10–16 boards) even among the leading partnerships, are pretty passive and ineffective when it comes to assisting companies, except possibly in helping with networking, or they don’t give the right advice.

And in my view, many investors haven’t done enough in their careers to earn the right to advise entrepreneurs, a role that I consider laden with responsibility and fraught with the potential to do more harm than good by giving bad advice. We constantly ask our less experienced team members “What have you done to earn the right to advise entrepreneurs?” I don’t want entrepreneurs to get inexperienced advice on important matters. Their startup is their life, their baby — it is not just another company in an investor’s portfolio. The companies need help from board members with hiring key executives and with introductions to unreachable candidates. They need help with critical decisions, and with handling internal conflicts. And they need board members who will push them to be as great as they can be without voting against them on their board or crossing the line of making board “decisions”. Boards in my view should rarely make decisions. They deserve brutal honesty rather than hypocritical politeness, even when it is inconvenient to give or get. They need to be pushed to think hard and critically about complex problems that board members can see with the benefit of experience, but they need to be left alone and empowered to make their own final decisions. Entrepreneurs in private companies need trusted advisors, not governance. They need venture assistants.

We are excited to have Dan join us. Dan was the President and COO of Box, and more importantly mentor to star CEO Aaron Levie, for the last seven years. He joined Box when Aaron was 24, and together they led the company from \$10MM to \$500MM in revenue. In the previous twenty years, Dan founded a couple of startups and held senior executive roles in several others — in addition to taking seven years out of his entrepreneurial efforts to run a large part of Intuit (the makers of TurboTax and Quickbooks), at the time an 8,000 person organization. A seasoned leader who has founded venture backed companies himself, and helped a 24 year old entrepreneur grow a business to billions of dollars in value — who went



through the ups and downs associated with that rapid growth — is exactly the kind of experienced coach and mentor that we believe should be available to young entrepreneurs; not some junior VC who happens to join a venture firm but has not earned the right to advise entrepreneur because they have never built a startup themselves.

During Box's phase of very rapid growth, when it was doubling in size year after year, Dan invested heavily in people and culture. He felt strongly that a great leadership team — not just at the eStaff level but several layers down in the organization, was critical to its success. For example, Dan held a class in the cafeteria and personally taught every people manager in the company how to craft a great review, give hard feedback, and reward outstanding performance. Even years later, when Box was over a thousand employees, Dan led a book club to help every leader in the company, and every Boxer who wanted to attend, to become a better manager.

Dan knew that if Box wanted decisions to be made quickly, leaders had to be empowered to make calls locally — and that required them to both understand the company's strategy and objectives, and to be operating with enough information to make good decisions.

He also knew that as the company grew, they would have to hire from the outside in order to add needed skills to the mix. But that if they could not grow talent quickly enough to enable them to promote from within as well — they would put their company culture at risk. Box established a goal of filling 50% of their management hires with existing Boxers — and reported out to the entire company every six months on their progress against that target — one that they never failed to hit.

But the only way that could happen — the only way that enough leadership talent could grow inside the company — was if leadership development was a key priority. Box made a huge statement when they hired Even Wittenberg, previously Chief Talent Officer at HP and Head of Global Leadership Development at Google!, to lead Box's people team. Evan and Dan went on to build one of the strongest leadership development programs ever seen in a young technology company — and as a result, were able to promote from within to a much greater extent than can most young companies.

Dan brings that passion for teaching and mentoring leaders to Khosla, where he will work to help every one of our portfolio CEO's become that best leader that they can be — and to solve critical challenges and entrepreneurial conflicts along the way with hands on advice and mentorship.

That leads me to one of my favorite questions around younger entrepreneurial companies: What is the role of an entrepreneurial advisor or board member?

Most of us don't know what we don't know when operating in a new area, or in a new (to us) job. We are, as the academics would say, unconsciously incompetent. The right advisor leverages their own experience (and their many mistakes!) to ask the questions you never knew were important, and by doing so, opens your eyes to the previously unseen. They also look beyond more immediate imperatives to longer term issues and to help create new "S" growth curves. They serve as guides, seeing around corners, and helping you navigate the difficult road of building a company from the ground up, using their experience to spot things that an entrepreneur might otherwise miss (risks and opportunities alike), or to look into the future by reflecting on their experiences with other, similar companies. They carry with them an extensive network that they can bring to bear on all the different problems and challenges that might crop up along the way, whether it's finding a critical hire with the perfect match of skills and experience, or getting a company a make-or-break meeting with a decision-maker at a potential marquee customer.

At Khosla Ventures, we also believe that a good investor should be able to bring expertise to the table that can solve real problems that you and your team face. Our investing team is chock full of experienced operators who can provide the kind of advice mentioned above — including 4 ex-CEO's. We are extremely hands-on — whether it is helping with fundraising decks, a product strategy session, discussing brand strategy, or even writing patents. Among those who have not run a company, four have PhD's in science or engineering fields, and two more had senior executive roles at companies like Google, TellMe and Square and many other startups.

And in addition, we have a group of operating partners who do nothing but teach and coach and mentor our portfolio companies — offering real targeted help, be it in leadership and management training, recruiting executives or engineers, AI technology or recruiting, strategy, design, manufacturing and more.

One critical area for all young technology companies is hiring great talent. You have to source amazing candidates, drive a thorough and thoughtful interview and selection process, and then close the best candidates in your pipeline. And you have to do it for some incredibly difficult roles, especially if you are based in Silicon Valley, where the talent war is raging out of control. Our recruiting team can provide expertise and assistance with technical talent as well as

executive leaders — and perhaps more importantly can help you to hire and train a great internal recruiting team so that you can grow quickly.

As we see other areas where we feel that our companies could leverage talent and expertise provided by an operating partner, we add that capability. We can help with AI and ML strategy, with Design Thinking and building design into the DNA of your company, with supply chain and manufacturing if you have a hardware component to your offering, and with blocking and tackling issues like finance and legal as well.

At Khosla Ventures, we believe that our role is to add value to our portfolio companies, not just to provide them with capital. That is why we call ourselves a Venture Assistance firm, and why we work so hard to live up to the expectations that that title sets. From mentorship about management to operational help in AI, design, brand, manufacturing, enterprise software, we strive to help entrepreneurs reach greater heights than they might on their own to the very lonely job of an entrepreneurial CEO by helping them expand their opportunity and fullest capability.

#### Article: THE INTERSECTION OF IOT AND BLOCKCHAIN

A key element of my investment thesis has been that entrepreneurs innovate when institutions can't — or won't. That's especially true in networking, where I've been proud to back winners who innovated their way past skeptics to create incredible value in the tech ecosystem. When networking was first rolled out into public networks, our support of TCP/IP was dismissed and telecom monopolies wanted to use the archaic ATM architecture to support public data networks in 1996. TCP/IP didn't end up just extending beyond wired networks; it became the framework for whole industries that were built to make wireless communications an integral part of the world's daily work and personal lives. Starting today, blockchain is going to fuel innovation in the Internet of Things just like TCP/IP did in the world of wireless.

The historical context above helps illustrate my point. When the wireless world was thinking of voice, innovators were thinking of data and TCP/IP. Innovators are always three moves ahead of the rest of us, and TCP/IP drove a wireless revolution that wired telcos couldn't capitalize on.

Brands like AT&T were made irrelevant and reconfigured (AT&T was essentially sold to Cingular in a complex multi-part transaction), and companies like Cisco, known as enterprise vendors back then, became household names.

Yet the more things change, the more they stay the same. Institutions like the telcos and Cisco, who were once innovators but are now incumbents — rose but then became complacent. They've been touting the promise of the Internet of Things for years, but consumers and the tech industry have seen little real progress outside of the occasional connected thermostat or wireless speaker, and even mature technology like Bluetooth gets glitchy after a few meters. A world that was once chomping at the bit to embrace IoT now regards it with a healthy dose of skepticism.

Helium, one of Khosla Ventures' portfolio companies, is using a bleeding edge combination of RF (radio) and a protocol blockchain to deliver IoT from its past missteps and create unbelievable value — and doing it faster than telecom giants could ever hope to and in a way compatible with TCP/IP. The blockchain adds unique capabilities which no network can offer. Decentralization, security, and native geolocation are built-in. At scale, Helium adds exactly what's missing in IoT — a new layer of connectivity that is less power-hungry than WiFi, has more range than Bluetooth, and is much more affordable than cellular. A physical blockchain providing an incentivization and economic layer for radio communication is a blueprint that can be applied to other networking technologies, even potentially disrupting cellular networks and city-wide WiFi infrastructure.

Helium's low-power, long-range connectivity doesn't just deliver on what IoT should have done already, it solves some of the Fortune 500's biggest problems. A sensor that fits in the top of a vial and costs practically nothing to monitor allows life sciences companies to visualize the location, temperature, and ambient conditions of vaccines as they are distributed globally. The same technology keeps track of goods in factories, enables new smart home solutions, monitors utility infrastructure, and much more.

But most interestingly, Helium is accelerating deployment of its networking technology by using blockchain to incentivize deployment, provision infrastructure, and bill usage. Most blockchain projects largely remain outside the domain of physical solutions, but Helium is using blockchain as a catalyst for change and value creation. IOT networks free to telco pricing will need strong network effects and the blockchain is perfect for creating such a network effect, compensating those who take the risk of joining early far more than those who join later. In Helium's case, the blockchain levels the playing field for anyone, regardless of means, to be a network provider and

earn passive income. The cost of deploying smart cities solutions should decrease dramatically making it possible to bring benefits of innovation to the most impoverished communities. These kinds of approaches are few and far between, but they have the power to change the world.

MIT's Technology Review has always been great at being out in front of the biggest tech trends. This story is a terrific breakdown of Helium. Watch this space to see how blockchain can create a new decentralized machine network and disrupt the IoT industry. It won't be the last you read about Helium. If you want to continue the conversation, please join Helium [here](#).

#### Article: MARTIN'S BEACH: A MATTER OF PRINCIPLE & PROPERTY RIGHTS

Contrary to press reports, free public access has never existed at Martin's Beach in almost a century (and longer), only paid parking to allow access through the property. But the harassment of the new owners and misperceptions of the situation is new. I want to share my views here and dare you to understand the facts. I feel coerced and extorted, hence the fight.

##### 1. What is the status of the legal dispute on Martin's beach?

On Monday, January 29, 2018, San Mateo County Superior Court Judge Steve Dylina issued a Statement of Decision and Judgment finding there is no right of public access at Martin's Beach. The case arises out of a lawsuit filed in 2012, by a group referred to as "Friends of Martins Beach". In the lawsuit, Friends of Martins Beach asserted 7 legal theories. The Judgment states "Judgment is entered in favor of Defendants Martins Beach entities on all causes of action" Incidentally, this was not generally covered by the press because, presumably, it was a victory or the "wrong side". The press, it feels to me, has been opining, not reporting. The Judgment goes on to state "...Defendants are the fee owners of the Property ...and Plaintiff and its predecessors, assigns, tenants, or agents, and all persons unknown, claiming any legal or equitable right, title, estate, lien, or interest in the Property adverse to Defendants' title, or any cloud on Defendants' title have no interest in the Property, including, but not limited to, any right of public access or easement for the public to use or access the Property for any purpose whatsoever." In October 2013, San Mateo County Superior Court Judge Gerald Buchwald granted summary judgment in favor of Martin's Beach entities on all claims, finding that there was no right of public access to

the property on any theory. The Court of Appeal affirmed the trial court's decision on all but one of the claims, which was resolved as described above in 2018.

Although the Court found no right of public access exists on the property, in a separate suit filed by the Surfrider Foundation, the San Mateo County Superior Court ruled that closing an existing gate's hours of operation (a gate that was installed decades ago) or changing the price of parking as a business constitutes "development" and requires a permit from the Coastal Commission. They are trying to get us to apply for a permit on the technicality that opening and closing an existing gate, or changing signs or prices is development! The Deeney's did not ever apply to close the gate or change or erect signs. Their hope, I presume, is that technicalities coupled with harassment on every move needed to maintain the property as the Deeney's (the former owners) did will be coercive enough to give them what they want, but don't have legal rights to.

## 2. A partial history of Martin's Beach

Martin's Beach is a beach-front community of around 47+ homes and there is a road through the property to the undisputedly public beach. The Deeney family owned the property since 1902, testified in court under oath that for as long as they can remember (for almost a century), the property was used as a business (and agriculture) which only allowed access for a fee for parking and use of the private access road to the beach. There was always a gate which was periodically locked or left open for the parking business. Whenever someone was caught violating this policy, they were asked to leave or the sheriff called. The Deeney's would also tow unauthorized vehicles, in addition to asking violators to leave or calling the sheriff if they did not. They believe that Martins Beach was one of the most patrolled properties on the California coast, under Deeney ownership. They had multiple sets of eyes (family/friends living on property), audio sensors, and cameras at any given time.

The Deeney family, per their court testimony which is public record, routinely closed the gate for private events, in the winter, when it was deemed uneconomic, and whenever an attendant was unavailable to collect the fee. They repaired the parking after every winter and did other maintenance. The Deeney family did not apply for a permit each time it closed the road leading to the beach, and were never told by any state agency or any public official that a permit was required. Headlines notwithstanding, the court cases were only about access thru the property and not about the public beach. The law on access to public spaces like beaches across private property is well established.

The Martin's Beach dispute is misunderstood. The issue is the right to close the business of charging for parking and access onto private property. The Deeney's testified in court that they sold the business as it was losing money and demand for parking use was declining. The new owners asked the staff to open to the gate on roughly a historical basis when cars were expected to come by. Most days no cars came by and written records of this were submitted to the courts for 2008 and 2009. The new owners not being resident on the property need to hire staff to keep the fee collection business open. There were ten cars in a whole day less than thirty days in the whole year, making even an hourly attendant uneconomic. The new owners, not being resident on the property, need to hire staff to keep the fee collection business open.

My opponents hope, I presume, is that technicalities coupled with harassment on every move needed to maintain the property as the Deeney's did will be coercive enough to give them what they want, but don't have legal rights to. The Coastal Commission is requiring us to jump through hoops for activities that OTHER FOLKS WERE ALLOWED TO DO.

### 3. The dispute

Soon after the new owner purchased the property in 2008, it was told by the state that it could not make basic decisions about the private access road to the beach and the amount of the fee, things the Deeney family regularly controlled and did. Thus, the owner had no choice but to assert its property rights. The county demanded that the gate be open for longer hours than ever maintained by the Deeney Family for the many decades that they operated the property and to roll back the parking fee to be charged to those charged in 1972! This clearly felt like harassment and felt very unfair.

It is the inherent right of any property owner to start, close, continue, or discontinue any legal business, especially when it is losing money as was the case with Martin's Beach. The controversy around Martin's Beach involves important property rights that only the courts can decide and a prescriptive state that wants to control when a business on the coast can be opened or closed or what prices it can charge. It is unfortunate that government agencies have refused to acknowledge the owner's fundamental property rights resulting in controversy and litigation and precluding any meaningful dialogue between the owners and the larger community. Until the issues are settled, a conversation is hard. When disputes arise as to interpretation one has to resort to the courts to clarify the law and not rely on populism, or press, or "what we wish was the law".

The various state agencies have treated other properties that closed a gate providing beach access very differently. The Red White and Blue Beach in Santa Cruz, for example, was once a popular clothing-optional beach and campground and charged a fee for parking. The Red White and Blue Beach closed its operations without obtaining a Coastal Development Permit with the state's knowledge, something the state now insists that Martin's Beach do. A key legal question is should every business require a permit to shut down? Should a business require a permit to change its hours or days of operation? Why impose different rules on Martin's Beach than on Red White & Blue beach for exactly the same business and actions? Martin's Beach planted some trees and the County asked them to remove the trees or get a permit. The trees were removed and given to our neighbor who planted the same trees. There was no objection to the neighbor's actions.

The Deeney's further testified that they sold the property because the business was not profitable, the beach was in serious state of disrepair, and interest in visiting the beach was declining every year. When the property was purchased in 2008, the new owners continued the Deeney's practice of charging a fee to people who wanted to use and access the beach. In fact, they hired one of the Deeney sons to run the business roughly per their previous practices, when they expected cars to come by.

In 2009, the County sent a letter demanding that the fee be reduced to 1972 levels (something they had never asked the Deeneys to do and had not done in county or state owned properties), presumably to coerce the new owners to open the beach on a different schedule than the previous owners. When the owners offered to keep the property open on the same terms that it had been historically open (as per the Deeney's testimony in court) when at least ten cars came by per day, the county refused to accept that alternative. The County also prevented the new owners from engaging in routine upkeep of the parking lot and routine maintenance of the property without a permit — activities the Deeneys did for decades without a permit. At that point, it became necessary to get a legal interpretation of the law. How can an owner maintain access to a parking lot when they are not allowed to maintain the spots in the parking lot? Why should an owner be required to operate a business that is losing money?

So why doesn't Martin's Beach apply for a permit? Why should you apply for a permit when you have not engaged in any activity that would require the government's permission? Is operating an existing gate to change the hours of a business "development" as defined under the coastal act? The Coastal Commission uses red tape and perpetual delays to coerce property owners into giving up property rights. After years of trying, Martin's Beach has not even been able to get a public hearing because of intentional bureaucratic delays and red tape. Numerous requests for a hearing have been made over the years. The staff specifically told representatives of the owners



that the Coastal Commission “knows how to deal” with people like them, that they have all of the “leverage”, and that they would wrap Martin’s Beach “in red tape”, and would never allow them to reach a hearing, until Martin’s Beach agrees to provide the access they want.

#### 4. Why this matters?

Is this kind of coercion and extortion what we should expect from a state agency? Can we expect a fair process with this agenda on part of the state? The state agencies have intentionally refused to pursue an enforcement action, or allow the new owners to reach a hearing, knowing that without doing so, the new owners cannot be afforded due process, cannot obtain a final determination on the issue, and cannot seek judicial relief. This is plain and simple coercion, that the US Supreme Court has previously ruled against “coercion” which was alleged in the well known Nolan case, a previous property dispute. According to the Nolan case, the Coastal Commission can require access as a condition to a permit only when the condition is “roughly proportional” to the impact of the proposed project. Here, there is no proposed project. The Coastal Act, itself, provides that the Coastal Commission cannot apply the Coastal Act in a manner that would violate the Takings Clause of the US Constitution and must protect private property rights.

According to the courts, the right to exclude others is the most valuable right in the “bundle of rights” that constitutes property. When that right is seized by the government, a “taking of property” in violation of the Federal Constitution occurs. In applying the coastal act, the interpretation of what is “development” must be clarified by the courts.

#### 5. Remedies

We understand that the State looked at purchasing the property but ultimately decided not to proceed before it was sold to the new owner. They now want for free what they were unwilling pay for. The Deeney’s real estate agent offered to negotiate with the state and P.O.S.T. BEFORE the property was put on the open market. The new owners have offered to sell the property to the state at assessed market value but the state must reasonably decide what is good use of state funds among the many priorities: education, homelessness, medical care.... etc.

We have on multiple occasions offered to keep the beach parking access open whenever, based on historical record, more than ten cars a day (less than one an hour) are expected to come by, but to no avail. At least the hourly cost of an attendant would be covered from our point of view. Why is something like this not reasonable, other than it makes great fodder for pandering politicians?

The Martin's Beach dispute has been a painful episode for me personally. I may be post-financial but am not post-facts. I have prided myself on always doing the right thing and living a caring principled life, always legal but beyond that ethical and fair, no matter how popular or unpopular my stances are (disparity, among others, is a principal goal I want to work on, but not the way Martin's Beach opponents would have it as beyond the law and through coercion & populism, rights be damned). I love transparency and brutal honesty over hypocritical politeness, and don't like to give in to coercion and extortion that seems to be the mode of the Martin's Beach opponents. If I was to give tens of millions in value up by giving free access to the public at Martin's Beach (something that has never existed at the property and the Deeny's testified to for the century they have owned the property!) over this property, would it be to surfers or would I give it to homeless housing efforts, a topic I am very interested in? This logic matters even if not always popular. I don't shy away from unpopular views.

I love the American system and values and humanistic progress. I have invested a large part of my wealth into technologies to assist with climate change and other societal impact and hope to keep doing that. Many of these technologies to help solve climate change and sustainability failed, some spectacularly, but I felt the world needed them and so I continued to support them. Others ARE making a difference and doing well in areas such as food, agriculture, automotive batteries, industrial dirty gas cleanup, building efficiency, power generation and geothermal. As a venture firm, we ALWAYS ask ourselves whether we believe a company is a net negative for society before we invest, and my passion is to be a venture assistant for entrepreneurs who want to build large meaningful, impactful companies that help society. I don't care much about wealth and hope to give most of it away, I am not embarrassed to use what I have earned. I came to this country with nothing and appreciate it. I want to use most of my wealth to do good for society and if I make any additional money, it will be used to do even more good, whether it is thru "for profit" or "not for profit" enterprises.

Instead, there are articles and misperceptions that are labeling me as a bad guy by press reports that inaccurately describe "public access that Khosla shut down". This wasn't ever the case as you have read above. To me, the Martin's Beach dispute, however unpopular and damaging, is about principles, of not being extorted or coerced into giving up property rights, a tactic many many coastal property owners have detailed for me as routine practice by the Coastal

Commission. My personal conversations with individuals in the Coastal Commission, outside of the courts, have been constructive, including with the former Executive Director and the well meaning staff of the Coastal Commission. But principles of being treated unfairly, being coerced by a state body or extrajudicial efforts, principles of law, and property rights are hard to compromise for public popularity. I'd rather do the harder right thing than the easier wrong thing by encouraging extrajudicial behavior.

In conclusion

The dispute here is about private property rights and exercising those rights, it is not about billionaires or green investors which are loaded words used to sensationalize the reporting. It is a matter of principals of property rights and appropriate state behavior. Despite all the headlines, like the NY Times wrongly stating "Khosla erected an imposing gate" (you can from the pictures judge if it is "imposing"; it definitely was erected a very very long time ago; or is it "all the news we want to print, fit or not"?), the lawsuit is not about beach access, but the technicality of "are changing the hours of a business development". It is not about a public beach (undisputed) but "access to it thru private property".

I have seen very little in the press that is thoughtful about the dispute. Most of it is factually incorrect. Only the courts can decide what the proper interpretation of the law here is. No media vilification campaigns or politically motivated opportunistic proclamations or state bills by pandering politicians can decide the issues at play. Rather the proper legal process must be followed to clarify both state and federal law.

I would like to find a way to maintain access thru the property to the beach but given the options I have been given by the state, I need to fight back against government overreach so this can be done in a productive and cooperative manner. The ownership is very aware of the larger community's interest and it is unfortunate that the legal process is necessary to defend fundamental property rights rather than a conversation with members of the public community about appropriate invitational use. If they are acknowledged, then dialog would be possible.

Again, I believe in fairness, principles and American mainstream norms, and wanted to share this different point of view. Asking hard questions and standing up for principles should not cause you to be demonized.

## Article: REINVENTING SOCIETAL INFRASTRUCTURE WITH TECHNOLOGY

We don't make most of the food we eat, we don't grow it, anyway. We wear clothes other people make, we speak a language other people developed, we use a mathematics other people evolved and spent their lives building. I mean we're constantly taking things. It's a wonderful ecstatic feeling to create something and put it into the pool of human experience and knowledge." — Steve Jobs

### 1. The Summary

As a technology optimist I like to say, "what can be imagined technologically reasonably can be invented" is more true than not and more a matter of time and focus. Technology and new inventions have always shaped the human world, and have disrupted the way we live and work, and yet we are only at the beginning. Innovation in the areas of food, digitization, robotics, artificial intelligence, as a few examples, have the potential to achieve food abundance, reshape cities, knit humanity, and enhance human capability exponentially.

The big needs in society, food, health, housing, transportation, financial services, entertainment and more are being and will even more so be reinvented by technology in an "increasingly more accessible to all" way. We need to turbocharge our efforts to utilize technology to accelerate accessibility. Many of society's GDP and business-related needs are being reinvented everyday in a truly innovative and non-institutional way. Seven hundred million (or so) people have the rich lifestyle, either in environment, energy, housing, healthcare, education, food, that seven billion people on this planet want. Technology is the necessary, though not sufficient, resource multiplier. It's the only thing that can multiply resources. Technology will enable bridging this gap here, and the key word being "non-institutional" reinvention is not only powerful in increasing innovation, and but more importantly for accessibility.

The future and my admiration belongs to those dreamers who think of these unreasonable possibilities, who aren't afraid of the high probability of failure, and who take, bold and, radical risks. They are willing to change the world by imagining what's possible. So, what comes next for reinvention? Public transportation? Construction? Buildings? Healthcare? Food? Cities?

Communications? Companionship? Financial system? Imagine the possible and take it from impossible to improbable to possible, but then again unlikely to plausible to probably to real! Individual entrepreneurs and their passion for a vision (and tons of good luck) give the improbable reality a shot. Now, many, even most, of these attempts will fail and the press will denigrate you for hubris, arrogance, fraud, naivety, and much more. Even so, it is these improbable attempts that will, when they occasionally squeak by the “existing reality, institutional noise (and fear)” will change the world (hopefully mostly for good). The future is not knowable, but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future.

If there is a 90 percent chance of failure on a transformative project then we have a 10 percent chance of transforming the world. That’s pretty great. If we have ten attempts (preferably a 100!) each at many different areas covered in this essay we will really change the world. Even if most attempts fail, change and innovation will be technology driven, non-institutional, let’s break the rules, radical kind of approach. And in this non-institutional way of doing things though less predictable is way more exciting and probably the main way we will get to getting seven billion people the kind of lifestyle they’d all want. Machines and systems can do medicine better than humans. But that’s just one of many. Or that most jobs will be replaced or fusion energy is possible in my lifetime or that AI can make work an option for most people who will work if they want to work, but not need to work because we will have sufficient abundance. Imagine the possible!

As Yogi Berra said “It’s tough to make predictions, especially about the future”, but if there is an answer this speculation is more likely to be right than any other single prediction I can think of. This reinvention will be chaotic, disruptive, unpredictable with many failed attempts, but failure won’t matter; the sparse successes will. The disruption will be temporarily painful to some as being disrupted is never fun. We have to get things right and meet society’s expectations of technology to help equality, diversity and more. New technologies also rock the world by reallocating power and wealth and accentuating inequality. Fortunately capitalism is by permission of democracy and the electorate will have the ability to rectify the inequalities if it isn’t self-regulated by the technologists. All these social factors will become urgent and critical to enable this transformation through democracy and the people who will be impacted. It’s impact in the less democratic societies is harder to predict.

2. We need large innovations!

As a technology optimist, I like to think “what can be imagined technologically can be invented” is more true than not, though on unpredictable timelines. Technology has always shaped the world and currently it is disrupting the way people work, live, and associate by providing radically new tools. New technologies are rewriting human aspirations. Innovations in the areas of clean energy, food technology, digitization, robotics, artificial intelligence, 3D-printing, transportation have the potential to mitigate climate change , achieve food abundance, reshape cities, knit humanity, and enhance human capability exponentially. But the future, as William Gibson wrote, isn’t evenly distributed. Some areas are making rapid progress while others need turbocharging! And though a technology trajectory may be established when it has a few percent penetration of the population, penetration itself may take a decade or more after the path gets cast!

Entrepreneurs are leveraging technology to reinvent the big needs in society, food, health, housing, transportation, financial services, entertainment, and more in a more democratic and accessible way though here again broad accessibility needs more turbocharging. The mechanism of invention by the “drivers of reinvention,” mostly capitalism and entrepreneurship, tends to focus the drivers on shorter term profit maximization (as it should be for them to survive and flourish) rather than societal good maximization, generally. The power of ideas driven often by technology and entrepreneurial energy are laying by the wayside institutional views about society’s providers. What seems most exciting is that many of society’s GDP and business-related needs are being reinvented everyday and all this is done in a very innovative and non-institutional way.

The big needs in society, food, health, housing, transportation, financial services, entertainment and more are being and will even more so be reinvented by technology in an “increasingly more accessible to all” way. We need to turbocharge our efforts to utilize technology to accelerate accessibility. Many of society’s GDP and business-related needs are being reinvented everyday in a truly innovative and non-institutional way. Non-institutional reinvention is a powerful means of increasing innovation, sustainable abundance, and eventually, accessibility. It all comes down to the fact institutions look back on the past to predict the future, instead of reinventing the futures the way entrepreneurs are able to. Such approach, perhaps optimistically, may provide us resources and time to address other pressing societal need, such as socio-emotional or environmental.

Approximately seven-hundred million people live the resource-rich lifestyle (environment-rich, energy-rich, housing-rich, health-care-rich, education-rich, food-rich ) that seven billion people on this planet want. There is a minimal level of basic needs that would make wealth secondary for many if not most people, I believe, and they will focus on other pleasures/passions, goals, interests, etc. I assume that to be roughly 90% percentile level today, or level of the best off 700

million people on the planet. Can we get 7 billion people to that level of resource richness in education, housing, transportation, healthcare without resource shortages and planet destruction? Technology, innovation and invention are necessary, even if not sufficient by themselves, to make this happen. What we really need are dreamers who can imagine the impossible and make it happen. Instead of being pragmatic, such people ask “Why not?” and with their entrepreneurial energy try and make these dreams come true.

Technology is the necessary, though not sufficient, resource multiplier. It’s the principle thing that can multiply resources. We need a 10x in resource utilization multiplication without needing 10x in the number of doctors, the number of buildings, the number of cars. Recently, I looked at all major parts of the non-governmental GDP in the United States and asked “what couldn’t be reinvented?” Not by 5% better, 10% better, but by 100% better, 500%, even 1000% better. Technology will enable bridging this gap here, but the key word here is “non-institutional” reinvention which is not only powerful in increasing innovation, but equally importantly for accessibility.

The keys are individual entrepreneurs and their passion for a vision. No matter how ludicrous their idea might seem, they give the improbable a shot. Of course, one needs tons of good luck, and many, probably most, of these attempts will fail. The press and other critics will have a field day and denigrate them for hubris, arrogance, fraud, naivete, and worse. However, it is these improbable attempts that will, when they occasionally squeak by the “wall of existing reality and institutional noise,” , disbelief, resistance fear and finally competition” will change the world (hopefully mostly for good). The future is not knowable, but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future they (and we) want. Not all changes are positive, but even in worst cases, there’s room to iterate to solutions. This iteration process and fits and starts are part and parcel of most large innovations.

The future and my admiration belongs to those dreamers and “possibilities” who think of these unreasonable possibilities, who aren’t afraid of the high probability of failure, and who take, bold and, radical risks. They are willing to change the world by imagining what’s possible. So, what comes next for reinvention? Public transportation? Construction? Buildings? Healthcare? Food? Cities? Communications? Companionship? Financial system? Imagine the possible and take it from impossible to improbable to possible to probably to real! Individual entrepreneurs and their passion for a vision (and tons of good luck and high accompaniment of failures) give the improbable reality a shot. Now, many, even most, of these attempts will fail and the press will denigrate the entrepreneurs for hubris, arrogance, fraud, naivety, and much more.

In twenty years when we look back at the pundits, reports, studies, and consultants we will find them to be largely wrong about the future of societal change. I shiver every time I see a UN Report, a McKinsey report, or an econometric projection going beyond the span of five years, especially coming from those pundits who have never done much themselves except pontificate. Instead of networking and all of the talk at Davos, for example, which that has little effect and a lot of retrospective predictors and extrapolation of the past, it's much better to do and build. The future is not knowable, but it is "inventable" and inevitable and discoverable through iterative learning and trial and error. Therefore, great entrepreneurs and technologists, please invent the future you want! The skeptics never did the impossible with their focus on why things won't work. Optimists attempt more, fail much more, and achieve more.

### 3. It's almost always the entrepreneurs, not institutions, that drive big innovations

Let's take a quick look at things not-imaginable by the institutional view. All you need to do is look back to 1995 and imagine the Internet upending telecom and all that has happened since. AT&T Wireless was sold to Cingular (formed only in 2000) for \$40 billion in 2004 (the technical details were more complex — later on in 2005, SBC Communications Inc. acquires AT&T Corp., becomes AT&T Inc. and then in 2006, AT&T Inc. and BellSouth Corp. merge) and Whatsapp was sold for half the price to Facebook a decade later. Why? AT&T was slow to adapt to cellular and the Internet. In fact they insisted that TCP/IP, the core protocol of the Internet, was not appropriate for public networks and ATM was their technology of choice. Outsiders purchased the rest of AT&T during its decline and it ended up in the hands of SBC, the parent company that formed Cingular. Only the AT&T brand remains, and of course the remnant assets.

Why is non-institutional innovation so necessary? Looking back in the last twenty years, the Internet upended telecom (AT&T refused to adopt to the internet and cellular till much later), Amazon upended retail with a clear vision of changing choice, processes, and cost structure that Walmart could not imagine. Google upended libraries, advertising, media, and many undefined industries. Amazon, along with Netflix, Youtube, and others are upending Hollywood and television. Over the last decade, Netflix has reinvented TV/entertainment, and Facebook/Youtube/Twitter reinvented media and may even reinvent elections and politics! And speaking of elections, Trump reinvented political campaigns using Twitter as a destructive tool against a well-managed "proper" political campaign. Even institutional measurements of our goals like GDP are being upended. Google and Facebook's success, in fact, reduces GDP as it makes previously valuable tasks free! Cellular is dominating landlines. The iPhone, barely existed ten years ago when the venerable Nokia and Motorola ruled the mobile phone world. Uber reinvented the limousine service and the taxi service, and it will likely drive changes to public transportation. AirBnB is starting to change hotels, or at least a subset of that market. Instagram



and Google Photos invented or reinvented the way we take, manage, and share memories in our lives. What about many other examples like space (SpaceX), cars (Tesla), pharma (Genetech), etc? Why is non-institutional invention so necessary? Most people in business reduce the risk of failure to the point where the consequences of success are inconsequential on society, but they can make money for their shareholders as they are obligated to. My philosophy is different. I'd rather invest in something with a higher probability of failure if the consequences of success are consequential. There is as much profit and increased social impact to be gained here, although with a higher variability. As I like to say, my willingness to fail gives me the ability to succeed. That is the exact opposite of how incentives are usually set up in larger, non-founder led institutions. Structure, processes, key metrics, and compensation incentives at large institutions oftentimes have the opposite effect to the expected one and often actually fuel and attract risk aversion for true innovation. Without risk and its concomitant failure, large innovation is just the matter of luck.

You get the picture here. These industries were not reinvented by large corporations, but in fact the power of ideas driven by technological advances and entrepreneurial energy. Most people in business reduce the risk of failure to the point where the consequences of success are inconsequential on society (but they can make money for their shareholders which they are obligated to do). Instead, the ideas that change the way we live and work are the ones that originally have a sparser space of higher probability of failure, but the consequences of success are consequential. There is as much profit and increased social impact to be gained through higher variability. As I personally say, my willingness to fail gives me the ability to succeed and contribute in my small way in causing good change to happen. In my view, it is only improbables that are important, we just don't know which improbable when it comes to large changes and innovations! Most experts and institutions assume improbable is unimportant (with only a few exceptions where true risk can be parlayed to someone else).

We have incumbents, institutions, consultants, and pundits predicting more of the same "extrapolation of the past to predict the future" worldview. Some are well meaning, while others are driven by personal or institutional self interest. They are authoritative and mostly wrong when it comes to large changes or big innovations. McKinsey reports and fancy speeches at Davos notwithstanding. There is a dissonance between them and technology entrepreneurs: The former believe improbable is not important, the latter think similarly of the status quo. Personally, I think mostly the improbables are important, but we just don't know which one it is.

This is the exact opposite of how incentives are usually set up in larger, non-founder led institutions. We have incumbents, institutions, and pundits predicting more of the same "extrapolation of the past" to "predict the future" world view. They focus on incremental

predictable progress from year to year. Most of their predictions are wrong when it comes to large changes or big innovations and their impact. I'd give you odds that few large innovations will come out of any institutional player.

It is only improbables that are important. Large institutions generally believe improbable is not important, while technology entrepreneurs believe the usual is not important. Improbable is what creates the next Facebook, Google, Apple, Uber, or Airbnb, Netflix, Square, Paypal driven, of course, by an entrepreneur's vision of the unreasonable possibility. Luckily, most of these players I named are still driven by founder vision, and aren't sensible in the way business school professors would teach their students. These founders ask "Why not?" and "Why not try it?" be it Alexa, AWS, space, driverless cars, global location maps, phones without keyboards. Big companies do help scale innovation and bring gobs of capital later when risk of a new phenomenon is low (the Tesla playing field for the next decade or so). But it's the seeds — what Uber, Tesla, Google with Waymo and driverless cars will do to completely replace much of transportation, as an example, with a new style of public and private transportation (this was inconceivable even five years ago by anyone in automobile, transportation business or city planning and is still largely being ignored in city planning)? Can we today envision a 10x better hamburger supply chain?

Change happens but is not credible until after the fact. Retrospective predictability by pundits is common, but until large change happens one sees mostly skepticism. I have hence come to believe in the power of ideas driven by entrepreneurial energy by almost foolish, somewhat naive entrepreneurs, by those who didn't know what could not be done. Almost no major change is driven by institutions that one would expect to have power to cause that change! Did Walmart innovate retail or Amazon? Did Boeing/Lockheed innovate space or SpaceX? Did GM innovate cars or Tesla and Waymo? Did Youtube/Netflix/Facebook/Twitter innovate media or NBC? Is there any area where a major innovation came from an institutional?

#### 4. Beyond the entrepreneur, what does it take?

So imagine the possible in the many of the areas of interest and let's imagine the axes and tools of innovation. The way I think about it is the greater the number of "axes" — that is the dimensions in which innovation is possible, and the better the tools for innovation, experimentation, and lower the cost of trials for ideas — the faster the rate of change. That means a bigger possibility of a surprise like an Amazon disrupting retail or Tesla and Google changing transportation with electric and driverless cars, respectively.

Computers and computation as a tool allow for innovation in practically any field, be it in biology, space exploration, or information technologies. That was compounded by networking (of people, computers, and things) through the Internet which allowed the lowly landline phone to morph into today's mobile which, paradoxically, is mostly used for everything other than talking. The device, though, impacted so many areas of our life. This was unimaginable even two decades ago at the birth of the Internet and was still unclear even after its commercialization with the founding of Netscape in 1995.

So, what is in store for us for the next twenty years? It's hard to forecast, but easier to speculate. It seems likely that 3D manufacturing, artificial intelligence, biology tools especially — new physics-based tools, biology fashions like CRISPR and its likely successors for precision biology and computational biology, along with traditional old standbys like increased computing and bandwidth will all form a soup which catalyzes many new ideas and reactions. Now, add to the soup the potential for new types of computing, like quantum computing, which might accelerate AI even beyond our wildest imagination. The possibilities become truly unpredictable. Here I speculate (I never claim to be able to predict anything) basing just on technology paths that seem plausible, even if they are improbable today. I don't posit yet atomic level assembly of objects, but just using improvements in 3D-printing, voice communication, AI, and basic quantum simulations. I am not imagining here completely new axis that will surely happen like broad quantum computing, fusion energy, or molecular assembly. There are many axes of innovation that are opening up so the next decade or two look promising. I won't mention all of them here. There are some I expect but seem too speculative even for me. Others, on the other hand, I haven't dreamed off but are today being developed by smart people all over the world in research efforts.

To make it possible, you need new tools and technical breakthroughs, a visionary and persistent founder, and evangelizing market participants with a passion for the vision. They must understand where this vision is going, and they need to be convinced they need to come along and ultimately change, especially if it's radical innovation. For instance, automotive companies had little appetite for electric vehicles. Nevertheless, Elon Musk had both the vision and the determination to create electric cars and gain adoption; that that allowed him to disrupt the automotive industry by building a better, more efficient car while paving the way for an autonomous future, as some would say. There's also a difference between invention and socially effective innovation, and then scaling which the innovator may or may not be involved. For while it's still not universally accepted, it has taken convincing the likes of government regulators, financial institutions, technology thought leaders, media, and the general public to change behavior and ways of doing what they were doing. As Mahatma Gandhi said, "First they ignore

you, then they laugh at you, then they fight you, then you win.” Many institutions have business interests that will cause them to slow down these changes. There are also many pretend social change entrepreneurs taking advantage of their “story” with little more than financial goals or hollow sincerity to the causes they profess. But the wheat comes with the chaff unfortunately.

There are macro trends, too. Marc Andreessen said “software eating the world” because it was the easiest way to describe what was happening. The same is happening with AI eating the world, as well as computational design, blockchain and 3D-printing. Some of the tools and axes of innovation defined below will end up being transformative, most likely this will be the case of AI, others will just be rapid facilitators. Older technologies, like mobile and Internet, will keep turbocharging these newer innovations.

