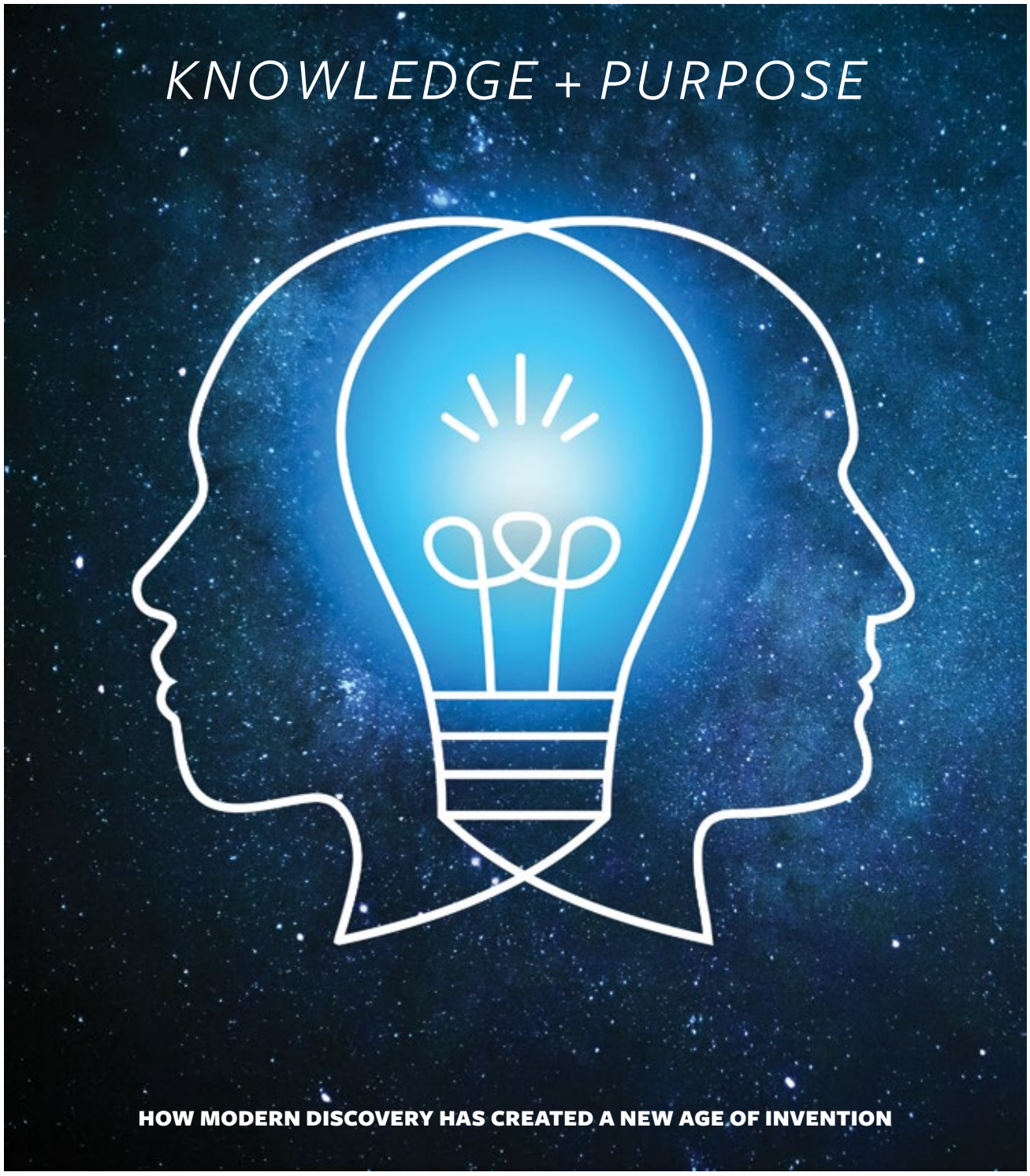
TREND

Analysis of the Facts, Numbers, and Trends Shaping the World
THE PEW CHARITABLE TRUSTS



in·ven·tion

[in′ven(t)SH(ə)n]

noun

1. a device or process originated after study. **2.** to produce something useful for the first time through imagination, ingenious thinking, and experimentation. **3.** to put knowledge to purpose for the public good.

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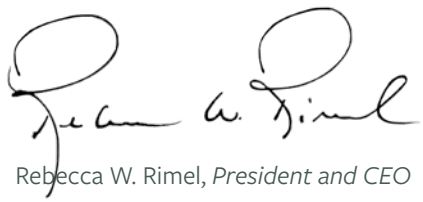
INVENTING THE FUTURE

Invention is deeply embedded in the history of The Pew Charitable Trusts. In business, the Pew family patented groundbreaking technologies and offered their employees benefits that were equally novel, including one of the earliest profit-sharing plans in the country. Their desire to innovate in pursuit of progress extended to their philanthropy, with early investments devoted to researching cures for cancer and helping historically black colleges and universities educate a new generation of young leaders.

