50 Grand Challenges for the 21st Century

By Bryan Lufkin, 1 April 2017
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BBC Future Now

Over the past month, Future Now has been covering the "grand challenges" we face as a society in a series of articles, videos and graphics. We polled a panel of people from various fields about the vital issues they believe deserve more attention – you can browse 50 of those responses below, which we'll continue to draw on throughout this year. There's a lot to digest in one sitting – so dip in, reflect, come back...

Grand Challenges

We asked experts from the world of science and technology to describe the societal challenges that they think matter in 2017 and beyond. Read the full list of responses below.

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Alexios Mantzarlis	Chair of the International Fact Checking Network
Will Moy	Director of Full Fact, an independent fact checking organisation based in the UK
Paul Resnick	Professor of Information at the University of Michigan who developed a tool for identifying rumours on social media called RumourLens
Victoria Rubin	Director of the Language and Information Technology research lab at Western University, Ontario, Canada

ARTIFICIAL INTELLIGENCE

Danah Boyd, Principal Researcher at Microsoft Research

Data-driven technologies are increasingly being integrated into many different parts of society, from judicial decision-making processes to automated vehicles to the dissemination of news. Each of these implementations raises serious questions about what values are being implemented and to whom these implementations are accountable. There is increasing desire by regulators, civil society, and social theorists to see these technologies be "fair" and "ethical," but these concepts are fuzzy at best. Meanwhile, there are significant trade-offs and local decisions that technical actors face on a day-to-day basis that shape the very structure of these systems. Developing responsible sociotechnical systems will require bridging the social-technical gap that can easily emerge as social actors and technical actors speak past one another.

Missy Cummings, Professor, Humans and Autonomy Lab, Duke University
I think one of the most important challenges faced by robotic systems of the future, which include driverless cars, drones, surgical and manufacturing robots, is how will we be able to certify these systems as safe, particularly those that embed artificial intelligence? By their very nature, artificial intelligence algorithms reason probabilistically and as uncertainty increases in the world, uncertainty increases in an algorithm's ability to successfully and safely come to a solution. Presently we have no commonly-accepted approaches and without an industry standard for testing such stochastic systems, it is difficult for these technologies to be widely implemented.

Kate Darling, Research Specialist at MIT Media Lab. Fellow at the Harvard Berkman Center for Internet & Society
Companies are going to follow their market incentives. That's not a bad thing, but we can't rely on them just to be ethical for the sake of it, for the most part. It helps to have regulation in place. We've seen this in privacy, or whenever we have a new technology, and we figure out how to deal with it.

Ezekiel Emanuel, Vice Provost for Global Initiatives and chair of the Department of Medical Ethics and Health Policy at the University of Pennsylvania
I think one of the big issues is going to be unemployment: automation, artificial intelligence, virtual reality. It seems pretty inevitable it's going to create displacement of workers, ie unemployment. If you look at what gives people meaning in their lives, it's three things: meaningful relationships, passionate interests, and meaningful work. Meaningful work is a very important element of someone's identity.

Viktor Mayer Schonberger, Professor of Internet Governance and Regulation, Oxford Internet Institute
My #1 issue is not the future of democracy (or related issues such as fake news, Trump, social networking bubbles, or even cybersecurity), but the future of humanity. As we are developing more and more ways to let computers take over reasoning through adaptive learning, we are faced with an existential question: what is it – long term – that makes us human? It used to be doing calculus, playing Chess (or Go), flying airplanes, driving cars, having a conversation, playing Jeopardy, or cooking (to name a few). What if data-driven, learning algorithms can do all that? What's the essence of being human – is it radical creativity, irrational originality, craziness and illogicality? And if so, are we then shaping our learning institutions to help humans develop and nurture exactly these skills (our competitive advantages). In short, for me 2017 marks the year, when intra-human problems slowly begin to pale when compared to this more fundamental and existential one.

Peter Norvig, Director of Research, Google
Artificial intelligence has proven to be quite effective at practical tasks – from labeling photos, to understanding speech and written natural language, to helping identify diseases. The challenge now is to make sure everyone benefits from this technology. It's important that machine learning be researched openly, and spread via open publications and open source code, so we can all share in the rewards.

Richard Alan Peters, Associate Professor of Electrical Engineering, Vanderbilt University
In my opinion, the most important breakthrough in robotics and AI to come is the learning of concepts by learning sensory-motor coordination. An intelligent agent (animal or robot) that can manipulate the physical world while sensing the results of said manipulation forms one half of a complex dynamical system. The other half is the world. Complex dynamical systems form patterns in nature. In the case of an animal (including humans) that pattern occurs in the brain and spinal cord system. It relates sensing to action and vice-versa. In a robot, I like to call this “natural intelligence” to distinguish it from artificial intelligence which is usually acquired by a disembodied computer. Among other things this approach solves the symbol grounding problem (how an agent’s internal symbols relate to the physical world. This has been puzzled over since Aristotle.) And it solves the “frame problem” by providing a physical context for deliberative thought.
AI, although very useful, will never approach human intelligence until it is embodied. That is, of course, a hypothesis, a conjecture that has yet to be proven. But I believe we are close. These ideas were first set down by Rodney Brooks at MIT in the 1980’s. Brooks hypothesis is: *Intelligence is an emergent phenomenon that is the result of embodiment, situatedness, development and interaction.*

Bruce Schneier, International security technologist
The Internet of Things is giving computers the ability to affect the world in a direct physical manner. As this happens to more and more things, the particular ways in which computers fail will become the way everything fails. This means more catastrophic failures, as bugs and vulnerabilities affect every instance of a piece of software. This will completely change how wethink about the risks of computerised cars, computerised appliances, computerised everything.