5. Looking at the infrastructure of society, what can be reimagined and reinvented?

Let’s take a closer, albeit speculative, look at possible ways in which these revolutions fundamental to a better world imagined by the majority of us and the economists, might happen. While other definitions of “better worlds” are possible, that is something left for a different discussion.

Where could a single entrepreneur driven by passion and a vision enter the market with simple products and drive to much larger scale over twenty years or so? Remember that twenty years ago in 1997 Google didn’t exist, and neither did Facebook. Media had not felt the push of Facebook, Youtube, Twitter. Amazon was very nascent and not yet starting to reinvent retail. Apple was under traditional “proper management” struggling to survive, while Uber, AirBnB, Pinterest were not even glimmers. Phones were made by traditional institutions like Motorola and Nokia, the mobile phone as we know it did not exist, and the Motorola and Nokia phones were mostly used for “talking.” There was no “app for that”. India was still trying to scale only landlines!

I was personally ridiculed when I suggested then that the Internet should not be ATM protocols but rather TCP/IP. In fact, Juniper Networks was the only company committed to building TCP/IP Internet protocols for the public Internet (No, Cisco was building routers for the Internet but had bought an ATM protocol company that would be their public Internet network play). Going further back through my career, in 1985 the idea of a computer in every home was considered absurd, grandma using email in 1990 was thought ridiculous, and the Internet was a crazy idea

and never going to be an important public network in 1995. AT&T assumed that 64 KBPS ISDN was all the data anyone needed.

What are the non-governmental components of GDP that can be re-imagined/reinvented with an entrepreneurial rather than a policy/legislative/regulatory approach?

Transportation and related city services

Health, disease diagnosis and management, drug discovery

Manufacturing, Construction, Buildings, building efficiency and cities

Food and Agriculture

Financial, insurance and legal services

Energy

Consumer consumption items, services, education, durable goods

Most of the non-governmental components of GDP can be re-imagined and reinvented with an entrepreneurial rather than a policy/legislative/regulatory approach (which will usually follow later) be it 1) Transportation and related city services 2) Health, disease diagnosis and management, drug discovery 3) Manufacturing, Construction, Buildings, building efficiency and cities 4) Food and Agriculture 5) Financial, insurance and legal services 6) Energy 7) Consumer consumption items, services, education, durable goods.

We'll look at each of these individually, but suffice it to say that almost all the non-government components of GDP can be reinvented with hundreds of percentages change in their resource

intensity, cost, quality, and accessibility — be it education, healthcare, transportation, housing, financial services, consumer products and services, and more!

Large change happens, but is not credible until after the fact. Retrospective predictability by pundits is common, but until large change happens one sees mostly skepticism, as witnessed by the number of electric cars forecast in 2010 or the political support for Trump forecast in early 2016. I have hence come to believe in the power of ideas driven by entrepreneurial energy by almost foolish, somewhat naive entrepreneurs, by those who didn't know what could not be done. Most major change is not driven by institutions that one would expect to have power to cause that change! Skeptics never did the impossible! They are often right, but wrong when it matters the most.

## 6. The technology soup enabling societal innovations

Fundamental reinvention has never been more possible than it is today. There are a range of new recent technological axes of development that give me hope. Driver technology tools that are plausible and visible today and are feeding on each other and on other research include:

AI and large scale data capability

Robotics

Additive manufacturing / 3D printing

Biotechnology ("omic measurement", CRISPR, gene synthesis, precision control of genes, pathways...)

Computational design, computational modelling/simulation for materials or process to biology and more

Social connectivity and networking; distributed access

Software eating the world

Blockchain

Increasing research breakthroughs in all areas

Other new still fermenting ideas I have surely missed or underestimated (open for candidate suggestions)

Fundamental reinvention has never been more possible than it is today. There are a range of new recent technological axes of development that give me hope. Driver technologies that are plausible and visible today are listed above. The “older technologies” that will continue to be axes of innovation that continue to have impact and provide benefit include: software, computing and cloud computing, Internet, semiconductor technologies, financial instruments, sensors, cameras and mobile.

Artificial Intelligence

AI will, inevitably, change the structure of our society. This is a statement about exciting future technical developments, and an observation about what is mostly possible in the near-term , although has not yet achieved widespread adoption. The rate of change of new AI capability, the building block for changing businesses and human activity, is very rapidly expanding.

Fundamentally, we can now or soon will be able to achieve human-like (and occasionally super-human) performance on tasks that were, just a few years ago, regarded as completely out of reach for machines. Probably the greatest example is computer vision. It was stagnant for decades, but has made so much progress in the last years we can now have computers classify images and videos with super human performance, provided we have enough training data in the domain, be it face recognition or reading MRI images. The same is becoming true in recognizing human speech and even generating voice, or reading someone’s mood or mental health status from their voice in superhuman ways. Just thinking about machines with the

capability to understand vision and recognizing voice by itself, will fundamentally change how we think of work in general and what our interface with machines will look like in the future.

That being said, there is likely an even greater progress possible near term. Currently, the best performing AI systems require huge amounts of data to train to human-like performance. However, work is underway to reduce this burden in various domains; often all that is needed are humans being to feed just a few examples to guide the neural nets. This will enable us to apply AI to domains where little data exists or the data is hard to get for structural or legal reasons, greatly widening the applicability of AI in all business and societal processes.

Model-building of the world as humans do is another dimension of innovation. For example, an AI may be able to predict how much force would knock over a glass of water. AIs are also learning fast from the world of simulations and games. I suspect the Lego blocks of intelligence will expand from a few (names like CNN's, RNN's, GAN's, to more recent additions like probabilistic programming, Bayes nets (redone), graph models, .... to all kinds of new capability hard to predict or name today) to many different types of intelligences capable of being combined to do unusual things; much like today's lego blocks sets can enable building very complex structures compared to the original red and yellow blocks that allowed us to mostly build simplistic things.

It is not only the ability of AI to "judge" and recognize images and audio that is a driver here. We are now on the cusp of having AI generate images in a domain, at high resolution, and high quality that mimic art or any desired input distribution. The same now goes for music where we can create AI that can mimic and improvise play in any style. "Creativity" used to be one of the standard answers to the question of what defines humanity. Nonetheless, it looks increasingly doubtful that even that claim is irrefutable. One day, we might see a short film, generated solely by an AI or a top ten music hit that never had a human composer or a new art style generated by AI that appeals to humans

One last comment that should make us quite hopeful about the accessibility of these technologies is that most of the fundamental breakthroughs have been out in the open, published, and discussed publicly. Yes, AI talent is hard to come by today. At the same time, it is also one of the most popular areas of study these days and sooner or later this challenge is going to be overcome. Coupled with high-quality frameworks for AI research and deployment now being freely available as open source, rapid progress on both research and applications is at hand.



In a talk to the National Bureau of Economic Research on the “Economic Implications of AI,” I looked at the top twenty employment categories in the US and concluded most jobs in most of these categories would be eliminated or change substantially for humans. Technology will reallocate where and how people spend time and resources. We will have great abundance, growing productivity, and GDP but with increasing income disparity. Further, changes will be slow, almost imperceptible in terms of employment the first five or ten years, and take decades before going exponential in actual number of jobs impacted. But by the time the first 5 percent of jobs are impacted, the future will be inevitable.

#### Robotics:

The renewed interest in robotics is, to a large extent, similar to the renewed interest in AI. For a long time we had robots that were amazingly durable, amazingly precise, but fundamentally simply examples of good mechanical engineering and careful motor control. This was enough to solve manufacturing tasks in very structured environments where all parts have defined positions and the manufacturing line does not change rapidly. A core example here is the chassis production of cars which has little human involvement today. But no robot could replace a human in the sorting of eggs by size and grade, only human assembly line workers could do that. They were mostly programmed machines, but not rapidly and broadly learning machines.

The new path in robotics involves robots that can make decisions in a largely unstructured environment. Probably the most discussed example of this today are self-driving cars that have to make decisions in the real world and not in a defined, pre-planned environment. But there are other, equally broad implications on the horizon. A company struggling with automation due to dealing with soft materials and rapidly changing product mixes right now faces large costs of automation. However, the next generation robots might change this by being able to learn new tasks rapidly on little data and with no programming

The main driver for this is two-fold. One is straightforward: it is simply the availability of very low-cost, high-resolution sensors, in particular camera systems, microphones, ultrasonics, radar and other environmental acquisition technologies. The other boils down to the fact we can now interpret vision and 3D data by learning from examples instead of having to hand-code the rules. Reinforcement learning, learning from simulation, and understanding how to reduce the training samples required are the core elements of modern robotics. Adding general learning including concepts, concept hierarchies physics, and more will happen.

Those robots are a very different breed from the old and the trade-off space will be vastly different. Formerly, we got precision from adding tighter motor control or heavier arms.. This new class of robots have cheaper, lighter arms and still get the precision back by relying on visual servoing. In essence, it means the vision system is able to correct the robotic arm as it gets close to the object we wish to manipulate. A robot arm capable of doing human tasks should not weigh any more than a human arm does and then scale sub-linearly from there. This makes this next generation of robots cheaper, able to handle very flexible tasks, and quick to deal with environments that have been thought as impossible in robotics before. There will be many contributions to robotics, but AI learning systems will be a big factor.

From a societal and economic perspective this enables a completely new way of thinking about production lines. Proximity to the end-customer, thus, becomes more important than the availability of cheap labor for menial tasks in unstructured environments or the need for scale. This is especially true when combined with new technologies like 3D-printing. Custom, personalized, and local may become economically better in areas like producing jeans, sofas and beds or many types of fresh food.

#### Additive Manufacturing/3D printing

Additive manufacturing -in essence printing objects instead of manufacturing them traditionally — has already made inroads in multiple areas. It consists of a family of technologies that can manufacture polymer parts to high-density metal parts. Even composites are being 3D-printed. The current beachheads for those technologies have been largely in design and prototyping environments. This means shortening the design cycle as we can almost instantly have a prototype part; it has actually already become a standard feature for many industries.

This is, however, changing and with robotics. For instance, we are seeing a complete transformation of supply chain and materials with one of our companies, Feetz, that's reinventing how shoes are made. We are seeing more and more production parts made by additive manufacturing. Using these techniques to create performance critical parts that are not manufacturable with traditional methods is already becoming commonplace. Examples here include turbine parts, rocket engine components, and implants. This acts as the key catalyst to move the industry from using the technology for prototyping to a manufacturing regime. We climb down the cost curve as an ever greater number of parts that used to be hard to customize, not buildable at all, or consisted of multiple assemblies, can now be built with these machines.

We are now tackling some of the fundamental limitations of the technology, such as cost per part, materials we can use, removal or avoidance of necessary support structures to make this family of technologies even more widely applicable. These technologies, in turn, are also changing conventional wisdom like benefits of scale, locations, and schedules for manufacturing, supply chains, spare parts, or maintenance. Do we need to make shoes in China for US consumption or can they be 3D-printed locally and customized to each foot? Do we need to stock every spare part for a Boeing 727 in every airport in the world? Should it take six months to get a sofa manufactured in China only to see it does not fit in your small studio apartment?

This has significant consequences for the way we think about complexity in our design. If complexity becomes in essence free, that is not tied to manufacturing steps, our possible design space explodes. In particular, if manufacturing complexity is not the bottleneck or cost factor anymore, designing structures will be the new bottleneck. Instead of designing by hand, we will likely create them by specifying the input loads and tasks fed into AI systems. Optimization software will process the data to create structures looking a lot more organically than now and producible ONLY by additive manufacturing. The technologies of robotics, AI, 3D printing, will feed on each other making exponential change on products, materials, and supply chains.

## Computational Design / Learning Physics

In design of objects we have long used computer tools from EDA tools for the electronics industry to CAD tools for physical objects and from simulations for verification of performance of the designed objects.

We are now moving into a regime where the actual act of designing a structure is now becoming part of the duty of our tools and humans act more as a trainer, judge and specifier of external conditions. And even those roles may change to just specifying goals given constraints and preferences. Let's take designing a structure for an aircraft. It has to fulfill various structural loads and remain as light as possible at the same time. We will in the coming decades let the algorithms decide the design to minimize weight and specify the external loads. This has been possible before via optimization procedures, but unlike before, we can "learn" from past successful designs and guide the search space and be much less dependent on human guidance or judgement.

In no place is this more apparent than in the design of drug targets. Instead of running quantum simulations to understand the binding of molecules to targets, a slow and costly procedure, at systems in the future be able to learn from past binding data to automatically come up with novel designs that might be good candidates for a new drug. A general principle behind it being that even though we often understand the underlying physics of what we are trying to design, the exploration process is too costly to run by brute force exploration of the design space. Learning from past successful designs, be they molecules designed for a target, physical objects, or different layouts on a circuit board, allows us to meaningfully change the performance of these objects. We may soon see a new range of computationally-designed materials beyond copper, steel, and aluminium alloys for everything, from medical devices to body organs to your car and sofa. A decade ago computers learnt to beat humans at chess by brute force computation. Soon systems like AlphaGo Zero will use “intuition” to do the same to make designs, drugs, and materials.

## Biotechnology/CRISPR

Innovations in biotechnology might be grouped into three different levels: measurement, understanding/modeling, and modification. Our ability to measure biomolecules at continually higher resolution and in greater bandwidth is enabling steady improvements of our measurements of individual organisms (like humans), but also groups of organisms (from the microbiome of a human gut to the complex commensal relationships of organisms in a coral reef or in a patch of forest floor). This amount of data acquisition these days is extremely complex and high-dimensional. Currently, only AI is able to create accurate predictive models and, thus, an efficient form of understanding the data. This, however, requires considerable advances in data storage and analytics. The third element is in the increasingly advanced and precise toolkit being developed for editing biology down to a single molecule. Tools like the Cas family of CRISPR associated proteins are enabling very specific, rapid editing of DNA, the blueprint for most of what we consider living things. These capabilities will dramatically improve and become more diverse over time.

George Church has likened studying the diversity and complexity of biology to an advanced alien civilization leaving all its technology in our backyard for us to analyze. Biology has been able to create the machinery to very efficiently convert wide ranges of energy from one form to another,. It is able to harness that energy into vast abilities to transmute forms of matter. This alchemy of biology still produces the vast majority of materials of interest to humanity. We are developing a deep control of the machinery of biology, which is just as crucial as the initial domestication of plants and animals thousands of years ago. Synthetic biology will impact chemicals and materials, energy, and human and animal editing, which will have great economic

and societal implications. These and future capabilities will give us god-like powers (with its benefits and danger) over the next decade or two.

Food products and pharmaceuticals are largely the result of biochemical processes. Basic components of our environment, like the oxygen we require to breathe, are the result of biological processes. Changing these systems with tools like a shovel or hammer would be impossible. However, we are gaining the potential to have molecular level control of all living things, giving us powerful new ways of combating issues like food security or climate change.

If human history has been a push to control of the world for human good, then we are at the start a major new type of development. This process started with the quest for control over environmental exposure by development of fire, buildings, and clothing; extending to gaining control over supply of food and materials by domestication of plants and animals, efficient agriculture, creating mining and mineral extraction and the industrial revolution; and then recently control over information and data through the development of language and literacy to modern methods of data transmission, storage, and analysis. For the first time, we are gaining control over modifying ourselves directly Biohackers are already CRISPR hacking their own bodies. It will become systematic starting with fixing genetic defects in babies.

The tools for editing DNA are only the first step in modifying the physiology of an adult living being. In order to do this, we have to target the cells and tissues we want to address specifically. Nevertheless, technological development in that direction is ongoing. We are also developing the ability to modify cells that can be introduced into the body with new genetics and designed molecular biochemistry or to modify and edit embryos prior to their implantation. We are learning to genetically modify a pig embryo to produce human compatible organs for transplantation, or 3D print organs. We can change our body composition, but we may also decide to edit ourselves from the very start. In terms of editing human embryos directly, we as a society need to determine how we want to use this technology; there are clearly many opportunities for improving health and wellness, and some large dangers as well.

One of the more promising avenues is to capture human knowledge in biomedicine, reconcile inconsistencies automatically, and be able to simulate at the molecular level every pathway and all omics in the body computationally. This could lead to true understanding of normal and deviations from normal, the usual definition of disease. Drugs and their effects on a particular person could be modeled and dosages calculated. The possibilities for human or animal biology management are exciting though impossible to specifically predict if we develop this capability.

## Social Networking

Social networking has changed our access and rate in which we access communication and how we collaborate. It has spurred new ideas and influenced the way we think about democracy. It has democratized information in a way that enhances education and new ideas. Twitter, as an example, has changed how we get news. It has influenced the end of regimes, and depending on the point of view, has had a positive or negative effect on politics. Social networking is a powerful tool that has allowed people to have a voice and connect globally. And it's not all just cat pictures and status updates. Slack has brought social networking to industries and enterprises. It enabled more voices to collaborate and be heard, and helped making processes and businesses more efficient.

Like anything powerful, social networks can have negative and positive implications on the world. They are undoubtedly a powerful tool to both spur innovative ideas and, influence them to get traction. They allow us to aggregate opinion, to get feedback for product designs and product reviews, and to have new channels of democracy (and it's subterfuge, as well as fake news). Scientific social networks accelerate communication and collaboration and increase the rate of progress or discussion. There are many ways in which industrial progress is leveraging these social tools. This tool is speeding the pace of change and innovation across key areas like education, health, and government. AI systems added to social networks and messaging will change them materially again. I am continuously optimistic this will be for the better.

## Blockchain

A marriage of the Internet and cryptography created the blockchain which has given rise to the distributed ledger, new payment systems, and cryptocurrencies like Bitcoin. This will be critical axes of innovation that will enable new businesses and paradigms, whether it be smart contracts to rethinking workflows, food traceability, medical records, and other mission critical data tools. Blockchain will be a new way to use technology to rethink complete industries like the financial system or being full transparency and tracing into supply chains. When Haiti was hit by the hurricane, many or most of the records were lost. This could have been easily avoided. Blockchain could allow people, businesses, and governments to rethink how they are storing and using their data, such as documents, information, payments. Keep in mind there are dangers of misuse, volatility, diversion into fraud and illicit use as dangers.

Old tools that still have impact...

The “older technologies will continue to be axes of innovation that continue to have impact and provide benefit include (but are not limited to): Software

Computing and cloud computing

Internet

Sensors and cameras

Mobile

Biology, chemistry, and physics tools

The way I think about it is the greater the number of axes (dimensions in which innovation is possible) and the better the tools for innovation, experimentation, and lower the cost of trials for ideas, the faster the rate of change and the more possibility of a surprise like Amazon or Tesla or Google or Instagram or Paypal or Uber. Combinations of technology can be exponential and autocatalytic by accelerating each other.

It’s hard to forecast, but somewhat easier to speculate what might be new tools for the next decade. Again though, the best reinvention is seemingly unimaginable. All the “known” axes today form a soup which catalyzes many new ideas and reactions. Add the potential for new types of computing like quantum or AI hardware, which might accelerate computation and AI even beyond our imagination today, are truly unpredictable. New axes will surely happen, perhaps with sophisticated broad quantum-computing, fusion energy, or molecular assembly. Computation remains a fundamentally underutilized resource in physics, chemistry, biology, simulations, materials, and much more in society.

## 7. Reinventing Transportation

Key drivers: Driverless technology, electric cars, reimagined public transportation, batteries, dedicated self driving public transit lanes, mobile hailing and scheduling solutions.

#### Transportation Trends:

From public transportation to flying cars... it can all be reinvented. When you take the cost structure of an Uber, multiply its usage by 5–10X in any given city, assume cars that are used 100,000–200,000 miles per year (amortized as a few cents per passenger mile serviced over its million mile designed life) instead of 12,000 and as a result operating costs become much more important than capital costs. Thus, electric cars become much more cost effective. Interest and maintenance costs decline because of scale and the cost of the driver disappears because of driverless technology. At the moment, the driver is the largest part of a Uber or taxi service and would approach a few cents per passenger mile., Scheduling, hailing, and other operations are automated through intelligent AI and mobile devices. It becomes hard to see how owning a car makes sense except for a small fraction of the population. For instance, we could have public transportation in smart cities, enabled by clever legislation, point to point on demand, that is cheaper than today's fixed route, fixed schedule transit services run by most cities enabled by electric cars/pods and driverless technology.

A little pod that seldom crashes, with streets dedicated to it should not cost more than a dollar a ride. Batteries and electricity would be the main cost per passenger mile. These pods, given the service time, will need to be electric, which incidentally lowers carbon per passenger mile for cities that are carbon sensitive about their electric supply. It also means higher reliability because of fewer moving parts.

Because these pods will be less prone to crashing, they will be lighter and cheaper, which will allow them to go much further on a kilowatt hour of electricity, reducing battery costs. A light bicycle is 17 pounds. Would a four passenger pod that can be frequently recharged need more than a few hundred pounds to carry 1,000 pounds of four people? Electricity cost would be very small at 50–100 pounds of vehicle weight per person for each mile. One could summon specialty pods for wheelchairs or other specialty loads. For forward-looking cities, we may see these as anywhere to anywhere on demand public transportation for a few dollars or maybe near free!



The Ubers of the world and the Volkswagen's of the world may be marginalized. Cars will remain a thing for car enthusiasts. However, besides special use cases for the vast percentage of passenger miles cars, trains and public transportation will be reinvented. All that dramatically reduces cost for cities and citizens. And then there will be flying taxis. So, lots of tools allowing for innovation and transportation and its implications for cities. Just as cars changed cities, electric and driverless technology could change them again, especially if applied to public transportation.

Parking lots and spaces could be replaced by parks or housing, or commuter lanes. Commute distances may expand, housing may get cheaper, and environmental pollution decline. Driverless car technology may kill the combustion engine and set the oil industry in permanent decline. Cities could be redesigned to work differently, especially if one adds in improved communications technology. The number of cars could decline five fold or more. The need for natural resources like steel, rubber and plastics decline concomitantly.

Parking lots and spaces could be replaced by parks or housing, commuter lanes by driverless lanes or streets, commute distances may expand, housing may get cheaper and environmental pollution decline. One may need to accommodate new factors such as pickup and dropoff spots on streets. Driverless car technology may kill the combustion engine and set the oil industry in permanent decline. Cities could be redesigned to work differently, especially if one adds communications technology and space efficiency and reuse paradigms. And the number of cars could decline by 5X or more and the need to natural resources like steel, rubber and plastics decline concomitantly.

Automobiles as a large part of GDP could change dramatically. Even trains could become autonomous pods on roads or tracks, dispatched on demand, instead of being enormous beasts carrying 100,000 pound cabins (that go empty much of the day) that only make economic and climate sense when fully loaded and whose schedule is limited by when they can carry a breakeven number of passengers. A key metric might be average pounds and costs of material required to carry a human. Ideally, we start with key arteries. Let's take the airport to the strip section of Las Vegas and reimagine it as a driverless-only free service. Then, let the service spread organically from there, with more reserved streets to offer anywhere to anywhere public transportation on demand which could be cheaper than today's transit tickets and more economical for the city. More and more of the city streets might become driverless and public utility only, much like today's "reserved lanes" in a city like San Francisco. Cities will have increasing incentive to make more of the publicly paid for streets driverless only for public "transport pods" only.

If residents of a city get closer to their destination, they might even walk the last half mile, which could have beneficial influence on their health. Incidentally, with the increasing number of driverless pods, the “reach of the city” or distance possible within a certain fixed commute time will increase. Thus, it can ease housing shortages and improve housing affordability. Parking land would be freed up for parks and low-cost housing. The city without automobiles would be a different animal. To understand what drives cities check out A Physicist Solves the City!

The city without automobiles (mostly in most but not all places) would be a different animal. With 80% fewer resources we could have dramatically more transport capacity, speed, and convenience. The pattern of adoption is not yet clear. The rate of adoption will depend upon how the technology is targeted at social solutions. It might happen first on elder care communities, with free taxi service to avoid the disadvantages of having average age 70 drivers and enable everyone in age restricted communities to have more freedom.

On the other hand, it may be an incentive to make affordable housing more prevalent by guaranteeing a certain commute time with free service in dedicated lanes from certain communities to work centers? Or it may be used in order to relieve traffic congestion in cities like inner London; offering near point to point convenient and affordable service can render private transportation unnecessary. Another likely development is to relieve truck drivers of tedious jobs by letting driverless trucks ply the freeways and the drivers to take over when off the freeway initially? Adoption and social acceptance in my view will have a huge path dependence and a range of adoption options are available.

Possibility 2050:

Driverless automotive technology will be pervasive. Public transit might replace cars as we know them in small pods instead of large buses and will be unscheduled and point to point, on demand. Certain streets will be dedicated to autonomous public transit pods only. Larger distance travel will also be autonomous, possibly on “tracks” (evolution of today’s trains but with small “rail pods” instead of large trains); autonomous driving, except in special circumstances, will drive us towards smaller “pods” of less than 200 pounds of vehicle (think grown up “weather protective” scooters or golf carts that seldom crash) per passenger rather than today’s 2000 pounds of steel per passenger. These will be augmented by flying autonomous taxis changing our notion of commute distances and navigable terrain/roads/rivers/mountain passes/bays. Trucks on freeways will be completely autonomous and autonomous vehicles will dominate local

transport too and become much more diverse in size and configurations from sidewalk or bike lane delivery robots to small local delivery vehicles to larger freeway vehicles. The focus will be on throughput per lane for each modality of transportation and safety. And just maybe, if we are optimistic, we will have Shanghai to San Francisco in a 30 minutes rocket flight.

#### Transportation 2025:

Early driverless robo taxi services and trucks on many routes, often the simpler and easier to map ones, and possibly flying electric planes. Electric and driverless technology maturing for cars, trucks, trains, planes, helicopters and more, driving major shifts in economics and land use patterns and transportation resource consumption from steel to oil to roads. Even though “market penetration” may only be a few percent in each category, the inexorable trends will be evident and on a rapidly improving and iterating path. Freeways will be routinely plied by autonomous trucks but city driving will be largely human drivers. Flying cars may be common personal curiosities with small penetration. Electric transport airplanes will be starting to enter service.

#### 8. Reinventing Health, Disease Diagnosis and Management, Drug Discovery

Key drivers: Artificial intelligence for comprehensive understanding of medical knowledge, new measurement techniques enabled by and for machines allowing for 1000x or more data for algorithms to use, new algorithms to discover new knowledge in medicine, new tools for imaging the body and biomarker data acquisition from blood to physiologic (ECG, HRV, BP etc) to phenotypic biomarkers (wearables, voice, etc), better research based on more data, more , better drug discovery using AI, and AI guided robotic surgery. And eventually, much more causal models of disease and computational models of the human system.

#### Healthcare Trends:

Is it likely that technology could multiply doctors including many, if not most, specialties many-fold? Perhaps it could even, invent a better doctor, making them always available everywhere, accessible, and affordable or near free like Google search? A personal, broadly knowledgeable AI doctor for all 7 billion people on this planet is possible, even likely. Maybe people should only provide the human element of medical care? There are probably a million doctors in the United

States, give or take, but with AI systems, we could create ten or a few hundred million doctors worth of expertise and use human doctors only for what they love to do, which is interfacing with patients, making health more personal, accessible, convenient, and less costly.

We imagine an idealized doctor today but the reality of medicine today is very different. Doctors have a few minutes per patient visit for the top half of the planet's population and little to none for everyone else. In the future, almost certainly data science and AI will provide much better diagnosis, monitoring, and follow-up than most human doctors, as per my paper in 2016. It will do much better prescription, whether prescribing a drug or a procedure. We will have real science behind medicine. Doctors today learn mostly from constantly improving iterative practice and that has resulted in better medicine than we have ever had before. But it could be substantially better with rapid acceleration in quality as we move from the practice of medicine to the science of medicine. Every AI agent will be updated with the latest research and up-to-date with every specialty, instead of being knowledgeable in just their own vertical specialty. That will allow for a holistic approach to treating patients because of integrative knowledge, as opposed to the current separating of the specialists, like patient's cardiologist from their orthopedist or endocrinologist. AI will do much better diagnosis, monitoring, and follow-up than most human doctors and complement the human element of care humans might provide.

Medicine is much better than it has ever been, so we have to acknowledge every aspect of medicine has improved over the last ten years, thirty years, hundred years. That, however, does not mean it cannot be even better. At the moment, the "iteration of practice" has done a good job to improve medicine; when AI does medicine, it will be so much better. AI will enable less errors in doctor diagnosis and surgery, better drug discovery, and personalized prescriptions. Care will be based on thousands of biomarkers, genes, transcriptome, proteome, sometimes called "all omics medicine". We will be able to measure many more variables (thousands or millions per sample/patient/time point or more) and make decisions based on complexity no human doctor could master. It will be possible to even specify dosage for drugs for each patient's current state and monitor disease progression as well as side effects at the molecular level.

It seems silly there is one dosage prescription for aspirin or opioids for seven billion people on the planet. Drug discovery and surgery will change primarily to computational techniques, opening up more possibilities. Procedures like surgery and anesthesia could get roboticized, either with a human assisting robot or the other way around. Should you have bypass surgery or a stent? Most of that medicine is based on debatable evidence. According to the American Heart Association, there is class A evidence for only about 11 percent of their cardiac-related recommendations, meaning evidence from multiple randomized trials or meta-analyses exists to

support the diagnosis. Whereas 45 percent are based on recommendations founded on expert opinion (level C evidence, the worst kind).

And great quality will only be possible to achieve because of very low marginal costs, as has happened in so many other computationally based services. Better and faster patient outcomes, lesser healthcare costs, and more accessibility to all people are most likely to happen simultaneously. Technology has generally increased healthcare costs, but hopefully, it will be different this time as marginal cost will be much lower, as opposed to those of proton beam accelerators.

Much has been discussed about precision medicine. Unfortunately, however, it is mostly focused on genomic data. That is mostly tunnel vision; a much more promising “all omics” medicine has the potential to use your genome, your microbiome, your blood transcriptome, proteome, metabolome, exposome and generally “all omics” as well as custom computational models of each human body to precisely characterize the state of each human body and body subsystem. Network medicine will treat all the metabolic pathways in the body simultaneously as a connected network system, not as individual pathways. Such approach would be more personalized than precision medicine. I suspect most diseases will be defined and diagnosed this way, with broad terms like “diabetes” becoming obsolete and patients being classified by the molecular pathways, causing the high blood sugar “symptom” to become obsolete just as the term “dropsy” has, thus marginalizing symptom-based medicine. One of the fundamental limitations in medical practice has been the propensity to collect data that people can interpret. What is promising to me is the number of fundamental technologies being attempted to collect large AI scale data from everything, from an MRI image to a blood sample to the lowly ECG. If one had 30,000 biomarkers from every drop of blood for the same cost as today’s blood test and diabetes was defined and differentiated based on patterns of these markers, one would be able to predict which diabetic was at risk of cardiac disease and which of diabetic neuropathy. All this would be much better for the patient. Imaging is also ripe for reinvention, using computational capabilities and consumerized components. Much more is possible than we settle for today, in X-rays, ultrasound, MRI, CT scans, fMRI and more, with reimaged imaging with new math and physics offering more detail, faster at higher resolution and lower cost and increased accessibility. Looking into the body should be routine, radiation-free and inexpensive.

In my view, very little about medicine needs to stay the same. We have to get away from the idea that we use symptoms to diagnose disease. Data science should diagnose disease and monitor progress or recommended dosage of a medication and therapy to best treatment. We should get away from the notion of one prescription for all seven billion people on the planet based mostly on their weight. As I described on Quora last year, one should take a million

people, measure hundreds, if not thousands of variables, their blood and their microbiome and their physiology, every week, for a year. That way we'd have fifty million data points, each data point being thousands of data points in itself. Such a data set could predict most diseases, diagnose most diseases, and do it early — when it is truly beginning, not when it becomes symptomatic. This can not only contribute to preventive health. It can and will combat diseases and cancer by very early diagnosis. Plus, layer this into gene editing techniques and microbiome research. There is much to be done around personalization and targeted medicine. That's the startup I would do and get excited about doing. We have already seen entrepreneurs working on it in bits and pieces. While it's very complex and cannot be done in one step today, we will get there in the end. As I only half jokingly told the Stanford Medical School audience about it three years ago: "If I wanted to be a really good doctor in fifteen years, I would not go to the med school, I'd go to the math department."

Here are the facts: if you give a doctor five thousand data points, they wouldn't know how to diagnose you. If you give a system five-thousand data points, it can do really good diagnosis, and if you do fifty-thousand more, it'd be better. We can get enough information to recommend whether you really, are at high risk and should get a colonoscopy This analysis will get better and, eventually lead to generalized early cancer detection.

Disease will be detected early. Right now, most people with heart disease learn about their disease from a heart attack, not twenty years earlier when it started. When this is no longer the norm, we will move closer to healthcare from the sickcare we have today. We should have real science behind medicine. Medicine is much better than it has ever been, so we have to acknowledge every aspect of medicine has improved over the last ten, thirty or hundred years. But that doesn't mean it's as good as it can be. The people who object to this, don't realize that at least three billion of the seven billion people on this planet have never seen a doctor, don't have access to one, or cannot afford one. They definitely couldn't afford the drugs that pharma companies have been putting out recently. It is criminal that they cannot, especially if medication exists.

Possibility 2050:

Every consumer will be the CEO of his own health informed mostly by AI. Not subject to the whims or availability or opinions of a doctor. We will go from the practice of medicine to the science of medicine with the ability to see how every personal parameter, among hundreds, is affected as one administers a drug or procedure. We mostly eliminate the notion of symptom-

based medicine or symptom-based diagnosis with predictive capability dramatically predicting most disease onsets days, weeks, months and even years in advance.

Imagine near free physicians for everybody (nursing specialties will still cost money and back offices which account for a lot of healthcare personnel will be dramatically reduced). Every person on the planet will have access to a 24/7 personal AI “near free” physician which is also an integrative “all specialty” physician. All seven billion people on the planet may have this personal AI “primary care” or “all care” doctor when they need it, a personal psychiatrist, a personal oncologist, a personal cardiologist and more for about the cost of Google search. We will treat patients holistically because of integrative knowledge and not separate their cardiologist from their orthopedist or endocrinologist. The annual physical will be dramatically more quantitative and predictive of future health without costing more. Routine (even checkup) blood and other tests will massively multiplex data (10,000 or more biomarkers periodically at costs below that of a simple blood draw). Imaging will be much higher resolution, more functional and detailed compared to today, likely with full 3D dynamic/functional models of hearts and brains. Full body ten minute scans and functional characterizations (like arterial flow rates, perfusion rates, or fMRI ) will be routine. Fine grained mental health treatments will be based on hundreds of quantitative biomarkers not the current DSM-5 manual for psychiatrists. Disease progression measurement for diseases like Alzheimer’s will be quantitative.

Drugs, including narrowly specific biologics will be personalized. Humans will have fully computational models to predict the effects of interventions like drugs and personalized testing options like organoid systems before serious interventions for in vitro testing in addition to in silico systems. Network medicine using interactions among large number of biomarkers and pathways simultaneously will be dominant with models with hundreds or thousands of parameters.

Disease will be detected early (it’s a shame that most people with heart disease learn about their disease from a heart attack, not twenty years earlier when it started) and we will move closer to healthcare from the sickcare we have today. Data and AI technology intensive healthcare could be a lot cheaper, accessible and better. And just as a library research project is as cheap and more comprehensive generally through a google search, medicine will follow similar cost and quality curves (though healthcare incumbents, from hospitals to the AMA will still be fighting this better, lower cost care with fud and scare tactics).

Healthcare 2025:

We will start to do short to medium term prediction of disease, disease prognosis, dosing, prescription and new forms of imaging. AI will be preeminent in its features though not deeply penetrated. Diagnostics will include all omics but in a physician assisted way but the amount and cycle of testing for everything from blood biomarkers will be based on larger scale multiplexed techniques and will be more immediate and much lower cost. Human physicians will be bionically assisted by AI systems but will be primary caregivers, diagnosticians, prescribers. Consumers will, when they are so desirous, will be much better informed by AI systems. Microbiomes and foods will become start to be important in everyday physician prescriptions with both recognized by the mainstream medical world as important “drugs” and curatives. New techniques from AI and robotics will dramatically improve drug discovery, drug targeting to personal omics and even dosing. The number of gene specific biological drugs like anti-sense oligos will start to accelerate and small molecule drugs will significantly improve their approval rate. New biomarkers like HRV, vagal tone, EEG and ECG sub-features, detailed ultrasounds will augment traditional less precise markers like blood pressure, heart rate, ECG, temperature and physical exams. Genomics, transcriptomics, proteomics, metabolics will enter traditional medical practice.

## 9. Reinventing Manufacturing, Construction, Buildings, Building Efficiency and Cities

Key drivers: automated construction using manufacturing techniques, 3D printing, new materials, robotic delivery, “transformer” type spaces, shared and higher percentage reuse, 3D printing of buildings and furniture, social networking and increase in community spaces and relationships.

Buildings are a big part of our urban landscape and a large consumer of resources. Construction and building account for more carbon emissions in the US than transportation or industry. LED lighting is enabling 80 percent less electricity use, although unfortunately efficiency in light generation goes hand in with the increase its use.

Possibility 2050:

Buildings are a key part of our urban landscape and a large consumer of resources and given their lifetimes, they will overtly look similar. But techniques of new building construction will



change dramatically. Housing will be dematerialized and manufacturing techniques including partial 3D printing and lessons from automotive will be applied universally to construction.

What if space was reconfigurable and we would need half only as much to live comfortably? Some startups are building cost effective “transformer furniture” systems powered by modular robotics, so that they can seamlessly adapt space to activities and can be installed in a true plug and play fashion. Affordability and availability would go up and land use would decline for housing of large numbers of people. Space would become more cost-effective, and developers would be able to adopt their buildings retroactively. Buildings purpose built for WeWork-like uses and reconfigurable could add additional virtual space. And new community spaces through reuse may change the equation further.

Further imagine buildings were manufactured like automobiles, reducing costs dramatically. Possibly, next generation buildings would be 3D-printed in concrete or other materials and maybe steel or carbon fiber reinforced and designed with AI. For example, using generative design, they could possibly weigh a 50–80% less with much better insulation and use fewer quantity of materials. Structural elements like beams could use far less steel or could be 3D-printed with composites. For instance, 3D-printed carbon fiber beams can be five times stronger than titanium, and when 3D-manufactured with no human labor, more cost effective. All unnecessary material unneeded for structure could be subtracted with AI design and 3D-printed. And what if shared office spaces could turn into residences or hotels at night or be “WeWorked?”

Could we accommodate twice as many people twice as affordability in the same city? Of course, we won’t take down buildings or rebuild a whole city immediately. Yet, all those freed up parking spaces and new construction would be an opportunity to transform the city gradually over the course of two to five decades. A very large percentage of buildings are non-compliant with current code; the combination of forced compliance and upside economic opportunity with much more cost-effective space may motivate developers.

One can imagine delivery robots reducing chores as well as traffic using sidewalks. Or virtual clinic visits reducing medical visits. The complex ecosystem is hard to predict but will offer many opportunities. Robotic kitchens for burgers and delivery robots for home delivery would reduce the need for restaurant space. Here, I’m sticking with more linear ideas that might motivate an entrepreneur to pursue the change by themselves and build the next Google or Tesla.

Manufacturing, starting from cars to furniture and other durable goods, could also use techniques dreamed about above. Construction would put them on a different cost trajectory than in the past, and could potentially end up messing up our GDP numbers as much as computing has! They could be printed locally on-demand when possible (from walls to sofas) and minimally assembled locally; this might not be feasible for automobiles, but easier for furniture.

Autos would have different material consumption curves because of these techniques and others, like autonomous driving, would eliminate most accidents and hence reduce the need for bulk and crash protection! Add new battery technologies that cut weight in half and accelerate the decline of the internal combustion engine and its pollution. 3D-printed composite structure could mean crashproof automobiles. Public transportation in small pods travelling 10x more miles per year than today's automobile on average will put pundits prognostications about our transportation needs to smithereens over a few decades. In general trends towards dematerialization of things will have accelerated.

Cities and urban living can be hundreds of percentages more efficient, sustainable, and with dramatically less costs and more community. Imagine a city world where we need less restaurant space because of robotic kitchens, robotic food delivery, self picking mini grocery store warehouses for Instacart like ordering with robotic delivery, virtual entertainment and get together, more parks for being outdoors that substitute for parking lots, or houses that multiply space because of AirBnB like models to reduce need for hotel rooms and increase space efficiency. WeWork like space efficient buildings that are further reused for homeless housing or hotels in the evenings with transforming furniture? New housing could half the space because of robotic transforming furniture improving space efficiency. Our assumptions about space, cities, density, efficiency, transportation, parks could change in unpredictable ways. This is a far cry from the 5–10% building efficiency environmentalists talk about and it will involve very little sacrifice of convenience.