In this second edition of *Trend*, we explore the theme of putting knowledge to purpose, looking at the many aspects of invention today. From engineering to public policy to the internet, human ingenuity constantly changes how we analyze risk, prevent and treat disease, find information, travel, steward our resources, and govern ourselves. As award-winning epidemiologist Dr. Alfred Sommer explains, it's both risk-taking and persistence that lead to breakthrough discoveries across diverse fields of endeavor.

There's no doubt that experimentation can save lives, build prosperity, and leave the world a better place for future generations. But new knowledge—and innovative ways to live and work that are the result of technological change—also present new dilemmas. One is what Lee Rainie of the Pew Research Center calls the "great re-sorting" of the roles people play in the world and the functions that machines will assume. While there are clear benefits, are we giving up too much of our privacy? How do we prepare workers for the computers and robots that alter their way of earning a living? And how do we assess and manage the impact of allowing algorithms that emphasize profit and efficiency to become more influential than human judgment?

Trend takes a close look at how some of these challenges are being addressed and why we must consider the broader implications of our own technological progress. We also examine how new discoveries can be harnessed to help us collaborate and solve problems, illustrating the fascinating ways in which data, science, and human creativity can spark astonishing advancements. I invite you to read along and offer your own thoughts about the blessings and quandaries that come with inventing the future.



Rebecca W. Rimel, *President and CEO*

PLEASE SHARE YOUR THOUGHTS ON THIS ISSUE OF *TREND* BY WRITING US AT TREND@PEWTRUSTS.ORG, OR JOIN THE CONVERSATION ON TWITTER WITH #PEWTREND.

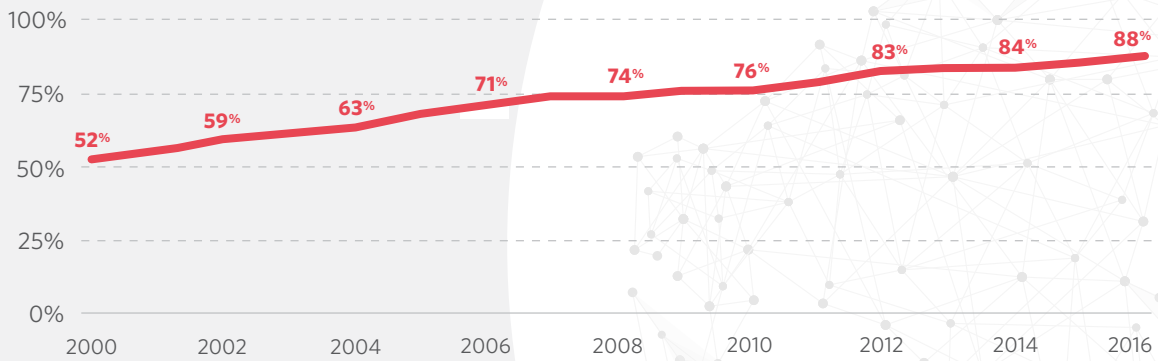
CRUNCH

The Revolution Is Digital

The modern age of discovery has been defined by the digital revolution. Enabling access to information in ways unheard of even a generation ago, the internet has transformed how people around the globe gather information, invent new products, communicate, and lead their daily lives. The revolution has produced boundless opportunities, altered the dynamics of international competitiveness—and created new challenges about our definitions of fairness and equality.

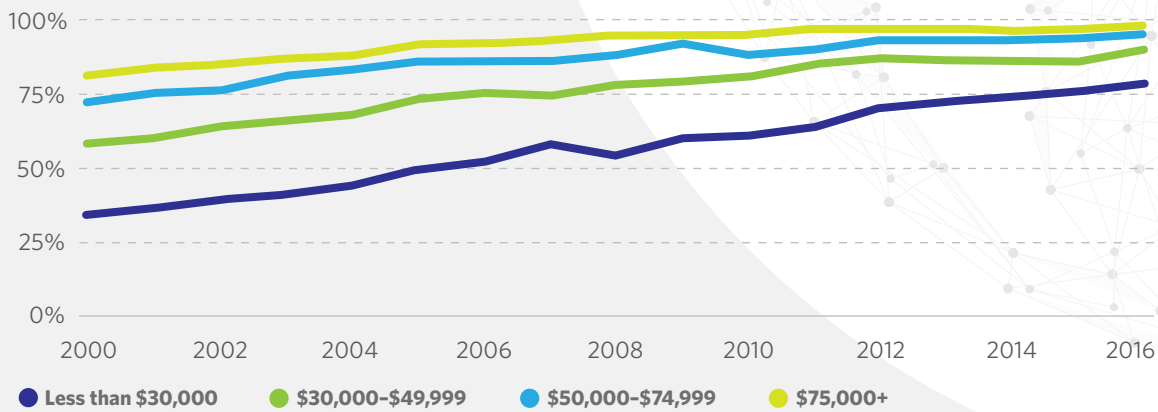
INTERNET USE OVER TIME

In early 2000, about half of all adults in the U.S. were already online. Today, roughly 9 in 10 American adults use the internet.



WHO USES THE INTERNET?

While internet usage is nearly ubiquitous in the U.S. for such demographic groups as young adults and college graduates, there is a distinct gap for factors such as income.