Tomotaka Takahashi, Founder of Kyoto University’s Robo Garage
In 2017, cloud funding and hardware start ups are going to collapse. Because of the fake demo videos, people’s expectations to technology is getting too high, and no product can satisfy them. Only a few strong companies and products, such as Amazon Echo, can survive. I believe people are going to demand Echo with more humanity and portability, and social robots like RoBoHoN will find its market in five years.

Jonathan Zittrain, Professor of International Law at Harvard Law School and the Harvard Kennedy School of Government, Professor of Computer Science at the Harvard School of Engineering and Applied Sciences, Director of the Harvard Law School Library, and Faculty Director of the Berkman Center for Internet & Society
I'm concerned about the reduction of human autonomy as our systems -- aided by technology -- become more complex and tightly coupled. Artificial intelligence is making some real progress right now, and our work is less to worry about a science fiction robot takeover, and more to see how technology can be used to help with human reflection and decisionmaking rather than to entirely substitute for it. If we "set it and forget it," we may rue how a system evolves, and that there is no clear place for an ethical dimension to be considered.

Back to AI

CITIES AND GLOBAL DEVELOPMENT

Mary Barra, CEO, General Motors
The auto industry stands at an inflection point where rapidly advancing technology and evolving customer needs offer a unique opportunity to transform our relationship with customers, communities and the environment. Thanks to connectivity, electrification, autonomous vehicles and car- and ridesharing, the way customers interact with our vehicles is going to change in a way that hasn't happened since the industry was born more than 100 years ago. Some view this as a disruption – we believe it represents a tremendous opportunity to make people's lives safer, simpler and better. *Realising these changes demands the ability to recruit from a talented pool of diverse candidates with Science, Technology, Engineering and Math (STEM) expertise. Today, there is more demand for some STEM areas than there is available new talent and the demand continues to grow. It's one of the reasons we are committed to doing all we can to encourage young people to pursue careers in STEM, particularly in Technology and Engineering.*

Nootan Bharani, Lead Design Manager, Place Lab – Place Lab, University of Chicago
A pivot from just climate change to segregation. Specifically, the widening gap between wealthy and impoverished people, worldwide. Climate change is a causal factor in the increased(ing) disparity. So too are racism and classism.
Climate change exacerbates the challenges thrust upon impoverished people. The use and habitation of spaces demonstrates this clearly – the quantity, quality, and increasingly, the ability of one's space to protect from harsher and unexpected elements.

Solutions should be structural as well as grass roots. Sound policy as well as micro-local community-based. Intentional systems got us into this pickle, and intentional systems will need to be part of the process to reach toward common vision and goals. Scratching the surface are programmes offered by governments and utilities, to assist homeowners to weatherise their structures. Impoverished communities still lack the resource/capacity to capture full use of technologies – methods are already known and commonplace in sustainable new construction. The most robust and innovative energy efficiency programs are yet to benefit those that would feel the greatest impact from the captured savings.
Culture is intersectional, is an arbiter. Culture is part of the solution to finding common ground between wealthy and impoverished (and all in-between).
Vernacular architectures are expressions of the people and culture in a particular locale, in particular climates. My “dream” of seeing more vernacular architecture overlapped with contemporary design is a desire to see cultural identities expressed as much as it is a desire to see climate adaptive solutions for space.

Larry Burns, former corporate vice president of Research and Development for General Motors

According to the World Health Organisation, over 1.2 million people a year die from crashes on the world’s roadways. This is epidemic in scale. Traffic safety experts predict that over 90% of roadway fatalities can be eliminated when driverless vehicle technology reaches its full potential. Regulators, police organisations and liability experts responsibly caution that we cannot let driverless technology get in front of safety. However, like with all epidemics, we also have a responsibility to realise the full potential of cures as soon as possible. While we must be prudent, we also must not let those with vested interests in human driven cars slow progress. We must work together to safely accelerate the realisation of driverless vehicles. Reaching this imperative one-day sooner could save over 3,000 lives!

Vishaan Chakrabarti, Associate Professor of Practice at Columbia Graduate School of Architecture, Planning and Preservation

The major new challenge for the fields of architecture and urbanism will be to build what I call the "Public Metropolis," which means cities that are more ecologically sound, more equitable, more humane in their deployment of technology, more intense in their creation of new infrastructure, and more fervent in their roles as beacons for a free, diverse and open global society in a time when nativism and fascism are on the rise. The debate of whether to build dense, transit-based cities as the most environmentally sound growth model in a world in which billions are reaching the middle class is largely settled: the question that remains is not whether to build better cities, but how. Great civic architecture for both public and private projects will be pivotal to this question by

enabling the creation of new cultural buildings, commercial projects, and infrastructures that read and write with the specifics of a place, so that we maintain local identities in a global world.

Lucy Jones, Science Advisor for Risk Reduction for the United States Geological Survey

We do a great job as a society of funding and supporting innovative research – we really admire that aspect of it. What we do a very bad job at is making the interface between that esoteric research and how people can actually use the information. People want predictions (for earthquakes). But people have to understand the scientific process. That's problem number one: The communication phase. People on the outside turn to us (researchers) for answers, and we are so caught up in the scientific process that we know no answer that we're talking about is final. There's this gap that we're not helping people understand, and it's actively discouraged – if you have a young scientist who's brilliant on TV explaining earthquakes, they may say no, I'm not going to do this because it's going to hurt my career.