What might manufacturing look like in 2050? Dematerialized, efficient, just in time, very local. Little inventory, no long supply chains, nothing made in China taking 3 months to ship — you get the idea. The nature of a car or shirt or furniture may or may not change but need for cars will and how shirts are made will change. Blockchain-based supply chains will transform our efficiency. A Kuka robot arm shouldn't weigh 3 tons and could be replaced by smarter arms used for broader scale manufacturing and 3D printing. More technologies could invert the supply chain to more local, product cycles and costs in unpredictable ways. Customized, dematerialized composites or metals 3D printed in generative design derivatives may make manufacturing a different world with very different tradeoffs of cost, complexity of design, supply chain, materials, inventory, and customer preferences including retailing. And all this would apply to

many if not most parts of our consumption from buildings and houses to transportation to appliances. Materials choices for building things will be numerous.

Manufacturing and construction 2025:

Housing will be start to be dematerialized and manufacturing techniques including partial 3D printing and lessons from automotive will be applied to construction. Space will start to be reused or used more efficiently with robotics. Every restaurant in San Francisco is underutilized during certain times of the day. That shouldn't be the case. WeWork and Airbnb are starting to address space efficiency and that may become more of the norm for many use cases. Making a 500-square-foot apartment behave like a 1,000 square-foot apartment through robotic transformation of furniture. Because the furniture moves and transforms, the bed goes in and out. You don't need 3 feet in front of your closet when you're not using your closet. All this kind of space efficiency. Robotics companies are reducing or eliminating kitchens in restaurants. Robotic deliveries. Rethinking how construction has to be done and the start of AI software driven design, planning, scheduling and building of construction.

We will have AI robotics driven assembly lines with ease of configurability replacing lines in China locally with the intelligence and dexterity to replace much of human capability be it assembling an iPhone or selecting eggs by size. We don't need humans doing mind-numbing robotic jobs. 3D printed composites or metals based consumer goods and industrial goods will be common from shoes to bicycles and maybe even some houses. Your normal wrench will have much less material in it and complexity in furniture may be near free. New materials will proliferate. The supply chain from the far east to the west will start to invert for specialty items from small volume manufacturing to shoes to clothes and furniture, though the east will start to create new local demand that will be locally filled.

## 10. Reinventing Food and Agriculture

Key drivers: Robotics, machine vision and AI, plant by plant care eliminating much of herbicides and insecticides, meat alternatives, sensory technologies to pack sensation with nutrition, better land use, drone and satellite imaging, better seed and chemical technologies, microorganisms, precision agriculture, fermentation & synthesis technologies, indoor farming, dense farming, microorganisms.

Whether any of the current “meat equivalent” food production companies changes the world or not, in order to get past the ills of animal husbandry and return our planet and land to its healthy, diverse ecosystem, something like Impossible Foods is necessary to match the taste of red meat. Whether it becomes a huge googlesque impact, a role model, or a footnote in history, it proved the possibility of food reinvention. Multiple entities working on reducing the impact of meat production, consuming a very large part of the planet’s usable land mass and a humongous percentage of freshwater use on the planet. It takes 1,800 gallons of water to produce a pound of beef. Growing the amount of feed grains necessary for just raising livestock accounts for 56 percent of the U.S water consumption. Similar efforts are underway in dairy alternatives. It is possible to reduce the land required for animal husbandry by 50 percent or more, despite the increasing demand. New sensory tools are being developed.

Traditional agriculture companies developing robotic technologies are dramatically reducing the need for herbicides and eventually other chemicals. Even plant-by-plant care, dosing of fertilizer or herbicide or insecticide in a million plant field is entirely feasible with robotic technologies. This can lead to higher yield, lower inputs, and lower environmental damage. Why spray herbicides on the whole field when one can weed mechanically, and, perchance, eliminate herbicides all together? Perhaps we can using robotic mechanical weeding to mostly eliminate herbicides in agriculture and get rid of the hated Roundup and dramatically reduce insecticide use? Maybe we can even allow GMO plants that are generally good for society but much maligned because of the negative impact that glyphosphates (Roundup) has on environments and GMO plants are most closely associated with Roundup Ready plants, can be freed from it. Eventually, these technologies will allow for plant by plant care even in a field of millions of plants. They will allow for far less nitrogen use, more yield per plant, less chemicals, and far less land use. Any technology that can reduce land use is very valuable given the amount of land is fixed on this planet, and we need to reforest millions of acres to find the easiest path to pulling carbon out of the air. Over a hundred out of the 116 models in the IPCC carbon reduction scenarios involve using some technology like reforestation to pull carbon out of the air). It is encouraging that area under farmland worldwide is finally declining and there is potential for the decline to accelerate.

Possibility 2050:

There could be far less land use for farming, far less chemicals, and far less factory farming of animals. Many drugs will be replaced by “medical foods” and food may become among the more important pharmaceuticals.

Precision agriculture also implies the use of such technologies as data science, aerial imaging, early disease detection. Further development of AI for imaging and data analysis, more easily and frequently accessed satellites, bio techniques like increased microbial communities, all aided by the use of fewer chemicals that would traditionally sterilize the soil because of new roboticized weeding and insect targeting will dramatically reduce the impact of and land use for agriculture. And it might even be that for specialized crops, vertical farms and data science lead to yield maximization coupled with robotic labor make a real change in the yield or resource or acres used. Of course, driverless tractors, drones, satellites, driverless trucks and sidewalk delivery robots to take care of the deliveries may change resource needs broadly.

Another dimension of innovation is the creation of new foods, such as beef without cows, milk from plants, eggs without chickens, all far less environmentally harmful at that. For example, 30–50% of our planet's land is dedicated to animal husbandry. Impossible uses 90–97% less land and 70% less water — being both good for the environment and people's health. This new foods will not only shift food production processes, be healthier for end consumers, but reduce environmental issues with very dramatic changes to land use for agriculture. Replacing animal husbandry may become one of the better tools for mitigating climate change and animal husbandry cruelty. Our factory food system with its many benefits and ills is due for massive disruption which will be substantially in progress by 2050.

2025:

There's so many axes of innovation in food. I used to think food isn't open to innovation but when I looked the possibilities surprised me. Every area I looked into was open. Even hamburgers was open into innovation and it was clear we could use far less land, water fertilizer, chemicals, animal husbandry. The Impossible Burger is an example. This is how we go from 10% of the world's population to the 100% being fed well and healthier. And of course, my favorite, 80% less cruelty to animals.

Eggs and dairy are being reinvented. Blue River, which John Deere acquired, used AI to do mechanically robotic weeding so you don't have to use chemical herbicides. You can do plant by plant fertilizer dosing in a million plant field because it's robotic. Far less fertilizer, far less insecticide, herbicide. Vertical farming and indoor farming will start to establish itself as a material force from what is a curiosity today. Food production systems worldwide change slowly so trends visible in 2025 will likely take much longer to achieve material penetration of the ecosystem.

## 11. Reinventing Financial, Insurance and Legal Services

Key drivers: AI technology to replace people functions and judgement (biases and cost), blockchain, mobility, data, software automation, secure reliable software services.

The pundit economists/Goldman Sachs/JP Morgan/Citibank view of financial systems and economics we are used to is being significantly challenged. Even basics like GDP as the right measure is being questioned. Entrepreneurs keep getting outraged that financial services, which should just be a service to real products and services being produced, are taking up such a large share of profits of all industry. It is possible to reinvent most of these services and especially those that rely on human labor or intermediaries. Though companies like Square, Stripe and Affirm are changing things for consumers and small businesses by disrupting incumbents, much more can be done and will likely happen. Others are creating radical new business models, like Even, hourly employee payment insurance, the bank app that plans so customers do not have to. Financial institutions impose massive taxes on fundraising organised by different industries. Those should diminish by order of magnitude based just on cost of providing this service and shared crowdsourced research. Research analysts provide valuable services in capital formation, but the costs are multiplied and much of capital formation is mispriced. The tax reduction should also apply to consumer banking and financial services costs. It could be that blockchain-based services and software contracts in finance and insurance, which could dislodge centralized control or “financial tax”. It could have identity verification, as well as traditional fraud and illegal activity controls like AML, KYC added on to the blockchain.

It could be simpler disintermediation of everything from foreign exchange to lending and insurance services. Insurance could be based on real costs, better actuarial tables, regulation around what is or is not legal to differentiate on, and low overhead. It is likely that legal services are automated by AI; there are only about seven million cases in US legal history. They are more structured and seem easier to computerize based on federal and state laws that these cases interpret than a technology like Google Home or Amazon Alexa which cover a far less structured and much broader range of conversational topics. Computerizing law and lawyers with or without software contracts will enable every citizen to have a personal lawyer(s) at a low cost or no cost at all? A few hundred thousand dollars a year of legal and medical services will cost almost nothing. It is possible that AI will replace many of the supposed value added functions, as it has already been proven in stock trading and financial planning. Judgement and estimation tasks in this data rich segment should be algorithmically driven and AI will likely replace human judgement where there is enough transaction volume (read volume, margins, profits), and much

of the back office work done by humans can be replaced by AI. One firm has already appointed an AI as a board member. What is clear is the ten percent of all financial transactions (a wild guesstimate) actually add value to society. Industry can be done at a fraction of the cost with less overhead or transaction taxes, and it can be done more fairly by more objective algorithms. The rest is speculation and circular trading worth trillions of dollars daily! This will add a lot more transparency, although it may introduce other problems.

Financial, insurance, and legal services will be freed of capitalistic lock-in and open to much more competition from relatively more transparent players; this could translate into far more affordable and accessible services. For instance, in Jordan, refugees are able to pay for food with blockchain technology, which is faster, cheaper, and more secure. Blockchain enables and creates trust, reduces risk, opens up banking to those who might not have bank accounts. In traditional banking, there are middlebank and inefficiencies in the more formal system that exists today, whereas with blockchain that's not the case, thus breaking socioeconomic challenges. Another example, is making access to legal services more affordable through AI, essentially replacing the lawyer. Whether for contract law, IP, or personal law, most if not all the work will be done through technology.

Possibility 2050:

Human mediation of financial, legal and insurance services will be relatively small compared to higher quality services offered by AI systems. Wealth advice, legal advice, insurance, lending, fraud, trust will be AI driven worlds to a large degree. The nature of services and needs is almost impossible to predict. Some form of Universal Basic Income will likely be a more broadly accepted concept though at a lower level than needed to provide full income support for recipients. The nature of the "firm" will be different but hard to say how. The nature of "work" will trend towards jobs people want to do and not what they have to do. Whether the speculation and circular trading worth trillions of dollars daily that will be minimized to the bare essentials is harder to say! Many if not most aspects of finance can be replaced with technology that make financial services more affordable and accessible.

By 2025:

The basic functions of banking, lending, borrowing, investing, capital formation, insurance, mortgages and legal can be done much better, more fairly, cheaper with less overhead and broader accessibility. All the people with fancy wealth advisors will do far worse than somebody

who just relies on AI at very little cost. Credit should be pervasive, easier and not mediated by humans. Algorithms will be biased but we will identify how to detect these biases and often correct for them. In any case algorithms will be much less biased than the current state of affairs with humans making judgements. Mortgages and supply chains may start to take advantage of blockchain and likely the cost of centralized agents (like banks or bankers) will be substantially reduced because of competition from distributed trust systems.

The financial tax of intermediaries will start to be minimal in most routine transactions and AI's may construct many unique transactions and services. The same will happen in financial services whether it's insurance or loans or access to investment opportunities. They will be dematerialized with few humans needed. Lots of new axes of innovation and data will allow for much more lower cost insurance from salary insurance for hourly employees to helping small business do what larger businesses do with AI based systems at low cost. So many new services will appear that suddenly don't need big banks or big financial institutions. We will start to remake most consumer and business financial and insurance services and put pressure on larger institutions to adopt or get left behind. Risk bearing assets will have more direct access to markets with fewer intermediaries.

## 12. Reinventing Energy Services

Key drivers: Scientific talent and long view funding.

The best minds getting PhDs are not going into energy or cleantech today, which poses a fundamental problem. Entrepreneurs realize it is hard to get funding, and for that reason, we are not seeing as many startups as we'd like to see. And energy services need technology as a driver to make environmentally great energy services market competitive. Cleantech is very capital-intensive and although there was a period of too much exuberance in the area, now it is met with investor disinterest. While it will slow down innovation long-term, hopefully, it won't stop it altogether.

Organizations like Breakthrough Energy Ventures are trying to address this. There are a number of audacious fusion projects and equally unlikely geothermal energy projects where linear cost for deeper drilling instead of exponential cost per foot when drilling at depth is the key breakthrough needed, storage, new materials and manufacturing, building materials, new agriculture and food. It is possible but the going has been slow.. This is the hardest area in which to visualize breakthrough step impact progress. I am still hopeful and feel that many high-risk



projects with high probability of failure must be attempted. Though 5–10–20 percent improvements are still fundable, 500–1000 percent change innovations are less clear to me. There are many areas in which it must be attempted: from fusion to geothermal to storage to new materials and new agriculture and food. Food is the easiest area to see radical resource efficiency.

That is likely the way to providing seven billion people a rich lifestyle as defined earlier without destroying the planet, depleting its resources (can we produce 10x the steel, copper, glass, cement, or use 10x less of each), and irreversible climate change. Low-carbon/low-cost power is a major need and achieve extremely hard to find solution to. Nevertheless, a much worse option from trying and failing will be failing to try. I have personally failed at trying to do this and had only limited success. Others like Tesla and Waymo/Google serve as role models and are changing the transportation industry forever. Additionally, AI may help accelerate progress in energy, and with quantum computers help with design, and exploration like at least fusion reactor containment structure, or find a solution for dark matter physics. Perhaps, it could help in designing more energy-efficient buildings or design cities that align more with structures in nature (highly recommend reading Scale by Geoffrey West.

One of the largest inefficiencies in energy, is when it comes to agriculture. The production process is wildly broken. The Alliance for Water Efficiency estimates that \$13–15B boost to the U.S. economy could be possible through more water and energy efficiency efforts, in general. With technology and innovation, water can be better conserved and utilized across the full agricultural process — whether it is in irrigation, crop yield, or distribution. Satellite advancements, robotics in fields, vertical farming, soil sensors, analytics using AI (for things like weather information or when and how to take actions or utilize water will increase efficiencies.

I am hopeful that a few breakthroughs, with fusion and geothermal (where linear cost for deeper drilling instead of exponential cost per foot when drilling at depth is the key breakthrough needed) being my best candidates, will help us over the next few decades. A caution is in order. Most attempts in energy look for 10–20–30% improvements in energy r resource efficiency. We need 100–500–1000% improvements in energy, water, land use, minerals and mining and in general everything that uses physical resources. Buildings have to for example use 80% less materials by weight and water efficiency of meat and ag production has to improve by similar amounts. This is hard.

Having said that the decline of oil as an energy source in transportation has clearly started and will be even more firmly a trend by 2025. The path to clean nuclear like fusion energy will take

luck and persistence for stationary energy services. Alternatives will be EGS geothermal or large scale energy storage by 2050 to complement intermittent sources like solar and wind.

### 13. Reinventing Consumer Services from Retailing, Entertainment to Elder Care to Delivery

Key drivers: Mobile, AI, internet, communications, social networking, voice and image technology, sensor and cameras, data, mass personalized manufacturing.

The way we shop and consume products and services has started to change over the last decade. The decline of traditional brick and mortar companies is clear but this does not necessarily point to the downfall of brick and mortar itself.

Technology is changing the way we discover products (Pinterest), how we order them (Instacart), how we make purchases (Apple Pay or Square), and how we find what's right for us. The supply chain is being reinvented, starting from one hour deliveries from a virtual pantry within minutes from many homes, all the way to completely reinvented grocery stores. Wallet share is changing as well from physical products to technology-enabled experiences like more personalized hotels or "stay rooms" such as AirBnB. Space is transforming to be more efficient and serve people for multiple purposes — the brick and mortar as we know it will shift, and we are already seeing this. 3D printing will allow us to print items on-demand, and even recycle, whereas AI will transform the experience to be truly personalized, whether that is tailored furniture or food plan unique for each individual. Lastly, robotics are changing how we interact from food delivery to Amazon Echo.

Yet we are seeing more physical local bookstores, which might actually mean a rebirth of the community experience, unlike product experiences of Amazon! We might even see more display retail rather than full inventory stores to provide community and shared time experiences with friends. However, these dynamics are hard to predict to the point it is hard to gauge the direction of change. Will the future hold more or less local retail? More of less community experiences and spaces? Instacart is disrupting the need for full grocery stores, while retail stores are also doubling as coffee shops or yoga studios when not in use. Retail will be more efficient for more than just selling products or serving as local distribution hubs and product display hubs. We may even see the rise of mobile spaces taking over parking lots or having the ability to use space better and reach out to people.

Experiences, especially shared and community experiences, will be more in demand, be it Sephora or yoga or coffee. Retailing may take on other manifestations too hard to predict, but inventory carrying stores may be passe. As costs are lower to create products, strong branding will be more important and values based brands will become more important. On the other hand, custom clothing on the spot fit to your body, made robotically, may not be too far away. 3D-printed custom items from sofas to shoes? As a result, with tools like robots and AI, we will be more efficient and will reduce costs to redistribute to other places. For instance, will we see roboticized restaurants building customized, fresher, and less expensive, or more accessible, fresh, fast food with no food deserts?

In the future, we will be able to fully customize fabrics or outlets, we may be even able to 3D print these on-demand, disrupting supply chains. Sensors will become smaller and cheaper to enable more, if not most, things to be connected and controlled in a seamless way. We will have more data about us (whether it's microbiome/genetic data for food, size/fit data for clothes, or music taste for buying composed music just for us using AI), that will allow for further personalization of our shopping list. Microbiome/genetic data could influence our for grocery shopping, size/fit data — clothes, or music taste for buying composed music just for us. All that can be enabled by the use of AI. Nevertheless, the use of such detailed data carries a possible danger connected to it, too. Regulation will have to strengthen on who controls and owns what data.

When it comes to services, the current labor force will shift. Large companies will have less of a hold on workforce. Because of technology, workforce will become more independent and flexible based on how these workers will want to spend their time. Whether a dog walker works for Wag on his/her own time, or a hairstylist no longer works at a Salon and goes direct to the consumer via an on-demand app, services will come to the person in a higher quality, more affordable, and more personalized way. Labor mobility and nature of jobs will change substantially.

I want more data about me and I want to control it, share it temporarily for a particular purpose to provide me services and rescind permission at will. Will the blockchain allow this without centralized trust? AI is also allowing us to have more tailored experiences to either design the right furniture for our home. It can, make new foods using algorithms, be it Watson cookbook or startups using AI to characterize proteins and design new foods., It can redefine our interactions with customer service when ordering an item. Robotics are also changing the game — starting with Amazon Echo which changes how we interact with our environment, including shopping, e.g. via voice in our home.

Consumer facing robots will become more functional and empathetic. For instance, Elderly care robotics can take care their needs or prevent elderly from getting lonely, to robotics that optimize manufacturing times and deliveries. Robots will monitor elderly for their food and drink consumption and remind them to take their prescriptions but more importantly will entertain then and engage them in conversation and community connections, combating loneliness. Technology will also enable families and kids of elderly to have a better grasp of their loved one's health and status. Robots will also transform the way kids can learn, creating more interactive, personalized education, and also robots for special needs people will create new ways to provide care.

When it comes to entertainment, TV, music, and other media are transforming. Music that was once the creation of songwriters and popstars, will be taken over by AI music and the same goes for TV shows. Whether it be Netflix or Amazon, shows will be created based on what people want. Entertainment will transform to be more than just 2D in the way we watch it today — whether it be holographic or virtual reality, entertainment will use more of our senses than what it exists today. The future will be dominated by new kinds of light field displays, new sound and haptic capabilities, AI driven robotics, AI driven music, art, entertainment and comedy in conjunction with human entertainers, artists, musicians enhancing the entertainment that can be done. Plentiful designs, local supply chains, almost transparent retailing, AI driven and AI robotic assisted elderly care with human supplementation of elder services on an exception basis.

#### 14. Reinventing Education

Key drivers: AI to personalize education, open source content, AI tutors, mobile and internet create more accessibility to knowledge and education, AI/AR/VR changing how students can get information.

I recently asked a simple question: Is majoring in liberal arts a mistake for students? The problem, I argued, is that the current liberal arts education does not teach critical thinking and scientific progress in the way that it should or in the way that STEM does. Now, STEM perhaps, doesn't teach enough of liberal arts — how to create real businesses from science and technology, and applications for best impacting the world.

Ironically, the more AI-driven changes we postulate here happen, the more necessary a real liberal arts education will be, something I now call “Modern Thinking.” Liberal Arts was what Greek elites indulged in when they did not have to work and servants and slaves did much of the work. Schools teach “in the box” thinking, standardized bubbles tests versus encouraging creativity and thinking in new paradigms. The education system is full of opportunity, and yet, it’s an industry that’s challenging and complex to change. The purpose of education will be less about employment and more about inquiry (scientific and other), stimulation, curiosity, ethics/values and similar more ephemeral less quantifiable goals. I have argued for a new discipline called “Modern Thinking” as the principal curriculum for non-professional majors. By 2050 this trend will be clear as will be clear we need to redefine the nature of work and education to “understand, pursue passion, pursue inquiry, not to get a job” as many routine jobs get roboticized or AI’ed. Communities of people, virtual or physical, will play a large part in education and intellectual pursuit.

With technology and new tools, accessibility and equality in education will change, no matter what style or subject of education you want. The ideal “tutor” for the task will always be available. AI tutors will not only allow for more affordable or free accessibility 24x7, but they will personalize education for each person. They will be able to assess where a student is, know the map of their knowledge and gaps in it and be able to guide a student through to their personal learning objectives. With technology and new tools, accessibility and equality in education will change, no matter what style or subject of education you want. The ideal “tutor” for the task will always be available. AI tutors will not only allow for more affordable or free accessibility 24x7, but they will personalize education for each person and widely accessible at low marginal cost.

Even for traditional grade or employment-oriented education this is a massive multiplier of teacher resources, letting them be the human element of teaching and not stranding those for whom teachers and tutors are a luxury. And for skills or humanities education AI and social networking enable community learning is an additional multiplier. In the near future, there will be more diverse, location independent education at low cost. No need to go to Stanford, there will be AI discussion in groups which will change cost structure. In the case that a majority of jobs get displaced by AI over time, this will also focus education to shift to teach other skills and change the curriculum. Perhaps, because of this personalization, the very notion of majors such as STEM or Liberal Arts will change altogether. These systems will serve humans.

15. Reinventing Business, Cyber, defense, Governmental Services

Without too much elaboration, it is worth point out that business services, resource uses, and products have been changing and will change even more. The change will continue and even accelerate on both the production and services side. No business, be it fintech, consumer goods design and production, industrial products design, drug research or manufacturing, materials design, manufacturing, spare parts, sales AI agents, or customer support agents, will remain untouched. The entrepreneurial opportunity will be immense, but the areas are too diverse to cover individually.

Technology will have an impact all of these, though my focus here is on things an individual entrepreneur can drive, not on governmental or regulatory services. Space and cyber will be often entrepreneurially driven, although the latter will have many state actors. I am less concerned here about governmental parts of GDP, except to note that safety nets for citizens will be easier to provide and such things as our traditional notions of taxes or redistributions will have to change. Tea party folks, you have not seen anything yet.

On cyber services I refer you to AI: Scary for the right Reasons but suffice it to say that massive entrepreneurial opportunities in defensive and offensive cyber tools and services will exist. There will be a large overlap with state institutions though corporate needs and markets will also escalate and grow. AI will dramatically escalate incidents of cyber warfare as rogue nations and criminal organizations use it to press their agendas, especially when it is outside our ability to assess or verify. This transition will resemble what we see when wind becomes a hurricane or a wave becomes a tsunami in terms of destructive power. Imagine an AI agent trained on something like OpenAI's Universe platform, learning to navigate thousands of online web environments, and being tuned to press an agenda. This could unleash a locust of intelligent bot trolls onto the web in a way that could destroy the very notion of public opinion. GAN type AI approaches will make these continuously learning, continuously stressed and hence improving machines. Alternatively, imagine a bot army of phone calls from the next evolution of Lyrebird.ai with unique voices harassing the phone lines of congressmen and senators with requests for harmful policy changes. This danger, unlike the idea of robots taking over, has a strong chance of becoming a reality in the next decade. My biggest concern in the next decade is that AI will dramatically worsen today's cyber security issues and be less verifiable than nuclear technology.

Massive entrepreneurial opportunities in defensive and offensive cyber tools and services will exist. Entrepreneurs will need to push further innovation across these areas for true innovation to happen. Much danger also lurks in these areas.

16. Some Khosla Ventures companies addressing these areas:

At Khosla Ventures, we look for companies who are aiming to make strides in the areas mentioned above. There will be many attempts, many will evolve, most will fail, and a few will hopefully become radical transformers. Though, many seem like small efforts, as a group they will form a tsunami, and will sweep through impacting innovation and change.

Health and medicine:

AI and data driven change from “practice of medicine to science of medicine” and specialty by specialty reinvention of the expertise, meaning virtual primary care doctors, cardiologists, psychiatrists, oncologists, is happening in our portfolio. Companies like Alivecor enable personal cardiologist-like functions around ECG like diagnosing atrial fibrillation or reading an ECG for normality, although nothing as forward as a full cardiologist yet and definitely not the interventional cardiologist yet; to partially substitute a therapist like Ginger.io, or perhaps the primary care doctor experience like Forward, or create an AI physician like Curai.

Others impact health by making accessible, population-scale genetics services like Color, or transforming xenotransplantation into an everyday, lifesaving medical procedure. Genalyte is tackling blood testing results and making it easier to get them in almost real-time in the doctor’s office versus a third-party lab. Rethinking Oncology is the domain of Guardant Health or Oncobox, which is personalizing genetic profiling to help oncologists decide which drug to use. Conquering infectious diseases through the innovative use of next-generation sequencing to analyze microbial cell-free DNA is something Karius does, being able to scan for 1,300 viruses simultaneously.

Other companies are using data-centric design to entirely rebuilding the next-gen health insurance company, like Oscar does. How about anticipating diseases with tools that enable physicians to predict Alzheimer’s disease before the symptoms appear like Neurotrak? Viome is using predictive biomarkers to your microbiome’s transcriptome and your blood transcriptome at the strain or RNA level. Using the microbiome, others are creating microbial therapeutics for inflammatory diseases (Siolta) or to target bacteria based on genome (Eligo).

Two Pore Guys is building a digital, hand-held, testing platform for DNA and RNA that’s as accurate as medical lab equipment, but is as inexpensive and easy to use as a blood glucose monitor. Zebra is using AI to rethink most radiologist functions for MRI, CT, x-rays for as little as

\$1, while Vicarious Surgical is enabling surgeons to do much much more with robots and AR (augmented reality). Heartvista is developing a robust commercial MRI system that will give comprehensive cardiovascular evaluation — real-time data with much less skilled technicians! Q Bio is trying to reinvent the annual physical to be far more quantitative and useful

#### Pharmaceuticals:

We believe that there will be AI-based reinvention from small molecule chemicals to precise regulation of genes using biologicals in the pharmaceutical space. Companies are predicting potential drug cures with the use of supercomputers, artificial intelligence, and a specialized algorithm that runs through millions of molecular structures. This can potentially reduce the cost and time involved in making new drug discoveries as our company Atomwise is doing, or combine world-leading expertise in machine learning and genome biology to transform medicine. Such is the case with Deep Genomics who are designing biologicals, or offering low-cost personalized genetic profiling to help cancer doctors decide which drugs will be most effective like Oncobox.

#### Food and food production:

AI, plant by plant robotics, and new methods to reducing chemicals, and precision agriculture are changing the way we produce and consume food. From reinventing the burger to be all plant-based to end animal husbandry, while at the same time reducing environmental impact, like Impossible Foods to creating a new plant-based egg substitute using science like Hampton Creek. What if you could develop sustainable and nutritious food products by matching the protein, fat, and carbohydrate distribution and content of traditional dairy products with a mixture of the proteins, fats, and carbohydrates from plants like Ripple?

In terms of food production and restaurants, companies are using robotics to make restaurants more efficient, increase food safety, and reallocate funds to higher quality food. On the agricultural process side, imagine using computer vision and robotics to improve agriculture like Blue River (sold to John Deere), who specifically enables farmers to spray herbicides only where weeds are present. Or to make farms more manageable with Granular (sold to Dupont) or climate insurance more accessible with Climate Corporate (sold to Monsanto)? Satellite imaging is allowing farmers to better predict and optimize farming practices like, the services provided by both Rocket Lab. Imagine a world where we can use robotics and AI to reduce pesticides, increase efficiency, and create healthier foods — we are only at the beginning.



## Financial system:

Large institutional bodies are often the most posed for disruption from financial services, risk and insurance, blockchain and software contracts-based services, efficient exchanges, accessibility, and even legal services. New small business and consumer services like are provided to by Square. Affirm or Fundbox can make larger purchases, banking, loans, professional help more accessible without credit risk, while Stripe can make payment processing easier.

Even, as an example, is rethinking insurance and credit for the modern consumer — managing one's salary, allowing the customer to allocate a small portion per month to an “emergency” amount to be used when a customer may be in a financial bind. Other companies are using blockchain to reimagine aspects of the financial system — for instance, digitizing experimental money to support blockchain to render it more liquid like BlockStream or allowing users to build Bitcoin applications using an enterprise-grade blockchain API like Chain. Adding to liquidity and efficiency are companies like Opendoor which make home selling much easier and faster.

## Construction and buildings, Housing:

3D-printing, modular factory built, and housing efficiency are a few areas that have opportunity. Imagine 3D-printing a house, or using manufacturing techniques to create lower cost units like Katera, or using robots to transform a small apartment into what feels like a larger space like Ori. Other companies are using robotics to make kitchens and restaurants more efficient like Spyce, and Momentum is changing city spaces by fully roboticized restaurant kitchens. Arevo, as an example, makes ultra-strong 3D-printed carbon fiber composite materials, while Vicarious is creating robots who can help construct and build, replacing human workers.

## Education:

AI and open source reduce need for infrastructure as well as manpower for education. Imagine a platform for academics to share research papers like academia.edu or an online platform that facilitates interaction among students and instructors like Piazza. New platforms from Piazza (college) a and Kiddom for K-12, now used by one in ten of all US teachers, allow for teachers

and students to share assignments, provide feedback, grade, and review reports all in one place are enabling more collaboration and better results in education. CK12, a related non-profit, is making K-12 content free and multi-dimensional while also building AI tutors to make quality education accessible.

#### Manufacturing:

3D printing, robotics, new materials, AI design. Imagine 3D-printing metals like Digital Alloys. Velo3D develops a technology that will disrupt 3D-printing in metals and Arevo that is changing composites manufacturing and affordability. Add robotics technologies like Vicarious, Berkshire Grey and manufacturing, which has been relatively isolated from change is feeling the pressures and innovation.

#### Transportation:

Imagine rethinking transportation with autonomous cars and ways to help people get where they need to go faster, cheaper, and with less impact on the environment. In the future, we will simply have self-driving cars as part of a fleet of taxis such as Voyage, or perhaps have alternate shorter destination methods of getting around, such as electric skateboards, like Boosted Boards. Hyperloop, Arevo.

#### Energy and climate, including water:

Some companies are developing a completely new high-power, long-cycle life, low-cost battery technology for stationary applications like Natron, or building a flexible solar cell design that minimizes the amount of semiconducting material used like Caelux. There are breakthroughs in energy storage for automotive such as QuantumScape, a company developing the first commercial solid state electrical energy storage devices for automotive applications. Others are trying to develop and commercialize new battery technology or develop stabilization for electric grids like Varentec or minimize home electricity consumptions like Bidgely or View making window glass more efficient.

There are companies who are using new techniques and approaches with technology for geothermal energy and Altarock or Lanzatech using waste gases from steel and other industrial process to turn that into useful products. Like all great technology, nuclear energy can be used to create new options for converting low-level waste into vast energy sources like Terrapower, while companies like View Glass and Sora reduce building energy consumption. And, of course, efforts like Breakthrough Energy Ventures have the potential for incubating long-term technologies for decarbonization.

## 17. The Silicon Valley culture

I'm very optimistic about Silicon Valley. The way to look at Silicon Valley is to ask "How many new things are starting up?". It is especially important in contrasting it to the rest of the world. The rest of the world thinks they know what's important, but the Silicon Valley psych (to me Silicon Valley is a culture not a place and is starting to spread into many parts of the world from Shanghai, Bangalore, Helsinki to Tel Aviv) is to be open-minded. It means to discover and not assume, learn not know, be unreasonable but pragmatic, and determined in not giving up when the going gets rough. It is not being foolish and yet foolish enough to try things others won't, to be naive enough to not be dissuaded easily, ask fundamental questions around "Why not?", and not "How has it been done before or tried before"....

Ask anyone in Washington or Wall Street or any other institutional agent what's important in energy, in climate? It's General Electric and Siemens. I'd give you odds that no large innovation will come out of any institutional player. Silicon Valley doesn't know what's important either, but what Silicon Valley does really, really well is originated interesting ideas and experiments to test these ideas, instead of opining, pontificating or asserting specialty or seniority without proof of merit.

You think Uber is a mess. I think of Uber as having started the change in our notion of transportation, started with a limo service at the very high-end; just like AirBnB started with brokering rooms in Philadelphia in 2008 during the Democratic National Convention and the brokering of rooms. That seed of an idea ends up being way more important than Hilton Hotels after almost a hundred years since they have been around. That's what is crucial. To me, that is what's really most important about Silicon Valley. While the world thinks they know what's important; that Volkswagen or General Motors is important to innovation in cars, the fact is they're largely irrelevant to innovation (except incremental innovation). It is 'some improbable' that really matters. These improbables, once they get a toehold, expand, evolve and improve and can become disproportionate compared to their humble start. They also feed on other new

innovations. When they fail their efforts appear to be hubris but apriori categorization of what is hubris and what is world changing is near impossible.

That improbable initially was Tesla (and they can still fail), but will be supercharged by the Google/Waymo and the Uber experiments. The combination almost certainly will upend public transportation in the future, whether either of these efforts fails or succeeds because they have put the world on a different trajectory. It will enable anywhere to anywhere ride on-demand for \$1 in most cities in America with public, transportation while providing better service and lower cost than any public transit service of consequence. Incidentally, it may remove the need for large scale city parking spots and open space for parks or housing. It may shrink distances and commutes, eliminate more than half the auto industry and its needs for steel and rubber, and collateral GDP! This loss of GDP (near zero if service is free or near free like libraries or information search are today) will be a good thing. It's the improbable, like Uber, Tesla and Waymo in 2010, that's important. The seed of ideas along with passion to try it starts new paradigms and it almost doesn't matter who best commercializes them.

I will even admit that Silicon Valley driven change will sometimes be scaled because of or by large companies (we welcome GM to driverless cars!) but the initiation of new directions is what is socially important. You know, Volkswagen's not going to reinvent transportation. Big companies do help scale innovations and bring gobs of capital later when risk of a new phenomenon is low (Walmart in retail?) but they'd rather stay safe and not be wrong. Uber can get lots of flack . Nevertheless, the fundamental innovation they have caused, what Uber started, Tesla started; Google started with Waymo and driverless cars, will completely replace all public transportation, whether Uber succeeds or fails, with what is the new style of public transportation. This seemed completely inconceivable five years ago by anyone in auto or transportation businesses and inconceivable coming from and driven by any large institutional thinking.

Self-driving cars and even electrics were fifty years away till Waymo asked "Why?"! What will be interesting and completely unpredictable is whether cities will run it, like they do public transportation or will they contract it out to a Waymo or a Google or a Tesla, or somebody else. In 2004 I gave a talk titled "The device that used to be a phone" (I had stolen that title idea from somebody but not sure who) and I got right the basic idea that a phone would not be used mostly for talking, but what I got embarrassingly wrong was the cases it would be used for. I was wrong in unimportant ways, but spot on in the most important trends, the general direction of other uses for a mobile device. This is the essence of Silicon Valley, and why reinvention will be driven by Silicon Valley and not the institutions we rely on and take comfort in.

What people confuse outside of Silicon Valley is this notion that I'm almost certain of that the big guys are unimportant to real "big step" innovation. What's hard to say is the opposite. Improbable, like Uber was, or AirBnB was, or Google was in 1998, is not unimportant. In fact, the only thing that's probably important is the improbable. We have no way of telling which improbable is important. And because Silicon Valley runs so many experiments and people love to write about all the failures, the hubris, the messes, the trivial, the fraudulent, or self-aggrandizing claims because they, Uber, Theranos, Juicero, Soylent, make best headlines. These same factors are critical to get the self-delusional attempts at grandiose or evolutionary innovation. If these entrepreneurs had normal expectations, they would not attempt the things they do attempt. And their failures and diversion into societally good or bad business is a necessary side effect. Most businesses are improbable and fail but the few (1 in 1000? 1 in 10,000?) that emerge as game changers have disproportionately large impact. As Martin Luther King Jr. said, human progress depends upon the socially maladjusted. And George Bernard Shaw said that reasonable people adapt themselves to the world, the unreasonable man (he should have added "and woman" but he didn't) adapts the world to them. Hence, human progress depends upon the unreasonable man.

Writers can write about or rail against or laugh at all the naive attempts, the hubris, the pretend unicorn valuations and the vast amount of drama that is Silicon Valley. However, all these things are largely irrelevant in the long run though they make a good "People" magazine for Silicon Valley and cause clicks on headlines. They do keep the media in business though with salacious content! Yes, investors get misled or just plain lose their money. Yes, they cause false hopes and even collateral damage to helpful institutions. But it's the 1 percent or even 0.1 percent that succeed that cause the majority of technology-driven change in society.

All I'm saying is startups drive the vast majority of innovation, not the institutional incumbents. It is this non-institutional driven change that frees us from the straitjacket of conventional wisdom and lets us really change the world. The experts that inhabit this world are experts in a previous version of the world and live by extrapolation. They do not aim at inventing a new future and as skeptics never do the seemingly impossible. Great entrepreneurs, and there are plenty of incremental ones too that do good work, invent the future they want. I would also state without proof but with plenty of experience across many industries, from Wall Street to more mainstream businesses, that Silicon Valley entrepreneurs have a larger percentage of people who are mission-driven, whether the mission is societal or local or silly, than most other businesses I have seen. Though it is important to acknowledge that Silicon valley has its good and bad apples and public scrutiny will help improve things. And that it's generally positive impact

has many downsides we must consider and worry about as discussed in one dimension in “AI: Scary for the Right Reasons”.

Some of these innovations, not surprisingly, have disruptive effects, both good ones and bad ones. But in areas with large changes most of the effects are unpredictable or unknowable in advance. With every large advantage comes some disadvantages but contrary to punditry about “they should have known” or it “causes job losses” the discovery and fixes necessarily have to be iteratively discovered and iteratively fixed, sometimes with regulatory or public activists oversight. The counter push for “no change” is often driven by those disrupted who are in an uncomfortable business position of being disrupted (the car business or taxi business or the advertising business for example) and who may leverage the genuine concerns of activists or press. This part of the “process” comes from inability to foresee “how and driven by whom”, companies and ideas develop (the alternative is not to do anything innovative, not to know in advance every consequence or path). Naivety of traditionalists can and does slow down great benefit to society from these disruptive changes. The traditional ugly factory farming cattle business or egg business has no love for much better food alternatives like better burgers or better mayonnaise.

It is these improbable sounding experiments that are really, really important about Silicon Valley. What is becoming even more exciting and healthy isn't IPO's, but the number of new areas the Valley is attempting to innovate in. A few years ago, we invested in this hamburger company Impossible Foods. Now, there are probably forty or fifty PhDs and another probably forty or fifty other technologists working on designing the perfect hamburger. Why? The founders have started it, because thirty to fifty percent of our planet's land area (and until Elon Musk gets us to Mars, this is the only planet we have) is dedicated to animal husbandry, and he wanted an environmental better way of producing meat. In addition to other practices, he wants to avoid cruelty to animals, unhealthy food, environmental degradation, antibiotics in our food chain, etc. He wanted a couple of million dollars to run an experiment. Could he do this? This kind of entrepreneur is the core of the Silicon Valley culture and though there are others abusing the public trust as has been widely and accurately reported, there is far more good than bad in this culture. There are good and bad people in any culture but Silicon Valley feels to me much more mission driven than most other cultures.

It's now gotten into a robust product that's today a niche product, but the goal, clearly, for the founder, is to replace all animal husbandry. You are not going to get that from Cargill or Archer Daniels Midland or Chevron or Exxon. They won't innovate because they don't really care as much about the mission of a sustainable planet, despite their proclamations and Madison

Avenue ads saying the contrary. And this disruption may disrupt their income statements. To be fair, anything else goes against their promise to their shareholders.