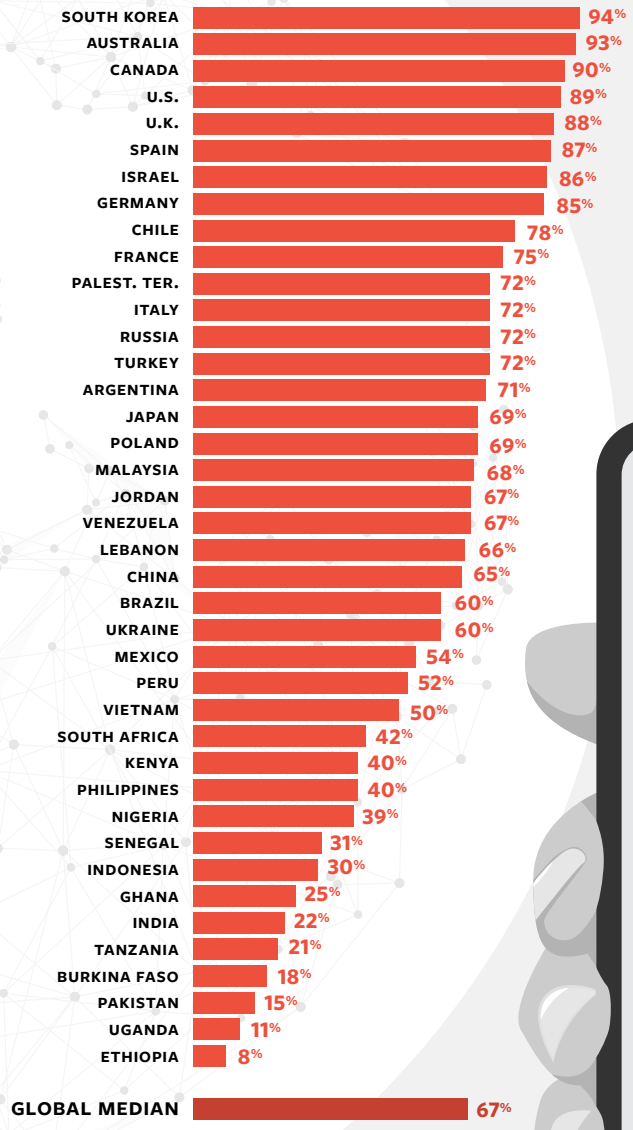


Source: Pew Research Center

INTERNET USE IS GROWING GLOBALLY...

Most adults in advanced countries use the internet, according to data from 2015, but that's less true in developing nations.

Adults who use the internet at least occasionally or report owning a smartphone



...AND SOME AFRICAN AND ASIAN COUNTRIES ARE SEEING DOUBLE-DIGIT INCREASES IN DAILY USE

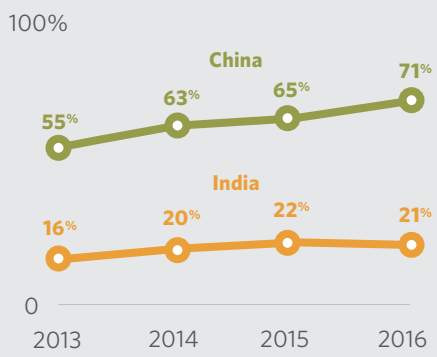
Adult internet users or reported smartphone owners who access the internet several times a day

	2014	2015	Change
NIGERIA	38	58	+20
GHANA	35	54	+19
CHINA	45	58	+13
MALAYSIA	51	63	+12
INDONESIA	32	43	+11
INDIA	31	42	+11
MEXICO	43	51	+8
VENEZUELA	31	39	+8
UGANDA	19	27	+8
SENEGAL	22	29	+7
ARGENTINA	52	58	+6
RUSSIA	49	55	+6

CHINA LEADS INDIA

The world's two most populous countries are emerging economic powers, and in the digital race, China in 2016 continued to stay out front.

Adults who use the internet at least occasionally or report owning a smartphone



HOW TO INVENT THE FUTURE

BY BRIAN DAVID JOHNSON

The future is not fixed. It is not a set point over the horizon that we are all running toward, helpless to do anything about it. The future is built every day by the actions of people.

When people ask me how they can prepare for the future, I tell them that they are asking the wrong question. We build the future—the way to prepare for the future is to invent it. If we do not take action, we cede control, turning the future over to others—or worse, to the mindless efficiencies of technology or economic greed.

People and organizations can all invent their futures. The first step is research, pulling together a wide variety of disparate and multidisciplinary sources of data to inform their vision. This is putting knowledge to purpose, using a mix of social science, technical research, cultural history, economic and trend analysis, global interviews, and even a little science fiction to envision a range of futures.

The next step is to ask, based on this research, what is the future we want and what's the future we want to avoid? Both are important. Understanding the dark futures and the steps we need to take to avoid them is possibly even more important than determining the tomorrows we do want to inhabit.

Next, we turn around from our 10-year-out vision and ask: What are the steps we need to take today, tomorrow, or five years from now to get to these positive futures and avoid the negative? As an organization, what needs to happen in four years? How will we build upon this to reach a new set of goals eight years from now? These incremental steps allow us to shape and invent the future.

Along the way, we explore what actions an organization can take but also consider what events, breakthroughs, and tragedies are out of our control and likely to happen so that we can anticipate how they might affect the futures we have envisioned.