Rochelle Kopp, founder and Managing Principal of Japan Intercultural Counseling

I would say that one of the biggest challenges for the 21st Century as relates to Japan and Asia, and indeed the rest of the world, is related to questions of immigration (which includes refugee issues). These have of course received a lot of attention in the media, but the discussions are often stuck at a basic level, and governmental policies and programs are often not sufficiently addressing the issues.

Specifically as for Asia: Japan, as well as Korea and China, are rapidly ageing and thus there will be increasing demand for labor in those countries, whereas many surrounding countries have surplus amounts of labour. Already we see Japan is very dependent on foreign labor in sectors like agriculture and construction, although not through formal immigration but rather through exploitative "trainee" programs.

Part of the debate around immigration and acceptance of refugees, both in Japan and other countries, relates to how to integrate people from another culture into a society. This is my field, of cross-cultural communication and understanding. There is a lot of room for further application of the lessons of the cross-cultural field in areas outside of business (where they are most often being utilised today), to help countries address issues related to immigrants and refugees.

Chris Leinberger, Nonresident Senior Fellow – Metropolitan Policy Program, Brookings Institute

The real political and societal changes I'm seeing are taking place at the micro-local level: the biggest sociopolitical movement has been the organisation at the "place" level of the neighbourhood level, at least in this country. It's under the radar screen – we are

fundamentally inserting a new level of governance in society, and it's taking the form of neighbourhood associations at the super local level, taking the form of improvement districts, special assessment districts, like in Midtown Manhattan. All of these places are becoming organised.

Every neighbourhood in this country has a neighbourhood organisation – 30 years ago this didn't exist. Today, virtually every neighbourhood is organised. Business improvement districts in particular are making leaps and bounds in the management of our society and they are recognising and working with technology firms to far better understand how these places work. The next big technological jump is a software jump: we now have the hardware. The issue is coming up with software that will create the mega database that will understand every part of the built environment at the place level, and eventually, the metropolitan level.

Right now, nobody knows what's in Midtown [Manhattan]. We don't know what percentage of that is office; what percentage of that is retail. We didn't have those data sets 15 years ago, and we didn't have the software, and we certainly didn't have the computing capability.

So when a city or when a business improvement district makes a major capital investment in the future, you could foresee the time that we'll be able to say, 'okay, let's build the Second Avenue subway. It'll cost us $5bn and this is the expected economic and tax revenues we will get from that based on this data set, and we will then decide what to do – and we will look at secondary consequences like gentrification and see how we're going to address that based upon those future projects we make.' We will learn much better how to plan, build, and pay for these places; invest in the right thing. Right now conclusions are based on guestimations, like ridership. We're getting closer to saying this is going to be the economic and fiscal benefit of doing that, and here are the unintended consequences we need to be concerned about: congestion, gentrification, displacement, whatever. All those tools will help place managements. This is a new field of place management.

Edward Paice, Director, Africa Research Institute

In Africa, very rapid urban growth – spatial and demographic – is occurring without adequate planning (or, in many locations, any planning at all). Even where master plans have been drawn up, these tend to be either 'fantasy designs' drawing on wholly inappropriate models such as Dubai or Singapore; or they mimic equally inappropriate plans drawn up for cities in Europe or the US. Urbanisation in Africa is occurring in its own distinctive fashion and there are significant variations within and between countries. But one common feature is that the economies of nearly all towns and cities are predominantly informal. The creation of long-term, decent jobs by the state and private enterprise is woefully inadequate; industrialisation remains for the most part absent. For African urbanisation to become a positive economic and social development, as

opposed to a ticking time-bomb, urban planning needs to incorporate total populations, not simply the rich and middle classes; this is the only way that the economic potential of the majority can be harnessed for the national good. How can this be done? Firstly, citizens have to be involved. Community participation in slum redevelopment initiatives has proven to be a far more productive and cheaper way of going about things than imposing ill-conceived, expensive schemes from above. Secondly, the technology exists to facilitate the rapid planning required – for example, data collection with mobile phones and satellite imagery have already been beneficial. Thirdly, urban-dwellers everywhere – voters – can mobilise even more effectively to ensure that their elected representatives deliver more. We are seeing this occurring in more and more towns and cities and it is a very positive development for cities, for infrastructure development and for democracy. Even in autocracies there is always room for citizens to organise and thereby secure services or rights that they have been denied. The final, essential, component is political will. This has been conspicuously lacking, but more determined and competent mayors and city leaders are emerging and the power of example is considerable.

The majority of Africans will live in towns and cities by 2050. Management consultancies and international financiers routinely claim that rapid urbanisation is one of the great pluses in the investment case for Africa. As things stand, this is hyperbolic nonsense. For towns and cities to drive economic growth and livelihood improvement, more imaginative and effective urban planning and management are imperative; and the provision of public goods must replace a narrow focus on the wellbeing of elites.

Nick Reed, Academy Director at the Transport Research Laboratory

Safety of travel – by that I mean not just the 1.3m that die on the roads each year (clearly unacceptable) but also the broader implications (effects on mental health and respiratory illness through poor air quality; need to move sustainable travel – walking and cycling to tackle obesity, diabetes etc)

Automation – as we move towards automated, electric vehicles, need to consider the effect on employment and wider implications of how we access mobility. Travelling on busy roads at peak hours could become the preserve of those who can afford to pay – how does that affect commuting etc; how will this change urban planning etc.