Do you think you could have innovation outside of this region? The one thing to realize is innovation can happen anywhere and everywhere. It is much more about the mindset and a culture than it is about a place. What makes it harder in other places is that when somebody innovates, they don't get that support around them. Silicon Valley is different. I'm sorry to say if you have been fifteen years at Hewlett-Packard or Cisco, you're not qualified to do any important job in the startup world. Every other part of the world people say "Wow, you work for GE or Citibank!" Here, they say "You've been working for GE and Cisco for fifteen years?" You're not hireable by anybody trying to really experiment and innovate. You're not qualified in any way if you're at Cisco for fifteen years, or IBM for fifteen years, or Cargill for fifteen years, or United Healthcare for fifteen years. Again, it's the mindset that enables new ideas or new tools for testing that creates the disruptive innovation that matters. Here too much experience can be a handicap.

I have gone through an exercise of trying to just see if I could find a large innovation coming out of big companies in the last twenty five years, a major innovation (there's plenty of minor innovations, incremental innovations that come out of big companies) but I couldn't find one in the last twenty-five years. You look at retail, did Amazon innovate this or Walmart? Media: Did ABC, NBC, CBS do it or Twitter/Youtube/Facebook? Did Boeing or Lockheed innovate space or SpaceX? Did GM which started early in electric cars and spent more money change cars or Tesla/Waymo/Uber? Did Wells Fargo or Bank of America change financial services or did Square/Stripe/Affirm do that? Did IBM change computing or Sun/VMWARE/Amazon AWS? Yes, the credit card 40–50 years ago was "credit on plastic" was the largest existing company, "barely large innovation" I could come up with though I am sure there are a few others. No, 3M does not qualify with the yellow sticky in my view.

## 18. Conclusion

The way to look at the world is seven hundred million people or so on the planet have a rich lifestyle. It's energy rich, it's resource rich, it's healthcare services rich, it's transportation rich, it's a rich lifestyle. Seven billion people want it. Can we do ten times as much of everything the same way? The obvious answer is no. Technology is the necessary, albeit not sufficient, resource multiplier. It is the only thing that can multiply resources. Now, politics can still screw all that up, and that's why I say technology is necessary and the only thing that can multiply resources, but it is not sufficient. Social, political and cultural issues matter immensely. This is why I am so bullish

about the role Silicon Valley can play in meeting social needs. And it's fun to do and do it in a non-institutional way, meaning CitiBank won't solve financial inclusion, Square will. If anybody does it.

The vast majority of U.S. jobs in 1900 were in agriculture. By the year 2000, it was approximately two percent of all jobs, so most jobs got displaced. I have recently looked at the top twenty job categories in the United States, and it was very clear that at least fifteen of them will have more than fifty percent of the jobs replaceable. I cannot say with precision whether it will happen in twenty-five years or fifty years. It depends on which entrepreneur takes it upon themselves to go innovate that job category. Such dramatic social change will render all the economic metrics that everybody in Washington pays attention to, "mostly meaningless but looking great". And it will feel very painful to the people who are affected as this The Next Technology Revolution will Drive Abundance and Income Disparity. That's the inclusiveness part. This is what worries me about technology. I'm a technology optimist, but there are consequences and side effects that aren't great — that we should all worry about. We will, however, have the resources to address them adequately.

It is important to note the cautions here. There is extreme variability in the timing and even the nature of the innovations that will emerge. There is also a huge path dependence based on when, who and why they innovate and that may cause the end result to be different. There are all kinds of entrepreneurs with good, bad and indifferent objectives in Silicon Valley. Who does what matters to where we get.

There are a huge number of unknown unknowns in this speculation (and yes it is all speculation, not forecast). Almost certainly this document will look naive in twenty five years. But the biggest of the big unknowns is artificial intelligence (AI) and even more so artificial general intelligence (AGI). I have had intelligent people forecast it as 5–10 years away and others say 10x that time. Personally, I'd peg that at the boundary of this document or around 5–10 cycles of 2–3 year individual innovation cycles in AI. That could change everything. It may only need a few hardware breakthroughs to scale computing 1000x or it may need many years of software invention. Regardless, when it happens it may be impact equivalent of a 100x nuclear-like technologies (again for good and evil!). And unlike nuclear it may not be verifiable as to who has what technology. The world would be very dramatically different. In short time we may need to adjust capitalism which was designed for economic efficiency to a new era of abundance, concentration of power and much more of a winner take all world. Life will be very, very different. Fortunately, capitalism is by permission of democracy and I hope that the means to reduce disparity and minimum living standards will be taken advantage of by societal choices.



If there is a 90 percent chance of failure on a transformative project, then we have a 10 percent chance of transforming the world. That's pretty great. If ten such fusion projects were attempted, we would possibly change the world. And if we have ten attempts (or a hundred) each at many different areas covered in this essay, we will really change the world. Change and innovation will be technology driven, non-institutional, breaking the rules, all radical approach. Let's not throw the baby out with the bathwater when things go wrong but instead focus on net societal benefit. And in this non-institutional way of doing things, though less predictable, it is way more exciting. It is probably the main way we will get to getting seven billion people the kind of lifestyle they'd all want.

As Yogi Berra said "It's tough to make predictions, especially about the future," but if there is an answer, this speculation is more likely to be right than any other single prediction.

On a more personal note, I'm going to keep making mistakes, because I'm speculating on a lot of things and then backing them. My willingness to fail allows me to succeed. And if I was too afraid to fail, I wouldn't try the things and I would, well, fail to try, instead of trying and failing. There's a world of a difference difference between those two. I think most people fail to try and so they never fail, but in my view, they always fail, because they fail to even attempt something. It is a really important cultural difference.

Another thing you learn in our business is humility. How often you're wrong. The best of you entrepreneurs (I'd love to see a large institution prove me wrong on my mostly non-institutional reinvention thesis) work on these kinds of problems, and that's what's so exciting to me, that is what keeps me motivated. That is why I am working eighty hours a week at age sixty two. I get so much flack for believing machines and systems can do medicine better than humans. However, that's just one of many. Or that most jobs will be replaced or fusion energy is possible in my lifetime or that AI can make work an option for most people who will work if they want to work, but not need to work because we will have sufficient abundance. It may or may not work but these ideas are worth attempting. Imagine the possible!

To elaborate more on founders — if you don't have strong religious beliefs about what you're trying to do, you tend to not succeed. So, you have to be totally obstinate about your vision, but flexible about your tactics. Most founders don't get to their vision in a straight line. It zig-zags, goes left, goes right, survives long enough, evolve, get lucky. No one has yet reached Everest without getting to multiple base camps. So while being obstinate about one's vision, one has to

be flexible on one's tactics. A pragmatic visionary so to speak in a world where most people are one or the other. And above all luck plays a huge part of success, and good founders give themselves multiple shots on goal. You want founders to think flexibly, listen but not be agreeable with everybody who gives them advice.

This reinvention will be chaotic, disruptive, unpredictable with many failed attempts but failure won't matter; successes will. Media folks will have a field day with stories of hubris, missed or misled expectations and failure. The disruption will be temporarily painful to some as being disrupted is never fun. We have to get things right and meet society's expectations of technology to help equality, diversity and more. New technologies also rock the world by reallocating power and wealth and accentuating inequality. Fortunately, capitalism is by permission of democracy, and the electorate will have the ability to rectify the inequalities. All these social factors will become urgent and critical to enable this transformation through democracy and to be fair to the people who will be impacted. It's impact in the less democratic societies is harder to predict. The future is not knowable, but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future now.

Article: IS MAJORING IN LIBERAL ARTS A MISTAKE FOR STUDENTS?

Critical Thinking, Knowledge basics and the Scientific Process First — Humanities Later

If luck favors the prepared mind, as Louis Pasteur is credited with saying, we're in danger of becoming a very unlucky nation. Little of the material taught in liberal arts programs today is relevant to the future.

Consider all the science and economics that has been updated, the shifting theories of psychology, the programming languages and political theories that have been developed, and even how many planets our solar system has. Much, like literature and history, should be evaluated against updated, relevant priorities in the 21st century. There is more need for process thinking and model think than knowledge today in undergraduate education.

I feel that liberal arts education in the United States is a minor evolution of 18th century European education. The world needs something more than that. Non-professional undergraduate education needs a new system that teaches students how to learn and judge using the scientific process on issues relating to science, society, and business.

Though Jane Austen and Shakespeare might be important, they are far less important than many other things that are more relevant to make an intelligent, continuously learning citizen, and a more adaptable human being in our increasingly more complex, diverse and dynamic world. When the rate of change is high, what one needs in education changes from knowledge to the process of learning.

I am going to now suggest we call this basic education “Modern Thinking”. I suggest universities introduce it as a much more rigorous and demanding version of traditional Liberal Arts for those not pursuing undergraduate professional or STEM education. Let’s try and separate the old “get through college easily and leave time for partying” student set from those that want a rigorous education with many more demanding, broad and diverse minimum requirements. Let’s keep the old and construct a new higher honors-like separate program with much more rigor.

The test for Modern Thinking would be quite simple: at the end of an undergraduate education, is a student roughly able to understand and discuss a broad set of topics like the Economist, end-to-end, every week. That covers everything economics, politics, literature, drama, business, culture and more. Of course, there are other surrogates for the Economist that would be just as valid if broad enough. This modern, non-professional education would meet the original “Greek life purpose” of a liberal arts education, updated for today’s world.

The most important things for a general, non-professional or vocational education are critical thinking, abstract model building, generalization skills and problem-solving skills, familiarity with logic and the scientific process, and the ability to use these in forming opinions, discourse, and in making decisions. Other general skills that are also important include — but are not limited to — interpersonal skills and communication skills.

So, what is wrong with today’s typical liberal arts degree?

Neither the old definition of liberal arts nor the current implementation of it is the best use of four years of somebody's education (if it is to be non-professional — I am explicitly not suggesting everyone do STEM “profession” oriented degrees!). The hardest (and most lucrative, but that is less relevant here) problems to solve are non-technical problems. In my opinion, getting a STEM degree gives you the tools to think about those problems more effectively than a Liberal Arts degree today; though it is far from a complete way of thinking, and a Modern Thinking degree will do this in an even more complete form. If STEM was turned into a non-professional degree it'd teach more of the skills for this Modern Thinking education than a Liberal Arts degree AS PRACTICED generally does today. But Modern Thinking would go more directly at the education I'd recommend for non-professionals who want to operate at the highest levels of thinking.

Some of you will point to very successful people who've gone to Yale and done well, but you misuse or misunderstand statistics. A lot of successful people have started out as liberal arts majors. A lot haven't. If you're very driven and intelligent or lucky, you'll probably be successful in life, even with today's liberal arts degree. Then again, if you're that driven and intelligent, you could probably find success with any degree, or even no degree. Apple's Steve Jobs and Joi Ito (Director of the MIT media lab) are both college dropouts. Joi is a largely self-taught computer scientist, disc jockey, nightclub entrepreneur and technology investor and I think this diversity makes him better educated. The top 20% of people in any cohort will do well independent of what curriculum their education follows, or if they had any education at all. If we want to maximize the potential of the other 80%, then we need a new Modern Thinking curriculum.

What I am discussing in this piece is the median student who gets through a liberal arts curriculum, excluding the 20% who I believe will do well no matter what education (or lack thereof) that they get. That means what I am concentrating on is “what actually happens to the median student” as opposed to “what is possible with Liberal Arts education” or “what Liberal Arts is supposed to teach”. I will add though that even the definition of what Liberal Arts SHOULD be needs updating for the modern world.

Yale recently decided that Computer Science was important and I like to ask, “if you live in France, shouldn't you learn French? If you live in the computer world, shouldn't you learn Computer Science?” What should be the second required language in schools today if we live in a computer world? My goal is not that everyone be a programmer, but rather that they understand programmatic thinking. And if you live in a technology world what must you understand? Traditional education is far behind and the old world tenured professors at our universities with their parochial views and interests, their romanticism and ossification of ideas will keep dragging them back. My disagreement is not with the goals of a liberal arts education

but its implementation and evolution (or lack thereof) from 18th century European education and its purpose. There is too little emphasis on teaching critical thinking skills in schools and the grounding on which new knowledge, often technological, can be acquired, even though that was the original goal of such education. Many adults have little understanding of important science and technology issues or, more importantly, how to approach them, which leaves them open to poor decision-making on matters that will affect both their families and society, in general.

Connections matter and many Ivy League colleges are worth it just to be an alumnus. There are people with the view that Liberal Arts broadened their vision and gave them great conversational topics. There are those who argue that the humanities are there to teach us what to do with knowledge. As one observer commented: “They should get lawyers to think whether an unjust law is still law. An engineer should be able to contemplate whether Artificial Intelligence is morally good. An architect could pause to think on the merit of building a house fit for purpose. A doctor could be taught whether and how to justify using scarce medical resources for the benefit of one patient and not another. This is the role of humanities — a supplement to STEM and the professions.”

In my view, creativity, humanism, and ethics are very hard to teach, whereas worldliness and many other skills supposedly taught through the Liberal Arts are more easily self-taught in a continuously updating fashion if one has a good quantitative, logical and scientific process-oriented base education. The undergraduate level (graduate level degrees are a whole different matter and should be specialised on areas of study) degrees I associate (with all my biases) as the more likely to be “easy courses so you can party degrees” in most US universities is mostly what I am discussing here.

The argument goes that a scientific/engineering education lacks enough training in critical thinking skills, creativity, inspiration, innovation and holistic thinking. On the contrary, I argue that the scientific and logical basis of a better Modern Thinking education would allow some or all of this — and in a more consistent way. The argument that being logical makes one a linear problem solver and ill prepared for professions that require truly creative problem solving has no merit in my view. The old version of the Liberal Arts curriculum was reasonable in a world of the far less complex 18th century Eurocentric world and an elitist education focused on thinking and leisure. Since the 20th century, despite its goals, it has evolved as the “easier curriculum” to get through college and may now be the single biggest reason students pursue it (There are plenty of students who take it for other reasons, but I am talking percentages here).

I do not believe that today's typical Liberal Arts degree turns you into a more complete thinker; rather, I believe they limit the dimensionality of your thinking since you have less familiarity with mathematical models (to me, it's the dimensionality of thinking that I find deficient in many people without a rigorous education), and worse, statistical understanding of anecdotes and data (which liberal arts was supposedly good at preparing students for but is actually highly deficient at). People in the humanities fields are told that they get taught analytical skills, including how to digest large volumes of information, but I find that by and large such education is poor at imparting these skills. Maybe, that was the intent but the reality is very far from this idealization (again, excluding the top 20%).

There is a failing in many college programs that are not pragmatic enough to align and relate liberal arts program to the life of a working adult. From finance to media to management and administration jobs, necessary skills like strategic-thinking, finding trends, and big picture problem-solving, even human connections and workforce management have all evolved in my view to need the more quantitative and rational preparation than today's degrees provide.

Such skills, supposedly the purview of liberal arts education, are best learnt through more quantitative methods today. Many vocational programs from engineering to medicine also need these same skills and need to evolve and broaden to add to their training. But if I could only have one of a liberal art or an engineering/science education, I'd pick the engineering even if I never intended to work as an engineer and did not know what career I wanted to pursue.

I have in fact almost never worked as an engineer but deal exclusively with risk, evolution of capability, innovation, people evaluation, creativity and vision formulation. Design is my personal passion far more than business. That is not to say that goal setting, design, and creativity are not important or even critical. In fact, these need to be added to most professional and vocational degrees, which are also deficient for today's practical careers.

More and more fields are becoming very quantitative, and it's becoming harder and harder to go from majoring in English or History to having optionality on various future careers and being an intelligent citizen in a democracy. Math, statistics and science are hard, economics, psychology and philosophical logic take effort, and school is a great time to learn those areas, whereas many of the liberal arts courses can be pursued after college on the base of a broad education. But without training in the scientific process, logic and critical thinking, and a basis of science, mathematics and statistics, discourse and understanding are both made far more difficult.

A good illustrative example of the problems of today's liberal arts education can be found in the writing of well-known author, Malcolm Gladwell, a history major and a one-time writer for The New Yorker. Gladwell famously argued that stories were more important than accuracy or validity without even realizing it. The New Republic called the final chapter of Gladwell's *Outliers*, "impervious to all forms of critical thinking" and said that Gladwell believes "a perfect anecdote proves a fatuous rule." This, in my opinion, is too often the way many Liberal Arts graduates (but not all) think. Referencing a Gladwell reporting mistake in which Gladwell refers to "eigenvalue" as "Igon Value," Harvard professor and author Steven Pinker criticizes his lack of expertise: "I will call this the Igon Value Problem: when a writer's education on a topic consists in interviewing an expert, he is apt to offer generalizations that are banal, obtuse or flat wrong." Unfortunately, too many in today's media are similarly "uneducated" in their interpretation of experts. Storytelling and quotes become a misleading factor instead of being an aid to communicating the accurate facts more easily. His assertions around "10,000 hours" may or may not be true but his arguments for it carry very little weight with me because of the quality of his thinking.

Though one example of Malcolm Gladwell does not prove the invalidity of arguments for a Liberal Arts degree, I find this kind of erroneous thinking (anecdotally) true of many humanities and liberal arts graduates. In fact, I see the inconsistencies that Gladwell failed to understand (giving him the benefit of the doubt that these were unintentional) in the writings of many authors of articles in supposedly elite publications like The New Yorker and The Atlantic. Again, this is not a statistically valid conclusion but the impression across hundreds or thousands of examples of one person, me. When I do occasionally read articles from these publications, I make a sport of judging the quality of thinking of the writers as I read, based on false arguments, unsupported conclusions, confusion of storytelling with factual assertions, mistaking quotes from interviews as facts, misinterpreting statistics, etc. Similar lack of cogent thinking leads to bad decisions, uninformed rhetoric, and lack of critical thinking around topics like nuclear power and GMOs.

Unfortunately, in an increasingly complex world, all these topics skills that many liberal arts majors even at elite universities fail to master. The topic of risk and risk assessment from simple personal financial planning to societal topics like income inequality is so poorly understood and considered by most liberal arts majors as to make me pessimistic. I am not arguing that engineering or STEM education is good at these topics but rather that this is not its intent of STEM or professional education. The intent of Liberal Arts education is what Steven Pinker called a "building a self" and I would add "for the technological and dynamically evolving 21st century".

Learning new areas as career paths and interests evolve becomes harder. Traditional European liberal arts education was for the few and the elite. Is that still the goal today? People spend

years and a small fortune or lifelong indebtedness (at least in the US) to obtain it and employability should be a criterion in addition to an education's contribution to intelligent citizenry.

Wikipedia defines "the liberal arts as those subjects or skills that in classical antiquity were considered essential for a free person to know in order to take an active part in civic life, something that (for Ancient Greece) included participating in public debate, defending oneself in court, serving on juries, and most importantly, military service. Grammar, logic, and rhetoric were the core liberal arts, while arithmetic, geometry, the theory of music, and astronomy also played a (somewhat lesser) part in education." Today's ideal list, not anchored in "classical antiquity" would be more expansive and more prioritized in my view.

Idealists and those who perceive liberal arts education today as meeting these goals are wrong not in its intent but in assessing how well it does this function (and that is an assertion/opinion). I agree that we need a more humanistic education but it is hard to agree or disagree with the current curriculum without defining what humanistic means. Does it really teach critical thinking, logic or the scientific process, things every citizen should know in order to participate in society? Does it allow for intelligent discourse or decision-making across a diverse set of beliefs, situations, preferences, and assumptions? And I believe we need to extend these goals to have education form the basis of lifelong learning broadly across all areas in our increasingly technological and fast-changing world.

While one may argue that historical liberal arts education included what I am arguing for, the context for this education has changed. In the 21st century, with airplanes and societal mixing, the internet and global information and misinformation, artificial intelligence and a technology driven and challenged planet, with many more risks both local and global, the old definition needs to be adapted to the modern context. What we need for civic life today is far different than what's needed when liberal arts education originated.

I do think whether it is for employability or dealing with nuanced and ever changing issues like race or artificial intelligence, national borders or international citizenry, or the nature of work and politics, the ability to understand new areas or repurpose oneself over time should be a critical part of any education, especially an education like liberal arts not geared towards a particular profession.



Should we teach our students what we already know, or prepare them to discover more? Memorizing the Gettysburg address is admirable but ultimately worthless; understanding history is interesting, even useful, but not as relevant as topics from the Economist, unless history is used as a logic tool which it can be used as. A student who can apply the scientific process or employ critical thinking skills to solve a big problem has the potential to change the world (or at minimum get a better-paying job). They can actually debate a topic like #blacklivesmatter, income inequality or climate change without being subject to “Trumpism” or emotion and biases-based distortions.

While it is undoubtedly important to understand how others feel, think, etc., I don’t believe the median student with a liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning.

No wonder half the college graduates who fill jobs as some studies indicate, actually fill jobs that don’t need a college degree! Their degree is not relevant to adding value to an employer (though that is not the only purpose of a degree).

Further, even if an ideal curriculum can be stitched together, most liberal arts majors infrequently do it. If the goal is not professional education then it must be general education, which requires many more must-have requirements for me to consider a university degree respectable. Of course others are entitled to their own opinion, though the right answer is testable if one agrees that the goals of such an education are intelligent citizenry and/or employability.

For now, I am mostly leaving aside matters related to professional, vocational or technical curriculum. I’m also ignoring the not irrelevant and pragmatic issues of education affordability and the burden of student debt, which would argue for a more employment-enabling type of education. The failure I am referring to are two-fold: (1) the failure of curriculums to keep up with the changing needs of modern society and (2) liberal arts becoming the “easy curriculum” for those who shy away from the more demanding majors and prefer an easier, often (but not always) more socially-oriented college life. Ease, not value, or interest instead of value become key criteria in designing a curriculum for many students today. And for those of you who think

this is not true, I am asserting based on my experience this is true for the majority of today's students, but not for every liberal arts student.

Not every course is for every student but the criteria need to match the needs of the student and not their indulgences, taking interests and capability into account. "Pursue your passion" even if it increases the probability of getting you into unemployment or homelessness later is advice I have seldom agreed with (yes there are occasions this is warranted, especially for the top or the bottom 20% of students). More on passions later but I'm not saying passions are unimportant. What I am saying is with today's implementation of a liberal arts curriculum, even at elite universities like Stanford and Yale, I find that many Liberal Arts majors (excluding roughly the top 20% of students) lack the ability to rigorously defend ideas, make compelling, persuasive arguments, or discourse logically.

Steven Pinker — in addition to refuting Gladwell — has a brilliant, clarion opinion on what education ought to be, writing in *The New Republic*, "It seems to me that educated people should know something about the 13-billion-year prehistory of our species and the basic laws governing the physical and living world, including our bodies and brains. They should grasp the timeline of human history from the dawn of agriculture to the present. They should be exposed to the diversity of human cultures, and the major systems of belief and value with which they have made sense of their lives. They should know about the formative events in human history, including the blunders we can hope not to repeat. They should understand the principles behind democratic governance and the rule of law. They should know how to appreciate works of fiction and art as sources of aesthetic pleasure and as impetuses to reflect on the human condition."

Though I agree, I am not sure this curriculum is more important than the ideas below. Based on the skills defined below any gaps in the above education can be filled in by students post-graduation.

So, what should non-professional elite education entail?

If we had enough time in school, I would suggest we do everything. Sadly that is not realistic, so we need a prioritized list of basic requirements because every subject we do cover excludes some other subject given the fixed time we have available. We must decide what is better taught during the limited teaching time we have, and what subjects are easier learnt during personal time or as post-education or graduate pursuits. If there are a hundred things we learn but can only study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is

“base skill to learn other subjects from” versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs but base skills are harder to learn on your own.

In the new Modern Thinking curriculum I propose, students would master:

1. The fundamental tools of learning and analysis, primarily critical thinking, the scientific process or methodology, and approaches to problem solving and diversity.
2. Knowledge of a few generally applicable topics and knowledge of the basics such as logic, mathematics, and statistics to judge and model conceptually almost anything one might run into over the next few decades.
3. The skills to “dig deep” into their areas of interest in order to understand how these tools can be applied to one domain and to be equipped to change domains every so often
4. Preparation for jobs in a competitive and evolving global economy or preparation for uncertainty about one’s future direction, interest, or areas where opportunities will exist.
5. Preparation to continuously evolve and stay current as informed and intelligent citizens of a democracy

Critical subject matter should include economics, statistics, mathematics, logic and systems modeling, psychology, computer programming, and current (not historical) cultural evolution (Why rap? Why ISIS? Why suicide bombers? Why the Kardashians and Trump? Why environmentalism and what matters and what does not? What study to believe? What technology evolution might happen? What has important implications? And of course the question, are the answers to these questions expert opinions or have some other validity?).

Furthermore, certain humanities disciplines such as literature and history should become optional subjects, in much the same way that physics is today (and, of course, I advocate mandatory basic physics study along with the other sciences). And one needs the ability to think

through many, if not most, of the social issues we face (which the softer liberal arts subjects ill-prepare one for in my view).

Imagine a required course each semester where every student is asked to analyze and debate topics from every issue of a broad publication such as *The Economist* or *Technology Review*. And imagine a core curriculum that teaches the core skills to have the discussions above. Such a curriculum would not only provide a platform for understanding in a more relevant context how the physical, political, cultural and technical worlds function, but would also impart instincts for interpreting the world, and prepare students to become active participants in the economy.

Efficiency in undergraduate education matters given the wide array of subjects that need understanding, the inability to cover all of the subjects, and the constant change in what becomes more or less important or interesting to a person over time. It is for this reason I suggest that understanding the *Economist* on a weekly basis is important as it covers many diverse topics from politics to economics to culture, arts, science, technology, climate and global issues. A sufficiently diligent professor could in fact construct a more effective and efficient curriculum and hence the reference to the *Economist* was a short form for the concept of teaching broad understanding across a diversity of topics.

It would be essential to understand psychology because human behavior and human interaction are important and will continue to be so. I'd like people who are immune to the fallacies and agendas of the media, politicians, advertisers, and marketers because these professions have learned to hack the human brain's biases (a good description of which are described in Dan Kahneman's *Thinking Fast & Slow* and in Dan Gardner's *The Science of Fear*). I'd like to teach people how to understand history but not to spend time getting the knowledge of history, which can be done after graduation.

I'd like people to read a *New York Times* article and understand what is an assumption, what's an assertion by the writer, what are facts, and what are opinions, and maybe even find the biases and contradictions inherent in many articles. We are far beyond the days of the media simply reporting news, shown by the different versions of the "news" that liberal and conservative newspapers in the US report, all as different "truths" of the same event. Learning to parse this media is critical. I'd like people to understand what is statistically valid and what is not. What is a bias or the color of the writer's point of view?

Students should learn the scientific method, and most importantly how to apply its mental model to the world. Building models in our head is critical to understanding and reasoning in my view. The scientific method requires that hypotheses be tested in controlled conditions; this can diminish the effects of randomness and, often, personal bias. This is very valuable in a world where too many students fall victim to confirmation biases (people observe what they expect to observe), appeal to new and surprising things, and narrative fallacies (once a narrative has been built, its individual elements are more accepted). There are many, many types of human biases defined in psychology that people fall victim to. Failure to understand mathematical models and statistics makes it substantially more difficult to understand critical questions in daily life, from social sciences to science and technology, political issues, health claims, economics and much more.

I'd also suggest tackling several general and currently relevant topic areas such as genetics, computer science, systems modeling, econometrics, linguistics modeling, traditional and behavioral economics, and genomics/bioinformatics (not an exhaustive list) which are quickly becoming critical issues for everyday decisions from personal medical decisions to understanding minimum pay, economics of taxes and inequality, immigration, or climate change. E.O. Wilson argues in his book "The Meaning of Human Existence" that it is hard to understand social behavior without understanding multi-level selection theory and the mathematical optimization that nature performed through years of evolutionary iterations. I am not arguing that every educated person should be able to build such a model but rather that they should be able to "think" such a model qualitatively.

Not only do these topics expose students to a lot of useful and current information, theories, and algorithms, they may in fact become platforms to teach the scientific process — a process that applies to (and is desperately needed for) logical discourse and social sciences as much as it applies to science. The scientific process critically needs to be applied to all the issues we discuss socially in order to have intelligent dialog. Even if the specific information becomes irrelevant within a decade (who knows where technology will head next; hugely important cultural phenomena and technologies like Facebook, Twitter, and the iPhone didn't exist before 2004, after all), it's incredibly useful to understand the current frontiers of science and technology as building blocks for the future.

It's not that history or Kafka are not important, but rather it is even more critical to understand if we change the assumptions, environmental conditions and rules that applied to historical events, would that alter the conclusions we draw from historical events today. Every time a student takes one subject they exclude the possibility of taking something else. I find it ironic that those who rely on "history repeating itself" often fail to understand the assumptions that

might cause “this time” to be different. The experts we rely on for predictions have about the same accuracy as dart-throwing monkeys according to at least one very exhaustive study by Prof Phil Tetlock. So it is important to understand how to rely on “more likely to be right” experts, as defined in the book *Superforecasters*. We make a lot of judgments in everyday life and we should be prepared to make them intelligently.

Students can use this broad knowledge base to build mental models that will aid them in both further studies and vocations. Charlie Munger, the famous investor from Berkshire Hathaway, speaks about mental models and what he calls “elementary, worldly wisdom.” Munger believes a person can combine models from a wide range of disciplines (economics, mathematics, physics, biology, history, and psychology, among others) into something that is more valuable than the sum of its parts. I have to agree that this cross-disciplinary thinking is becoming an essential skill in today’s increasingly complex world.

“The models have to come from multiple disciplines because all the wisdom of the world is not to be found in one little academic department,” Munger explains. “That’s why poetry professors, by and large, are so unwise in a worldly sense. They don’t have enough models in their heads. So you’ve got to have models across a fair array of disciplines... These models generally fall into two categories: (1) ones that help us simulate time (and predict the future) and better understand how the world works (e.g. understanding a useful idea like autocatalysis), and (2) ones that help us better understand how our mental processes lead us astray (e.g., availability bias).” I would add that they provide the “common truth” in discussions where the well-educated discussants disagree.

After grasping the fundamental tools of learning and some broad topical exposure, it’s valuable to “dig deep” in one or two topic areas of interest. For this, I prefer some subject in science or engineering rather than literature or history (bear with me before you have an emotional reaction; I’ll explain in a minute). Obviously, it’s best if students are passionate about a specific topic, but passion is not critical as the passion may develop as they dig in (some students will have passions, but many won’t have any at all). The real value for digging deep is to learn how to dig in; it serves a person for the duration of their life: in school, work, and leisure. As Thomas Huxley said, “learn something about everything and everything about something,” though his saying that does not make it true. Too often, students don’t learn that a quote is not a fact.

If students choose options from traditional liberal-education subjects, they should be taught in the context of the critical tools mentioned above. If students want jobs, they should be taught skills where future jobs will exist. If we want them as intelligent citizens, we need to have them

understand critical thinking, statistics, economics, how to interpret technology and science developments, and how global game theory applies to local interests. Traditional majors like international relations and political science are passé as base skills and can easily be acquired once a student has the basic tools of understanding. And they and many other traditional liberal arts subjects like history or art will be well served in graduate level work. I want to repeat that this is not to claim those “other subjects” are not valuable. I think they are very appropriate for graduate level study.

Back to history and literature for a moment — these are great to wrestle with once a student has learned to think critically. My contention is not that these subjects are unimportant, but rather that they are not basic or broad enough “tools for developing learning skills” as they were in the 1800s, because the set of skills needed today has changed. Furthermore, they are topics easily learned by someone trained in the basic disciplines of thinking and learning that I’ve defined above. This isn’t as easy the other way around. A scientist can more easily become a philosopher or writer than a writer or philosopher can become a scientist.

If subjects like history and literature are focused on too early, it is easy for someone not to learn to think for themselves and not to question assumptions, conclusions, and expert philosophies. This can do a lot of damage.

Separating the aspirational claims by universities from the reality of today’s typical liberal arts education I tend to agree with the views of William Deresiewicz. He was an English professor at Yale from 1998–2008 and recently published the book “Excellent Sheep: The Miseducation of the American Elite and the Way to a Meaningful Life.” Deresiewicz writes on the current state of liberal arts, “At least the classes at elite schools are academically rigorous, demanding on their own terms, no? Not necessarily. In the sciences, usually; in other disciplines, not so much. There are exceptions, of course, but professors and students have largely entered into what one observer called a ‘nonaggression pact.’” Easy is often the reason students pick liberal arts subjects today.

Lots of things are important but what are the most important goals of an education?

To repeat, school is a place where every student should have the opportunity to become a potential participant in whatever they might want to tackle in the future, with an appropriate focus not only on what they want to pursue but also, pragmatically, what they will need to do to be productively employed or productive and thinking member of society. By embracing thinking

and learning skills, and adding a dash of irreverence and confidence that comes from being able to tackle new arenas (creative writing as a vocational skill, not a liberal arts education, may have a role here, but Macbeth does not make my priority list; we can agree to disagree but if we discourse I want to understand the assumptions that cause us to disagree, something many students are unable to do), hopefully they will be lucky enough to help shape the next few decades or at least be intelligent voters in a democracy and productive participants in their jobs .

With the right critical lens, history, philosophy, and literature can help creativity and breadth by opening the mind to new perspectives and ideas. Still, learning about them is secondary to learning the tools of learning except possibly the right approach to philosophy education. Again I want to remind you that none of this applies to the top 20% of students who learn all these skills independent of their education or major. Passions like music or literature (leaving aside the top few students who clearly excel at music or literature) and its history may be best left to self-pursuit, while exploring the structure and theory of music or literature may be a way to teach the right kind of thinking about music and literature!

For some small subset of the student body, pursuing passions and developing skills in subjects such as music or sports can be valuable, and I am a fan of schools like Juilliard, but in my view this must be in addition to a required general education especially for the “other 80%”. It’s the lack of balance in general education which I am suggesting needs to be addressed (including for engineering, science and technology subjects’ students. Setting music and sports aside, with the critical thinking tools and exposure to the up-and-coming areas mentioned above, students should be positioned to discover their first passion and begin to understand themselves, or at the least be able to keep up with the changes to come, get (and maintain) productive jobs, and be intelligent citizens.

At the very least they should be able to evaluate how much confidence to place in a New York Times study of 11 patients on a new cancer treatment from Mexico or a health supplement from China and to assess the study’s statistical validity and whether the treatment’s economics make sense. And they should understand the relationship between taxes, spending, balanced budgets, and growth better than they understand 15th century English history in preparation for “civic life” to quote the original purpose of a liberal arts education. And if they are to study language or music, Dan Levitin’s book “This Is Your Brain on Music: The Science of a Human Obsession” should be first reading or its equivalent in linguistics. It can teach you about a human obsession but also teach you how to build a mathematical model in your head and why and how Indian music is different than Latin music. In fact, these should be required for all education, not just liberal arts education, along with the other books mentioned above.



The role of passion and emotion in life is best epitomized by a quote (unknown source) I once saw that says the most important things in life are best decided by the heart and not logic. For the rest we need logic and consistency. The “what” may be emotion and passion based but the “how” often (yes, sometimes the journey is the reward) needs a different approach that intelligent citizens should possess and education should teach.

As Atul Gawande, in an inspiring commencement address, says “we are battling for what it means to be citizens” and that is the original purpose of liberal arts. We are battling the ability to have debates and to have a basis to agree or disagree, that is logical and consistent, yet accommodates our emotions, feelings, our versions of humanity. I highly recommend the commencement speech by Atul Gawande: The Mistrust of Science as it is very relevant to modern thinking.

I am sure I have missed some points of view, so I look forward to starting a valuable dialogue on this important topic.

Additional Responses to Comments and Questions:

Sciences have always been at their core of Liberal Arts. The traditional liberal arts consists not just of the trivium (grammar, logic, rhetoric) but also the quadrivium: arithmetic, geometry, music, astronomy. While those are medieval categories, there’s nothing inherent in “liberal arts” that would prevent one from updating them for contemporary reality. Ironically, you may even be seen as arguing for a return to liberal arts.

How many liberal arts graduates today are proficient in the sciences, or can argue cogently or understand philosophy or logic, let alone modern requirements for civic life like economics, technology literacy etc? I agree that there here is nothing inherent in its definition but practically there is a different reality. And beyond subjects taught the goal of liberal arts was to prepare for civic life. Sad that this goal is not being met. I am arguing for non-professional degrees to return to a rigorous description of the goals of liberal arts (as opposed to the old unevolved version of liberal arts) and away from what it has become today. It is the ability to learn new things that a non-professional curriculum should teach that I call modern thinking. If you move to working for an NGO after hedge fund trading the same education should help you learn this faster and

understand the new area's issues and critically analyze them! There is much inefficiency among the best intentioned because of this inability to critically think comprehensively about new areas.

Let us not forget that the "liberal arts" are essentially what helps students develop empathy and multifaceted understandings of how others feel, think, love, know, and live. This is especially important now because the influence of religion is weakening.

I agree on the importance of understanding how others feel, think, etc ... and explicitly discuss that with regards to understanding "Black Lives Matter" and the role of emotion. But I don't believe the median liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning. I do think setting goals should derive from empathy in many cases but more often than not how to achieve them requires rigorous, unemphathetic, brutal cost benefit thinking.

How did you measure the level of importance of Jane Austen and Shakespeare?

I don't measure the importance of Shakespeare but argue if there are a hundred things we learn and only can study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is "base skill to learn other subjects from" versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs, but argue base skills are harder to learn on your own.

As a high school senior who's applying to small liberal arts schools, what should I keep in mind as I choose what college to attend and what path to pursue once I'm on campus?

Don't go for the easy classes. Go for subjects that teach you to think. This can be done at a liberal arts college but isn't done by many. Go for diversity in the subjects you take and more than anything go for rigor instead of the easy subjects.

## Article: REINVENTING SOCIETAL INFRASTRUCTURE WITH TECHNOLOGY: THE SUMMARY

This is the summary of “Reinventing Societal Infrastructure with Technology”. The full version and slightly revised version will be released the end of January. Feedback, questions, and new ideas are welcomed.

We need large innovations!

“What can be imagined technologically reasonably can be invented” is more true than not. Technology and new inventions have always shaped the human world, and have disrupted the way we live and work, and yet we are only at the beginning. Innovation in the areas of clean energy, food tech, digitization, robotics, artificial intelligence, as a few examples, have the potential to prevent climate change, achieve food abundance, reshape cities, knit humanity, and enhance human capability exponentially.

The big needs in society, food, health, housing, transportation, financial services, entertainment and more are being and will even more so be reinvented by technology in an “increasingly more accessible to all” way. We need to turbocharge our efforts to utilize technology to accelerate accessibility. Many of society’s GDP and business-related needs are being reinvented everyday in a truly innovative and non-institutional way. Seven hundred million (or so) people have the rich lifestyle, either in environment, energy, housing, healthcare, education, food, that seven billion people on this planet want. Technology is the necessary, though not sufficient, resource multiplier. It’s the only thing that can multiply resources. Technology will enable bridging this gap here, and the key word being “non-institutional” reinvention is not only powerful in increasing innovation, and but more importantly for accessibility.

The future belongs to those dreamers who think of these unreasonable possibilities, who aren’t afraid of the high probability of failure, and who take, bold and, radical risks. They are willing to change the world by imagining what’s possible. So, what comes next for reinvention? Public transportation? Construction? Buildings? Healthcare? Food? Cities? Communications? Companionship? Financial system? Imagine the possible and take it from impossible to improbable to possible, but then again unlikely to plausible to probably to real! Individual

entrepreneurs and their passion for a vision (and tons of good luck) give the improbable reality a shot. Now, many, even most, of these attempts will fail and the press will denigrate you for hubris, arrogance, fraud, naivety, and much more. Even so, it is these improbable attempts that will, when they occasionally squeak by the “existing reality, institutional noise (and fear)” will change the world (hopefully mostly for good). The future is not knowable, but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future.

It's almost always the entrepreneurs, not institutions, that drive large innovations

Why is non-institutional innovation so necessary? Looking back in the last twenty years, the Internet upended telecom (AT&T refused to adopt the internet and cellular), Amazon disrupted Walmart with a clear vision of changing choice and cost structure that Walmart could not imagine. Netflix, Youtube, Facebook reinvented media, maybe even the elections and politics! Airbnb changed hotels, Google changed libraries and many new and old markets, Uber took over the taxi service, Google Photos and Instagram reinvented how we capture moments. You get the picture here. These industries were not reinvented by large corporations, but in fact the power of ideas driven by technological advances and entrepreneurial energy. Most people in business reduce the risk of failure to the point where the consequences of success are inconsequential on society (but they can make money for their shareholders which they are obligated to do). Instead, the ideas that change the way we live and work are the ones that originally have a sparser space of higher probability of failure, but the consequences of success are consequential. There is as much profit and increased social impact to be gained through higher variability. As I personally say, my willingness to fail gives me the ability to succeed and contribute in my small way in causing good change to happen. In my view, it is only improbables that are important, we just don't know which improbable when it comes to large changes and innovations!