This futurecasting process is not simply a method for inventing the future. It is a framework, a way for people and organizations to envision multiple futures, to take action to shape them—while also giving us a way to process new information and unexpected events.

This futurecasting is not about prediction, either. Instead, it allows us to embrace the many uncertainties that lie between today and the futures we are exploring. These uncertainties are our potential for innovation and opportunity. Without these possibilities, the future would be fixed and closed, stamped with an expiration date and unable to be changed.

The final step is to construct our stories of the future, expressing both the positive and the negative. This requires being able to tell people those stories in an understandable way. When I work with organizations, I find these stories provide

a shared language for their people to talk about the future and refer to the underlying research and science and even to argue about the future. After all, discovering two conflicting futures is an important part of invention, and finding people with different perspectives to debate these futures is a gift. That's because of another important reality: No vision of the future is completely correct, and the reality of the future will likely lie somewhere in the middle of those different perspectives.

Ultimately, the way we invent the future is to change the story we tell ourselves about the future that we will live in. If we change the story, we see different possibilities, make different decisions, and take different actions. Human beings are story-believing machines. Our very consciousness is based on our ability to tell and, just as importantly, understand other people's stories.

A well-researched and informed vision for the future can change lives, transform companies, and vastly improve the public good. As an applied futurist, I've seen it happen over the past half-century—we boldly envisioned our future in space, and we now see Mars on the horizon. But we must ask ourselves: What is the future we want? What is the future we want to avoid? And finally, what are we going to do about it?

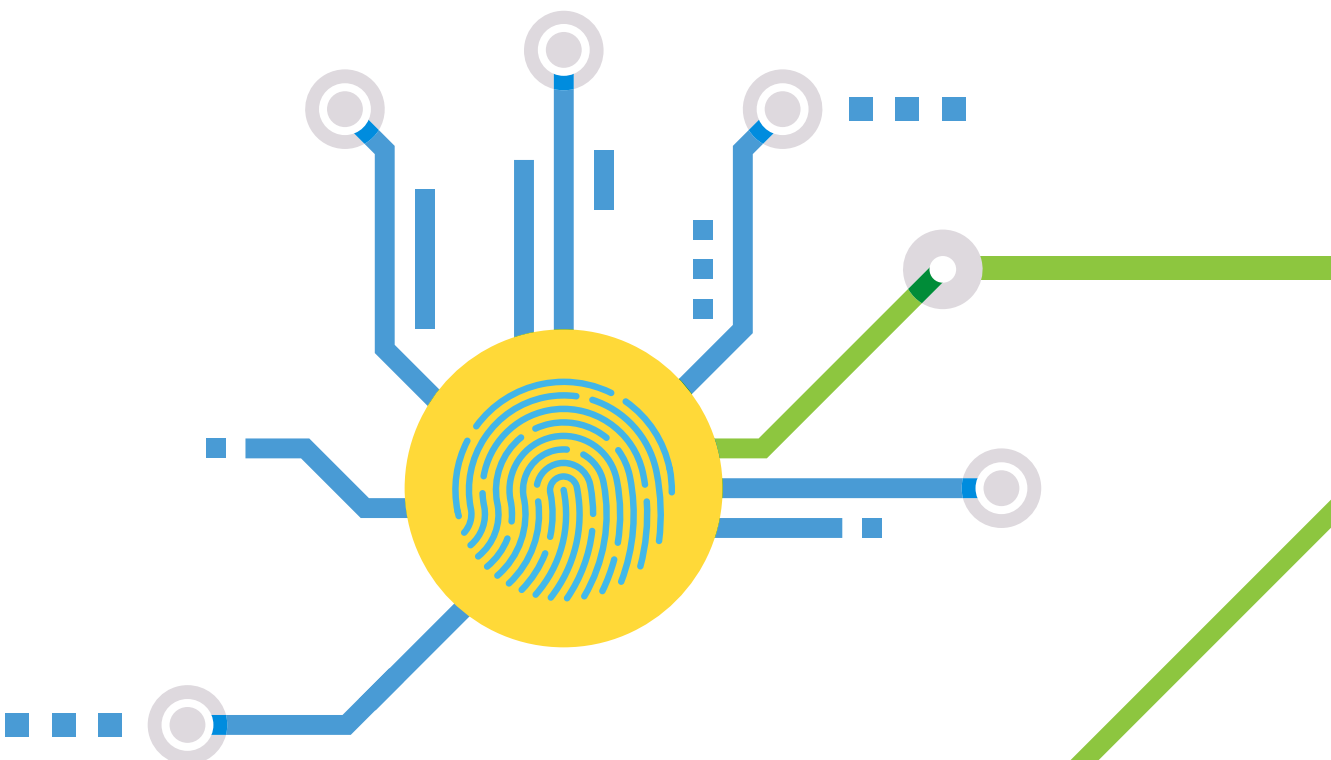
We all must actively work to invent the future; it's too important to be left to chance.

Listen to a conversation with Brian David Johnson about inventing the future at pewtrusts.org/afterthefact

WHAT IS THE FUTURE WE WANT AND WHAT'S THE FUTURE WE WANT TO AVOID? BOTH ARE IMPORTANT.