AI – automated vehicles are one application of AI but what are the wider implications for employment (need for universal basic income?), privacy and security

Shin-pei Tsay, Executive Director, Gehl Institute

Within urban areas, a significant constraint today and into the future will be how people move around the city. Many extoll the potential of technology to overcome that problem. Whatever technology may accomplish, we will still need to think about how space is used: automated and ride-sharing vehicles take up as much room as regular cars,

whether they're on the road or parked off the street. Going into the future, urban space still needs to be designed to maximize places for people to congregate, which are key to building social connections, fostering a sense of belonging, and encouraging community efficacy. Space for human connection is often not considered at all against technological solutions in cities.

Without the design of places to support a social dimension, cities will not thrive regardless of how much technology we attempt to integrate, design for, and adopt. Public health outcomes increase when isolation diminishes and people connect. We save billions in environmental costs if we plan for places that encourage people to spend time outside. We even reduce economic limitations in labor markets when we plan for places that allow people to shorten their commute distances and have access to stores, schools, and other daily services.

It's always fun to consider panaceas that can theoretically solve age-old problems (in this case, growing populations with increasing travel needs). However, not nearly enough attention is given to the social impacts of these new solutions. We must carefully consider how they may change the physical shape and design of our cities in the future. Most importantly, we must be aware of how they might isolate us. After all, by limiting our ability to socialize, technology may only generate new problems to replace the ones it "solved."

Back to Cities

HEALTH AND HUMANITY

Nicholas Agar, professor of ethics at the Victoria University of Wellington

Recent advances in gene editing suggest a future in which we can radically upgrade human genomes. We might use tools including CRISPR to rewrite genes that influence traits such as intelligence and lifespan. We should bear in mind when we contemplate this enhanced future that the obvious answers aren’t always the right ones. The human genome isn’t something we should seek to build a wall around, protecting it from all change. But a rush to enhance ourselves may erase aspects of our humanity that proper reflection reveals as valuable. More IQ points aren’t better than fewer in the straightforward way that more money is better than less. We risk oversimplifying what’s involved in enhancement. Proper reflection on what about us we might want to preserve takes time – it should draw on a wide range of perspectives about what it means to be human. It’s difficult to set aside this time for ethical reflection when new technological possibilities seem to be coming thick and fast.

Luke Alphey, visiting professor, Department of Zoology, University of Oxford

Agricultural pest insects, and mosquitoes transmitting diseases, are long-standing problems for which we still have no satisfactory solution, indeed the problems are

becoming more pressing. Modern genetics can potentially provide powerful new means for controlling these ancient enemies with greater effectiveness and precision – for example minimal off-target effects on the environment – than currently-used methods. Gene drives are just one aspect of this, but perhaps encapsulate some of the issues. One gene drive system, involving inserting into mosquito cells a large amount of foreign (to the mosquito) DNA in the form of an intracellular bacterium (Wolbachia), has entered field trials in several countries. This specific system has avoided the “genetic” or “GMO” label and regulatory system by adroit marketing and some technicalities and perhaps illustrates what could be done if the field were not caught up in the baggage and polarised politics of the GM crops “debate”. Potential applications of genetic methods in public health and conservation biology, for example, have very little in common with GM crops; lumping them together risks poor debate, poor policy and – in my view – potential delay or loss of huge human and environmental benefits.

Elizabeth Bradley, Professor of Grand Strategy, Head of Branford College, Professor of Public Health and Faculty Director of the Yale Global Health Leadership Institute

The tremendous impact that social, environmental and behavior factors have on our health overall. Recent research has shown that a country’s ratio of health to social service spending is predictive of some key health outcomes, like life expectancy, infant mortality, and maternal mortality. Genetics and health care play a role, but social, environmental, and behavioral factors have far greater impact on the whole health of a population.

Some examples of social service investments include job training, supportive housing, and nutritional support – all of which have traditionally had an underestimated focus of attention. Health and social services should be better integrated toward the achievement of common metrics, like lower rates of smoking, obesity, and depression. More research is needed, to measure the health care cost savings of early childhood education or income support programs, and to identify the most sustainable integrated models. Meaningful change in our world’s health may come less from investing in medical care than in addressing the social determinants of health.

Chelsea Clinton, Vice Chair, Clinton Foundation

Read Clinton’s extended response about the US opioid epidemic.

Jennifer Doudna, Professor of Molecular and Cell Biology and Chemistry at the University of California, Berkeley, co-inventor of CRISPR-Cas9 technology

As a co-inventor of CRISPR-Cas9 gene editing technology, I am delighted to see that this groundbreaking ability to “cut and paste” genes so efficiently is being harnessed as

a strategy to create new food, therapeutics, materials and methods for controlling the spread of diease.
A challenge moving forward is how to best engage the public with this fundamental science that really can positively impact human life and the world we live in. I believe that we must continue to discuss and consider the profound societal and ethical impacts of CRISPR technology and ensure that it is not abused.c