This is the exact opposite of how incentives are usually set up in larger, non-founder led institutions. We have incumbents, institutions, and pundits predicting more of the same “extrapolation of the past” to predict the future” world view. Most of these are wrong when it comes to large changes or big innovations. I'd give you the odds that no large innovation will come out of any institutional player. They believe improbable is not important, while technology entrepreneurs believe the usual is not important. Improbable is what creates the next Facebook, Google, Apple, Uber, or Airbnb, driven, of course, by an entrepreneur's vision of the unreasonable possibility. Luckily, most of these players I named are still driven by founder vision, and aren't sensible in the way business school professors would teach their students. These founders ask “why not” and “why not try it” be it Alexa, AWS, space, driverless cars, global location maps, phones without keyboards. Big companies do help scale innovation and bring gobs of capital later when risk of a new phenomenon is low. But it's the seeds — what Uber, Tesla,

Google with Waymo and driverless cars will do to completely replace all public transportation, as an example, with a new style of public transportation (this was inconceivable even five years ago by anyone in auto or transportation business).

Beyond the entrepreneur, what does it take? The greater the number of axes, that is the dimensions in which innovation is possible, and the better the tools for innovation, experimentation, and lower the cost of trials for ideas, the faster the rate of change. That means more the possibility of a surprise like an Amazon disrupting retail or Tesla or Google changing transportation with electric and driverless cars, respectively. So, what is in store for us for the next twenty years? It's hard to forecast, but easier to speculate. It seems likely that 3D-manufacturing, artificial intelligence, biology tools especially new physics-based tools, biology fashions like CRISPR and it's likely successors for precision biology and computational biology, along with traditional old standbys like increased computing and bandwidth will all form a soup which catalyzes many new ideas and reactions. Now, add to the soup the potential for new types of computing, like quantum computing, which might accelerate AI even beyond our wildest imagination. The possibilities become truly unpredictable.

To make the new possible, you need new tools, a visionary and persistent founder, and evangelizing market participants. They must understand where this vision is going, and they need to be convinced they need to come along and ultimately change, especially if it's radical innovation.

Looking at the infrastructure of society, what can be reimagined and reinvented?

Most of the non-governmental components of GDP can be re-imagined and reinvented with an entrepreneurial rather than a policy/legislative/regulatory approach be it 1) Transportation and related city services 2) Health, disease diagnosis and management, drug discovery 3) Manufacturing, Construction, Buildings, building efficiency and cities 4) Food and Agriculture 5) Financial, insurance and legal services 6) Energy 7) Consumer consumption items, services, education, durable goods.

Change happens, but is not credible until after the fact. Retrospective predictability by pundits is common, but until large change happens one sees mostly skepticism. I have hence come to believe in the power of ideas driven by entrepreneurial energy by almost foolish, somewhat naive entrepreneurs, by those who didn't know what could not be done. Almost no major change is driven by institutions that one would expect to have power to cause that change!

## The technology soup enabling societal innovations

Fundamental reinvention has never been more possible than it is today. There are a range of new recent technological axes of development that give me hope. Driver technology tools that are plausible and visible today are: 1) AI and large scale data capability, 2) Robotics, 3) Additive manufacturing a la 3D printing, 4) Biotechnology (ohmic measurement, CRISPR, gene synthesis, precision control of genes, pathways...), 5) Computational design, computational modelling/simulation and computer networking, 6) Social connectivity and networking; distributed access, 8) Software eating the world, 9) Blockchain, 10) other new still fermenting ideas I have surely missed or underestimated. The “older technologies will continue to be axes of innovation that continue to have impact and provide benefit include: software, computing and cloud computing, Internet, sensors and cameras, mobile.

The way I think about it is the greater the number of axes (dimensions in which innovation is possible) and the better the tools for innovation, experimentation, and lower the cost of trials for ideas, the faster the rate of change and the more possibility of a surprise like Amazon or Tesla or Google.

It's hard to forecast, but easier to speculate what might be new tools for the next two decades, again though, the best reinvention is seemingly imaginable. All the “known” axes today form a soup which catalyzes many new ideas and reactions. Add the potential for new types of computing like quantum, which might accelerate AI even beyond our wildest imagination today, are truly unpredictable. New axes will surely happen, perhaps with sophisticated broad quantum-computing, fusion energy, or molecular assembly.

## Reinventing Transportation

Key drivers: Driverless technology, electric cars, reimagined public transportation, batteries, dedicated self driving public transit lanes, mobile hailing and scheduling solutions. From public transportation to flying cars... it can all be reinvented. For instance, we could have public transportation in smart cities, enabled by clever legislation, point to point on demand, that is cheaper than today's fixed route, fixed schedule transit services in most cities enabled by electric cars/pods and driverless technology. With dedicated lanes or even car free cities it would be much faster, cheaper, safer and environmentally better. Batteries and electricity would be the

main cost per passenger mile if vehicles were driven 10x more than today's private cars. Just as cars changed cities, electric and driverless technology could change them again. Parking lots and spaces could be replaced by parks or housing, commuter lanes by driverless lanes or streets, commute distances may expand, housing may get cheaper and environmental pollution decline. Driverless car technology may kill the combustion engine and set the oil industry in permanent decline. Cities could be redesigned to work differently, especially if one adds communications technology and space efficiency and reuse paradigms. And the number of cars could decline by 5X or more and the need to natural resources like steel, rubber and plastics decline concomitantly. The city without automobiles (mostly in most but not all places) would be a different animal.

#### Reinventing Health, disease diagnosis and management, drug discovery

Key drivers: Artificial intelligence for comprehensive understanding of medical knowledge, new measurement techniques enabled by and for machines allowing for 1000x or more data for algorithms to use, new algorithms to discover new knowledge in medicine, better research based on more data, more, better drug discovery using AI, and AI guided robotic surgery. There are probably a million doctors in the United States, give or take, but with AI systems, we could create ten or a few hundred million doctors worth of expertise and use human doctors only for what they love to do, which is interfacing with patients, making health more more personal, accessible, convenient, and less costly. AI will do much better diagnosis, monitoring, and follow-up than most human doctors and complement the human element of care.

We will treat patients holistically because of integrative knowledge and not separate their cardiologist from their orthopedist or endocrinologist. Medicine's much better than it has ever been, so we have to acknowledge every aspect of medicine has improved over the last many decades, but that doesn't mean it's as good as it can be. We will be able to measure many more variables (thousands or hundreds of thousands per sample of blood for example or exquisite feature extraction beyond today's human capability from an ECG) and make decisions based on complexity and knowledge no human doctor could master, and even specify dosage for drugs for each patient's current state, monitor disease progression as well as side effects at the molecular level. Disease will be detected early (it's a shame that most people with heart disease learn about their disease from a heart attack, not twenty years earlier when it started) and we will move closer to healthcare from the sickcare we have today. Data and AI technology intensive healthcare could be a lot cheaper, accessible and better.

#### Reinventing Manufacturing, Construction, Buildings, building efficiency and cities

Key drivers: automated construction, robotic delivery, “transformer” type spaces, shared and higher percentage reuse, 3D printing of buildings and furniture, social networking and increase in community spaces and relationships. Buildings are a key part of our urban landscape and a large consumer of resources. If space was reconfigurable and we needed half as much to live comfortably? Affordability and availability would go up and land use would decline for housing of large numbers of people. Further, imagine buildings were manufactured like automobiles reducing cost dramatically or possibly next generation buildings were 3D printed locally and designed with AI, and weighed a fifth as much with much better insulation because of air pockets? What if structural elements like beams needed far less steel or could be 3D printed with composites because all unnecessary material unneeded for structure could be subtracted with AI design (generative design being one avenue) and 3D printed? What if we could accommodate twice as many people twice and services like restaurants, gyms, bookstores and work spaces in the same square feet of space?

Cities and urban living can be far more efficient, sustainable, and with dramatically less costs and more community. Imagine a city world where we need less restaurant space because of robotic kitchens, robotic food delivery, self picking mini grocery store warehouses for Instacart like ordering with robotic delivery, virtual entertainment and get togethers, more parks for being outdoors that substitute for parking lots, or houses that multiply space because of AirBnB like models to reduce need for hotel rooms and increase space efficiency. WeWork like space efficient buildings that are further reused for homeless housing or hotels in the evenings with transforming furniture? Our assumptions about space, cities, density, efficiency, transportation, parks could change in unpredictable ways.

## Reinventing Food and Agriculture

Key drivers: Robotics, machine vision and AI, plant by plant care eliminating much of herbicides and insecticides, meat alternatives, sensory technologies to pack sensation with nutrition, better land use, drone and satellite imaging, better seed and chemical technologies, microorganisms, precision agriculture. Precision agriculture also implies the use of such technologies as data science, aerial imaging, early disease detection. Further development of AI for imaging and data analysis, more easily and frequently accessed satellites, bio techniques like increased microbial communities, all aided by the use of fewer chemicals that would traditionally sterilize the soil because of new roboticized weeding and insect targeting will dramatically reduce the impact of and land use for agriculture. And it might even be that for specialized crops, vertical farms and data science led yield maximization coupled with robotic labor make a real change in the yield or



resource or acres used. Of course, our sidewalk delivery robots take care of the deliveries. Another dimension of innovation is the creation of new foods, such as beef without cows, milk from plants, eggs without chickens, all far less environmentally harmful at that.

## Reinventing Financial, insurance and legal services

Key drivers: AI technology to replace people functions and judgement, blockchain, mobility, data, software automation. While some companies are changing banking, lending, payment, investing and planning for consumers and small businesses by disrupting incumbents, others are creating radical new business models. Lower cost, algorithmic based financial services are now possible. Blockchain-based services and software contracts that eliminate overhead and people costs. For many insurance and financial institutions the business model has become “fine print jargon gotchas”. Their profits are a “financial tax” that in my view far exceeds the value of the services they provide.. It is possible that AI and other technologies will replace many of the supposed value added functions, as it has already been proven in stock trading and financial planning? Why not in capital formation? It appears to me that 10 percent of all financial transactions (a wild guesstimate) actually add value to society and the rest is for the benefit of financial institutions. Industry’s financial needs can be met at a fraction of the cost with less overhead or transaction taxes, and it can be done more fairly by more objective algorithms. The speculation and circular trading worth trillions of dollars daily that could be minimized to the bare essentials! Many if not most aspects of finance can be replaced with technology that make financial services more affordable and accessible.

## Reinventing Energy Services

Key drivers: Scientific talent and long view funding. The best minds getting PhD’s are not going into energy or cleantech today, which poses the fundamental problem. People realize it is hard to get funding, and for that reason, we are not seeing as many entrepreneurial efforts as I’d like to see. Cleantech is very capital intensive, and although there was a period of too much exuberance in the area, now it is met with investor disinterest. Organizations like Breakthrough Energy Ventures are trying to address this. There are many areas in which large breakthroughs must be attempted: From fusion to geothermal where linear cost for deeper drilling instead of exponential cost per foot when drilling at depth is the key breakthrough needed), storage, new materials and manufacturing, building materials, new agriculture and food.

## Reinventing Consumer services from retailing, entertainment to elder care to delivery

Key drivers: Mobile, AI, Internet, communications, social networking, voice and image technology, sensor and cameras, data, mass personalized manufacturing. Technology is changing the way we discover products, how we order them (products with groceries), how we make purchase, and how we find what's right for us, and personalized manufacturing. The supply chain is being reinvented, starting from 1 hour deliveries, a virtual pantries within minutes from many homes, all the way to completely re-invented grocery stores. Wallet share is changing as well from physical products to technology-enabled experiences, often community experiences. 3D printing will allow us to print items on-demand, whereas AI will transform the experience to be truly personalized, whether that is tailored furniture or food plan unique for each individual. Lastly, robotics are changing how we interact from food delivery to Amazon Echo.

### Reinventing Education

Key drivers: AI to personalize education, open source content, AI tutors, mobile and Internet create more accessibility to knowledge and education, AR/VR changing how students can get information. I recently asked a simple question: Is majoring in liberal arts a mistake for students? The problem, I argued, is that the current liberal arts education does not teach critical thinking and scientific progress in the way that it should or in the way that STEM does. Now, STEM perhaps, doesn't teach enough of liberal arts — how to create real businesses from science and technology, and applications for best impacting the world. The education system is full of opportunity, and yet, it's an industry that's challenging and complex to change. With technology and new tools, accessibility and equality in education will change, no matter what style or subject of education you want. The ideal "tutor" for the task will always be available. AI tutors will not only allow for more affordable or free accessibility 24x7, but they will personalize education for each person. Perhaps, because of this personalization, the very notion of majors such as STEM or Liberal Arts will change altogether.

### Reinventing Business, Cyber, defense, governmental services

Without too much elaboration, it is worth point out that business services, resource uses, and products have been changing and will change even more. No business, be it fintech, consumer goods design and production, industrial products design, drug research or manufacturing, materials design, manufacturing, spare parts, sales AI agents, or customer support agents, will remain untouched. Technology will have an impact all of these, though my focus here is on things an individual entrepreneur can drive, not on governmental or regulatory driven change

though those are often necessary followers. Space and cyber will be often entrepreneurially driven, although the latter will have many state actors. On cyber services I refer you to AI; Scary for the right Reasons but suffice it to say that massive entrepreneurial opportunities in defensive and offensive cyber tools and services will exist. Entrepreneurs will need to push further innovation across these areas for true innovation to happen.

## Silicon valley culture

Whether it's Washington, Wall Street, or Silicon Valley, no one really knows what's important, but what Silicon Valley does really, really well is originated interesting experiments. For instance, while you may think Uber is a mess, I think of Uber having started the change in our notion of transportation and started with a limo service at the very high end, and Airbnb started with rooms in Philadelphia in 2008 during the Democratic National Convention and brokering rooms. That seed of an idea ends up being way more important than Hilton Hotels after almost a hundred of years. While the world thinks they know what's important; that Volkswagen or General Motors is important to innovation in cars; reality is they are largely irrelevant to innovation. It's the improbably that's important.

Because Silicon Valley runs so many experiments and people love to write about failures, the hubris, the messes, the trivial, the fraudulent or self-aggrandizing claims, be it Uber, Theranos, Juicero, Soylent, make better headlines. These same factors are critical to get the self delusional attempts at grandiose or evolutionary innovation. If these entrepreneurs had normal expectations, they would not attempt the things they do. And their failures and diversion into societally good or bad business is a necessary side effect. Most businesses are improbable and fail but the few (1 in 1000? 1 in 10,000?) that emerge as game changers have disproportionately large impact. As Martin Luther King said, "Human progress depends upon the socially maladjusted". And George Bernard Shaw said that, "reasonable people adapt themselves to the world, the unreasonable man (he should have added woman) adapts the world to them." Hence, human progress depends upon the unreasonable man or woman.

It's not just the improbable sounding experiments that are really important about Silicon Valley and what's becoming even more exciting and healthy isn't IPOs, it's the number of new areas the valley is attempting to innovate in. For example, a few years ago, we invested in this hamburger company Impossible Foods, now there's probably forty or fifty PhDs and probably forty or fifty other technologists working on designing the perfect hamburger. Why? The founders started it, because thirty to fifty percent of our planet's land area, (and till Elon Musk gets us to Mars, this is the only planet we have) is dedicated to animal husbandry and he wanted an environmental

better way of producing meat (in addition to other practices he wants to avoid like cruelty to animals, unhealthy food, environmental degradation, antibiotics in our food chain). He wanted a couple of million dollars to run an experiment. Could he do this? It's now gotten into a robust product that's today a niche product, but the goal, clearly, for the founder, is to replace all animal husbandry (oh, and Silicon Valley is much more mission-driven than anywhere else, in my view, though one can find plenty of strictly money making, even cheating, hacking attempts at money making here too).

Silicon Valley is much more about the mindset and a culture than it is about a place. What makes it harder in other places is that when somebody innovates they don't get that support around them. In Silicon Valley, I'm sorry to say if you're fifteen years at Hewlett-Packard, or Cisco, you're not qualified to do any important job in the startup world. Every other part of the world, and I grew up in India, people go "wow, you work for GE or Citibank!" Here, "you work for GE and Cisco for fifteen years?" Again, it's the mindset that enables new ideas or new tools for testing that creates the disruptive innovation that matters. Here too much experience can be a handicap.

## Conclusion

If there is a 90% chance of failure on a transformative project then we have a 10% chance of transforming the world. That's pretty great. If we have ten attempts each at many different areas covered in this essay we will really change the world. Change and innovation will be technology driven, non-institutional, let's break the rules, radical kind of approach. And in this non-institutional way of doing things though less predictable is way more exciting and probably the main way we will get to getting seven billion people the kind of lifestyle they'd all want. Machines and systems can do medicine better than humans. But that's just one of many. Or that most jobs will be replaced or fusion energy is possible in my lifetime or that AI can make work an option for most people who will work if they want to work, but not need to work because we will have sufficient abundance. Imagine the possible!

As Yogi Berra said "It's tough to make predictions, especially about the future", but if there is an answer this speculation is more likely to be right than any other single prediction I can think of. This reinvention will be chaotic, disruptive, unpredictable with many failed attempts, but failure won't matter; the sparse successes will. The disruption will be temporarily painful to some as being disrupted is never fun. We have to get things right and meet society's expectations of technology to help equality, diversity and more. New technologies also rock the world by reallocating power and wealth and accentuating inequality. Fortunately capitalism is by permission of democracy and the electorate will have the ability to rectify the inequalities. All

these social factors will become urgent and critical to enable this transformation through democracy and the people who will be impacted. It's impact in the less democratic societies is harder to predict.

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Conclusion

Article: THE CONCLUSION

Section 17 from "Reinventing Societal Infrastructure with Technology" which will be released the end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

The way to look at the world is seven hundred million people or so on the planet have a rich lifestyle. It's energy rich, it's resource rich, it's healthcare services rich, it's transportation rich, it's a rich lifestyle. Seven billion people want it. Can we do ten times as much of everything the same way? The obvious answer is no. Technology is the necessary, albeit not sufficient, resource multiplier. It is the only thing that can multiply resources. Now, politics can still screw all that up, and that's why I say technology is necessary and the only thing that can multiply resources, but it is not sufficient. Social, political and cultural issues matter immensely. This is why I am so bullish about the role Silicon Valley can play in meeting social needs. And it's fun to do and do it in a non-institutional way, meaning CitiBank won't solve financial inclusion, Square will. If anybody does it.

The vast majority of U.S. jobs in 1900 were in agriculture. By the year 2000, it was approximately two percent of all jobs, so most jobs got displaced. I have recently looked at the top twenty job categories in the United States, and it was very clear that at least fifteen of them will have more than fifty percent of the jobs replaceable. I cannot say with precision whether it will happen in twenty-five years or fifty years. It depends on which entrepreneur takes it upon themselves to go innovate that job category. Such dramatic social change will render all the economic metrics that everybody in Washington pays attention to, “mostly meaningless but looking great”. And it will feel very painful to the people who are affected as this The Next Technology Revolution will Drive Abundance and Income Disparity. That’s the inclusiveness part. This is what worries me about technology. I’m a technology optimist, but there are consequences and side effects that aren’t great — that we should all worry about. We will, however, have the resources to address them adequately.

It is important to note the cautions here. There is extreme variability in the timing and even the nature of the innovations that will emerge. There is also a huge path dependence based on when, who and why they innovate and that may cause the end result to be different. There are all kinds of entrepreneurs with good, bad and indifferent objectives in Silicon Valley. Who does what matters to where we get.

There are a huge number of unknown unknowns in this speculation (and yes, it is all speculation, not forecast). Almost certainly this document will look naive in twenty five years. But the biggest of the big unknowns is artificial intelligence (AI) and even more so artificial general intelligence (AGI). I have had intelligent people forecast it as 5–10 years away and others say 10x that time. Personally, I’d peg that at the boundary of this document or around 5–10 cycles of 2–3 year individual innovation cycles in AI. That could change everything. It may only need a few hardware breakthroughs to scale computing 1000x or it may need many years of software invention. Regardless, when it happens it may be impact equivalent of a 100x nuclear-like technologies (again for good and evil!). And unlike nuclear it may not be verifiable as to who has what technology. The world would be very dramatically different. In short time, we may need to adjust capitalism which was designed for economic efficiency to a new era of abundance, concentration of power and much more of a winner take all world. Life will be very, very different. Fortunately, capitalism is by permission of democracy and I hope that the means to reduce disparity and minimum living standards will be taken advantage of by societal choices.

If there is a 90 percent chance of failure on a transformative project, then we have a 10 percent chance of transforming the world. That’s pretty great. If ten such fusion projects were attempted, we would possibly change the world. And if we have ten attempts each at many different areas covered in this essay, we will really change the world. Change and innovation will

be technology driven, non-institutional, breaking the rules, all radical approach. And in this non-institutional way of doing things, though less predictable, it is way more exciting. It is probably the main way we will get to getting seven billion people the kind of lifestyle they'd all want.

As Yogi Berra said "It's tough to make predictions, especially about the future," but if there is an answer, this speculation is more likely to be right than any other single prediction.

On a more personal note, I'm going to keep making mistakes, because I'm speculating on a lot of things and then backing them. My willingness to fail allows me to succeed. And if I was too afraid to fail, I wouldn't try the things and I would, well, fail to try, instead of trying and failing. There's a world of a difference difference between those two. I think most people fail to try and so they never fail, but in my view, they always fail, because they fail to even attempt something. It is a really important cultural difference.

Another thing you learn in our business is humility. How often you're wrong. The best of you entrepreneurs work on these kinds of problems, and that's what's so exciting to me, that is what keeps me motivated. That is why I am working eighty hours a week at age sixty two. I get so much flack for believing machines and systems can do medicine better than humans. However, that's just one of many. Or that most jobs will be replaced or fusion energy is possible in my lifetime or that AI can make work an option for most people who will work if they want to work, but not need to work because we will have sufficient abundance.

To elaborate more on founders — if you don't have strong religious beliefs about what you're trying to do, you tend to not succeed. So, you have to be totally obstinate about your vision, but flexible about your tactics. Most founders don't get to their vision in a straight line. It zig-zags, goes left, goes right, survives long enough, evolve, get lucky. No one has yet reached Everest without getting to multiple base camps. So while being obstinate about one's vision, one has to be flexible on one's tactics — a pragmatic visionary so to speak in a world where most people are one or the other. And above all luck plays a huge part of success, and good founders give themselves multiple shots on goal. You want founders to think flexibly, but not be agreeable with everybody who gives them advice.

This reinvention will be chaotic, disruptive, unpredictable with many failed attempts, but failure won't matter; successes will. Media folks will have a field day with stories of hubris, missed or misled expectations and failure. The disruption will be temporarily painful to some as being disrupted is never fun. We have to get things right and meet society's expectations of technology



to help equality, diversity and more. New technologies also rock the world by reallocating power and wealth and accentuating inequality. Fortunately, capitalism is by permission of democracy, and the electorate will have the ability to rectify the inequalities. All these social factors will become urgent and critical to enable this transformation through democracy and to be fair to the people who will be impacted. The future is not knowable, but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future now.

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

#### Article: THE SILICON VALLEY CULTURE

Section 16 from “Reinventing Societal Infrastructure with Technology” which will be released the end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

I’m very optimistic about Silicon Valley. The way to look at Silicon Valley is to ask “How many new things are starting up?”. It is especially important in contrasting it to the rest of the world. The rest of the world thinks they know what’s important, but the Silicon Valley psyche (to me, Silicon Valley is a culture not a place and is starting to spread into many parts of the world from Shanghai, Bangalore, Helsinki to Tel Aviv) is to be open-minded. It means to discover and not assume, learn not know, be unreasonable but pragmatic, and determined in not giving up when the going gets rough. It is not being foolish and yet foolish enough to try things others won’t, to be naive enough to not be dissuaded easily, ask fundamental questions around “Why not?”, and not “How has it been done before or tried before?” ....

Ask anyone in Washington or Wall Street or any other institutional agent what’s important in energy, in climate? It’s General Electric and Siemens. I’d give you odds that no large innovation will come out of any institutional player. Silicon Valley doesn’t know what’s important either, but what Silicon Valley does really, really well is to originate interesting experiments.

You think Uber is a mess. I think of Uber as having started the change in our notion of transportation and started with a limo service at the very high-end; just like AirBnB started with brokering rooms in Philadelphia in 2008 during the Democratic National Convention. That seed of an idea ends up being way more important than Hilton Hotels after almost a hundred years since they have been around. That's what is crucial. To me, that is what's really most important about Silicon Valley. While the world thinks they know what's important; that Volkswagen or General Motors is important to innovation in cars when the fact is they're largely irrelevant to innovation. It is "some improbable" that really matters.

That improbable initially was Tesla, but will be supercharged by the Google/Waymo and the Uber experiments. The combination almost certainly will upend public transportation in the future. It will enable anywhere to anywhere ride on-demand for \$1 in most cities in America with public transportation while providing better service and lower cost than any public transit service of consequence. Incidentally, it may remove the need for large-scale city parking spots and open space for parks or housing. It may shrink distances and commutes, eliminate more than half the auto industry and its needs for steel and rubber, and collateral GDP! This loss of GDP (near zero if service is free or near free like libraries or information search are today) will be a good thing.

I will even admit that Silicon Valley driven change will sometimes be scaled because of or by large companies, but the initiation of new directions is what is socially important. You know, Volkswagen's not going to reinvent transportation. Big companies do help scale innovations and bring gobs of capital later when risk of a new phenomenon is low (Walmart in retail?), but they'd rather stay safe and not be wrong. Uber can get lots of flack. Nevertheless, the fundamental innovation they have caused is what Uber started, Tesla started. What Google started with Waymo and driverless cars will completely replace all public transportation with what is the new style of public transportation. This seemed completely inconceivable five years ago by anyone in auto or transportation businesses and inconceivable coming from and driven by any large institutional thinking.

Self-driving cars and even electrics were fifty years away until Waymo asked "Why?"! What will be interesting and completely unpredictable is whether cities will run it, like they do public transportation or will they contract it out to a Waymo or a Google or a Tesla, or somebody else. In 2004, I gave a talk titled "The device that used to be a phone" (I had stolen that title idea from somebody but not sure who) and I got right the basic idea that a phone would not be used mostly for talking, but what I got embarrassingly wrong was the cases it would be used for. I was wrong in unimportant ways, but spot on in the most important trends, the general direction of other uses for a mobile device. This is the essence of Silicon Valley, and why reinvention will be driven by Silicon Valley and not the institutions we rely on and take comfort in.

What people confuse outside of Silicon Valley is this notion, that I'm almost certain of, that the big guys are unimportant to real "big step" innovation. What's hard to say is the opposite. Improbable, like Uber was, or AirBnB was, or Google was in 1998 is not unimportant. In fact, the only thing that's probably important is the improbable. We have no way of telling which improbable is important. And because Silicon Valley runs so many experiments and people love to write about all the failures, the hubris, the messes, the trivial, the fraudulent, or self-aggrandizing claims because they, Uber, Theranos, Juicero, Soylent, make best headlines. These same factors are critical to get the self-delusional attempts at grandiose or evolutionary innovation. If these entrepreneurs had normal expectations, they would not attempt the things they do attempt. As Martin Luther King Jr. said, "human progress depends upon the socially maladjusted". And George Bernard Shaw said that reasonable people adapt themselves to the world, the unreasonable man (he should have added "and woman" but he didn't) adapts the world to them. Hence, human progress depends upon the unreasonable man or woman.

Writers can write about or rail against or laugh at all the naive attempts, the hubris, the pretend unicorn valuations and the vast amount of drama that is Silicon Valley. However, all these things are largely irrelevant in the long run. They do keep the media in business though with salacious content! Yes, investors get misled or just plain lose their money. Yes, they cause false hopes and even collateral damage to helpful institutions. But it's the 1 percent or even 0.1 percent that succeed that cause the majority of technology-driven change in society.

All I'm saying is startups drive the vast majority of innovation, not the institutional incumbents. It is this non-institutional driven change that frees us from the straitjacket of conventional wisdom and lets us really change the world. The experts that inhabit this world are experts in a previous version of the world and live by extrapolation. They do not aim at inventing a new future and as skeptics never do the seemingly impossible. Great entrepreneurs, and there are plenty of incremental ones too that do good work, invent the future they want. I would also state without proof but with plenty of experience across many industries, from Wall Street to more mainstream businesses, that Silicon Valley entrepreneurs have a larger percentage of people who are mission-driven, whether the mission is societal or local or silly, than most other businesses I have seen. Though it is important to acknowledge that Silicon valley has its good and bad apples, and public scrutiny will help improve things. And that it's generally positive impact has many downsides we must consider and worry about as discussed in one dimension in "AI: Scary for the Right Reasons".

It is these improbable sounding experiments that are really, really important about Silicon Valley. What is becoming even more exciting and healthy isn't IPO's, but the number of new areas the Valley is attempting to innovate in. A few years ago, we invested in this hamburger company Impossible Foods. Now, there are probably forty or fifty PhDs and another probably forty or fifty other technologists working on designing the perfect hamburger. Why? The founders have started it, because thirty to fifty percent of our planet's land area (and until Elon Musk gets us to Mars, this is the only planet we have) is dedicated to animal husbandry, and he wanted an environmental better way of producing meat. In addition to other practices, he wants to avoid cruelty to animals, unhealthy food, environmental degradation, antibiotics in our food chain, etc. He wanted a couple of million dollars to run an experiment. Could he do this? This kind of entrepreneur is the core of the Silicon Valley culture and though there are others abusing the public trust as has been widely and accurately reported, there is far more good than bad in this culture. There are good and bad people in any culture but Silicon Valley feels to me much more mission-driven than most other cultures.

It's now gotten into a robust product that's today a niche product, but the goal, clearly, for the founder, is to replace all animal husbandry. You are not going to get that from Cargill or Archer Daniels Midland or Chevron or Exxon. They won't innovate because they don't really care as much about the mission of a sustainable planet, despite their proclamations and Madison Avenue ads saying the contrary. And this disruption may disrupt their income statements. To be fair, anything else goes against their promise to their shareholders.

Do you think you could have innovation outside of this region? The one thing to realize is innovation can happen anywhere and everywhere. It is much more about the mindset and a culture than it is about a place. What makes it harder in other places is that when somebody innovates, they don't get that support around them. Silicon Valley is different. I'm sorry to say if you have been fifteen years at Hewlett-Packard or Cisco, you're not qualified to do any important job in the startup world. Every other part of the world people say "Wow, you work for GE or Citibank!" Here, they say "You've been working for GE and Cisco for fifteen years?" You're not hireable by anybody trying to really experiment and innovate. You're not qualified in any way if you're at Cisco for fifteen years, or IBM for fifteen years, or Cargill for fifteen years, or United Healthcare for fifteen years.

I have gone through an exercise of trying to just see if I could find a large innovation coming out of big companies in the last twenty five years, a major innovation (there's plenty of minor innovations, incremental innovations that come out of big companies), but I couldn't find one in the last twenty five years. You look at retail, did Amazon innovate this or Walmart? For media, did ABC, NBC, CBS do it or Twitter/Youtube/Facebook? Did Boeing or Lockheed innovate space

or SpaceX? Did GM which started early in electric cars and spent more money change cars or Tesla/Waymo/Uber? Did Wells Fargo or Bank of America change financial services or did Square/Stripe/Affirm do that? Did IBM change computing or Sun/VMWARE/Amazon AWS? Yes, the credit card 40–50 years ago was “credit on plastic” was the largest existing company, “barely large innovation” I could come up with, though I am sure there are a few others. And no, 3M does not qualify with the yellow sticky in my view. Rather, it’s the entrepreneurs, startups, and Silicon Valley mindset that asks, “Why Not?” and does something about it.

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: KHOSLA VENTURES’ COMPANIES MAKING A DIFFERENCE RIGHT NOW

Chapter 15 from “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

This is a list of some of the Khosla Ventures’ portfolio companies that are making the biggest difference in the world today. I’ve tried to be thorough with my analysis but I may have missed one or two along the way. For that I apologize. That said, all of these companies are the reason I get out of bed in the morning and the reason I believe we are all moving forward.

Health & medicine:

AI & data driven change from “practice of medicine to science of medicine” and specialty by specialty reinvention of the expertise, meaning virtual primary care doctors, cardiologists, psychiatrists, oncologists, is happening in our portfolio. Companies like Alivecor enable personal cardiologist-like functions around ECG like diagnosing atrial fibrillation or reading an ECG for normality, although nothing as forward as a full cardiologist yet and definitely not the interventional cardiologist yet; to partially substitute a therapist like Ginger.io, or perhaps the primary care doctor experience like Forward, or create an AI physician like Curai.

Others impact health by making accessible, population-scale genetics services like Color, or transforming xenotransplantation into an everyday, lifesaving medical procedure with eGenesis. Genalyte is tackling blood testing results and making it easier to get them in almost real-time in the doctor's office versus a third-party lab. Rethinking Oncology is the domain of Guardant Health or Oncobox, which is personalizing genetic profiling to help oncologists decide which drug to use. Conquering infectious diseases through the innovative use of next-generation sequencing to analyze microbial cell-free DNA is something Karius does, being able to scan for 1,300 viruses simultaneously.

Other companies are using software for hospitals to help doctors and nurses improve key workflows and coordinate a patient's care through Medisas, or are focused on entirely rebuilding the next-gen health insurance company, like Oscar does. How about anticipating diseases with tools that enable physicians to predict Alzheimer's disease before the symptoms appear like Neurotrak? For instance, Viome is using predictive biomarkers to your microbiome's transcriptome and your blood transcriptome at the strain or RNA level. Using the microbiome, others are creating microbial therapeutics for inflammatory diseases (Siolta) or to target bacteria based on genome (Eligo).

Two Pore Guys is building a digital, hand-held, testing platform for DNA and RNA that's as accurate as medical lab equipment, but is as inexpensive and easy to use as a blood glucose monitor. Zebra is using AI to rethink most radiologist functions for MRI, CT, x-rays for as little as \$1, while Vicarious Surgical is enabling surgeons to do much much more with robots. Heartvista is developing a robust commercial MRI system that will give comprehensive cardiovascular evaluation — real-time data with much less skilled technicians!

Pharmaceuticals:

We believe that there will be AI based reinvention from small molecule chemicals to precise regulation of genes in the pharmaceutical space. Companies are predicting potential drug cures with the use of supercomputers, artificial intelligence, and a specialized algorithm that runs through millions of molecular structures. This can potentially reduce the cost and time involved in making new drug discoveries as our company Atomwise is doing, or combine world-leading expertise in machine learning and genome biology to transform medicine. Such is the case with Deep Genomics who are designing biologicals, or offering low-cost personalized genetic profiling to help cancer doctors decide which drugs will be most effective like Oncobox.

## Food & food production:

AI, plant by plant robotics, and new methods to reducing chemicals, and precision agriculture are changing the way we produce and consume food. From reinventing the burger to be all plant-based to end animal husbandry, while at the same time reducing environmental impact, like Impossible Foods to creating a new plant-based egg substitute using science like Hampton Creek. What if you could develop sustainable and nutritious food products by matching the protein, fat, and carbohydrate distribution and content of traditional dairy products with a mixture of the proteins, fats, and carbohydrates from plants like Ripple?

In terms of food production and restaurants, companies are using robotics to make restaurants more efficient, increase food safety, and reallocate funds to higher quality food. On the agricultural process side, imagine using computer vision and robotics to improve agriculture like Blue River (sold to John Deere), who specifically enables farmers to spray herbicides only where weeds are present. Or to make farms more manageable with Granular (sold to Dupont) or climate insurance more accessible with Climate Corporate (sold to Monsanto)? Satellite imaging is allowing farmers to better predict and optimize farming practices like, the services provided by both Rocketlabs and Skybox. Imagine a world where we can use robotics and AI to reduce pesticides, increase efficiency, and create healthier foods — we are only at the beginning.

## Financial system:

Large institutional bodies are often the most poised for disruption from financial services, risk & insurance, blockchain and software contracts-based services, efficient exchanges, accessibility, and even legal services. New small business and consumer services like are provided to by Square. Affirm or Fundbox can make larger purchases more accessible without credit risk, while Stripe can make payment processing easier.

Even, as an example, is rethinking insurance and credit for the modern consumer — managing one's salary, allowing the customer to allocate a small portion per month to an “emergency” amount to be used when a customer may be in a financial bind. Other companies are using blockchain to reimagine aspects of the financial system — for instance, digitizing experimental money to support blockchain to render it more liquid like BlockStream or allowing users to build

Bitcoin applications using an enterprise-grade block chain API like Chain. Add adding to liquidity and efficiency are companies like Opendoor which make home selling much easier and faster.

#### Construction & buildings, Housing:

3D-printing, modular factory built, and housing efficiency are a few areas that have opportunity. Imagine 3D-printing a house, or using manufacturing techniques to create lower cost units like Katera, or using robots to transform a small apartment into what feels like a larger space like Ori. Other companies are using robotics to make kitchens and restaurants more efficient like Spyce, and Momentum is changing city spaces by fully roboticized restaurant kitchens. Arevo, as an example, makes ultra-strong 3D-printed carbon fiber composite materials, while Vicarious is creating robots who can help construct and build, replacing human workers.

#### Education:

AI & open source reduce need for infrastructure as well as manpower for education. Imagine a platform for academics to share research papers like academia.edu or an online platform that facilitates interaction among students and instructors like Piazza. New platforms from Piazza (college) and Kiddom for K-12, now used by one in ten of all US teachers, allow for teachers and students to share assignments, provide feedback, grade, and review reports all in one place are enabling more collaboration and better results in education.

#### Manufacturing:

3Dprinting, robotics, new materials, AI design. Imagine 3D-printing metals like Digital Alloys. Velo3D develops a technology that will disrupt 3D-printing in metals and Arevo that is changing composites manufacturing and affordability. Add robotics technologies like Vicarious, Berkshire Grey and manufacturing, which has been relatively isolated from change is feeling the pressures and innovation.

#### Transportation:



Imagine rethinking transportation with autonomous cars and ways to help people get where they need to go faster, cheaper, and with less impact on the environment. In the future, we will simply have self-driving cars as part of a fleet of taxis such as Voyage, or perhaps have alternate shorter destination methods of getting around, such as electric skateboards, like Boosted Boards. Hyperloop?

Energy & climate, including water:

Some companies are developing a completely new high-power, long-cycle life, low-cost battery technology for stationary and select transit applications like Natron, or building a flexible solar cell design that minimizes the amount of semiconducting material used like Caelux. There are breakthroughs in energy conversion such as Quantumscape, a company developing the first commercial solid state electrical energy storage devices for automotive applications. Others are trying to develop and commercialize new battery technology or develop stabilization for electric grids like Varentec.

There are companies who are using new techniques and approaches with technology for geothermal energy and Altarock or consuming waste gases from steel and other industrial process to turn that into useful products. Like all great technology, nuclear energy can be used to create new options for converting low-level waste into vast energy sources like Terrapower, while companies like View Glass and Sora reduce building energy consumption. And, of course, efforts like Breakthrough Energy Ventures have the potential for incubating long-term technologies for decarbonization.

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: REINVENTING BUSINESS, CYBER, DEFENSE, GOVERNMENTAL SERVICES

Section 14 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress

Without too much elaboration, it is worth point out that business services, resource uses, and products have been changing and will change even more. The change will continue and even accelerate on both the production and services side. No business, be it fintech, consumer goods design and production, industrial products design, drug research or manufacturing, materials design, manufacturing, spare parts, sales AI agents, or customer support agents, will remain untouched. The entrepreneurial opportunity will be immense, but the areas are too diverse to cover individually.

Technology will have an impact all of these, though my focus here is on things an individual entrepreneur can drive, not on governmental or regulatory services. Space and cyber will be often entrepreneurially driven, although the latter will have many state actors. I am less concerned here about governmental parts of GDP, except to note that safety nets for citizens will be easier to provide and such things as our traditional notions of taxes or redistributions will have to change. Tea party folks, you have not seen anything yet.

On cyber services I refer you to AI: Scary for the Right Reasons, but suffice it to say that massive entrepreneurial opportunities in defensive and offensive cyber tools and services will exist. There will be a large overlap with state institutions though corporate needs and markets will also escalate and grow.

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: REINVENTING EDUCATION

Section 13 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: AI to personalize education, open source content, AI tutors, mobile and internet create more accessibility to knowledge and education, AR/VR changing how students can get information.

I recently asked a simple question: Is majoring in liberal arts a mistake for students? The problem, I argued, is that the current liberal arts education does not teach critical thinking and scientific progress in the way that it should or in the way that STEM does. Now, STEM perhaps, doesn't teach enough of liberal arts — how to create real businesses from science and technology, and applications for best impacting the world.

Ironically, the more AI-driven changes we postulate here happen, the more necessary a real liberal arts education, something I now call “Modern Thinking”. Liberal Arts was what Greek elites indulged in when they did not have to work and servants and slaves did much of the work. Schools teach “in the box” thinking, standardized bubbles tests versus encouraging creativity and thinking in new paradigms. The education system is full of opportunity, and yet, it's an industry that's challenging and complex to change.