TECHNOLOGICAL INNOVATION? THAT'S THE EASY PART

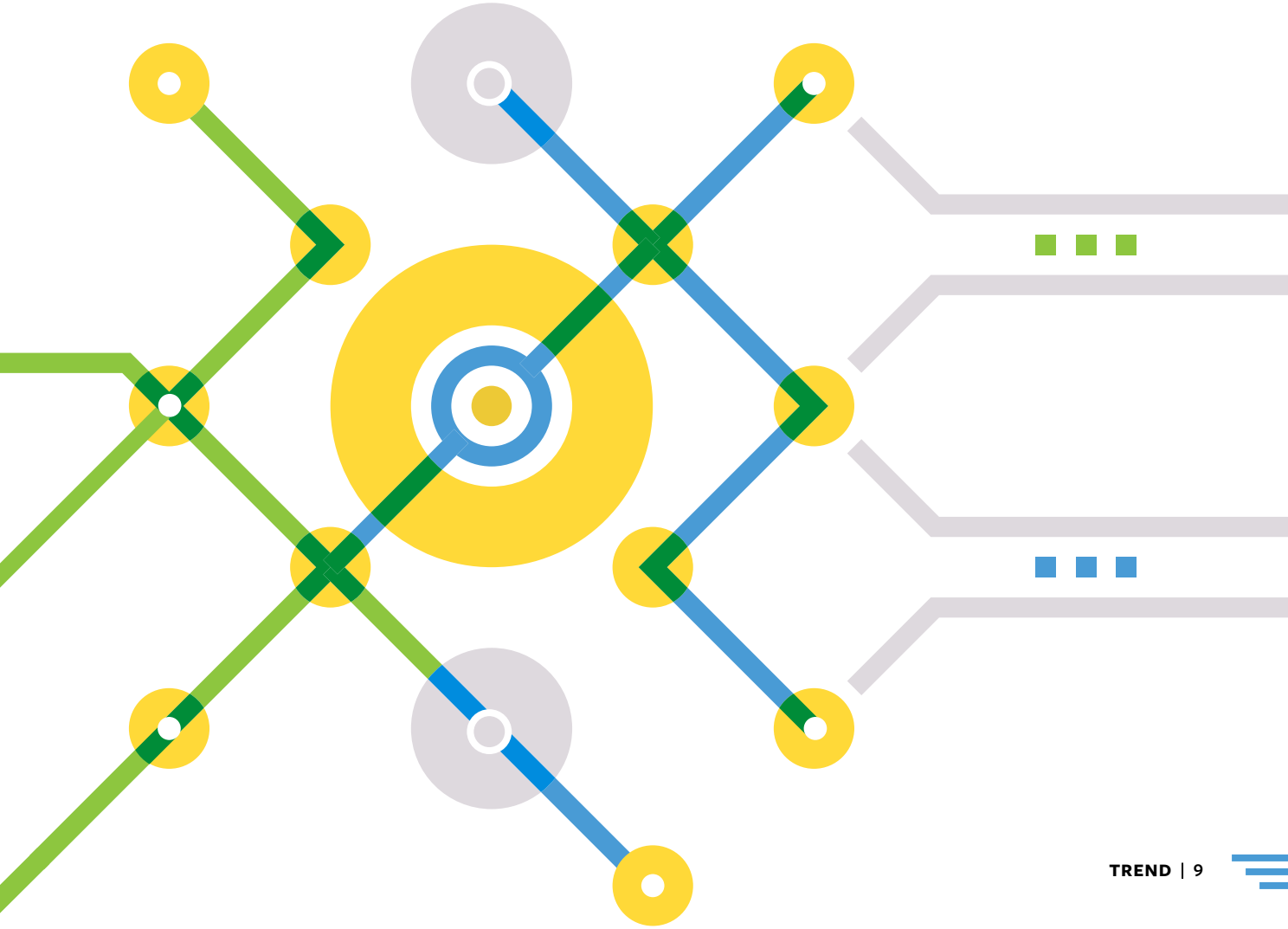
BY LEE RAINIE



As digital technology infuses everyday life, it will change human behavior—raising new challenges about equality and fairness.

In a single generation, this has become the new normal: Nearly all adult Americans use the internet, with three-fourths of them having broadband access in their homes. And the internet travels with them in their pockets—95 percent have a cellphone, 81 percent have a smartphone. This ability to constantly connect has changed how people interact, especially in their social networks—more than two-thirds of adults are on Facebook or Twitter or another social media platform.

Digital innovations have made it easier for people to find more information than ever before, and made it easier to create and share material with others. From smartphone-delivered directions to voice-driven queries to on-demand news, people's lives have been transformed by these technologies. Yet today's inventions and innovations mark only the start, and tomorrow's digital disruption, which is already underway, will probably dwarf them in impact.



The next digital evolution is the rise of the internet of things—sometimes now called the "internet on things." This refers to the growing phenomenon of building connectivity into vehicles, wearable devices, appliances and other household items such as thermostats, as well as goods moving through business supply chains. It also covers the rapid spread of data-emitting or tracking sensors in the physical environment that give readouts on everything from crop conditions to pollution levels to where there are open parking spaces to babies' breathing rates in their cribs.