Joel Garreau, author, journalist, Professor of Law, Culture and Values, Sandra Day O'Connor College of Law, Arizona State University
The major challenge consuming me is that the wheels are coming off the Enlightenment right now, on our watch, and it's our own damn fault.
The GRIN technologies – the genetics, robotics, information and nano revolutions – are advancing on a curve. Meanwhile, we humans are trying to process this exponential change with our good old v. 1.0 brains. With precious little help at all from those creating this upheaval.
Folk are not stupid. They can clearly detect the ground moving beneath their feet, and that of their children and jobs and futures. When the ground moves beneath her feet, any sane primate looks for something apparently solid to hold onto. Anybody with apparently simple stories about what's going on, forcefully told, *will* get attention.
You've doubtless seen the data about how the most common job in the vast majority of states is truck driver. So what are we doing? We're obsoleting these jobs as fast as we can, with a hand wave about how, "Oh, they'll find better jobs." While, meanwhile, the rate of suicide and drug addiction and protest voting among the solid middle-aged former middle-class soars. These guys are not stupid. They know they've been had. And we're going to pay for it. And don't tell me the solution is to have the robots just give them a guaranteed income. Humans require meaning as surely as food.
The days when scientists could not [care] about the impact of their work on cultural, values and society are over. If they ever existed, which they didn't, but that's water over the dam.
I can't tell you how many times I've talked to guys working on, oh, something like massively increasing the number and power of mitochondria in human cells. And I'm like, you know that if you massively increase the amount of energy creation in cells, you're talking about changing what it means to be human, right? Are you intentionally trying to create supermen? And the answer every time is "Wow, what a fascinating question, I never thought of that."
It's not that these scientists are stupid, obviously. It's that they're tunnel-vision. They don't wake up thinking about how they can change the human race. They wake up thinking about how they're going to wire the goddamn monkey. That's just the way these guys are.

Fix it. Get out of your silo. If you can't figure out the societal and cultural implications of what you're doing, start seeking out people who might, and start systematically having lunch with them. And then invite the most interesting ones into your lab with the goal of them becoming partners.

One example of this was the scientist who was spending her life finding the biomarkers for a disease for which there was no cure. Mercifully, her lab was among the first to start systematically bringing in partners from entirely outside. One of them asked, "What's the point of creating despair? Might it be possible for you to find it interesting to search for a biomarker for a disease to which there is a cure?" To which she replied, of course, "Wow, what a fascinating question, I never thought of that." But once it was pointed out to her, she happily did find another interesting biomarker problem that was culturally useful.

Culture moves slower than does innovation. That's just what humans are like. Deal with it, or watch the collapse of the Enlightenment as they ever increasingly come at you with torches and pitchforks – and correctly so. Mary Shelley knew her humans.

My wife and I used to raise border collies. Border collies make terrible pets. You can not give an intelligent species nothing to do. If you don't give them sheep, or something comparably interesting, they will come up with something to occupy their great minds. And you may not like it.

Laurie Garrett, Pulitzer Prize-winning science journalist, senior fellow for global health at the Council on Foreign Relations

1. Greatest frustration: It is deeply annoying and vexing that CRISPR-cas9 and other gene editing techniques are being applied to treatment of rare diseases and a host of pharmacology development, but little investment is directed toward application of state-of-the-art gene editing or metagenomic sequencing and detection for point-of-care diagnostics creation. There are many exciting developments at the lab bench level that could translate into "Star Trek"-like abilities to wade into epidemic hysteria and swiftly identify who is infected, and with what organism. There are even innovations that allow identification on-the-spot of infections with previously unknown microbes, based on conserved genetic regions found in classes of viruses or bacteria. But nobody seems interested in bankrolling such game-changing innovations for production on a mass scale. It's a market failure issue – a where's-the-profits problem. If Ebola broke out somewhere tomorrow we are better off today in that some methods for quickly identifying the virus in blood samples exist, but even now they remain noncommercial, require a laboratory and have no relevance to real-world conditions.

2. In 2009-10 some in the national security community were obsessed with concern about gain-of-function research, mainly on flu viruses. Researchers were deliberately creating forms of H5N1 and H7N9 and H1N1 that could be passed mammal-2-mammal, probably human-to-human. The goal on researchers' parts was to understand what

genetic switches had to occur to turn a bird flu into a potentially catastrophic human airborne transmissible pandemic strain. But of course the work was very dangerous – especially if it got into the wrong hands.
That was then, this is now: The technology of gene modification is far more advanced, and application of cutting edge gene excision and incision techniques makes gain-of-function work potentially far easier, and more dangerous. The two governments that were taking the lead on dual-use research of concern issues (UK and US) are both preoccupied now with very different problems and new leadership. And the WHO was the lead global agency – it is facing a major leadership change. So we have no guidance regarding how governments are likely to view these issues.

Tim Jinks, Head of Drug Resistant Infections at Wellcome Trust
Modern medicine depends on doctors having effective drugs to treat infections. But many common infections are becoming more difficult to treat because bacteria are becoming resistant to the drugs available. Drug-resistant infection – or antimicrobial resistance – is a very serious health threat to us all. Already it results in around 700,000 deaths a year globally. Within a generation it could be 10 million; it could mean we can no longer safely carry out not only complex, lifesaving treatments such as chemotherapy and organ transplants but also more routine operations like caesareans and hip replacements. More needs to be done to improve our ability to diagnose, treat and prevent drug resistant infections and to speed up development of new antibiotics to replace those no longer effective in protecting us against deadly infections.