With technology and new tools, accessibility and equality in education will change, no matter what style or subject of education you want. The ideal “tutor” for the task will always be available. AI tutors will not only allow for more affordable or free accessibility 24x7, but they will personalize education for each person. They will be able to assess where a student is, know the map of their knowledge and gaps in it and be able to guide a student through to their personal learning objectives.

Even for traditional grade or employment-oriented education this is a massive multiplier of teacher resources, letting them be the human element of teaching and not stranding those for whom teachers and tutors are a luxury. And for skills or humanities education AI and social networking enable community learning is an additional multiplier.

**\*\***This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: REINVENTING CONSUMER SERVICES: FROM RETAILING, ENTERTAINMENT TO ELDER CARE TO DELIVERY

Section 12 from “Reinventing Societal Infrastructure with Technology” which will be released the end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: Mobile, AI, internet, communications, social networking, voice and image technology, sensor & cameras, data, mass personalized manufacturing.

The way we shop and consume products and services has started to change over the last decade, with the decline of traditional brick and mortar companies, although not necessarily leading to the downfall of brick and mortar itself.

Technology is changing the way we discover products (Pinterest), how we order them (Instacart with groceries), how we make purchase (Apple Pay or Square), and how we find what’s right for us (Stitchfix for buying more personalized clothes). The supply chain is being reinvented, starting from 1 hour deliveries, a virtual pantries within minutes from many homes, all the way to completely reinvented grocery stores. Wallet share is changing as well from physical products to technology-enabled experiences like more personalized hotels or “stay rooms” such as AirBnB. Space is transforming to be more efficient and serve people for multiple purposes — the brick and mortar as we know it will shift, and we are already seeing this.

Yet we are seeing more physical local bookstores, which might actually mean a rebirth of the community experience, unlike product experiences of Amazon! We might even see more display retail rather than full inventory stores to provide community and shared time experiences with friends. However, these dynamics are hard to predict to the point it is hard to gauge the direction of change. Will the future hold more or less local retail? More of less community

experiences and spaces? Instacart is disrupting the need for full grocery stores, while retail stores are also doubling as coffee shops or yoga studios when not in use. Retail will be more efficient for more than just selling products or serving as local distribution hubs and product display hubs. We may even see the rise of mobile spaces taking over parking lots or having the ability to use space better and reach out to people.

Experiences, especially shared and community experiences, will be more in demand, be it Sephora or yoga or coffee. Retailing may take on other manifestations too hard to predict, but inventory carrying stores may be passe. On the other hand, custom clothing on the spot fit to your body, made robotically, may not be too far away. 3D printed custom items from sofas to shoes as well, or fully personalized products. As a result, with tools like robots and AI, we will be more efficient and will reduce costs to redistribute to other places. For instance, will we see roboticized restaurants building customized, fresher, and less expensive, or more accessible, fresh, fast food with no food deserts?

In the future, we will be able to fully customize fabrics or products, we may be even able to 3D print these on-demand, disrupting supply chains. Sensors will become smaller and cheaper to enable more, if not most, things to be connected and controlled in a seamless way. We will have more data about us (whether it's microbiome/genetic data for food, size/fit data for clothes, or music taste for buying composed music just for us using AI), that will allow for further personalization of our shopping list. Microbiome/genetic data could influence our for grocery shopping, size/fit data — clothes, or music taste for buying composed music just for us. All that can be enabled by the use of AI. Nevertheless, the use of such detailed data carries a possible danger connected to it, too. Regulation will have to strengthen on who controls/owns what data.

I want more data about me and I want to control it, share it temporarily for a particular purpose to provide me services and rescind permission at will. Will the blockchain allow this without centralized trust? AI is also allowing us to have more tailored experiences to either design the right furniture for our home. It can make new foods using algorithms, be it Watson cookbook or startups using AI to characterize proteins and design new foods. It can redefine our interactions with customer service when ordering an item. Robotics are also changing the game — starting with Amazon Echo which changes how we interact with our environment, including shopping, e.g. via voice in our home. Elderly care robotics can take care their needs or prevent elderly from getting lonely, while other robotics can optimize manufacturing times and deliveries. These tools and technologies, be it voice technology, AI, or robotics, are changing the way we live and work and this will only be accelerated in years ahead.

**\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).**

## Article: REINVENTING ENERGY SERVICES

Section 11 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: Scientific talent & long view funding.

The best minds getting PhD’s are not going into energy or cleantech today, which poses the fundamental problem. People realize it is hard to get funding, and for that reason, we are not seeing as many startups as we’d like to see. Cleantech is very capital intensive, and although there was a period of too much exuberance in the area, now it is met with investor disinterest. While it will slow down innovation long-term, hopefully, it won’t stop it altogether.

Organizations like Breakthrough Energy Ventures are trying to address this. There are a number of audacious fusion projects to unlikely geothermal energy projects. This is the hardest area for me to visualize breakthrough step impact progress in. I am still hopeful and feel that many high-risk projects with high probability of failure must be attempted. Though 5–10–20 percent improvements are still fundable, 500–1000 percent change innovations are less clear to me. There are many areas in which it must be attempted: From fusion to geothermal to storage to new materials and new agriculture and food.

That is likely the way to providing seven billion people a rich lifestyle as defined earlier without destroying the planet, depleting its resources (can we produce 10x the steel, copper, glass, cement, or use 10x less of each), and the irreversible climate change. Stationary, low carbon low cost power is a major need and extremely hard to find solution to. Nevertheless, a much worse option from trying and failing will be failing to try. I have personally failed at trying to do this and had only limited success. Others like Tesla and Waymo/Google have provided role models that

are changing the transportation industry forever. I have long invested with the philosophy that while most people in business reduce the risk of failure to the point where the consequences of success are inconsequential on society (but they can make money for their shareholders which they are obligated to do). I'd rather invest in the sparser space of higher probability of failure but where the consequences of success are consequential. There is as much profit and increased social impact to be gained here though with higher variability. Additionally, AI may help accelerate progress in energy, design quantum computers or at least fusion reactor containment structure, or find a solution for dark matter physics. Perhaps, it could help in designing more energy-efficient buildings or design cities that align more with structures in nature (highly recommend reading Scale by Geoffrey West ).

I am hopeful that a few breakthroughs, with fusion and geothermal (where linear cost for deeper drilling instead of exponential cost per foot when drilling at depth is the key breakthrough needed) being my best candidates, will help us over the new few decades.

\*\*This is a section from "Reinventing Societal Infrastructure with Technology". To read the previous section, [click here](#).

Article: REINVENTING FINANCIAL, INSURANCE AND LEGAL SERVICES

Section 10 of "Reinventing Societal Infrastructure with Technology" which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: AI technology to replace people functions and judgement, blockchain, mobility, data, software automation.

The pundit economists' and banks' (Goldman Sachs/JP Morgan/Citibank) view of financial systems and economics we are used to is being significantly challenged. Even basics like GDP as the right measure is being questioned. Entrepreneurs keep getting outraged that financial

services, which should just be a service to real products and services being produced (which may be reinvented too), are taking up such a large share of profits of all industry.

Though companies like Square, Stripe and Affirm are changing things for consumers and small businesses by disrupting incumbents, much more can be done and will likely happen. Others are creating radical new business models, like Even, hourly employee payment insurance and the bank app that plans so customers do not have to, as an example. Financial institutions impose massive taxes on fundraising organized by different industries. Those should diminish by order of magnitude based just on cost of providing this service. The tax reduction should also apply to consumer banking and financial services costs. It could be that blockchain-based services and software contracts that eliminate the nonsense of fine print jargon gotchas in finance and insurance, which could dislodge centralized control or “financial tax”. It could have identity verification, as well as traditional fraud and illegal activity controls like AML, KYC added on.

It could be simpler disintermediation of everything from foreign exchange to lending and insurance services. Insurance could be based on real costs, better actuarial tables, regulation around what is or is not legal to differentiate on, and low overhead. It is likely that legal services are automated by AI; there are only about seven million cases in US legal history. They are more structured and seem easier to computerize based on federal and state laws that these cases interpret than a technology like Google Home or Amazon Alexa which cover a far less structured and much broader range of conversational topics. Computerizing law and lawyers with or without software contracts will enable every citizen to have a personal lawyer(s) at a low cost or no cost at all? A few hundred thousand dollars a year of legal and medical services will cost almost nothing. It is possible that AI will replace many of the supposed value added functions, as it has already been proven in stock trading and financial planning. Judgement and estimation tasks in this data rich segment should be algorithmically driven and AI will likely replace human judgement where there is enough transaction volume (read volume, margins, profits). One firm has already appointed an AI as a board member. What is clear is the ten percent of all financial transactions (a wild guesstimate) actually add value to society. Industry can be done at a fraction of the cost with less overhead or transaction taxes, and it can be done more fairly by more objective algorithms. The rest is speculation and circular trading worth trillions of dollars daily! This will add a lot more transparency, although it may introduce other problems.

Financial, insurance, and legal services will be freed of capitalistic lockin and open to much more competition from relatively more transparent players; this could translate into far more affordable and accessible services.



**\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).**

## Article: REINVENTING FOOD & AGRICULTURE

Section 9 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: Robotics, machine vision and AI, plant by plant care eliminating much of herbicides and insecticides, meat alternatives, sensory technologies to pack sensation with nutrition, better land use, drone and satellite imaging, better seed and chemical technologies, microorganisms, precision agriculture.

Whether any of the current “meat equivalent” food production companies changes the world or not, in order to get past the ills of animal husbandry and return our planet and land to its healthy, diverse ecosystem, something like Impossible Foods is necessary to match the taste of red meat. Whether it becomes a huge googlesque impact, a role model, or a footnote in history, it proved the possibility of food reinvention. Multiple entities working on reducing the impact of meat production, consuming a very large part of the planet’s usable land mass and a humongous percentage of freshwater use on the planet. It takes 1,800 gallons of water to produce a pound of beef. Growing the amount of feed grains necessary for just raising livestock accounts for 56 percent of the U.S water consumption. Similar efforts are underway in dairy alternatives. It is possible to reduce the land required for animal husbandry by 50 percent or more, despite the increasing demand.

Traditional agriculture companies developing robotics technologies are dramatically reducing the need for herbicides and eventually other chemicals. Even plant by plant care, dosing of fertilizer or herbicide or insecticide in a million plant field is entirely feasible with robotic technologies. This can lead to higher yield, lower inputs, and lower environmental damage. Why spray herbicides on the whole field when one can weed mechanically, and, perchance, eliminate herbicides all together? Perhaps we can using robotic mechanical weeding to mostly eliminate

herbicides in agriculture and get rid of the hated Roundup and dramatically reduce insecticide use? Maybe we can even allow GMO plants that are generally good for society but much maligned because of the negative impact that glyphosphates (Roundup) has on environments and GMO plants are most closely associated with Roundup Ready plants, can be freed from it. Eventually, these technologies will allow for plant by plant care even in a field of millions of plants. They will allow for far less nitrogen use, more yield per plant, less chemicals, and far less land use. Any technology that can reduce land use is very valuable given the amount of land is fixed on this planet, and we need to reforest millions of acres to find the easiest path to pulling carbon out of the air; over a hundred out of the 116 models in the IPCC carbon reduction scenarios involve using some technology like reforestation to pull carbon out of the air). It is encouraging that area under farmland worldwide is finally declining and I suspect the decline will accelerate.

Precision agriculture also implies the use of such technologies as data science, aerial imaging, early disease detection. Further development of AI for imaging and data analysis, more easily and frequently accessed satellites, bio techniques like increased microbial communities, all aided by the use of fewer chemicals that would traditionally sterilize the soil because of new roboticized weeding and insect targeting will dramatically reduce the impact of and land use for agriculture. And it might even be that for specialized crops, vertical farms and data science led yield maximization coupled with robotic labor make a real change in the yield or resource or acres used. Of course, our sidewalk delivery robots take care of the deliveries.

Another dimension of innovation is the creation of new foods, such as beef without cows, milk from plants, eggs without chickens, all far less environmentally harmful at that.

**\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).**

Article: REINVENTING MANUFACTURING, CONSTRUCTION, BUILDINGS, BUILDING EFFICIENCY

Section 8 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: automated construction, robotic delivery, “transformer” type spaces, shared and higher percentage reuse, 3D printing of buildings and furniture, social networking and increase in community spaces and relationships.

Buildings are a big part of our urban landscape and a large consumer of resources. Construction and building account for more carbon emissions in the US than transportation or industry. LED lighting is enabling 80 percent less electricity use, although unfortunately efficiency in light generation goes hand in hand with the increase its use.

What if space was reconfigurable and we would need half only as much to live comfortably? Some startups are building cost effective “transformer furniture” systems powered by modular robotics, so that they can seamlessly adapt space to activities and can be installed in a true plug & play fashion. Affordability and availability would go up and land use would decline for housing of large numbers of people. Space would become more cost-effective, and developers would be able to adopt their buildings retroactively. Buildings purpose built for WeWork-like uses and reconfigurable could add additional virtual space.

Further imagine buildings were manufactured like automobiles, reducing costs dramatically. Possibly, next generation buildings would be 3D-printed (in concrete or other materials and maybe steel or carbon fiber reinforced?) and designed with AI, like, for example, in the case of generative design. Thus, they could possibly weigh a fifth as much with much better insulation because of air pockets? What if structural elements like beams needed far less steel or could be 3D-printed with composites. For instance, 3D-printed carbon fiber beams can be five times stronger than titanium, and when 3D-manufactured with no human labor, more cost effective. All unnecessary material unneeded for structure could be subtracted with AI design and 3D-printed? And what if shared office spaces could turn into residences or hotels at night or be “WeWorked”? Could we accommodate twice as many people twice as affordably in the same city? Of course, we won’t take down buildings or rebuild a whole city immediately. Yet, all those freed up parking spaces and new construction would be an opportunity to transform the city gradually over the course of two to five decades. A very large percentage of buildings are non-compliant with current code; the combination of forced compliance and upside economic opportunity with much more cost-effective space may motivate developers.

One can keep imagining delivery robots reducing chores as well as traffic using sidewalks. Or virtual clinic visits reducing medical visits. The complex ecosystem is hard to predict but will offer many opportunities. Robotic kitchens for burgers and delivery robots for home delivery would reduce the need for restaurant space. Here, I'm sticking with more linear ideas that might motivate an entrepreneur to pursue the change by themselves and build the next Google or Tesla.

Manufacturing, starting from cars to furniture and other durable goods, could also use techniques dreamed about above. Construction would put them on a different cost trajectory than in the past, and could potentially end up messing up our GDP numbers as much as computing has! They could be printed locally on-demand when possible (from walls to sofas) and minimally assembled locally; this might be not not feasible for automobiles, but easier for furniture.

Autos would have different material consumption curves because of these techniques and others, like autonomous driving, would eliminate most accidents and hence the need for bulk and crash protection! Add new battery technologies that cut weight in half and accelerate the decline of the internal combustion engine and its pollution. 3D-printed composite structure could mean crashproof automobiles. Public transportation in small pods travelling 10x more miles per year than today's automobile on average will put pundits prognostications about our transportation needs to smithereens over a few decades.

Cities and urban living can be far more efficient, sustainable, and much cheaper. Imagine a world of cities where we need less restaurant space because of robotic kitchens, robotic food delivery, self picking mini grocery store warehouses for Instacart-like ordering with robotic delivery, virtual entertainment and get-togethers. Parks could substitute parking lots, houses that multiply space as AirBnB like models reduce need for hotel rooms and increase space efficiency. New housing could half the space because of robotic transforming furniture improving space efficiency, WeWork-like space-efficient buildings that are further reused for homeless housing or hotels in the evenings with transforming furniture? Our assumptions about space, cities, density, efficiency, transportation, parks could change in unpredictable ways.

**\*\*This is a section from "Reinventing Societal Infrastructure with Technology". To read the previous section, [click here](#).**

## REINVENTING HEALTH, DISEASE DIAGNOSIS & MANAGEMENT, DRUG DISCOVERY

Section 7 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

The COVID-19 pandemic is likely to be one of the biggest disruptions we will face in some time.

In this difficult environment, we have found a commonality that makes us incredibly proud to be associated with our portfolio startups: the desire to help the nation and the world combat the pandemic. As mission-driven entities, we’re seeing our companies trade-off other priorities for this urgent societal need in a time when resources are scarce and it is not always easy to do “the right thing”. To be sure, some view it as a business opportunity. Many in our portfolio are working on deep tech, and are particularly well suited to help with critical needs like testing and treatment options. There are also efforts in managing the well being of those on the front lines, expanding access to medical care, and even fighting loneliness during periods of forced isolation among other needs. This breadth of effort is both admirable and astonishing and the short time periods surprising.

Some examples of current efforts (in alphabetical order) include:

Alivecor: FDA cleared QT duration measurement service for COVID medications that have a QT prolongation side effect (eg: Hydroxychloroquine, Azithromycin for example). Partnership with Mayo Clinic to diagnose long QT and build advanced algorithmic measurement of QT.

Augmenta: Searching for neutralizing therapeutic antibodies in patients who have recovered. They are scaling into a therapeutic which they hope to dose into patients by fall.

Caption Health: Deploying Caption AI to enable more frontline healthcare providers to quickly and accurately perform ultrasound echo exams, reducing personnel exposure and stretching limited resources, in the absence of skilled ultrasound technicians.

Clear Labs: Developing an automated, very low cost, and fast next-generation sequencing platform for deep-screening of COVID-19, which can simultaneously screen for the infection and generate deep genomic information that enables differentiating various RNA viruses, identifying infection clusters and transmission events, monitoring the evolution of the virus, and identifying cases of co-infections. FDA filing is expected in April.

Color: Launching a high-capacity COVID-19 testing lab and will open-source its design and protocols.

Curai: AI-based Virtual Primary Care and prescription of COVID testing to scale front end access to healthcare. Helps offload physicians who must decide whether a COVID test is warranted or some other urgent condition exists. This is part of their broad free primary care offering.

E25Bio: Makes direct antigen rapid tests for at-home use at a very affordable cost. All you need is your phone for the test, very much like a pregnancy test. They expect 100,000 tests per day in the next 30 days, subject to FDA approval.

Fundbox: Building a coalition of companies to #paytoday, encouraging large enterprises + government to pay SMBs outstanding receivables to alleviate financial burden.

Genalyte: A 15min serology test — IgG and IgM to multiple CoV proteins in April. No FDA clearance is needed on the already FDA approved Maverick instrument with this lab-developed test.

Ginger: Offering U.S.-based health systems free on-demand behavioral health coaching for their frontline healthcare workers.

Inflammatix: A host-response (mRNA) blood test run on COVID-19 positive patients to determine if hospitalization is needed and to decrease unnecessary admissions. The timeline is a few months if the system shows efficacy as expected in further trials. No such test exists to manage hospital capacity to our knowledge.

Luminostics: Developing, towards FDA EUA, a 15-minute high-sensitivity point-of-care test with smartphone readout for the parallel detection of SARS-CoV-2 virus from respiratory samples (to diagnose active COVID-19 infection) and anti-SARS-CoV-2 IgG/IgM antibodies from finger-stick blood (to quantitatively test for COVID-19 immunity).

Ontera: Building a molecular diagnostics point of care platform to conduct both nucleic acid and serology testing for both bacterial and viral pathogens using nanopore technology. The low-cost platform is expected by the fall.

Opentrons: An eight robot configuration for a fully automated qPCR testing pipeline. An eight robot \$100k configuration can do 2400 tests/day fully automated. Opentrons has deployed 60+ robots to fight COVID-19 in the last 3 weeks, many of which have already started testing live patients under emergency use authorization.

Prellis: Using their organ growth technology, Prellis constructs human lymph nodes outside of the body and can vaccinate them to rapidly isolate human antibodies against emerging pathogens for the direct treatment of patients. Because it is a fully human antibody there are minimal reported side effects therein a clinical trial with this antibody would happen extremely fast.

Replika: Teamed up with clinical psychologists from UC Berkeley to come up with more activities that can help deal with loneliness, financial uncertainty, homeschooling (for teens), sickness, caring for your family, having to work at crowded places (ie. grocery stores) and co-quarantining.

Totemic: Developing a wireless home fall detection and motion monitoring service, has launched a COVID-19 telephone concierge line, Ask Koko, which empowers older adults with the local services and tools they need to remain safely at home.

Viome: Applied to FDA for the only at-home collection COVID-19 test based on stool. Research shows the COVID virus shows up in stool even though it shows negative in a throat swab.

Many others are also helping in numerous other ways. Oscar is offering a risk assessment tool for non-members. Forward is offering care for non-members for COVID-19. Zocdoc is helping non-COVID-19 patients to connect to telemedicine. Carrot is offering its Pivot tobacco cessation app at no cost to all smokers to help people who smoke get started on a path to reducing or quitting to reduce risks of COVID-19. Creator has built an open-source design for a food Transfer Chamber to protect retail and delivery workers from virus spread. The chamber uses a positive pressure system combined with a self-sanitizing conveyor. Homebase is compiling and sharing data on how closures of businesses are impacting local communities and hourly workers. Gen1e is in the early stages of development of a drug for ARDS (acute respiratory distress syndrome), the primary cause of death from COVID-19. Model No, a related company, is working directly with Stanford and UCSF to develop an Aerosol Box. Based off a design from Taiwanese doctor Hsien Yung Lai, it's a clear plastic box that can be placed over a patient when intubated. This is a high-risk procedure for the doctor, for they are very likely to be exposed directly with droplets to their face, and the preferred full-ventilated suits for protection are in very short supply.

As always in startup land, not all of these will work, but some will and could have a significant impact. The nature of startups allows them to try avenues that would take too long in established companies, as they are more able to quickly pivot and shift resources in new directions, which will be especially critical in the pandemic landscape. We're proud of our companies' efforts in combating this pandemic, and celebrate all startups helping in this effort, be they in our portfolio or not. These are the companies in our portfolio but many more startups outside our portfolio are also trying to contribute in significant ways.

We strongly believe the startup community can bring a unique view and skillset to ameliorating this pandemic, and in this time of national crisis, it is important to bring to bear the best each sector of society has to offer.

\*This is by no means a comprehensive list, merely a quick snapshot of companies, and we apologize for any omissions of projects in our portfolio that are also contributing to the effort. In this list we prioritized companies that can have an impact within 2020.

Article: REINVENTING TRANSPORTATION

Section 6 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Key drivers: Driverless technology, electric cars, reimagined public transportation, batteries, dedicated self driving public transit lanes, mobile hailing and scheduling solutions.

From public transportation to flying cars... it can all be reinvented. When you take the cost structure of an Uber, multiply its usage by 5–10X in any given city, assume cars that are used 100,000–200,000 miles per year (amortized as a few cents per passenger mile serviced over its million mile designed life) instead of 12,000 and as a result operating costs become much more important than capital costs. Thus, electric cars become much more cost effective. Interest and maintenance costs decline because of scale, and the cost of the driver disappears because of driverless technology. At the moment, the driver is the largest part of a Uber, Lyft, or taxi service and would approach a few cents per passenger mile. Scheduling, hailing, and other operations are automated through intelligent AI and mobile devices. It becomes hard to see how owning a car makes sense except for a small fraction of the population.

Cars remain a thing for car enthusiasts. However, besides special use cases for the vast percentage of passenger miles cars, trains and public transportation will be reinvented. We could have public transportation in smart cities, enabled by clever legislation, point to point on demand. All that dramatically reduces cost for cities and citizens. Batteries and electricity would be the main cost per passenger mile. These pods, given the service time, will need to be electric, which incidentally lowers carbon per passenger mile for cities that are carbon sensitive about their electric supply. It also means higher reliability because of fewer moving parts.

Pods will be less prone to crashing. Hence, they will be lighter and cheaper, which will allow them to go much further on a kilowatt hour of electricity, reducing battery costs. A light bicycle is 17 pounds. Would a four passenger pod that can be frequently recharged need more than a few hundred pounds to carry 1,000 pounds of four people? Electricity cost would be very small at 50–100 pounds per person for each mile. One could summon specialty pods for wheelchairs or other specialty loads. For forward-looking cities, we may see these as anywhere to anywhere on demand public transportation for a few dollars or maybe near free!



Parking lots and spaces could be replaced by parks or housing, or commuter lanes. Commute distances may expand, housing may get cheaper, and environmental pollution decline. Driverless car technology may kill the combustion engine and set the oil industry in permanent decline. Cities could be redesigned to work differently, especially if one adds communications technology. The number of cars could decline five fold or more. The need to natural resources like steel, rubber and plastics decline concomitantly.

Automobiles as a large part of GDP could change dramatically. Even trains could become autonomous pods on roads or tracks, dispatched on demand, instead of being enormous beasts (the 100,000 pound cabins that go empty much of the day) that only make economic and climate sense when fully loaded and whose schedule is limited by when they can carry a breakeven number of passengers. A key metric might be average pounds and costs of material required to carry a human. Ideally, we start with key arteries. Let's take the airport to the strip section of Las Vegas and reimagine it as a driverless-only free service; then, let the service spread organically from there, with more reserved streets to offer anywhere to anywhere public transportation on demand, which could be cheaper than today's transit tickets and more economical for the city. More and more of the city streets might become driverless and public utility only, much like today's "reserved lanes" in a city like San Francisco. Cities will have increasing incentive to make more of the publicly paid for streets driverless only for public "transport pods" only.

And if residents of a city get closer to their destination, they might even walk the last half mile, which could have beneficial influence on their health. Incidentally, with the increasing number of driverless pods, the "reach of the city" or distance possible within a certain fixed commute time will increase. Thus, it can ease housing shortages and improve housing affordability. Parking land would be freed up for parks and low-cost housing. The city without automobiles would be a different animal. To understand what drives cities check out [A Physicist Solves the City!](#)

The pattern of adoption is not yet clear. The rate of adoption will depend upon how the technology is targeted at social solutions. It might happen first on elder care communities, with free taxi service to avoid the disadvantages of having average age 70 drivers and enable everyone in age restricted communities to have more freedom.

On the other hand, it may be an incentive to make affordable housing more prevalent by guaranteeing a certain commute time with free service in dedicated lanes from certain communities to work centers? Or it may be used in order to relieve traffic congestion in cities like inner London; offering near private point to point convenient and affordable service can

render private transportation unnecessary. Another likely development is to relieve truck drivers of tedious jobs by letting driverless trucks ply the freeways and the drivers to take over when off the freeway? Adoption and social acceptance in my view will have a huge path dependence and a range of adoption options are available.

**\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).**

Article: THE TECHNOLOGY SOUP

Section 5 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Fundamental reinvention has never been more possible than it is today. There are a range of new recent technological axes of development that give me hope. Driver technology tools that are plausible and visible today are:

AI & large scale data capability

Robotics

Additive manufacturing / 3D printing

Biotechnology (ohmic measurement, CRISPR, gene synthesis, precision control of genes, pathways...)

Computational design, computational modelling/simulation & computer networking

Social connectivity & networking; distributed access

Software eating the world

Blockchain

Other new still fermenting ideas I have surely missed or underestimated

Artificial Intelligence

AI will, inevitably, change the structure of our society. This is not a statement about exciting future technical developments, but merely an observation about what is ALREADY possible now, although has not yet achieved widespread adoption. The rate of change of new AI capability, the building block for changing businesses and human activity, is very rapidly expanding.

Fundamentally, we are now able to achieve human-like (and occasionally super-human) performance on tasks that were, just a few years ago, regarded as completely out of reach of machines. Probably the greatest example here is computer vision. It was stagnant for decades, but has made so much progress in the last years we can now have computers classify images and videos with super human performance, provided we have enough training data in the domain, be it face recognition or reading MRI images. The same is becoming true in recognizing human speech and even generating voice, or reading someone's mood or mental health status from their voice in superhuman ways. Just thinking about machines with the capability to understand vision and recognizing voice by itself, will fundamentally change how we think of work in general and what our interface with machines will look like in the future.

That being said, there is likely an even greater progress possible near term. Currently, the best performing AI systems require huge amounts of data to train to human-like performance. However, work is underway to reduce this burden in various domains; often all is needed are humans being to feed just a few examples to guide the neural nets. This will enable us to apply AI to domains where little data exists or the data is hard to get for structural or legal reasons, greatly widening the applicability of AI in all business and societal processes.

Model-building of the world as humans do is another dimension of innovation; an AI may be able to predict how much force would knock over a glass of water. AIs are also learning fast from the world of simulations and games. I suspect the lego blocks of types of intelligence will expand from a few (names like CNN's, RNN's, GAN's, to more recent additions like probabilistic programming, Bayes nets (redone), graph models, .... to all kinds of new capability hard to predict or name today) to many different types of intelligences capable of being combined to do unusual things; much like lego blocks can enable building very complex structures compared to the original red and yellow blocks.

It is not only the ability of AI to "judge" and recognize images and audio that is a driver here. We are now on the cusp of having AI generate images in a domain, at high resolution, and high quality that mimic art or any desired input distribution. The same now goes for music, where we can create AI that can mimic and improvise play in any style. "Creativity" used to be one of the standard answers to the question of what humans are uniquely good at that machines can never do. Nonetheless, it looks increasingly doubtful that even that claim is irrefutable. One day, we might see a short film, generated solely by an AI, or a top ten hit that never had a human composer.

One last comment that should make us quite hopeful about the accessibility of these technologies is that most of the fundamental breakthroughs have been out in the open, published, and discussed publicly. Yes, AI talent is hard to come by today. At the same time, it is also one of the most popular areas of study these days, and sooner or later this challenge is going to be overcome. Coupled with high-quality frameworks for AI research and deployment now being freely available as open source, rapid progress on both research and applications is at hand.

In a talk to the National Bureau of Economic Research on "Economic Implications of AI," I looked at the top twenty employment categories in the US and concluded most jobs in most of these categories would be eliminated or change substantially for humans. Technology will reallocate where and how people spend time and resources. We will have great abundance, growing productivity, and GDP but with increasing income disparity. Further, changes will be slow, almost imperceptible in terms of employment the first five or ten years, and take decades before going exponential in actual number of jobs impacted. But by the time the first 5% of jobs are impacted, the future will be inevitable.

## Robotics:

The renewed interest in robotics is, to a large extent, similar to the renewed interest in AI. As a society, for a long time we had robots that were amazingly durable, amazingly precise, but fundamentally were just acts of good mechanical engineering and careful motor control. This was enough to solve manufacturing tasks in very structured environments where all parts have defined positions and the manufacturing line does not change rapidly. A core example here is the chassis production of cars, which has little human involvement today; but come to sorting eggs by size and grade, and only human assembly line workers could do that.

The new part in robotics deals with robots that can make decisions in a largely unstructured environment. Probably the most discussed example of this today are self-driving cars that have to make decisions in the real world and not in a defined, pre-planned environment. But there are other, equally broad implications on the horizon. A company struggling with automation due to dealing with soft materials and rapidly changing product mixes right now faces large costs of automation. However, the next generation robots might change this.

The main driver for this is two-fold. One is straightforward, it is simply the availability of very low-cost, high-resolution sensors, in particular camera systems and 3D acquisition technologies. The other boils down to the fact we can now interpret vision and 3D data by learning from examples, instead of having to hand-code the rules. Reinforcement learning, learning from simulation, and understanding how to reduce the training samples required are the core elements of modern robotics.

Those robots are a very different breed from the old, and the trade-off space will be vastly different. Formerly, we got precision from adding tighter motor control or heavier arms.. This new class of robots have cheaper, lighter arms and still get the precision back by relying on visual servoing. In essence, it means the vision system is able to correct the robotic arm as it gets close to the object we wish to manipulate. A robot arm capable of doing human tasks should not weigh any more than a human arm does and then scale sub-linearly from there. This makes this next generation of robots cheaper, able to handle very flexible tasks, and deal with environments that have been thought as impossible in robotics before.

From a societal and economic perspective this enables a completely new way of thinking about production lines. Proximity to the end-customer, thus, becomes more important than the availability of cheap labor for menial tasks in unstructured environments or the need for scale.

This is especially true when combined with new technologies like 3D-printing. Custom, personalized, and local may become economically better in areas like producing jeans, sofas and beds or many types of fresh food.

### Additive Manufacturing/3D printing

Additive manufacturing, in essence printing objects instead of manufacturing them traditionally, has already made inroads in multiple areas. It consists of a family of technologies that can manufacture polymer parts to high-density metal parts. Even composites are being 3D-printed. The current beachheads for those technologies have been largely in design and prototyping environments. This means shortening the design cycle as we can almost instantly have a prototype part; it has actually already become a standard feature for many industries.

This is, however, changing. We are seeing more and more production parts made by additive manufacturing. Using these techniques to create performance critical parts that are not manufacturable with traditional methods is already becoming commonplace. Examples here include turbine parts, rocket engine components, and implants. This acts as the key catalyst to move the industry from using the technology for prototyping to a manufacturing regime. We climb down the cost curve as an ever greater number of parts that used to be hard to customize, not buildable at all, or consisted of multiple assemblies, can now be built with these machines.

We are now tackling some of the fundamental limitations of the technology, such as cost per part, materials we can use, removal or avoidance of necessary support structures to make this family of technologies even more widely applicable. These technologies, in turn, are also changing conventional wisdom like benefits of scale, locations, and schedules for manufacturing, supply chains, spare parts, or maintenance. Do we need to make shoes in China for US consumption or can they be 3D-printed locally and customized to each foot? Do we need to stock every spare part for a Boeing 727 in every airport in the world? Should it take six months to get a sofa manufactured in China only to see it does not fit in your small studio apartment?

This has significant consequences for the way we think about complexity in our design. If complexity becomes in essence free, that is not tied to manufacturing steps, our possible design space explodes. In particular, if manufacturing complexity is not the bottleneck anymore, designing structures will be the new bottleneck. Instead of designing by hand, we will likely create them by specifying the input loads and tasks. Optimization software will process the data

to create structures looking a lot more organically than now and producible ONLY by additive manufacturing.

## Computational Design / Learning Physics

In design of objects we have long used computer tools from EDA tools for the electronics industry to CAD tools for physical objects and from simulations for verification of performance of the designed objects.

We are now moving into a regime where the actual act of designing a structure is now becoming part of the duty of our tools and humans act more as a trainer, judge and specifier of external conditions. And even those roles may change to just specifying goals given constraints and preferences. Let's take designing a structure for an aircraft. It has to fulfill various structural loads and remain as light as possible at the same time. We are now capable to let the algorithms decide the design to minimize weight and specify the external loads. This has been possible before via optimization procedures, but unlike before, we can "learn" from past successful designs and guide the search space.

In no place is this more apparent than in the design of drug targets. Instead of running quantum simulations to understand the binding of molecules to targets, a slow and costly procedure, we can now learn from past binding data to automatically come up with novel designs that might be good candidates for a new drug. A general principle behind it being that even though we often understand the underlying physics of what we are trying to design, the exploration process is too costly to run by brute force exploration of the design space. Learning from past successful designs, be they molecules designed for a target, physical objects, or different layouts on a circuit board, allows us to meaningfully change the performance of these objects. We may soon see a new range of computationally-designed materials beyond copper, steel, and aluminium alloys for everything, from medical devices to body organs to your car and sofa.

## Biotechnology/CRISPR

Innovations in biotechnology might be grouped into three different levels: measurement, understanding/modeling, and modification. Our ability to measure biomolecules at continually higher resolution and in greater bandwidth is enabling steady improvements of our

measurements of individual organisms (like humans), but also groups of organisms (from the microbiome of a human gut to the complex commensal relationships of organisms in a coral reef or in a patch of forest floor). This amount of data acquisition these days is extremely complex and high-dimensional. Currently, only AI is able to create accurate predictive models and, thus, an efficient form of understanding the data. This, however, requires considerable advances in data storage and analytics. The third element is in the increasingly advanced and precise toolkit being developed for editing biology down to a single molecule. Tools like the Cas family of CRISPR associated proteins are enabling very specific, rapid editing of DNA, the blueprint for most of what we consider living things.

George Church has likened studying the diversity and complexity of biology to an advanced alien civilization leaving all its technology in our backyard for us to analyze. Biology has been able to create the machinery to very efficiently convert wide ranges of energy from one form to another. It is able to harness that energy into vast abilities to transmute forms of matter. This alchemy of biology still produces the vast majority of materials of interest to humanity. We are developing a deep control of the machinery of biology, which is just as crucial as the initial domestication of plants and animals thousands of years ago. Synthetic biology will impact chemicals and materials, energy, and human and animal editing, which will have great economic and societal implications.

Food products and pharmaceuticals are largely the result of biochemical processes. Basic components of our environment, like the oxygen we require to breathe, are the result of biological processes. Changing these systems with tools like a shovel or hammer would be impossible. However, we are gaining the potential to have molecular level control of all living things, giving us powerful new ways of combating issues like food security or climate change.

If human history has been a push to control the world for human good, then we are at the start a major new type of development. This process started with the quest for gaining control over environmental exposure by development of fire, buildings, and clothing; extending to gaining control over supply of food and materials by domestication of plants and animals, efficient agriculture, creating mining and mineral extraction and the industrial revolution; and then recently gaining control over information and data through the development of language and literacy to modern methods of data transmission, storage, and analysis. For the first time, we are gaining control over modifying ourselves directly.

The tools for editing DNA are only the first step in modifying the physiology of an adult living being. In order to do this, we have to target the cells and tissues we want to address specifically.



Nevertheless, technological development in that direction is ongoing. We are also developing the ability to modify cells that can be introduced into the body with new genetics and designed molecular biochemistry or to modify and edit embryos prior to their implantation. We are learning to genetically modify a pig embryo to produce human compatible organs for transplantation. We can change our body composition, but we may also decide to edit ourselves from the very start. In terms of editing human embryos directly, we as a society need to determine how we want to use this technology; there are clearly many opportunities for improving health and wellness.

One of the more promising avenues is to capture human knowledge in biomedicine, reconcile inconsistencies automatically, and be able to simulate at the molecular level every pathway and all omics in the body computationally. This could lead to true understanding of normal and deviations from normal, the usual definition of disease. Drugs and their effects on a particular person could be modeled and dosages calculated. The possibilities for human or animal biology management are exciting though impossible to specifically predict if we develop this capability.

## Social Networking

Social networking has changed our access and rate in which we access communication and how we collaborate. It has spurred new ideas and influenced the way we think about democracy. It has democratized information in a way that enhances education and new ideas. Twitter, as an example, has changed how we get news. It has influenced the end of regimes, and depending on the point of view, has had a positive or negative effect on politics. Social networking is a powerful tool that has allowed people to have a voice and connect globally. Slack, has brought social networking to industries and enterprises. It enabled more voices to collaborate and be heard, and helped making processes and businesses more efficient.

Like anything great, social networks can have negative and positive implications on the world. They are undoubtedly a powerful tool to both spur innovative ideas and, influence them to get traction. They allow to aggregate opinion, to get feedback for product designs and product reviews, and to have new channels of democracy (and it's subterfuge). Scientific social networks accelerate communication and collaboration and increase the rate of progress or discussion. There are many ways in which industrial progress is leveraging these social tools. This tool is speeding the pace of change and innovation across key areas like education, health, and government.

## Blockchain

The Internet and cryptography, the blockchain was created, which most notably has given rise to a distributed ledger — cryptocurrencies like bitcoin. This will be critical axes of innovation that will enable new businesses and paradigms from taking place, whether it be smart contracts, rethinking workflows, food traceability, medical records, blockchain will be a new way to use technology to rethink complete industries, like the financial system. When Haiti was hit by the hurricane, many or most of the records were lost. Blockchain, as an example, could allow people, businesses, and governments to rethink how they are storing and using their data, such as documents, information, payments.

Old tools that still have impact...

The “older technologies will continue to be axes of innovation that continue to have impact and provide benefit include:.

Software

Computing & cloud computing

Internet

Sensors & cameras

Mobile

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: WHAT CAN BE REIMAGINED AND REINVENTED?

Section 4 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Let’s take a closer, albeit speculative, look at possible ways in which these, so revolutions fundamental to a better world imagined by many of us and the economists, might happen. While other definitions of “better worlds” are possible, that is something left for a different discussion.

Where could a single entrepreneur driven by passion and a vision enter the market with simple products and drive to much larger scale over twenty years or so? Remember that twenty years ago in 1997 Google didn’t exist, and neither did Facebook. Media had not felt the push of Facebook, Youtube, Twitter. Amazon was very nascent and not yet starting to reinvent retail. Apple was under traditional “proper management” struggling to survive, while Uber, AirBnB, Pinterest were not even glimmers. Phones were made by traditional institutions like Motorola and Nokia, the mobile phone as we know it did not exist, and the Motorola and Nokia phones were mostly used for “talking.” There was no “app for that”.