The Pew Research Center and Elon University in North Carolina invited hundreds of technology experts in 2014 to predict the future of the internet by the year 2025, and the overriding theme of their answers addressed this reality. They predicted that the growth of the internet of things will soon make the internet like electricity—less visible, yet more deeply embedded in people's lives, for good and for ill.

The internet of things will have literally life-changing impact on innovation and the application of knowledge in the coming years. Here are four major developments to anticipate.

THE EMERGENCE OF THE 'DATACOSM'

The spread of the internet of things will accelerate the digitization of data, spawning creation of record amounts of information. Data and connectivity will be ubiquitous in an environment sometimes called the "datacosm"—a term used to describe the importance of data, analytics, and algorithms in technology's evolution. As previous information revolutions have taught us, once people—and things—get more connected, their very nature changes. "When we are connected, power shifts. It changes who we are, what we might expect, how we might be manipulated, attacked, or enriched," writes Joshua Cooper Ramo in his new book, *The Seventh Sense*. Networks of constant connection "destroy the nature of even the most solid-looking objects." Connected things and connected people become more useful, more powerful, but also more hair-trigger and more destructive because their power is multiplied by a networking effect. The more connections they have, the more capacity they have for good and harmful purposes.

On the human level, the datacosm arising from the internet of things could function like a "fifth limb," an extra brain lobe, and another layer of "skin" because it will be enveloping and omnipresent. People will have unparalleled self-awareness via their "lifestreams": their genome, their current physical condition, their memories, and other trackable aspects of their well-being. Data ubiquity will allow reality to be augmented in helpful—and creepy—ways. For instance, people will be able to look at others and, thanks to facial recognition and digital profiling, simultaneously browse their digital dossiers through an app that could display the data on "smart" contact lenses or a nearby wall surface. They will gaze at artifacts such as paintings or movies and be able to download material about how the art was created and the life story of the creator. They will take in landscapes and cityscapes and be able to learn quickly what transpired in these places long ago or what kinds of environmental problems threaten them. They will size up buildings and have an overlay of insight about what takes place inside them.

Part of the reason that data will be infused into so much is that the interfaces of connectivity and the ability to summon data will be radically enhanced. Human voices, haptic interfaces that can be manipulated by finger movements (think of the movie "Minority Report"), real-time language translators, data dashboards that give readouts on a user's personally designed webpage, even, eventually, brain-initiated commands will make it possible for people to bring data into whatever surroundings they find themselves. Not only will this allow people to apply knowledge of all kinds to their immediate circumstances, but it will also advance analysts' understanding of entire populations as their "data exhaust" is captured by their GPS-enabled devices and web clickstream activity.

Many experts in the Pew Research Center's canvassings expect major benefits to emerge from this growth and spread of data, starting with the fact that knowledge will be ever-easier to apply to real-time decisions such as which custom-designed medicine a person should receive, or

The internet of things will have literally life-changing impact on innovation and the application of knowledge in the coming years.

which commuting route to take to work. Beyond that, this data overlay and growing analytic power will allow swifter interventions when public health problems arise, weather emergencies threaten, environmental stressors mount, educational programs are introduced, and products are brought to the market.

This new reality will also cause major hardships. When information is superabundant, what is the best way to find the best knowledge and apply it to decisions? When so much personal data is captured, how can people retain even a sliver of privacy? What mechanisms can be created to overcome polarizing propaganda that can weaken societies? What are the right ways to avoid "fake news," disinformation, and distracting sideshows in a world of info-glut?

Struggles over people's "right relationship" to information will be one of the persistent realities of the 21st century.

GROWING RELIANCE ON ALGORITHMS

The explosion of data has given prominence to algorithms as tools for finding meaning in data and using it to shape decisions, predict humans' behavior, and anticipate their needs. Analysts such as Aneesh Aneesh of the University of Wisconsin, Milwaukee foresee algorithms taking over public and private activities in a new era of "algocratic governance" that supplants the way current "bureaucratic hierarchies" make government decisions Others, like Harvard University's Shoshana Zuboff, describe the emergence of "surveillance capitalism" that gains profits from monetizing data captured through surveillance and organizes economic behavior in an "information civilization."

The experts' views compiled by the Pew Research Center and Elon University offer several broad predictions about the algorithmic age. They predicted that algorithms will continue to spread everywhere and agreed that the benefits of computer codes can lead to greater

human insights into the world, less waste, and major safety advantages. A share of respondents said data-driven approaches to problem-solving will often improve on human approaches to addressing issues because the computer codes will be refined at much greater speeds. Many predicted that algorithms will be effective tools to make up for human shortcomings.

But respondents also expressed concerns about algorithms.

They worried that humanity and human judgment are lost when data and predictive modeling become paramount. These experts argued that algorithms are primarily created in pursuit of profits and efficiencies and that this can be a threat; that algorithms can manipulate people and outcomes; that a somewhat flawed yet inescapable "logic-driven society" could emerge; that code will supplant humans in decision-making and that, in the process, humans will lose skills and specialized, local intelligence in a world where decisions are based on more homogenized algorithms; and that respect for individuals could diminish.