Anit Mukherjee, policy fellow at the Center for Global Development
Technological innovation is progressing rapidly not only in the digital sphere but also in areas such as health, education, nutrition, food safety and life-saving/enhancing drugs. However, the gains of these new technologies are being captured by a minority of the population both domestically and internationally. While the digital divide has received more attention (and being bridged significantly), inequality is manifesting in other sectors that ultimately affect peoples' well being. One outcome is human migration which is not only political but also economic and social. The other is the more frequent outbreaks of diseases, epidemics and pandemics such as ebola, MARS and Zika. In a world where there is a sentiment against movement of goods and people, how can developing societies adapt to increasing inequalities and build systems of governance to ensure human security?

Pardis Sabeti, Associate Professor of Organismic and Evolutionary Biology and of Immunology and Infectious Diseases, Harvard University

The recent Ebola and Zika epidemics exposed our global vulnerabilities to deadly microbial threats and highlighted the need for proactive measures in advance of outbreaks and swift action during them. At the same time it shows our ability to prevent, diagnose, and treat deadly infectious diseases through new technologies. It is a time of great potential for devastation or advancement for one of the greatest challenges of our lifetimes.

Robert Sparrow, adjunct professor, Centre for Human Bioethics, Monash University

What does justice require of wealthy Northern states when confronted by mass migration from increasingly impoverished Southern countries as a result of accelerating climate change?

How should we respond, both ethically and emotionally, to the knowledge that we are living through one of history's fastest periods of extinction and that this catastrophe is the result of humankind's activities?

As technological developments increasingly drive social change, how can democratic societies empower ordinary people to have a say in the decisions that shape the technological trajectories that will in turn determine what the future looks like?

How can the public have meaningful input into the character of the algorithms that will increasingly determine both the nature of their relationships with other people on social media and their access to various important social goods?

How can we prevent an underwater arms race involving autonomous submersibles over the coming decades?

Should we use "gene drives" to try to eliminate disease vectors in nature?

How can we ensure that questions about meaning and values, and not just calculations of risks and benefits, are addressed in decisions about human genome editing?

Eric Topol, Scripps Transatlantic Science Institute

Our major challenge is related to our new capability of digitizing human beings. That is, via biosensors, DNA sequencing and imaging, we can define each individual's medical essence. But the problem is that this generates many terabytes of data, which includes real-time streaming of key metrics like blood pressure. Aggregating and processing the data, derived from many sources, with algorithms and artificial intelligence (particularly deep learning) is a daunting task. Once we can do this, we'll be on our way to a virtual medical coach – your smartphone providing instantaneous feedback on all your health and medical metrics to help prevent you from getting sick.

Mike Turner, Head of Infection and Immunobiology at Wellcome Trust

Infectious disease outbreaks are a growing threat to health and prosperity in our modern world. Vast amounts of international travel, increasing urbanisation and a changing climates means that viruses can cross borders and spread around the globe faster than ever before. Recent outbreaks like Sars, Ebola and Zika have all shown how unprepared the world is to deal with epidemics. To stand any chance of tackling this threat, we need new vaccines, stronger healthcare systems and a better coordinated global response.

At Wellcome, we're working to address this threat in a variety of ways; we are a founding partner of the Coalition for Epidemics Preparedness Innovations (Cepi) that will develop new vaccine candidates against infections we know could cause a serious epidemic. The WHO also needs to be much better funded and have the mandate to respond swiftly and effectively when diseases do begin to spread. Only by investing, coordinating and working together can we expect to prepare the world for the next inevitable epidemic.

Watch our animation with words by Bill Gates on Cepi's vaccine plans.

Gavin Yamey, professor of the practice of global health, Duke University Global Health Institute

I believe one of the most urgent global issues that we face in 2017 and beyond, and one that we are woefully ill-prepared for, is the threat of epidemics and pandemics. We have three enormous gaps in the global system of preparedness. First, many countries have weak national systems for detecting and responding to outbreaks. Second, we have too few vaccines, medicines, and diagnostics for emerging infectious diseases with outbreak potential. Third, at the international level, we simply don't yet have a robust, joined-up approach to providing the essential components of a preparedness and response system – like surge capacity in producing vaccines in a crisis, an inter-connected global surveillance system, or a global reserve corps of emergency responders. Closing these three gaps is one of the most urgent global priorities if we are to avert a potential world catastrophe. For example, if we suffer another flu pandemic similar to the 1918 "Spanish flu," the World Bank estimates that there could be 71 million deaths and a global recession costing over $3 trillion.

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ENERGY

Homi Kharas, senior fellow and deputy director of Brookings Institute's Global Program

The battle for sustainable development will be won or lost in cities. 150 million people are moving to cities each year. By 2050, over 7 billion people will live in cities (80% of the world), and cities will be responsible for 75% of global carbon emissions. Cities are places where infrastructure gets locked in for decades, if not centuries, but city planners must make investments now in a world where technology is changing rapidly where people live, work and play, and how they access buildings, transport, energy and waste management. The fastest growth is happening in thousands of secondary cities where mayors and city managers are not well schooled in technical urban planning. Often, these secondary cities must collaborate with each other to deliver services effectively across boundaries within larger metropolitan areas.

Carey King, assistant director, University of Texas at Austin Energy Institute
We need a discussion as to what political leaders, business leaders, and citizens think is an appropriate distribution of wealth across the entire population. This focuses on the real question (how many people have what, independent of the size of the economy, though the two are linked) instead of discussing how to shape policies and taxes to achieve an unspecified growth target independent of wealth distribution. Trump, Brexit, and Le Pen are representations that people understand growth only for the elite in the West is no longer tenable.
An issue that has not received enough attention in the media and popular understanding is that the Earth is finite and this fact will have real world physical, economic, social, and political implications. Neoclassical economics ignores this obvious fact, yet it is used to guide most policy (eg, economic projections and scenarios), including that for climate change mitigation. Thus, we are using an economic theory that is simply incapable and inapplicable for informing an unprecedented transformation of the economy.