I was personally ridiculed when I suggested then that the Internet should not be ATM protocols but rather TCP/IP. In fact, Juniper Networks was the only company committed to building TCP/IP Internet protocols for the public Internet (No, Cisco was building routers for the Internet but had bought an ATM protocol company that would be their public Internet network play). Going further back through my career, in 1985 the idea of a computer in every home was considered absurd, grandma using email in 1990 was thought ridiculous, and the Internet was a crazy idea and never going to be an important public network in 1995.

Change happens but is not credible until after the fact. Retrospective predictability by pundits is common, but until large change happens one sees mostly skepticism. I have hence come to believe in the power of ideas driven by entrepreneurial energy by almost foolish, somewhat naive entrepreneurs, by those who didn’t know what could not be done. Almost no major change is driven by institutions that one would expect to have power to cause that change! Did Walmart innovate retail or Amazon? Did Boeing/Lockheed innovate space or SpaceX? Did GM

innovate cars or Tesla and Waymo? Did Youtube/Netflix/Facebook/Twitter innovate media or NBC? Is there any area where a major innovation came from an institution?

What are the non-governmental components of GDP that can be re-imagined/reinvented with an entrepreneurial rather than a policy/legislative/regulatory approach?

Transportation & related city services

Health, disease diagnosis & management, drug discovery

Manufacturing, Construction, Buildings, building efficiency & cities

Food & Agriculture

Financial, insurance and legal services

Energy

Consumer consumption items, services, education, durable goods

\*\*This is a section from “Reinventing Societal Infrastructure with Technology”. To read the previous section, [click here](#).

Article: BEYOND THE ENTREPRENEUR, WHAT DOES IT TAKE?

Section 3 of “Reinventing Societal Infrastructure with Technology” which will be released end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

So imagine the possible in the many of the areas of interest and let’s imagine the axes and tools of innovation. The way I think about it is the greater the number of axes, that is the dimensions in which innovation is possible, and the better the tools for innovation, experimentation, and lower the cost of trials for ideas, the faster the rate of change. That means more the possibility of a surprise like an Amazon disrupting retail or Tesla or Google changing transportation with electric and driverless cars, respectively.

As an example, computers and computation as a tool allow for innovation in practically any field, be it in biology, space exploration, or information technologies. That was compounded by networking (of people, computers, and things) through the Internet which allowed the lowly landline phone to morph into today’s mobile which, paradoxically, is mostly used for everything other than talking. The device, though, impacted so many areas of our life. This was unimaginable even two decades ago at the birth of the Internet the Internet browser in 1993, even after its commercialization with the founding of Netscape in 1995.

So, what is in store for us for the next twenty years? It’s hard to forecast, but easier to speculate. It seems likely that 3D-manufacturing, artificial intelligence, biology tools especially new physics-based tools, biology fashions like CRISPR and it’s likely successors for precision biology and computational biology, along with traditional old standbys like increased computing and bandwidth will all form a soup which catalyzes many new ideas and reactions. Now, add to the soup the potential for new types of computing, like quantum computing, which might accelerate AI even beyond our wildest imagination. The possibilities become truly unpredictable. Here I speculate (I never claim to be able to predict anything) basing just on technology paths that seem plausible, even if they are improbable today. I don’t posit yet atomic level assembly of objects, but just using improvements in 3D-printing, AI, and basic quantum simulations. I am not imagining here completely new axis that will surely happen like broad quantum computing, fusion energy, or molecular assembly. There are many axes of innovation that are opening up so the next decade or two look promising. I won’t mention all of them here. There are some I expect but seem too speculative even for me. Others, on the other hand, I haven’t dreamed of, but are today being developed by smart people all over the world in research efforts.

To make it possible, you need new tools, a visionary and persistent founder, and evangelizing market participants. They must understand where this vision is going, and they need to be

convinced they need to come along and ultimately change, especially if it's radical innovation. For instance, automotive companies had little appetite for electric vehicles. Nevertheless, Elon Musk had both the vision and the determination to create electric cars and gain adoption; that allowed him to disrupt the automotive industry by building a better, more efficient car while paving the way for an autonomous future. For while it's still not universally accepted, it has taken convincing the likes of government regulators, financial institutions, technology thought leaders, media, and the general public to change behavior and ways of doing what they were doing. As Mahatma Gandhi said, "First they ignore you, then they laugh at you, then they fight you, then you win."

There are macrotrends, too. Marc Andreessen said "software eating the world" because it was the easiest way to describe what was happening. The same is happening with AI eating the world, as well as computational design, blockchain and 3D-printing. Some of the tools and axes of innovation defined below will end up being transformative, most likely this will be the case of AI, others will just be rapid facilitators. Older technologies, like mobile and Internet, will keep turbocharging these newer innovations.

\*\*This is a section from "Reinventing Societal Infrastructure with Technology" that will be released the end of January. To read the previous section [click here](#).

Article: ENTREPRENEURS, NOT INSTITUTIONS, DRIVE BIG INNOVATION

Section 2 of "Reinventing Societal Infrastructure with Technology" which will be release end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

Just a quick look at things not-imaginable by the institutional view. All you need to do is look back to 1995 and imagine the Internet upending telecom and all that has happened since. AT&T Wireless was sold to Cingular (formed only in 2000) for \$40 billion in 2004 (technical details were more complex) and Whatsapp was sold for half the price to Facebook a decade later, because AT&T was slow to adapt to cellular and the Internet (they insisted that TCP/IP, the core protocol of the Internet was not appropriate for public networks and ATM was their technology of

choice). The rest of AT&T was purchased during its decline by SBC, the parent company that formed Cingular and the AT&T brand remains as it was adopted by SBC. Amazon upended Walmart with clear vision of changing choice and cost structure that Walmart could not imagine. Now, Amazon, along with Netflix, Youtube, and others are upending Hollywood and television. Over the last decade, Netflix has reinvented TV/entertainment, and Facebook/Youtube/Twitter reinvented media, maybe even elections & politics! And speaking of elections, Trump re-invented political campaigns using Twitter as his hysterical tool against a well-managed proper political campaign. Google upended libraries, media, and many undefined industries.

Google and Facebook's success, in fact, reduces GDP as it makes previously valuable tasks free! Even institutional measurements of our goals like GDP are being upended. Cellular is dominating over landlines. The iPhone, barely existed ten years ago when the venerable Nokia and Motorola ruled the mobile phone world. Uber reinvented the limousine service and the taxi service, and it will likely drive changes to public transportation. AirBnB is starting to change hotels, or at least a subset of that market. Instagram and Google Photos invented or reinvented the way we take, manage, and share memories in our lives. Why is non-institutional invention so necessary? Most people in business reduce the risk of failure to the point where the consequences of success are inconsequential on society, but they can make money for their shareholders as they are obligated to. My philosophy is different. I'd rather invest in something with a higher probability of failure if the consequences of success are consequential. There is as much profit and increased social impact to be gained here, although with a higher variability. As I like to say, my willingness to fail gives me the ability to succeed. That is the exact opposite of how incentives are usually set up in larger, non-founder led institutions. Structure, processes, key metrics, and compensation incentives at large institutions oftentimes have the opposite effect to the expected one, actually fueling and attracting risk aversion for true innovation. Without risk and its concomitant failure, large innovation is just the matter of luck.

We have incumbents and institutions and pundits predicting more of the same "extrapolation of the past to predict the future" world view. Some are well meaning, while others are driven by personal or institutional self interest. They are authoritative and mostly wrong when it comes to large changes or big innovations. There is a dissonance between them and technology entrepreneurs: The former believe improbable is not important, the latter think similarly of the status quo. Personally, I think only the improbables are important, but we just don't know which one is.

It is only improbables that are important. We just don't know which improbable is the next Facebook or Google or Apple or Uber or Twitter or AirBnB or [insert company]. In all cases, however, an entrepreneur-driven vision of the unreasonable possibility is important. Although

Amazon, Google, Facebook, and other driver entities are big companies, they are not institutional yet. They still driven by founder vision. They are not sensible as business school professors would have them be, otherwise Amazon would not buy Whole Foods or Google develop driverless cars. These founder-driven companies don't teach focus, market segments, or classical approaches. Instead, they teach "why not?" and "why not try it?" be it Alexa, AWS, space, driverless cars... We are most limited by our thinking, NOT by what is actually possible, so we must be taught and reinforced to think beyond our normal patterns.

\*\*This is a section from "Reinventing Societal Infrastructure with Technology". To read the previous section, [click here](#).

Article: WE NEED LARGE INNOVATIONS

Section 1 of "Reinventing Societal Infrastructure with Technology" which will be release end of January. I will be posting a new section daily. Please share your feedback as this is a work in progress.

"What can be imagined technologically can be invented" is more true than not. Technology has always shaped the human world and currently it is disrupting the way people work, live, and associate by providing radically new tools. New technologies are rewriting human aspirations. Innovations in the areas of clean energy, food technology, digitization, robotics, artificial intelligence, 3D-printing, transportation have the potential to prevent climate change, achieve food abundance, reshape cities, knit humanity, and enhance human capability exponentially. But the future, as William Gibson wrote, isn't evenly distributed. Some areas are making rapid progress while others need turbocharging!

Entrepreneurs are leveraging technology to reinvent the big needs in society, food, health, housing, transportation, financial services, entertainment, and more in a more democratic and accessible way though here again broad accessibility needs more turbocharging. The mechanism of invention by the "drivers of reinvention" mostly capitalism and entrepreneurship, tends to focus the drivers on shorter term profit maximization (as it should be for them to survive and flourish) rather than societal good maximization, generally. The power of ideas driven often by



technology and entrepreneurial energy are laying by the wayside institutional views about society's providers. What seems most exciting is that many of society's GDP and business-related needs are being reinvented everyday, and all that is done in a very innovative and non-institutional way.

Non-institutional reinvention is a powerful means of increasing innovation and eventually accessibility. It all comes down to the fact institutions look back on the past to predict the future, instead of reinventing the futures the way entrepreneurs are able to. Such approach, perhaps optimistically, may provide us resources and time to address other pressing societal need, such as socio-emotional or environmental.

Approximately seven hundred million people have the resource rich lifestyle (environment rich, energy rich, housing rich, health care rich, education rich, food rich ) that seven billion people on this planet want. Technology, innovation and invention are necessary, even if not sufficient by themselves, to make this happen. And what we really need are dreamers that can imagine the impossible and make it happen. Instead of being pragmatic, such people ask "why not?" and with their entrepreneurial energy try and make these dreams come true.

What comes next for reinvention? Public transportation? Construction? Buildings? Healthcare? Food? Cities? Communications? Companionship? Elder care? Space? Financial system? What entrepreneurs do is they imagine what feels impossible to most people, and take it all the way from impossible, to improbable, to possible but unlikely, to plausible, to probable, to real!

The key is individual entrepreneurs and their passion for a vision and no matter how ludicrous their idea might seem, they give the improbable a shot. Of course, one needs tons of good luck, and many, probably most, of these attempts will fail. The press and other critics will have a field day and denigrate them for hubris, arrogance, fraud, naivety, and worse. However, it is these improbable attempts that will, when they occasionally squeak by the "wall of existing reality and institutional noise," change the world for the better (hopefully mostly for good, though not without some collateral damage or consequences).

Looking back in twenty years the pundits, reports, studies, consultants will be largely wrong about the future of societal changes. I shiver every time I see a UN Report, a McKinsey report, an econometric projection going beyond the span of five years, especially coming from those pundits who have never done much themselves except pontificate... The future is not knowable,

but it is inevitable and inventable so we need great entrepreneurs and technologists to invent the future.

#### Article: 2017 BOOK RECOMMENDATIONS

Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies: The physics behind biology, cities, economics and companies. Do they grow, scale and die by the same math equations? New insights that are enlightening and delightful.

Lying : One of my favorite one hour reads about intellectual honesty. I wish more people were this honest!

Behave: The Biology of Humans at Our Best and Worst: Among the best insights into our brain and behavior. A top of the charts for me for this year, along with Scale.

Homo Deus: A History of Tomorrow: Not that I agree with all of it, but it is still mind-bending speculation about our future as a follow-up to a previous favorite, Sapiens. It's directionally right.

Eating the Big Fish: How Challenger Brands Can Compete Against Brand Leaders: Brand building for entrepreneurs trying to upset the incumbents. One of the few "how to" books I enjoyed.

The Brand Flip: Why customers now run companies and how to profit from it (Voices That Matter): Wish all books maximized learning per hour of reading time. A very well done book on branding and new brand values. It will be the death of many incumbents.

Dunk Tank Pink: And Other Unexpected Forces That Shape How We Think, Feel, and Behave: Fun read about our biases and how our brain functions.

Case Against Sugar : Not surprising but explicit description of the American psych on sugar and fat by the sugar industry. I would not have believed this much influence is possible.

Your Brain On Music: The. Science of a Human Obsession: Fascinating though older book.

Against Empathy: The Case for Rational Compassion: Surprising, but will feel very obvious to the rationalists. A good case against too much empathy.

McMafia: A Journey Through the Global Criminal Underworld: Fun though older book.

From Bacteria to Back and Back: The Evolution of Minds: Another of my favorites this year. Long but worth every page.

The Last Days of Night: I don't read fiction, but this almost historical fiction is fun especially for Silicon Valley types.

Astrophysics for people in a hurry: Great, very quick overview of astrophysics. Easily accessible.

The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World: If you want speculation about what the master AI might need (one view). For a slightly more technical read, I'd suggest Ian Goodfellow's Deep Learning.

Mindfulness in Plain English : Easy access to meditation

Other People's Money: Inside the Housing Crisis and the Demise of the Greatest Real Estate Deal Ever Made: Not very far from the truth on the financial services industry though the authors' biases come through. Not all correct (in my view), but still worth reading.

## Article: AI: SCARY FOR THE RIGHT REASONS

Artificial intelligence, AI, has grabbed headlines, hype, and even consternation at the beast we are unleashing. Every powerful technology can be used for good and bad, be it nuclear or biotechnology, and the same is true for AI. While much of the public discourse from the likes of Elon Musk and Stephen Hawking reflects on sci-fi like dystopian visions of overlord AI's gone wrong (a scenario certainly worth discussing), there is a much more immediate threat when it comes to AI. Long before AI goes uncontrollable or takes over jobs, there lurks a much larger danger: AI in the hands of governments and/or bad actors used to push self-interested agendas against the greater good.

For background, as a technology optimist and unapologetic supporter of further development, in 2014 I wrote about the massive dislocation in society AI may cause, and while our economic metrics like GDP, growth, and productivity may look awesome as a result, it may worsen the less visible, but in my opinion, far more critical metrics around income disparity and social mobility. More importantly, I argued why this time might be different than the usual economists' refrain that productivity tools always increase employment. With AI, the vast majority of current jobs may be dislocated regardless of skill or education level. In the previous industrial revolution, we saw this in agriculture between 1900–2000, when it went from a majority of US employment to less than 2%, and in industrial jobs, which today are under 20% of US employment. This time, the displacement may not happen to just lower skill jobs — truck drivers, farm workers and restaurant food preparers may be less at risk than radiologists and oncologists. If skilled jobs like doctors and mechanical engineers are displaced, education may not be a solution for employment growth (it is good for many other reasons) as is often proposed by simplistic economists who extrapolate the past without causal understanding of reasons why. In this revolution, machines will be able to duplicate the tasks they previously could not: those that require intellectual reasoning and fine grained motor skills. Because of this, it is possible that emotional labor will remain the last bastion of skills that machines cannot replicate at a human level and is one of the reasons I have argued that medical schools should transition to emphasizing and teaching interpersonal and emotional skills instead of Hippocratic reasoning.

We worry about nuclear war as we should, but we have an economic war going on between nations that is more threatening. The pundits like Goldman Sachs advocate internationalism because it serves their interests well and is the right thing if played fairly by all. And though the wrong answer, in my view, is economic nationalism, the right answer goes far beyond just a level playing field. While Trump-mania may somewhat correctly stem from feelings of unlevel playing fields in China, the problem is likely to get exponentially worse when AI is a factor in these economic wars. This problem of economics wars will likely get exponentially amplified by AI. The

capability to wage this economic war is very unequal among nation states like China, USA, Brazil, Rwanda or Jordan based on who has the capital and the drive to invest in this technology. As it's mildest implications, left to its own devices, AI technology will further concentrate global wealth to a few nations and "cause" the need for very different international approaches to development, wealth and disparity.

I wrote about the need to address this issue of disparity, especially since this transformation will result in enormous profits for the companies that develop AI, and labor will be devalued relative to capital. Fortunately, with this great abundance, we will have the means to address disparity and other social issues. Unfortunately, we will not be able to address every social issue, like human motivation, that will surely result. Capitalism is by permission of democracy, and democracy should have the tools to correct for disparity. Watch out Tea Party, you haven't seen the developing hurricane heading your way. I suspect this AI driven income disparity effect has more than a decade or more to become material, giving us time to prepare for it. So while this necessary dialogue has begun and led to the ideation of solutions such as robotic taxes and universal basic income, which may become valuable tools, disparity is far from the worst problems AI might cause and we need to discuss these more immediate threats.

In the last year alone, the world has seen some of the underpinnings of modern society shaken by the interference of bad actors using technology. We've directly seen the integrity of our political system threatened by Russian interference and our global financial system threatened by incidents like the Equifax hack and the Bangladesh Bank heist (where criminals stole \$100m). AI will dramatically escalate these incidents of cyberwarfare as rogue nations and criminal organizations use it to press their agendas, especially when it is outside our ability to assess or verify. This transition will resemble what we see when wind becomes a hurricane or a wave becomes a tsunami in terms of destructive power. Imagine an AI agent trained on something like OpenAI's Universe platform, learning to navigate thousands of online web environments, and being tuned to press an agenda. This could unleash a locust of intelligent bot trolls onto the web in a way that could destroy the very notion of public opinion. Alternatively, imagine a bot army of phone calls from the next evolution of Lyrebird.ai with unique voices harassing the phone lines of congressmen and senators with requests for harmful policy changes. This danger, unlike the idea of robots taking over, has a strong chance of becoming a reality in the next decade.

This technology is already on the radar of the authoritarian countries of today. For example, Putin has talked about how AI leaders will rule the world. Additionally, China, as a nation, has focused on very pointedly acquiring this powerful new AI technology. The accumulation of expertise beyond normal business competition and their very large funding directed here is a major concern. This is potentially equivalent to or worse than the US being the only nation with

nuclear capabilities when the Hiroshima attack was conducted. There was very little for our Japanese opponents to respond with. It is hard to say if this economic war weapon will be as binary as the nuclear bomb was, but it will be large and concentrated in a few hands and subject to little verifiability. Surreptitious efforts, given its great amplification potential, could create large power inequality.

Matters get worse if one realizes that major actors in AI development in the West, like Google, Facebook, and universities, have adopted a generally open policy publishing their technology approaches and results in scientific journals in order to share this technology more broadly. If individual state actors don't do that, and I doubt they will, we will have a one way flow of technology from the US. AI development in certain parts of the world will additionally have huge advantages because of policies against/for data. As Andrew Ng (a Stanford professor hired by massive Chinese company, Baidu, to lead it's AI efforts until he left to incubate his own ideas) has said, "Data is the rocket fuel for the AI engine". So while AI progress has been frenetic recently, it will be much faster when data privacy and occasional accidents are less important in the interest of "national security." This disregard for data privacy and one way transfer of technology will lend nationalistic countries like China and Russia a huge advantage in this generation's space race.

AI will be much more than an economic, business, or competition issue that it is talked about today. We will need to rethink capitalism as a tool for economic efficiency because efficiency will matter less, or at the very least, disparity will matter more, but that consideration may be many decades away. The biggest concern in the next decade is that AI will dramatically worsen today's cyber security issues and be less verifiable than nuclear technology. Nationalistic nations like China and thuggish dictators like Putin will have massively amplified clandestine power. I don't believe we, as a society, would be willing to give up the safeguards in our society like open progress and privacy to "keep up" with other nations. I have some thoughts as to what we can do here, but this is a complex problem without obvious solutions. Maybe we limit funding of non-NATO investors in US AI companies? Maybe having the US government or NATO invest in their own AI technologies for national security? An AI white hats force? Increased efforts in Black Swan developments like quantum computing? Less risk aversion, more patience, and less backlash from society and government to the risks, biases and shortcomings of new AI technology as it grows up? Regardless of what we do, what's clear is we need much more dialog, debate, and increased countermeasure funding; instead of generating hysteria about some far off dystopian possibility mired in uncertainties and what ifs, we need to focus on the immediate wave of danger before it hits. Not taking risks here might inadvertently be the largest risk we take.

## Article: IS MAJORING IN LIBERAL ARTS A MISTAKE FOR STUDENTS?

### Critical Thinking, Knowledge basics and the Scientific Process First — Humanities Later

If luck favors the prepared mind, as Louis Pasteur is credited with saying, we're in danger of becoming a very unlucky nation. Little of the material taught in liberal arts programs today is relevant to the future.

Consider all the science and economics that has been updated, the shifting theories of psychology, the programming languages and political theories that have been developed, and even how many planets our solar system has. Much, like literature and history, should be evaluated against updated, relevant priorities in the 21st century. There is more need for process thinking and model think than knowledge today in undergraduate education.

I feel that liberal arts education in the United States is a minor evolution of 18th century European education. The world needs something more than that. Non-professional undergraduate education needs a new system that teaches students how to learn and judge using the scientific process on issues relating to science, society, and business.

Though Jane Austen and Shakespeare might be important, they are far less important than many other things that are more relevant to make an intelligent, continuously learning citizen, and a more adaptable human being in our increasingly more complex, diverse and dynamic world. When the rate of change is high, what one needs in education changes from knowledge to the process of learning.

I am going to now suggest we call this basic education "Modern Thinking". I suggest universities introduce it as a much more rigorous and demanding version of traditional Liberal Arts for those not pursuing undergraduate professional or STEM education. Let's try and separate the old "get through college easily and leave time for partying" student set from those that want a rigorous education with many more demanding, broad and diverse minimum requirements. Let's keep the old and construct a new higher honors-like separate program with much more rigor.

The test for Modern Thinking would be quite simple: at the end of an undergraduate education, is a student roughly able to understand and discuss a broad set of topics like the Economist, end-to-end, every week. That covers everything economics, politics, literature, drama, business, culture and more. Of course, there are other surrogates for the Economist that would be just as valid if broad enough. This modern, non-professional education would meet the original “Greek life purpose” of a liberal arts education, updated for today’s world.

The most important things for a general, non-professional or vocational education are critical thinking, abstract model building, generalization skills and problem-solving skills, familiarity with logic and the scientific process, and the ability to use these in forming opinions, discourse, and in making decisions. Other general skills that are also important include — but are not limited to — interpersonal skills and communication skills.

So, what is wrong with today’s typical liberal arts degree?

Neither the old definition of liberal arts nor the current implementation of it is the best use of four years of somebody’s education (if it is to be non-professional — I am explicitly not suggesting everyone do STEM “profession” oriented degrees!). The hardest (and most lucrative, but that is less relevant here) problems to solve are non-technical problems. In my opinion, getting a STEM degree gives you the tools to think about those problems more effectively than a Liberal Arts degree today; though it is far from a complete way of thinking, and a Modern Thinking degree will do this in an even more complete form. If STEM was turned into a non-professional degree it’d teach more of the skills for this Modern Thinking education than a Liberal Arts degree AS PRACTICED generally does today. But Modern Thinking would go more directly at the education I’d recommend for non-professionals who want to operate at the highest levels of thinking.

Some of you will point to very successful people who’ve gone to Yale and done well, but you misuse or misunderstand statistics. A lot of successful people have started out as liberal arts majors. A lot haven’t. If you’re very driven and intelligent or lucky, you’ll probably be successful in life, even with today’s liberal arts degree. Then again, if you’re that driven and intelligent, you could probably find success with any degree, or even no degree. Apple’s Steve Jobs and Joi Ito (Director of the MIT media lab) are both college dropouts. Joi is a largely self-taught computer scientist, disc jockey, nightclub entrepreneur and technology investor and I think this diversity makes him better educated. The top 20% of people in any cohort will do well independent of



what curriculum their education follows, or if they had any education at all. If we want to maximize the potential of the other 80%, then we need a new Modern Thinking curriculum.

What I am discussing in this piece is the median student who gets through a liberal arts curriculum, excluding the 20% who I believe will do well no matter what education (or lack thereof) that they get. That means what I am concentrating on is “what actually happens to the median student” as opposed to “what is possible with Liberal Arts education” or “what Liberal Arts is supposed to teach”. I will add though that even the definition of what Liberal Arts SHOULD be needs updating for the modern world.

Yale recently decided that Computer Science was important and I like to ask, “if you live in France, shouldn’t you learn French? If you live in the computer world, shouldn’t you learn Computer Science?” What should be the second required language in schools today if we live in a computer world? My goal is not that everyone be a programmer, but rather that they understand programmatic thinking. And if you live in a technology world what must you understand? Traditional education is far behind and the old world tenured professors at our universities with their parochial views and interests, their romanticism and ossification of ideas will keep dragging them back. My disagreement is not with the goals of a liberal arts education but its implementation and evolution (or lack thereof) from 18th century European education and its purpose. There is too little emphasis on teaching critical thinking skills in schools and the grounding on which new knowledge, often technological, can be acquired, even though that was the original goal of such education. Many adults have little understanding of important science and technology issues or, more importantly, how to approach them, which leaves them open to poor decision-making on matters that will affect both their families and society, in general.

Connections matter and many Ivy League colleges are worth it just to be an alumnus. There are people with the view that Liberal Arts broadened their vision and gave them great conversational topics. There are those who argue that the humanities are there to teach us what to do with knowledge. As one observer commented: “They should get lawyers to think whether an unjust law is still law. An engineer should be able to contemplate whether Artificial Intelligence is morally good. An architect could pause to think on the merit of building a house fit for purpose. A doctor could be taught whether and how to justify using scarce medical resources for the benefit of one patient and not another. This is the role of humanities — a supplement to STEM and the professions.”

In my view, creativity, humanism, and ethics are very hard to teach, whereas worldliness and many other skills supposedly taught through the Liberal Arts are more easily self-taught in a

continuously updating fashion if one has a good quantitative, logical and scientific process-oriented base education. The undergraduate level (graduate level degrees are a whole different matter and should be specialised on areas of study) degrees I associate (with all my biases) as the more likely to be “easy courses so you can party degrees” in most US universities is mostly what I am discussing here.

The argument goes that a scientific/engineering education lacks enough training in critical thinking skills, creativity, inspiration, innovation and holistic thinking. On the contrary, I argue that the scientific and logical basis of a better Modern Thinking education would allow some or all of this — and in a more consistent way. The argument that being logical makes one a linear problem solver and ill prepared for professions that require truly creative problem solving has no merit in my view. The old version of the Liberal Arts curriculum was reasonable in a world of the far less complex 18th century Eurocentric world and an elitist education focused on thinking and leisure. Since the 20th century, despite its goals, it has evolved as the “easier curriculum” to get through college and may now be the single biggest reason students pursue it (There are plenty of students who take it for other reasons, but I am talking percentages here).

I do not believe that today’s typical Liberal Arts degree turns you into a more complete thinker; rather, I believe they limit the dimensionality of your thinking since you have less familiarity with mathematical models (to me, it’s the dimensionality of thinking that I find deficient in many people without a rigorous education), and worse, statistical understanding of anecdotes and data (which liberal arts was supposedly good at preparing students for but is actually highly deficient at). People in the humanities fields are told that they get taught analytical skills, including how to digest large volumes of information, but I find that by and large such education is poor at imparting these skills. Maybe, that was the intent but the reality is very far from this idealization (again, excluding the top 20%).

There is a failing in many college programs that are not pragmatic enough to align and relate liberal arts program to the life of a working adult. From finance to media to management and administration jobs, necessary skills like strategic-thinking, finding trends, and big picture problem-solving, even human connections and workforce management have all evolved in my view to need the more quantitative and rational preparation than today’s degrees provide.

Such skills, supposedly the purview of liberal arts education, are best learnt through more quantitative methods today. Many vocational programs from engineering to medicine also need these same skills and need to evolve and broaden to add to their training. But if I could only have

one of a liberal art or an engineering/science education, I'd pick the engineering even if I never intended to work as an engineer and did not know what career I wanted to pursue.

I have in fact almost never worked as an engineer but deal exclusively with risk, evolution of capability, innovation, people evaluation, creativity and vision formulation. Design is my personal passion far more than business. That is not to say that goal setting, design, and creativity are not important or even critical. In fact, these need to be added to most professional and vocational degrees, which are also deficient for today's practical careers.

More and more fields are becoming very quantitative, and it's becoming harder and harder to go from majoring in English or History to having optionality on various future careers and being an intelligent citizen in a democracy. Math, statistics and science are hard, economics, psychology and philosophical logic take effort, and school is a great time to learn those areas, whereas many of the liberal arts courses can be pursued after college on the base of a broad education. But without training in the scientific process, logic and critical thinking, and a basis of science, mathematics and statistics, discourse and understanding are both made far more difficult.

A good illustrative example of the problems of today's liberal arts education can be found in the writing of well-known author, Malcolm Gladwell, a history major and a one-time writer for The New Yorker. Gladwell famously argued that stories were more important than accuracy or validity without even realizing it. The New Republic called the final chapter of Gladwell's *Outliers*, "impervious to all forms of critical thinking" and said that Gladwell believes "a perfect anecdote proves a fatuous rule." This, in my opinion, is too often the way many Liberal Arts graduates (but not all) think. Referencing a Gladwell reporting mistake in which Gladwell refers to "eigenvalue" as "Igon Value," Harvard professor and author Steven Pinker criticizes his lack of expertise: "I will call this the Igon Value Problem: when a writer's education on a topic consists in interviewing an expert, he is apt to offer generalizations that are banal, obtuse or flat wrong." Unfortunately, too many in today's media are similarly "uneducated" in their interpretation of experts. Storytelling and quotes become a misleading factor instead of being an aid to communicating the accurate facts more easily. His assertions around "10,000 hours" may or may not be true but his arguments for it carry very little weight with me because of the quality of his thinking.

Though one example of Malcolm Gladwell does not prove the invalidity of arguments for a Liberal Arts degree, I find this kind of erroneous thinking (anecdotally) true of many humanities and liberal arts graduates. In fact, I see the inconsistencies that Gladwell failed to understand (giving him the benefit of the doubt that these were unintentional) in the writings of many authors of articles in supposedly elite publications like The New Yorker and The Atlantic. Again,

this is not a statistically valid conclusion but the impression across hundreds or thousands of examples of one person, me. When I do occasionally read articles from these publications, I make a sport of judging the quality of thinking of the writers as I read, based on false arguments, unsupported conclusions, confusion of storytelling with factual assertions, mistaking quotes from interviews as facts, misinterpreting statistics, etc. Similar lack of cogent thinking leads to bad decisions, uninformed rhetoric, and lack of critical thinking around topics like nuclear power and GMOs.

Unfortunately, in an increasingly complex world, all these topics skills that many liberal arts majors even at elite universities fail to master. The topic of risk and risk assessment from simple personal financial planning to societal topics like income inequality is so poorly understood and considered by most liberal arts majors as to make me pessimistic. I am not arguing that engineering or STEM education is good at these topics but rather that this is not its intent of STEM or professional education. The intent of Liberal Arts education is what Steven Pinker called a “building a self” and I would add “for the technological and dynamically evolving 21st century”.

Learning new areas as career paths and interests evolve becomes harder. Traditional European liberal arts education was for the few and the elite. Is that still the goal today? People spend years and a small fortune or lifelong indebtedness (at least in the US) to obtain it and employability should be a criterion in addition to an education’s contribution to intelligent citizenry.

Wikipedia defines “the liberal arts as those subjects or skills that in classical antiquity were considered essential for a free person to know in order to take an active part in civic life, something that (for Ancient Greece) included participating in public debate, defending oneself in court, serving on juries, and most importantly, military service. Grammar, logic, and rhetoric were the core liberal arts, while arithmetic, geometry, the theory of music, and astronomy also played a (somewhat lesser) part in education.” Today’s ideal list, not anchored in “classical antiquity” would be more expansive and more prioritized in my view.

Idealists and those who perceive liberal arts education today as meeting these goals are wrong not in its intent but in assessing how well it does this function (and that is an assertion/opinion). I agree that we need a more humanistic education but it is hard to agree or disagree with the current curriculum without defining what humanistic means. Does it really teach critical thinking, logic or the scientific process, things every citizen should know in order to participate in society? Does it allow for intelligent discourse or decision-making across a diverse set of beliefs, situations, preferences, and assumptions? And I believe we need to extend these goals to have

education form the basis of lifelong learning broadly across all areas in our increasingly technological and fast-changing world.

While one may argue that historical liberal arts education included what I am arguing for, the context for this education has changed. In the 21st century, with airplanes and societal mixing, the internet and global information and misinformation, artificial intelligence and a technology driven and challenged planet, with many more risks both local and global, the old definition needs to be adapted to the modern context. What we need for civic life today is far different than what's needed when liberal arts education originated.

I do think whether it is for employability or dealing with nuanced and ever changing issues like race or artificial intelligence, national borders or international citizenry, or the nature of work and politics, the ability to understand new areas or repurpose oneself over time should be a critical part of any education, especially an education like liberal arts not geared towards a particular profession.

Should we teach our students what we already know, or prepare them to discover more? Memorizing the Gettysburg address is admirable but ultimately worthless; understanding history is interesting, even useful, but not as relevant as topics from the Economist, unless history is used as a logic tool which it can be used as. A student who can apply the scientific process or employ critical thinking skills to solve a big problem has the potential to change the world (or at minimum get a better-paying job). They can actually debate a topic like #blacklivesmatter, income inequality or climate change without being subject to "Trumpism" or emotion and biases-based distortions.

While it is undoubtedly important to understand how others feel, think, etc., I don't believe the median student with a liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning.

No wonder half the college graduates who fill jobs as some studies indicate, actually fill jobs that don't need a college degree! Their degree is not relevant to adding value to an employer (though that is not the only purpose of a degree).

Further, even if an ideal curriculum can be stitched together, most liberal arts majors infrequently do it. If the goal is not professional education then it must be general education, which requires many more must-have requirements for me to consider a university degree respectable. Of course others are entitled to their own opinion, though the right answer is testable if one agrees that the goals of such an education are intelligent citizenry and/or employability.

For now, I am mostly leaving aside matters related to professional, vocational or technical curriculum. I'm also ignoring the not irrelevant and pragmatic issues of education affordability and the burden of student debt, which would argue for a more employment-enabling type of education. The failure I am referring to are two-fold: (1) the failure of curriculums to keep up with the changing needs of modern society and (2) liberal arts becoming the "easy curriculum" for those who shy away from the more demanding majors and prefer an easier, often (but not always) more socially-oriented college life. Ease, not value, or interest instead of value become key criteria in designing a curriculum for many students today. And for those of you who think this is not true, I am asserting based on my experience this is true for the majority of today's students, but not for every liberal arts student.

Not every course is for every student but the criteria need to match the needs of the student and not their indulgences, taking interests and capability into account. "Pursue your passion" even if it increases the probability of getting you into unemployment or homelessness later is advice I have seldom agreed with (yes there are occasions this is warranted, especially for the top or the bottom 20% of students). More on passions later but I'm not saying passions are unimportant. What I am saying is with today's implementation of a liberal arts curriculum, even at elite universities like Stanford and Yale, I find that many Liberal Arts majors (excluding roughly the top 20% of students) lack the ability to rigorously defend ideas, make compelling, persuasive arguments, or discourse logically.

Steven Pinker — in addition to refuting Gladwell — has a brilliant, clarion opinion on what education ought to be, writing in The New Republic, "It seems to me that educated people should know something about the 13-billion-year prehistory of our species and the basic laws governing the physical and living world, including our bodies and brains. They should grasp the timeline of human history from the dawn of agriculture to the present. They should be exposed

to the diversity of human cultures, and the major systems of belief and value with which they have made sense of their lives. They should know about the formative events in human history, including the blunders we can hope not to repeat. They should understand the principles behind democratic governance and the rule of law. They should know how to appreciate works of fiction and art as sources of aesthetic pleasure and as impetuses to reflect on the human condition.”

Though I agree, I am not sure this curriculum is more important than the ideas below. Based on the skills defined below any gaps in the above education can be filled in by students post-graduation.

So, what should non-professional elite education entail?

If we had enough time in school, I would suggest we do everything. Sadly that is not realistic, so we need a prioritized list of basic requirements because every subject we do cover excludes some other subject given the fixed time we have available. We must decide what is better taught during the limited teaching time we have, and what subjects are easier learnt during personal time or as post-education or graduate pursuits. If there are a hundred things we learn but can only study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is “base skill to learn other subjects from” versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs but base skills are harder to learn on your own.

In the new Modern Thinking curriculum I propose, students would master:

1. The fundamental tools of learning and analysis, primarily critical thinking, the scientific process or methodology, and approaches to problem solving and diversity.
2. Knowledge of a few generally applicable topics and knowledge of the basics such as logic, mathematics, and statistics to judge and model conceptually almost anything one might run into over the next few decades.
3. The skills to “dig deep” into their areas of interest in order to understand how these tools can be applied to one domain and to be equipped to change domains every so often

4. Preparation for jobs in a competitive and evolving global economy or preparation for uncertainty about one's future direction, interest, or areas where opportunities will exist.

5. Preparation to continuously evolve and stay current as informed and intelligent citizens of a democracy

Critical subject matter should include economics, statistics, mathematics, logic and systems modeling, psychology, computer programming, and current (not historical) cultural evolution (Why rap? Why ISIS? Why suicide bombers? Why the Kardashians and Trump? Why environmentalism and what matters and what does not? What study to believe? What technology evolution might happen? What has important implications? And of course the question, are the answers to these questions expert opinions or have some other validity?).

Furthermore, certain humanities disciplines such as literature and history should become optional subjects, in much the same way that physics is today (and, of course, I advocate mandatory basic physics study along with the other sciences). And one needs the ability to think through many, if not most, of the social issues we face (which the softer liberal arts subjects ill-prepare one for in my view).

Imagine a required course each semester where every student is asked to analyze and debate topics from every issue of a broad publication such as *The Economist* or *Technology Review*. And imagine a core curriculum that teaches the core skills to have the discussions above. Such a curriculum would not only provide a platform for understanding in a more relevant context how the physical, political, cultural and technical worlds function, but would also impart instincts for interpreting the world, and prepare students to become active participants in the economy.

Efficiency in undergraduate education matters given the wide array of subjects that need understanding, the inability to cover all of the subjects, and the constant change in what becomes more or less important or interesting to a person over time. It is for this reason I suggest that understanding the *Economist* on a weekly basis is important as it covers many diverse topics from politics to economics to culture, arts, science, technology, climate and global issues. A sufficiently diligent professor could in fact construct a more effective and efficient curriculum and hence the reference to the *Economist* was a short form for the concept of teaching broad understanding across a diversity of topics.



It would be essential to understand psychology because human behavior and human interaction are important and will continue to be so. I'd like people who are immune to the fallacies and agendas of the media, politicians, advertisers, and marketers because these professions have learned to hack the human brain's biases (a good description of which are described in Dan Kannehman's Thinking Fast & Slow and in Dan Gardner's The Science of Fear). I'd like to teach people how to understand history but not to spend time getting the knowledge of history, which can be done after graduation.

I'd like people to read a New York Times article and understand what is an assumption, what's an assertion by the writer, what are facts, and what are opinions, and maybe even find the biases and contradictions inherent in many articles. We are far beyond the days of the media simply reporting news, shown by the different versions of the "news" that liberal and conservative newspapers in the US report, all as different "truths" of the same event. Learning to parse this media is critical. I'd like people to understand what is statistically valid and what is not. What is a bias or the color of the writer's point of view?

Students should learn the scientific method, and most importantly how to apply its mental model to the world. Building models in our head is critical to understanding and reasoning in my view. The scientific method requires that hypotheses be tested in controlled conditions; this can diminish the effects of randomness and, often, personal bias. This is very valuable in a world where too many students fall victim to confirmation biases (people observe what they expect to observe), appeal to new and surprising things, and narrative fallacies (once a narrative has been built, its individual elements are more accepted). There are many, many types of human biases defined in psychology that people fall victim to. Failure to understand mathematical models and statistics makes it substantially more difficult to understand critical questions in daily life, from social sciences to science and technology, political issues, health claims, economics and much more.

I'd also suggest tackling several general and currently relevant topic areas such as genetics, computer science, systems modeling, econometrics, linguistics modeling, traditional and behavioral economics, and genomics/bioinformatics (not an exhaustive list) which are quickly becoming critical issues for everyday decisions from personal medical decisions to understanding minimum pay, economics of taxes and inequality, immigration, or climate change. E.O. Wilson argues in his book "The Meaning of Human Existence" that it is hard to understand social behavior without understanding multi-level selection theory and the mathematical optimization that nature performed through years of evolutionary iterations. I am not arguing that every

educated person should be able to build such a model but rather that they should be able to “think” such a model qualitatively.