Just as grave a concern is that biases exist in algorithmically organized systems that could worsen social divisions. Many in the expert sampling said that algorithms reflect the biases of programmers and that the data sets they use are often limited, deficient, or incorrect. This can deepen societal divides. Those who are disadvantaged could be even more so in an algorithm-organized future, especially if algorithms are shaped by corporate data collectors. That could limit people's exposure to a wider range of ideas and eliminate serendipitous encounters with information.

CONNECTED THINGS AND CONNECTED PEOPLE BECOME MORE USEFUL, MORE POWERFUL, BUT ALSO MORE HAIR-TRIGGER AND MORE DESTRUCTIVE BECAUSE THEIR POWER IS MULTIPLIED BY A NETWORKING EFFECT.

A NEW RELATIONSHIP WITH MACHINES AND COMPLEMENTARY INTELLIGENCE

As data and algorithms permeate daily life, people will have to renegotiate the way they use and think about machines, which now are in a state of accelerating learning. Many experts see a new equilibrium emerging as people take advantage of artificial intelligence that can be consulted in an instant, context-aware gadgets that "read" a situation and assemble relevant information, robotic devices that serve their needs, smart assistants or bots (possibly in the form of holograms) that help people navigate the world or help represent them to others, and device-based enhancements to their bodies and brains. "Basically, it is the Metaverse from *Snow Crash*," predicts futurist Stowe Boyd, referring to Neal Stephenson's sci-fi vision of a world where people and their avatars seamlessly interact with other people, their avatars, and independent artificial intelligence agents developed by third parties, including corporations.

Even if it does not fully reach that state, there will be a great re-sorting of the roles people play in the world and the functions machines assume. Now that

IBM's supercomputer Watson has beaten the world's best chess and "Jeopardy" players, and Google's AI system has vanquished the world's Go champion, there is strong incentive to bring these masterful machines into hospital operating rooms and have them help assess radiology readouts; to outsource them to stock trading and insurance risk analysts; to use them in self-driving cars and drones; to let them aid people's capacity to move around smart homes and smart cities.

The creation and application of all this knowledge has vast implications for basic human activity—starting with cognition. The very act of thinking is already undergoing significant change as people learn how to tap into all this information and cope with processing it. That impact will expand in the future. The quality of "being" will change as people are able to be "with" each other via lifelike telepresence. People's capacities are likely to expand as digital devices, prostheses, and brain-enhancing chips become available. Human behavior itself could change as an overlay of data gives people enhanced situational and self-awareness. The way people allocate their time and attention will be restructured as options proliferate. For instance, the manner in which they spend their leisure time is likely to be radically recast as people are able to amuse themselves in compelling new virtual worlds and enrich themselves with vivid new learning experiences.

GREATER INNOVATION IN SOCIAL NORMS, COLLECTIVE ACTION, CREDENTIALS, AND LAWS

With so much upheaval ahead, people, groups, and organizations will be forced to adjust. At the level of social norms, it is easy to envision social environments in which people must constantly negotiate what information can be shared, what kinds of interruptions are tolerable, what balance of fact-checking and gossip is acceptable, and what personal multitasking is harmful. In other words, much of what constitutes civil behavior will be up for grabs.

At a more formal level, some primary aspects of collective action and power are already altered as social networks become a societal force, both as pathways of knowledge sharing and as mechanisms for mobilizing others to do something. There are new ways for people to collaborate and solve problems. Moreover, there are a growing number of group structures that address problems ranging from microniche matters (my neighbors and I respond to a local issue) to macroglobal wicked problems (multinational alliances tackle climate change and pandemics).

Shifts in labor markets in the knowledge economy, which are constantly pressing workers to acquire new skills, will probably refashion some of the features of higher education and prompt change in work-related training efforts. Fully 87 percent of current U.S. workers believe it will be important or essential for them to

WE ARE LIKELY TO HAVE TO DEPEND ON OUR MACHINES TO HELP US FIGURE OUT HOW TO AVOID BEING CRUSHED BY THIS AVALANCHE.

pursue new skills during their work lives. Not many believe the existing certification and licensing systems are up to that job. A notable number of experts in another Pew Research Center-Elon University canvassing are convinced that the training system will begin breaking into several parts: one that specializes in basic work preparation education to coach students in lifelong learning strategies; another that upgrades the capacity of workers inside their existing fields; and yet another that is more designed to handle the elaborate work of schooling those whose skills are obsolete.

At the most structured level, new laws and court battles are inevitable. They are likely to address questions such as: Who owns what information and can use it and profit from it? When something goes wrong with an information-processing system (say, a self-driving car propels itself off a bridge), who is responsible? Where is the right place to draw the line between data capture—that is, surveillance—and privacy? Can a certain level of privacy be maintained as an equal right for all, or is it no longer possible? What kinds of personal information are legitimate to consider in assessing someone's employment, creditworthiness, or insurance status? Where should libel laws apply in an age when everyone can be a "publisher" or "broadcaster" via social media and when people's reputations can rise and fall depending on the tone of a tweet? Can information transparency regimes be applied to those who amass data and create profiles from it? Who's overseeing the algorithms that will be making so many decisions about what happens in society? (Several experts in the Pew Research Center canvassing called for new governmental regulations relating to the development and deployment of algorithms.) Which entities should define what is appropriate out-of-bounds speech for a community, a culture, a nation?