Vijay Padmanabhan, Asian Development Bank, Technical Advisor (Urban)
The one major challenge we will face due to urbanisation will be 'water security'. We are already grappling with this problem across our developing member countries and with deteriorating river or surface water quality, lack of sufficient ground water sources and increasing dependence on sea water as a supply source, we have to bring in innovations in water management. Treatment technology, water aquifer mapping, recycling and reuse of wastewater, etc. are areas of R&D investment.

ADB is working with a large number of utilities to address these issues and as we engage on a long term basis with many cities and utilities, we will be actively exploring opportunities to bring in value for money propositions so that the utility benefits in the long term. We are also connecting with industry leaders to understand market trends so that we can bring the best to our developing member countries.

William Ryerson, founder and president, the Population Institute and Population Media Center

Perhaps a summary is that the human enterprise has outgrown the long-ability of the planet's renewable resources to support us at our current numbers and our current rates of consumption and waste generation. Climate change is just one piece of evidence of this fact. Technological improvements, while potentially important in reducing per capita impact, are not sufficient to make us sustainable unless we also stop growth in human numbers and reduce average consumption, while simultaneously lessening the gap between the richest and the poorest people on the planet.

Sustainability is a term that is not well understood and is misused, but the reality is that any activity that is not sustainable will stop. So far, non-renewable resources are what are primarily driving our economic engine. But by definition, non-renewables are being depleted and for the most part will stop being economically available in this century. So we must plan rapidly for the day when humanity can live using just renewable resources, while maintaining the biodiversity that makes the planet habitable. In truth, sustainability is the ultimate environmental issue, the ultimate health issue, and the ultimate human rights issue.

Strategies that help to bring about changes in societal behaviour, including reproductive behavior, are critically important in achieving sustainability. Use of entertainment media is a key component of such strategies, since a large share of humanity consume entertainment mass media during free time. For that reason, Population Media Center utilises long-running serialised dramas in various countries to create characters that gradually evolve into positive role models for the audience to bring about changes in social norms on a broad array of critical issues. Attached are three documents that describe this work and its effects.

Jim Watson, Director of the UK Energy Research Centre

We need to think about how the system will fit together as our energy systems change. Globally speaking there is still a lot of people – 1.5 billion or so – who do not have access to modern energy services. There is going to be a lot of rising demand from regions like Africa.

One of the big challenges of deploying new energy technologies, particularly these intermittent renewables like wind and solar, is the impact they have on the system. It used to be that in the summer it was a really quiet time for the grid operator compared

to the winter, but now they are having this peak in generation in summer due to solar energy when demand is low. They are having to juggle this as we cannot store electricity in large quantities yet. This is a new way of operating for them.
With the sort of changes we are seeing in energy systems around the world, cheaper and better storage is going to be a big part of the solution. When it comes to heating for somewhere like the UK, you might need storage that lasts several months. You get a lot of energy generated in the summer and you might need it in the winter to heat homes. This is an area that is really ripe for innovation and we are really only at the start of deploying and trailing those. It is a critical part of this new system we are trying to create.

Back to Energy

FUTURE OF THE INTERNET, MEDIA AND DEMOCRACY

Peter Barron, VP Communications, EMEA, Google
Google was built on providing people with high-quality and authoritative results for their search queries. We strive to give users a breadth of diverse content from variety of sources and we're committed to the principle of a free and open web. Judging which pages on the web best answer a query is a challenging problem and we don't always get it right. When non-authoritative information ranks too high in our search results, we develop scalable, automated approaches to fix the problems, rather than manually removing these one-by-one. We recently made improvements to our algorithm that will help surface more high quality, credible content on the web. We'll continue to change our algorithms over time in order to tackle these challenges.

Rohit Chandra, VP Engineering, Yahoo
Search providers face a confluence of human and technology challenges. While we provide the portal for users to find information, we depend on content creators and distributors to apply journalistic discipline to what they are creating. The scale of popular social networks has democratized publishing, which effectively lets anyone – regardless of their intentions or qualifications – produce content that can appear journalistic.
Another challenge is that technology-driven online engines like ours learn through click-feedback or "crowd-sourcing." That runs the risk of perpetuating a "herd-mentality" – in which if lots of users start chasing a particular news source (maybe based on shock value rather than credibility), our AI-systems could accidentally "learn" and treat that source as highly valued or credible.
I do see a need in the market to develop standards, perhaps from an organization like Nielsen. Facebook and others are working on this, too. The answer has to be a combination of technology and editorial; we can't fact-check every story, but there must be enough human eyes on the content that we know the quality bar stays high.

Eddie Copeland, director of government Innovation at Nesta, a UK charity that has looked at the future of democracy in the digital world

Rather than waiting for politicians to make decisions and then we all argue over whether what they say reflects reality, we could have tools that engage people much earlier in the process so they can be involved in formulating ideas and drafting legislation, following the course of how ideas go from concept to becoming laws and how effective they are in reality. It might just give you a fighting chance of making people feel part of a system rather than observing it from the outside.