Not only do these topics expose students to a lot of useful and current information, theories, and algorithms, they may in fact become platforms to teach the scientific process — a process that applies to (and is desperately needed for) logical discourse and social sciences as much as it applies to science. The scientific process critically needs to be applied to all the issues we discuss socially in order to have intelligent dialog. Even if the specific information becomes irrelevant within a decade (who knows where technology will head next; hugely important cultural phenomena and technologies like Facebook, Twitter, and the iPhone didn’t exist before 2004, after all), it’s incredibly useful to understand the current frontiers of science and technology as building blocks for the future.

It’s not that history or Kafka are not important, but rather it is even more critical to understand if we change the assumptions, environmental conditions and rules that applied to historical events, would that alter the conclusions we draw from historical events today. Every time a student takes one subject they exclude the possibility of taking something else. I find it ironic that those who rely on “history repeating itself” often fail to understand the assumptions that might cause “this time” to be different. The experts we rely on for predictions have about the same accuracy as dart-throwing monkeys according to at least one very exhaustive study by Prof Phil Tetlock. So it is important to understand how to rely on “more likely to be right” experts, as defined in the book *Superforecasters*. We make a lot of judgments in everyday life and we should be prepared to make them intelligently.

Students can use this broad knowledge base to build mental models that will aid them in both further studies and vocations. Charlie Munger, the famous investor from Berkshire Hathaway, speaks about mental models and what he calls “elementary, worldly wisdom.” Munger believes a person can combine models from a wide range of disciplines (economics, mathematics, physics, biology, history, and psychology, among others) into something that is more valuable than the sum of its parts. I have to agree that this cross-disciplinary thinking is becoming an essential skill in today’s increasingly complex world.

“The models have to come from multiple disciplines because all the wisdom of the world is not to be found in one little academic department,” Munger explains. “That’s why poetry professors, by and large, are so unwise in a worldly sense. They don’t have enough models in their heads. So you’ve got to have models across a fair array of disciplines... These models generally fall into two categories: (1) ones that help us simulate time (and predict the future) and better understand

how the world works (e.g. understanding a useful idea like autocatalysis), and (2) ones that help us better understand how our mental processes lead us astray (e.g., availability bias).” I would add that they provide the “common truth” in discussions where the well-educated discussants disagree.

After grasping the fundamental tools of learning and some broad topical exposure, it’s valuable to “dig deep” in one or two topic areas of interest. For this, I prefer some subject in science or engineering rather than literature or history (bear with me before you have an emotional reaction; I’ll explain in a minute). Obviously, it’s best if students are passionate about a specific topic, but passion is not critical as the passion may develop as they dig in (some students will have passions, but many won’t have any at all). The real value for digging deep is to learn how to dig in; it serves a person for the duration of their life: in school, work, and leisure. As Thomas Huxley said, “learn something about everything and everything about something,” though his saying that does not make it true. Too often, students don’t learn that a quote is not a fact.

If students choose options from traditional liberal-education subjects, they should be taught in the context of the critical tools mentioned above. If students want jobs, they should be taught skills where future jobs will exist. If we want them as intelligent citizens, we need to have them understand critical thinking, statistics, economics, how to interpret technology and science developments, and how global game theory applies to local interests. Traditional majors like international relations and political science are passé as base skills and can easily be acquired once a student has the basic tools of understanding. And they and many other traditional liberal arts subjects like history or art will be well served in graduate level work. I want to repeat that this is not to claim those “other subjects” are not valuable. I think they are very appropriate for graduate level study.

Back to history and literature for a moment — these are great to wrestle with once a student has learned to think critically. My contention is not that these subjects are unimportant, but rather that they are not basic or broad enough “tools for developing learning skills” as they were in the 1800s, because the set of skills needed today has changed. Furthermore, they are topics easily learned by someone trained in the basic disciplines of thinking and learning that I’ve defined above. This isn’t as easy the other way around. A scientist can more easily become a philosopher or writer than a writer or philosopher can become a scientist.

If subjects like history and literature are focused on too early, it is easy for someone not to learn to think for themselves and not to question assumptions, conclusions, and expert philosophies. This can do a lot of damage.

Separating the aspirational claims by universities from the reality of today's typical liberal arts education I tend to agree with the views of William Deresiewicz. He was an English professor at Yale from 1998–2008 and recently published the book "Excellent Sheep: The Miseducation of the American Elite and the Way to a Meaningful Life." Deresiewicz writes on the current state of liberal arts, "At least the classes at elite schools are academically rigorous, demanding on their own terms, no? Not necessarily. In the sciences, usually; in other disciplines, not so much. There are exceptions, of course, but professors and students have largely entered into what one observer called a 'nonaggression pact.'" Easy is often the reason students pick liberal arts subjects today.

Lots of things are important but what are the most important goals of an education?

To repeat, school is a place where every student should have the opportunity to become a potential participant in whatever they might want to tackle in the future, with an appropriate focus not only on what they want to pursue but also, pragmatically, what they will need to do to be productively employed or productive and thinking member of society. By embracing thinking and learning skills, and adding a dash of irreverence and confidence that comes from being able to tackle new arenas (creative writing as a vocational skill, not a liberal arts education, may have a role here, but Macbeth does not make my priority list; we can agree to disagree but if we discourse I want to understand the assumptions that cause us to disagree, something many students are unable to do), hopefully they will be lucky enough to help shape the next few decades or at least be intelligent voters in a democracy and productive participants in their jobs .

With the right critical lens, history, philosophy, and literature can help creativity and breadth by opening the mind to new perspectives and ideas. Still, learning about them is secondary to learning the tools of learning except possibly the right approach to philosophy education. Again I want to remind you that none of this applies to the top 20% of students who learn all these skills independent of their education or major. Passions like music or literature (leaving aside the top few students who clearly excel at music or literature) and its history may be best left to self-pursuit, while exploring the structure and theory of music or literature may be a way to teach the right kind of thinking about music and literature!

For some small subset of the student body, pursuing passions and developing skills in subjects such as music or sports can be valuable, and I am a fan of schools like Juilliard, but in my view this must be in addition to a required general education especially for the "other 80%". It's the

lack of balance in general education which I am suggesting needs to be addressed (including for engineering, science and technology subjects' students. Setting music and sports aside, with the critical thinking tools and exposure to the up-and-coming areas mentioned above, students should be positioned to discover their first passion and begin to understand themselves, or at the least be able to keep up with the changes to come, get (and maintain) productive jobs, and be intelligent citizens.

At the very least they should be able to evaluate how much confidence to place in a New York Times study of 11 patients on a new cancer treatment from Mexico or a health supplement from China and to assess the study's statistical validity and whether the treatment's economics make sense. And they should understand the relationship between taxes, spending, balanced budgets, and growth better than they understand 15th century English history in preparation for "civic life" to quote the original purpose of a liberal arts education. And if they are to study language or music, Dan Levitin's book "This Is Your Brain on Music: The Science of a Human Obsession" should be first reading or its equivalent in linguistics. It can teach you about a human obsession but also teach you how to build a mathematical model in your head and why and how Indian music is different than Latin music. In fact, these should be required for all education, not just liberal arts education, along with the other books mentioned above.

The role of passion and emotion in life is best epitomized by a quote (unknown source) I once saw that says the most important things in life are best decided by the heart and not logic. For the rest we need logic and consistency. The "what" may be emotion and passion based but the "how" often (yes, sometimes the journey is the reward) needs a different approach that intelligent citizens should possess and education should teach.

As Atul Gawande, in an inspiring commencement address, says "we are battling for what it means to be citizens" and that is the original purpose of liberal arts. We are battling the ability to have debates and to have a basis to agree or disagree, that is logical and consistent, yet accommodates our emotions, feelings, our versions of humanity. I highly recommend the commencement speech by Atul Gawande: The Mistrust of Science as it is very relevant to modern thinking.

I am sure I have missed some points of view, so I look forward to starting a valuable dialogue on this important topic.

Additional Responses to Comments and Questions:

Sciences have always been at their core of Liberal Arts. The traditional liberal arts consists not just of the trivium (grammar, logic, rhetoric) but also the quadrivium: arithmetic, geometry, music, astronomy. While those are medieval categories, there's nothing inherent in "liberal arts" that would prevent one from updating them for contemporary reality. Ironically, you may even be seen as arguing for a return to liberal arts.

How many liberal arts graduates today are proficient in the sciences, or can argue cogently or understand philosophy or logic, let alone modern requirements for civic life like economics, technology literacy etc? I agree that there here is nothing inherent in its definition but practically there is a different reality. And beyond subjects taught the goal of liberal arts was to prepare for civic life. Sad that this goal is not being met. I am arguing for non-professional degrees to return to a rigorous description of the goals of liberal arts (as opposed to the old unevolved version of liberal arts) and away from what it has become today. It is the ability to learn new things that a non-professional curriculum should teach that I call modern thinking. If you move to working for an NGO after hedge fund trading the same education should help you learn this faster and understand the new area's issues and critically analyze them! There is much inefficiency among the best intentioned because of this inability to critically think comprehensively about new areas.

Let us not forget that the "liberal arts" are essentially what helps students develop empathy and multifaceted understandings of how others feel, think, love, know, and live. This is especially important now because the influence of religion is weakening.

I agree on the importance of understanding how others feel, think, etc ... and explicitly discuss that with regards to understanding "Black Lives Matter" and the role of emotion. But I don't believe the median liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning. I do think setting goals should derive from empathy in many cases but more often than not how to achieve them requires rigorous, unemphathetic, brutal cost benefit thinking.

How did you measure the level of importance of Jane Austen and Shakespeare?

I don't measure the importance of Shakespeare but argue if there are a hundred things we learn and only can study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is "base skill to learn other subjects from" versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs, but argue base skills are harder to learn on your own.

As a high school senior who's applying to small liberal arts schools, what should I keep in mind as I choose what college to attend and what path to pursue once I'm on campus?

Don't go for the easy classes. Go for subjects that teach you to think. This can be done at a liberal arts college but isn't done by many. Go for diversity in the subjects you take and more than anything go for rigor instead of the easy subjects.

Article: IS MAJORING IN LIBERAL ARTS A MISTAKE FOR STUDENTS?

Critical Thinking, Knowledge basics and the Scientific Process First — Humanities Later

If luck favors the prepared mind, as Louis Pasteur is credited with saying, we're in danger of becoming a very unlucky nation. Little of the material taught in liberal arts programs today is relevant to the future.

Consider all the science and economics that has been updated, the shifting theories of psychology, the programming languages and political theories that have been developed, and even how many planets our solar system has. Much, like literature and history, should be evaluated against updated, relevant priorities in the 21st century. There is more need for process thinking and model think than knowledge today in undergraduate education.

I feel that liberal arts education in the United States is a minor evolution of 18th century European education. The world needs something more than that. Non-professional

undergraduate education needs a new system that teaches students how to learn and judge using the scientific process on issues relating to science, society, and business.

Though Jane Austen and Shakespeare might be important, they are far less important than many other things that are more relevant to make an intelligent, continuously learning citizen, and a more adaptable human being in our increasingly more complex, diverse and dynamic world. When the rate of change is high, what one needs in education changes from knowledge to the process of learning.

I am going to now suggest we call this basic education “Modern Thinking”. I suggest universities introduce it as a much more rigorous and demanding version of traditional Liberal Arts for those not pursuing undergraduate professional or STEM education. Let’s try and separate the old “get through college easily and leave time for partying” student set from those that want a rigorous education with many more demanding, broad and diverse minimum requirements. Let’s keep the old and construct a new higher honors-like separate program with much more rigor.

The test for Modern Thinking would be quite simple: at the end of an undergraduate education, is a student roughly able to understand and discuss a broad set of topics like the Economist, end-to-end, every week. That covers everything economics, politics, literature, drama, business, culture and more. Of course, there are other surrogates for the Economist that would be just as valid if broad enough. This modern, non-professional education would meet the original “Greek life purpose” of a liberal arts education, updated for today’s world.

The most important things for a general, non-professional or vocational education are critical thinking, abstract model building, generalization skills and problem-solving skills, familiarity with logic and the scientific process, and the ability to use these in forming opinions, discourse, and in making decisions. Other general skills that are also important include — but are not limited to — interpersonal skills and communication skills.

So, what is wrong with today’s typical liberal arts degree?

Neither the old definition of liberal arts nor the current implementation of it is the best use of four years of somebody’s education (if it is to be non-professional — I am explicitly not suggesting everyone do STEM “profession” oriented degrees!). The hardest (and most lucrative,



but that is less relevant here) problems to solve are non-technical problems. In my opinion, getting a STEM degree gives you the tools to think about those problems more effectively than a Liberal Arts degree today; though it is far from a complete way of thinking, and a Modern Thinking degree will do this in an even more complete form. If STEM was turned into a non-professional degree it'd teach more of the skills for this Modern Thinking education than a Liberal Arts degree AS PRACTICED generally does today. But Modern Thinking would go more directly at the education I'd recommend for non-professionals who want to operate at the highest levels of thinking.

Some of you will point to very successful people who've gone to Yale and done well, but you misuse or misunderstand statistics. A lot of successful people have started out as liberal arts majors. A lot haven't. If you're very driven and intelligent or lucky, you'll probably be successful in life, even with today's liberal arts degree. Then again, if you're that driven and intelligent, you could probably find success with any degree, or even no degree. Apple's Steve Jobs and Joi Ito (Director of the MIT media lab) are both college dropouts. Joi is a largely self-taught computer scientist, disc jockey, nightclub entrepreneur and technology investor and I think this diversity makes him better educated. The top 20% of people in any cohort will do well independent of what curriculum their education follows, or if they had any education at all. If we want to maximize the potential of the other 80%, then we need a new Modern Thinking curriculum.

What I am discussing in this piece is the median student who gets through a liberal arts curriculum, excluding the 20% who I believe will do well no matter what education (or lack thereof) that they get. That means what I am concentrating on is "what actually happens to the median student" as opposed to "what is possible with Liberal Arts education" or "what Liberal Arts is supposed to teach". I will add though that even the definition of what Liberal Arts SHOULD be needs updating for the modern world.

Yale recently decided that Computer Science was important and I like to ask, "if you live in France, shouldn't you learn French? If you live in the computer world, shouldn't you learn Computer Science?" What should be the second required language in schools today if we live in a computer world? My goal is not that everyone be a programmer, but rather that they understand programmatic thinking. And if you live in a technology world what must you understand? Traditional education is far behind and the old world tenured professors at our universities with their parochial views and interests, their romanticism and ossification of ideas will keep dragging them back. My disagreement is not with the goals of a liberal arts education but its implementation and evolution (or lack thereof) from 18th century European education and its purpose. There is too little emphasis on teaching critical thinking skills in schools and the grounding on which new knowledge, often technological, can be acquired, even though that was

the original goal of such education. Many adults have little understanding of important science and technology issues or, more importantly, how to approach them, which leaves them open to poor decision-making on matters that will affect both their families and society, in general.

Connections matter and many Ivy League colleges are worth it just to be an alumnus. There are people with the view that Liberal Arts broadened their vision and gave them great conversational topics. There are those who argue that the humanities are there to teach us what to do with knowledge. As one observer commented: “They should get lawyers to think whether an unjust law is still law. An engineer should be able to contemplate whether Artificial Intelligence is morally good. An architect could pause to think on the merit of building a house fit for purpose. A doctor could be taught whether and how to justify using scarce medical resources for the benefit of one patient and not another. This is the role of humanities — a supplement to STEM and the professions.”

In my view, creativity, humanism, and ethics are very hard to teach, whereas worldliness and many other skills supposedly taught through the Liberal Arts are more easily self-taught in a continuously updating fashion if one has a good quantitative, logical and scientific process-oriented base education. The undergraduate level (graduate level degrees are a whole different matter and should be specialised on areas of study) degrees I associate (with all my biases) as the more likely to be “easy courses so you can party degrees” in most US universities is mostly what I am discussing here.

The argument goes that a scientific/engineering education lacks enough training in critical thinking skills, creativity, inspiration, innovation and holistic thinking. On the contrary, I argue that the scientific and logical basis of a better Modern Thinking education would allow some or all of this — and in a more consistent way. The argument that being logical makes one a linear problem solver and ill prepared for professions that require truly creative problem solving has no merit in my view. The old version of the Liberal Arts curriculum was reasonable in a world of the far less complex 18th century Eurocentric world and an elitist education focused on thinking and leisure. Since the 20th century, despite its goals, it has evolved as the “easier curriculum” to get through college and may now be the single biggest reason students pursue it (There are plenty of students who take it for other reasons, but I am talking percentages here).

I do not believe that today’s typical Liberal Arts degree turns you into a more complete thinker; rather, I believe they limit the dimensionality of your thinking since you have less familiarity with mathematical models (to me, it’s the dimensionality of thinking that I find deficient in many people without a rigorous education), and worse, statistical understanding of anecdotes and

data (which liberal arts was supposedly good at preparing students for but is actually highly deficient at). People in the humanities fields are told that they get taught analytical skills, including how to digest large volumes of information, but I find that by and large such education is poor at imparting these skills. Maybe, that was the intent but the reality is very far from this idealization (again, excluding the top 20%).

There is a failing in many college programs that are not pragmatic enough to align and relate liberal arts program to the life of a working adult. From finance to media to management and administration jobs, necessary skills like strategic-thinking, finding trends, and big picture problem-solving, even human connections and workforce management have all evolved in my view to need the more quantitative and rational preparation than today's degrees provide.

Such skills, supposedly the purview of liberal arts education, are best learnt through more quantitative methods today. Many vocational programs from engineering to medicine also need these same skills and need to evolve and broaden to add to their training. But if I could only have one of a liberal art or an engineering/science education, I'd pick the engineering even if I never intended to work as an engineer and did not know what career I wanted to pursue.

I have in fact almost never worked as an engineer but deal exclusively with risk, evolution of capability, innovation, people evaluation, creativity and vision formulation. Design is my personal passion far more than business. That is not to say that goal setting, design, and creativity are not important or even critical. In fact, these need to be added to most professional and vocational degrees, which are also deficient for today's practical careers.

More and more fields are becoming very quantitative, and it's becoming harder and harder to go from majoring in English or History to having optionality on various future careers and being an intelligent citizen in a democracy. Math, statistics and science are hard, economics, psychology and philosophical logic take effort, and school is a great time to learn those areas, whereas many of the liberal arts courses can be pursued after college on the base of a broad education. But without training in the scientific process, logic and critical thinking, and a basis of science, mathematics and statistics, discourse and understanding are both made far more difficult.

A good illustrative example of the problems of today's liberal arts education can be found in the writing of well-known author, Malcolm Gladwell, a history major and a one-time writer for The New Yorker. Gladwell famously argued that stories were more important than accuracy or validity without even realizing it. The New Republic called the final chapter of Gladwell's *Outliers*,

“impervious to all forms of critical thinking” and said that Gladwell believes “a perfect anecdote proves a fatuous rule.” This, in my opinion, is too often the way many Liberal Arts graduates (but not all) think. Referencing a Gladwell reporting mistake in which Gladwell refers to “eigenvalue” as “Igon Value,” Harvard professor and author Steven Pinker criticizes his lack of expertise: “I will call this the Igon Value Problem: when a writer’s education on a topic consists in interviewing an expert, he is apt to offer generalizations that are banal, obtuse or flat wrong.” Unfortunately, too many in today’s media are similarly “uneducated” in their interpretation of experts. Storytelling and quotes become a misleading factor instead of being an aid to communicating the accurate facts more easily. His assertions around “10,000 hours” may or may not be true but his arguments for it carry very little weight with me because of the quality of his thinking.

Though one example of Malcolm Gladwell does not prove the invalidity of arguments for a Liberal Arts degree, I find this kind of erroneous thinking (anecdotally) true of many humanities and liberal arts graduates. In fact, I see the inconsistencies that Gladwell failed to understand (giving him the benefit of the doubt that these were unintentional) in the writings of many authors of articles in supposedly elite publications like The New Yorker and The Atlantic. Again, this is not a statistically valid conclusion but the impression across hundreds or thousands of examples of one person, me. When I do occasionally read articles from these publications, I make a sport of judging the quality of thinking of the writers as I read, based on false arguments, unsupported conclusions, confusion of storytelling with factual assertions, mistaking quotes from interviews as facts, misinterpreting statistics, etc. Similar lack of cogent thinking leads to bad decisions, uninformed rhetoric, and lack of critical thinking around topics like nuclear power and GMOs.

Unfortunately, in an increasingly complex world, all these topics skills that many liberal arts majors even at elite universities fail to master. The topic of risk and risk assessment from simple personal financial planning to societal topics like income inequality is so poorly understood and considered by most liberal arts majors as to make me pessimistic. I am not arguing that engineering or STEM education is good at these topics but rather that this is not its intent of STEM or professional education. The intent of Liberal Arts education is what Steven Pinker called a “building a self” and I would add “for the technological and dynamically evolving 21st century”.

Learning new areas as career paths and interests evolve becomes harder. Traditional European liberal arts education was for the few and the elite. Is that still the goal today? People spend years and a small fortune or lifelong indebtedness (at least in the US) to obtain it and employability should be a criterion in addition to an education’s’ contribution to intelligent citizenry.

Wikipedia defines “the liberal arts as those subjects or skills that in classical antiquity were considered essential for a free person to know in order to take an active part in civic life, something that (for Ancient Greece) included participating in public debate, defending oneself in court, serving on juries, and most importantly, military service. Grammar, logic, and rhetoric were the core liberal arts, while arithmetic, geometry, the theory of music, and astronomy also played a (somewhat lesser) part in education.” Today’s ideal list, not anchored in “classical antiquity” would be more expansive and more prioritized in my view.

Idealists and those who perceive liberal arts education today as meeting these goals are wrong not in its intent but in assessing how well it does this function (and that is an assertion/opinion). I agree that we need a more humanistic education but it is hard to agree or disagree with the current curriculum without defining what humanistic means. Does it really teach critical thinking, logic or the scientific process, things every citizen should know in order to participate in society? Does it allow for intelligent discourse or decision-making across a diverse set of beliefs, situations, preferences, and assumptions? And I believe we need to extend these goals to have education form the basis of lifelong learning broadly across all areas in our increasingly technological and fast-changing world.

While one may argue that historical liberal arts education included what I am arguing for, the context for this education has changed. In the 21st century, with airplanes and societal mixing, the internet and global information and misinformation, artificial intelligence and a technology driven and challenged planet, with many more risks both local and global, the old definition needs to be adapted to the modern context. What we need for civic life today is far different than what’s needed when liberal arts education originated.

I do think whether it is for employability or dealing with nuanced and ever changing issues like race or artificial intelligence, national borders or international citizenry, or the nature of work and politics, the ability to understand new areas or repurpose oneself over time should be a critical part of any education, especially an education like liberal arts not geared towards a particular profession.

Should we teach our students what we already know, or prepare them to discover more? Memorizing the Gettysburg address is admirable but ultimately worthless; understanding history is interesting, even useful, but not as relevant as topics from the Economist, unless history is used as a logic tool which it can be used as. A student who can apply the scientific process or

employ critical thinking skills to solve a big problem has the potential to change the world (or at minimum get a better-paying job). They can actually debate a topic like #blacklivesmatter, income inequality or climate change without being subject to “Trumpism” or emotion and biases-based distortions.

While it is undoubtedly important to understand how others feel, think, etc., I don’t believe the median student with a liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning.

No wonder half the college graduates who fill jobs as some studies indicate, actually fill jobs that don’t need a college degree! Their degree is not relevant to adding value to an employer (though that is not the only purpose of a degree).

Further, even if an ideal curriculum can be stitched together, most liberal arts majors infrequently do it. If the goal is not professional education then it must be general education, which requires many more must-have requirements for me to consider a university degree respectable. Of course others are entitled to their own opinion, though the right answer is testable if one agrees that the goals of such an education are intelligent citizenry and/or employability.

For now, I am mostly leaving aside matters related to professional, vocational or technical curriculum. I’m also ignoring the not irrelevant and pragmatic issues of education affordability and the burden of student debt, which would argue for a more employment-enabling type of education. The failure I am referring to are two-fold: (1) the failure of curriculums to keep up with the changing needs of modern society and (2) liberal arts becoming the “easy curriculum” for those who shy away from the more demanding majors and prefer an easier, often (but not always) more socially-oriented college life. Ease, not value, or interest instead of value become key criteria in designing a curriculum for many students today. And for those of you who think this is not true, I am asserting based on my experience this is true for the majority of today’s students, but not for every liberal arts student.

Not every course is for every student but the criteria need to match the needs of the student and not their indulgences, taking interests and capability into account. “Pursue your passion” even if it increases the probability of getting you into unemployment or homelessness later is advice I have seldom agreed with (yes there are occasions this is warranted, especially for the top or the bottom 20% of students). More on passions later but I’m not saying passions are unimportant. What I am saying is with today’s implementation of a liberal arts curriculum, even at elite universities like Stanford and Yale, I find that many Liberal Arts majors (excluding roughly the top 20% of students) lack the ability to rigorously defend ideas, make compelling, persuasive arguments, or discourse logically.

Steven Pinker — in addition to refuting Gladwell — has a brilliant, clarion opinion on what education ought to be, writing in *The New Republic*, “It seems to me that educated people should know something about the 13-billion-year prehistory of our species and the basic laws governing the physical and living world, including our bodies and brains. They should grasp the timeline of human history from the dawn of agriculture to the present. They should be exposed to the diversity of human cultures, and the major systems of belief and value with which they have made sense of their lives. They should know about the formative events in human history, including the blunders we can hope not to repeat. They should understand the principles behind democratic governance and the rule of law. They should know how to appreciate works of fiction and art as sources of aesthetic pleasure and as impetuses to reflect on the human condition.”

Though I agree, I am not sure this curriculum is more important than the ideas below. Based on the skills defined below any gaps in the above education can be filled in by students post-graduation.

So, what should non-professional elite education entail?

If we had enough time in school, I would suggest we do everything. Sadly that is not realistic, so we need a prioritized list of basic requirements because every subject we do cover excludes some other subject given the fixed time we have available. We must decide what is better taught during the limited teaching time we have, and what subjects are easier learnt during personal time or as post-education or graduate pursuits. If there are a hundred things we learn but can only study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is “base skill to learn other subjects from” versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs but base skills are harder to learn on your own.

In the new Modern Thinking curriculum I propose, students would master:

1. The fundamental tools of learning and analysis, primarily critical thinking, the scientific process or methodology, and approaches to problem solving and diversity.
2. Knowledge of a few generally applicable topics and knowledge of the basics such as logic, mathematics, and statistics to judge and model conceptually almost anything one might run into over the next few decades.
3. The skills to “dig deep” into their areas of interest in order to understand how these tools can be applied to one domain and to be equipped to change domains every so often
4. Preparation for jobs in a competitive and evolving global economy or preparation for uncertainty about one’s future direction, interest, or areas where opportunities will exist.
5. Preparation to continuously evolve and stay current as informed and intelligent citizens of a democracy

Critical subject matter should include economics, statistics, mathematics, logic and systems modeling, psychology, computer programming, and current (not historical) cultural evolution (Why rap? Why ISIS? Why suicide bombers? Why the Kardashians and Trump? Why environmentalism and what matters and what does not? What study to believe? What technology evolution might happen? What has important implications? And of course the question, are the answers to these questions expert opinions or have some other validity?).

Furthermore, certain humanities disciplines such as literature and history should become optional subjects, in much the same way that physics is today (and, of course, I advocate mandatory basic physics study along with the other sciences). And one needs the ability to think through many, if not most, of the social issues we face (which the softer liberal arts subjects ill-prepare one for in my view).



Imagine a required course each semester where every student is asked to analyze and debate topics from every issue of a broad publication such as The Economist or Technology Review. And imagine a core curriculum that teaches the core skills to have the discussions above. Such a curriculum would not only provide a platform for understanding in a more relevant context how the physical, political, cultural and technical worlds function, but would also impart instincts for interpreting the world, and prepare students to become active participants in the economy.

Efficiency in undergraduate education matters given the wide array of subjects that need understanding, the inability to cover all of the subjects, and the constant change in what becomes more or less important or interesting to a person over time. It is for this reason I suggest that understanding the Economist on a weekly basis is important as it covers many diverse topics from politics to economics to culture, arts, science, technology, climate and global issues. A sufficiently diligent professor could in fact construct a more effective and efficient curriculum and hence the reference to the Economist was a short form for the concept of teaching broad understanding across a diversity of topics.

It would be essential to understand psychology because human behavior and human interaction are important and will continue to be so. I'd like people who are immune to the fallacies and agendas of the media, politicians, advertisers, and marketers because these professions have learned to hack the human brain's biases (a good description of which are described in Dan Kahneman's Thinking Fast & Slow and in Dan Gardner's The Science of Fear). I'd like to teach people how to understand history but not to spend time getting the knowledge of history, which can be done after graduation.

I'd like people to read a New York Times article and understand what is an assumption, what's an assertion by the writer, what are facts, and what are opinions, and maybe even find the biases and contradictions inherent in many articles. We are far beyond the days of the media simply reporting news, shown by the different versions of the "news" that liberal and conservative newspapers in the US report, all as different "truths" of the same event. Learning to parse this media is critical. I'd like people to understand what is statistically valid and what is not. What is a bias or the color of the writer's point of view?

Students should learn the scientific method, and most importantly how to apply its mental model to the world. Building models in our head is critical to understanding and reasoning in my view. The scientific method requires that hypotheses be tested in controlled conditions; this can diminish the effects of randomness and, often, personal bias. This is very valuable in a world where too many students fall victim to confirmation biases (people observe what they expect to

observe), appeal to new and surprising things, and narrative fallacies (once a narrative has been built, its individual elements are more accepted). There are many, many types of human biases defined in psychology that people fall victim to. Failure to understand mathematical models and statistics makes it substantially more difficult to understand critical questions in daily life, from social sciences to science and technology, political issues, health claims, economics and much more.

I'd also suggest tackling several general and currently relevant topic areas such as genetics, computer science, systems modeling, econometrics, linguistics modeling, traditional and behavioral economics, and genomics/bioinformatics (not an exhaustive list) which are quickly becoming critical issues for everyday decisions from personal medical decisions to understanding minimum pay, economics of taxes and inequality, immigration, or climate change. E.O. Wilson argues in his book "The Meaning of Human Existence" that it is hard to understand social behavior without understanding multi-level selection theory and the mathematical optimization that nature performed through years of evolutionary iterations. I am not arguing that every educated person should be able to build such a model but rather that they should be able to "think" such a model qualitatively.

Not only do these topics expose students to a lot of useful and current information, theories, and algorithms, they may in fact become platforms to teach the scientific process — a process that applies to (and is desperately needed for) logical discourse and social sciences as much as it applies to science. The scientific process critically needs to be applied to all the issues we discuss socially in order to have intelligent dialog. Even if the specific information becomes irrelevant within a decade (who knows where technology will head next; hugely important cultural phenomena and technologies like Facebook, Twitter, and the iPhone didn't exist before 2004, after all), it's incredibly useful to understand the current frontiers of science and technology as building blocks for the future.

It's not that history or Kafka are not important, but rather it is even more critical to understand if we change the assumptions, environmental conditions and rules that applied to historical events, would that alter the conclusions we draw from historical events today. Every time a student takes one subject they exclude the possibility of taking something else. I find it ironic that those who rely on "history repeating itself" often fail to understand the assumptions that might cause "this time" to be different. The experts we rely on for predictions have about the same accuracy as dart-throwing monkeys according to at least one very exhaustive study by Prof Phil Tetlock. So it is important to understand how to rely on "more likely to be right" experts, as defined in the book Superforecasters. We make a lot of judgments in everyday life and we should be prepared to make them intelligently.

Students can use this broad knowledge base to build mental models that will aid them in both further studies and vocations. Charlie Munger, the famous investor from Berkshire Hathaway, speaks about mental models and what he calls “elementary, worldly wisdom.” Munger believes a person can combine models from a wide range of disciplines (economics, mathematics, physics, biology, history, and psychology, among others) into something that is more valuable than the sum of its parts. I have to agree that this cross-disciplinary thinking is becoming an essential skill in today’s increasingly complex world.

“The models have to come from multiple disciplines because all the wisdom of the world is not to be found in one little academic department,” Munger explains. “That’s why poetry professors, by and large, are so unwise in a worldly sense. They don’t have enough models in their heads. So you’ve got to have models across a fair array of disciplines... These models generally fall into two categories: (1) ones that help us simulate time (and predict the future) and better understand how the world works (e.g. understanding a useful idea like autocatalysis), and (2) ones that help us better understand how our mental processes lead us astray (e.g., availability bias).” I would add that they provide the “common truth” in discussions where the well-educated discussants disagree.

After grasping the fundamental tools of learning and some broad topical exposure, it’s valuable to “dig deep” in one or two topic areas of interest. For this, I prefer some subject in science or engineering rather than literature or history (bear with me before you have an emotional reaction; I’ll explain in a minute). Obviously, it’s best if students are passionate about a specific topic, but passion is not critical as the passion may develop as they dig in (some students will have passions, but many won’t have any at all). The real value for digging deep is to learn how to dig in; it serves a person for the duration of their life: in school, work, and leisure. As Thomas Huxley said, “learn something about everything and everything about something,” though his saying that does not make it true. Too often, students don’t learn that a quote is not a fact.

If students choose options from traditional liberal-education subjects, they should be taught in the context of the critical tools mentioned above. If students want jobs, they should be taught skills where future jobs will exist. If we want them as intelligent citizens, we need to have them understand critical thinking, statistics, economics, how to interpret technology and science developments, and how global game theory applies to local interests. Traditional majors like international relations and political science are passé as base skills and can easily be acquired once a student has the basic tools of understanding. And they and many other traditional liberal arts subjects like history or art will be well served in graduate level work. I want to repeat that

this is not to claim those “other subjects” are not valuable. I think they are very appropriate for graduate level study.

Back to history and literature for a moment — these are great to wrestle with once a student has learned to think critically. My contention is not that these subjects are unimportant, but rather that they are not basic or broad enough “tools for developing learning skills” as they were in the 1800s, because the set of skills needed today has changed. Furthermore, they are topics easily learned by someone trained in the basic disciplines of thinking and learning that I’ve defined above. This isn’t as easy the other way around. A scientist can more easily become a philosopher or writer than a writer or philosopher can become a scientist.

If subjects like history and literature are focused on too early, it is easy for someone not to learn to think for themselves and not to question assumptions, conclusions, and expert philosophies. This can do a lot of damage.

Separating the aspirational claims by universities from the reality of today’s typical liberal arts education I tend to agree with the views of William Deresiewicz. He was an English professor at Yale from 1998–2008 and recently published the book “Excellent Sheep: The Miseducation of the American Elite and the Way to a Meaningful Life.” Deresiewicz writes on the current state of liberal arts, “At least the classes at elite schools are academically rigorous, demanding on their own terms, no? Not necessarily. In the sciences, usually; in other disciplines, not so much. There are exceptions, of course, but professors and students have largely entered into what one observer called a ‘nonaggression pact.’” Easy is often the reason students pick liberal arts subjects today.

Lots of things are important but what are the most important goals of an education?

To repeat, school is a place where every student should have the opportunity to become a potential participant in whatever they might want to tackle in the future, with an appropriate focus not only on what they want to pursue but also, pragmatically, what they will need to do to be productively employed or productive and thinking member of society. By embracing thinking and learning skills, and adding a dash of irreverence and confidence that comes from being able to tackle new arenas (creative writing as a vocational skill, not a liberal arts education, may have a role here, but Macbeth does not make my priority list; we can agree to disagree but if we discourse I want to understand the assumptions that cause us to disagree, something many

students are unable to do), hopefully they will be lucky enough to help shape the next few decades or at least be intelligent voters in a democracy and productive participants in their jobs .

With the right critical lens, history, philosophy, and literature can help creativity and breadth by opening the mind to new perspectives and ideas. Still, learning about them is secondary to learning the tools of learning except possibly the right approach to philosophy education. Again I want to remind you that none of this applies to the top 20% of students who learn all these skills independent of their education or major. Passions like music or literature (leaving aside the top few students who clearly excel at music or literature) and its history may be best left to self-pursuit, while exploring the structure and theory of music or literature may be a way to teach the right kind of thinking about music and literature!

For some small subset of the student body, pursuing passions and developing skills in subjects such as music or sports can be valuable, and I am a fan of schools like Juilliard, but in my view this must be in addition to a required general education especially for the “other 80%”. It’s the lack of balance in general education which I am suggesting needs to be addressed (including for engineering, science and technology subjects’ students. Setting music and sports aside, with the critical thinking tools and exposure to the up-and-coming areas mentioned above, students should be positioned to discover their first passion and begin to understand themselves, or at the least be able to keep up with the changes to come, get (and maintain) productive jobs, and be intelligent citizens.

At the very least they should be able to evaluate how much confidence to place in a New York Times study of 11 patients on a new cancer treatment from Mexico or a health supplement from China and to assess the study’s statistical validity and whether the treatment’s economics make sense. And they should understand the relationship between taxes, spending, balanced budgets, and growth better than they understand 15th century English history in preparation for “civic life” to quote the original purpose of a liberal arts education. And if they are to study language or music, Dan Levitin’s book “This Is Your Brain on Music: The Science of a Human Obsession” should be first reading or its equivalent in linguistics. It can teach you about a human obsession but also teach you how to build a mathematical model in your head and why and how Indian music is different than Latin music. In fact, these should be required for all education, not just liberal arts education, along with the other books mentioned above.

The role of passion and emotion in life is best epitomized by a quote (unknown source) I once saw that says the most important things in life are best decided by the heart and not logic. For the rest we need logic and consistency. The “what” may be emotion and passion based but the

“how” often (yes, sometimes the journey is the reward) needs a different approach that intelligent citizens should possess and education should teach.

As Atul Gawande, in an inspiring commencement address, says “we are battling for what it means to be citizens” and that is the original purpose of liberal arts. We are battling the ability to have debates and to have a basis to agree or disagree, that is logical and consistent, yet accommodates our emotions, feelings, our versions of humanity. I highly recommend the commencement speech by Atul Gawande: The Mistrust of Science as it is very relevant to modern thinking.

I am sure I have missed some points of view, so I look forward to starting a valuable dialogue on this important topic.

Additional Responses to Comments and Questions:

Sciences have always been at their core of Liberal Arts. The traditional liberal arts consists not just of the trivium (grammar, logic, rhetoric) but also the quadrivium: arithmetic, geometry, music, astronomy. While those are medieval categories, there’s nothing inherent in “liberal arts” that would prevent one from updating them for contemporary reality. Ironically, you may even be seen as arguing for a return to liberal arts.

How many liberal arts graduates today are proficient in the sciences, or can argue cogently or understand philosophy or logic, let alone modern requirements for civic life like economics, technology literacy etc? I agree that there here is nothing inherent in its definition but practically there is a different reality. And beyond subjects taught the goal of liberal arts was to prepare for civic life. Sad that this goal is not being met. I am arguing for non-professional degrees to return to a rigorous description of the goals of liberal arts (as opposed to the old unevolved version of liberal arts) and away from what it has become today. It is the ability to learn new things that a non-professional curriculum should teach that I call modern thinking. If you move to working for an NGO after hedge fund trading the same education should help you learn this faster and understand the new area’s issues and critically analyze them! There is much inefficiency among the best intentioned because of this inability to critically think comprehensively about new areas.

Let us not forget that the “liberal arts” are essentially what helps students develop empathy and multifaceted understandings of how others feel, think, love, know, and live. This is especially important now because the influence of religion is weakening.

I agree on the importance of understanding how others feel, think, etc ... and explicitly discuss that with regards to understanding “Black Lives Matter” and the role of emotion. But I don’t believe the median liberal arts education allows people to do that today. I do argue for kids who can understand other societies and people, have empathy and moral fiber. I have often wondered how best to teach empathy and understanding and (in my opinion) the happiness that ensues from being good human beings first rather than in winning or grabbing goods/wealth! I think the right education would allow each human being to arrive at the right conclusions given their circumstances, but would love to see an even better and more direct way to teach this important learning. I do think setting goals should derive from empathy in many cases but more often than not how to achieve them requires rigorous, unemphathetic, brutal cost benefit thinking.

How did you measure the level of importance of Jane Austen and Shakespeare?

I don’t measure the importance of Shakespeare but argue if there are a hundred things we learn and only can study 32 (say 8 semesters x 4 courses each) which 32 are the most important? What is “base skill to learn other subjects from” versus stuff you can learn later? And what do you need to learn how to learn? I argue for many liberal arts subjects as good graduate programs, but argue base skills are harder to learn on your own.

As a high school senior who’s applying to small liberal arts schools, what should I keep in mind as I choose what college to attend and what path to pursue once I’m on campus?

Don’t go for the easy classes. Go for subjects that teach you to think. This can be done at a liberal arts college but isn’t done by many. Go for diversity in the subjects you take and more than anything go for rigor instead of the easy subjects.