Nonny de la Pena, Virtual Reality journalist and CEO of Emblematic Group

Call me idealistic, but I really believe if you have an informed global citizenry, then people are going to make better decisions. We are going through the pain of, how do we convey information that's accurate? People may not be looking at traditional media for their solutions. I think for audiences, VR is a totally different type of story. There is nothing in print or radio or broadcast that can let you walk around in actual space. That kind of effort, of making those kinds of pieces, is going to get easier and easier. You'll be walking around the scene, not looking at flat screen or video.

When you walk around, it's a whole other level. Now your body can engage. Now when I go to the movies, I find the frames so artificial – I can see the box. I see the square. When I put on a headset, I see the world. The fact that audiences are going to be engaged with this kind of storytelling make sit a very important opportunity for journalism to embrace.

Ben Fletcher, senior software engineer at IBM Watson Research who worked on a project to build an AI fact checker

We got a lot of feedback that people did not want to be told what was true or not. At the heart of what they want, was actually the ability to see all sides and make the decision for themselves. A major issue most people face, without knowing it, is the bubble they live in. If they were shown views outside that bubble they would be much more open to talking about them.

Kevin Kelly, founding executive editor of Wired Magazine

The major new challenge in reporting news is the new shape of truth. Truth is no longer dictated by authorities, but is networked by peers. For every fact there is a counterfact. All those counterfacts and facts look identical online, which is confusing to most people. The only way a fact becomes accepted as true is to be networked with other facts consider to be true. Like in Science, all truth is provisional, although some is more provisional than others. The Truth is really a network of truths, and each of these true facts is probabilistic. The probability of a fact being true is increased by the degree it is

networked with other true facts and the reliability of truthfulness by its source. So the challenge before us is to begin to construct a truth signaling layer into the fabric of facts, particularly online. This will be a multi-generational effort that will resemble the construction of wikipedia, but goes far beyond it.

Stephan Lewandowsky, a psychologist at University of Bristol who studies persistence of misinformation in society

Having a large number of people in a society who are mis-informed and have their own set of facts is absolutely devastating and extremely difficult to cope with.

There are solutions available – using the technology that has given rise to this problem. Turning it upside down by changing the algorithms in Facebook or on Google to nudge people into sharing or consuming news that are slightly outside their normal comfort zone. What is happening now is that the cookies you gather as you browse the web will tell the website what it is you like.

The way to get out of this polarisation is for these algorithms to suggest something that I might not like or agree with but is not so offensive to me that I wouldn't look at it. That way you can keep people from self-radicalising in these ecological bubbles. That sort of technological solution is one good way forward. I think we have to work on that.

Alexios Mantzarlis, chair of the International Fact Checking Network

I see a challenge in the flood of reasonable-looking information out there making it harder to distinguish between sources of information. Search algorithms are as flawed as the people who develop them. We should think about adding layers of credibility to sources. We need to tag and structure quality content in effective ways.

Will Moy, director of Full Fact, an independent fact checking organisation based in the UK

Even if we have structures that impose constraints on people in power and we put pressure on powerful people to be honest with us, in a sense, all of that is being circumvented by social media. On Facebook, political bodies can put something out, pay for advertising, put it in front of millions of people, yet it is hard for those not being targeting to know they have done that. They can target those people based on how old they are, where they live, what skin colour they have, what gender they are.

These messages are so common and so targeted, they are capable of having a massive influence on public decisions. We have never had a time when it has been so easy to advertise to millions of people and not have the other millions of us notice. You can't take out an advert in a newspaper and not have the people you are not targeting not notice. that is a really profound change. We shouldn't think of social media as just peer to peer communication – it is also the most powerful advertising platform there has ever been.

We need a more equipped environment - we need watchdogs that will go around and say hang on, this doesn't stack up and ask them to correct the record. There is a role for watchdogs and there is also a role for all of us.

Paul Resnick, professor of information at the University of Michigan who developed a tool for identifying rumours on social media called RumourLens

The fundamental challenge we now face is how to handle a setting where anybody can get their views disseminated without intermediaries to prevent the distribution. Somehow there still has to be some process of collectively coming to some agreement of what we are going to believe and what we think are consensual facts.

A lot of what I have seen in terms of approaches to deal with that are trying to do things that are focused on assessing the content of factual claims to try to verify whether they are true or not.

I don't think that at its heart will be the mechanism. I think that it is going to be not figuring what to believe but who to believe.

Most individuals can't personally verify most factual claims that we hear. If you think about some of the things you personally believe that are fact, there are many that you have not personally verified. It would be tremendously inefficient for all of us to try to personally verify all of these things. We have to have a setting where we trust other people.

Victoria Rubin, director of the language and information technology research lab at Western University, Ontario, Canada

If there are people who are willing to blatantly refuse to believe that something is a lie, no matter how hard you try, they won't listen. I'm not sure what amount of evidence is needed in this new paradigm of journalism to get newsreaders out of their new bubbles. Human psychology is the main obstacle, unwillingness to bend one's mind around facts that don't agree with one's own viewpoint.

We're studying how news framing affects attribution of blame for events described in the news, and whether there is mitigating effect of partisan beliefs. The second newer misleading type of fakes that's gaining traction is native ads (specifically, in news), or sponsored content that's disguised as editorials, or what's formerly known as advertorials. Such misleading practice constitutes an internal threat to the profession of journalism and may further deteriorate mainstream media trust. If information users are unaware of the Native Ads original promotional nature, they may find themselves insufficiently informed or misled by its content.

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