The information revolution in the digital age is magnitudes faster than those of previous ages. Much greater movement is occurring in technology innovation than in social innovation—and this potentially dangerous gap seems to be expanding. As we grapple with this, it would be useful to keep in mind the Enlightenment sensibility of Thomas Jefferson. He wrote in 1816: "Laws and institutions must go hand in hand with the progress of the human mind. As that becomes more developed, more enlightened, as new discoveries are made, new truths disclosed, and manners and opinions change with the change of circumstances, institutions must advance also, and keep pace with the times."

We are likely to have to depend on our machines to help us figure out how to avoid being crushed by this avalanche.

FIND MORE ONLINE

LEARN: *Watch Lee Rainie showcase the kitchen of tomorrow at pewtrusts.org/trend/internetofthings.*

FOLLOW: *@lrainie*

THE TAKEAWAY

The growth of the internet of things will soon make the internet like electricity—less visible, yet more deeply embedded in people's lives, for good and for ill.

YIELD OF DREAMS

BY JESS LOWENBERG-DEBOER

Precision agriculture is reversing standardized approaches to mass food production, allowing farmers to customize each square foot they cultivate and extract more value from each seed.

Imagine a world in which each plant or animal raised for food received individual attention by robotic farmers who supply the exact amount of nutrients needed at just the right stage of growth. A farm where microdoses of pesticides are applied only on the specific insect or weed or disease posing a problem. Farmers who are able to choose seeds after tapping a worldwide database on how a plant performs in an environment just like their own.

With the need to feed a global population that the United Nations projects will hit 9.6 billion by 2050, there is some urgency to perfecting those kinds of methods. Fortunately, with the developing sciences behind precision agriculture, that world is not far off. Using big data and new technology, the potential exists to transform farming as we know it today, increasing food, feed, fiber, and fuel production while simultaneously reducing the pollution and other environmental footprints of agriculture. What's more, precision agriculture will transform the comparative advantage of many geographic regions and force a reorganization of farm production.

Precise agriculture technologies are already well in place in the United States, Europe, and many industrialized countries. The trend began with use of GPS in the 1980s and 1990s to monitor crop yields and guide application of fertilizer. As digital technology spreads to the world's farms, robotics, big data, and other uses of electronic information will become as common as tractors and combines. It will transform how people manage farms, vineyards, orchards, forests, and livestock. This transformation is nearly assured given technological and societal inventions in recent years. But what is less certain is how these changes might affect local and regional agricultural cultures and labor markets. Today's culture of food—the farm-to-table movement, the rise of organic farming, and concerns about genetically modified organisms and the use of water in some areas—includes lively debate and many policy implications. Tomorrow's yield of dreams is therefore one that requires careful application of policy as much as technology.

A REVOLUTION IN REVERSE

In the beginning, of course, farmers were more like gardeners, who grew crops to feed themselves and their families. Civilization's earliest workers of the land figured out which individual plants best suited the soils on their small plots, and yields were low. But as history progressed and farmers gained scientific knowledge and mechanical expertise, they developed machinery to reduce their manual labor, chemicals to protect and nurture their crops. They brought big production methods to farming, and for some crops, yields increased tenfold from the 19th century to today.

But precision agriculture is reversing these standardized approaches and allows farmers to customize each square foot they cultivate, extracting as much value as possible from each seed.

It began in 1983, when the U.S. government made GPS technology available to the civilian sector. GPS found a ready audience among American farmers. They quickly adopted GPS guidance, mainly because it helped them to reduce the places they inadvertently missed or covered twice when applying fertilizer or pesticides, providing significant savings. According to the Purdue-CropLife survey, by 2015 almost 90 percent of fertilizer dealers used GPS guidance to custom apply fertilizer. Farmer adoption of GPS guidance has followed a similar path.

Another GPS application that has been around for several decades is "variable rate technology," which allows farmers to apply fertilizers at different rates throughout a field. Farmers test their fields at predetermined spots to determine levels of acidity, phosphorous, and potassium, and then an agronomist maps out recommended fertilizers for each area to maximize production. A GPS-guided fertilizer spreader follows the map to apply the nutrients in the right places. But in spite of government subsidies in some parts of the U.S. and Europe, the system has yet to move beyond a 20 percent adoption rate because conducting the initial soil testing and making the recommendation map remain expensive. But researchers are working on ways to do that more cheaply, and a substantial amount of public research funding is available for site-specific soil nutrient management.

Another agricultural advancement is the development of sensors that analyze the color of a plant to determine its fertilizer needs. A plant with too little nitrogen tends to turn pale green or yellow. These sensors can be placed on the front of a tractor so that plants are scanned in motion, which would then trigger an applicator at the back of the tractor that would apply the necessary dose of fertilizer.

Drones are another new area of technology that the farm media have touted as the solution to crop scouting, management of grazing livestock, and other data collection for large-scale agriculture. In 2015, the Purdue-CropLife survey reported that 16 percent of agricultural retailers

offered drone imagery services and that those retailers provided imagery on only 2 percent of their clients' crop area, leaving drones' cost effectiveness an open question.

While drones are the high-profile technological solution, it may instead be cheaper and easier for farmers to download microsatellite images from the internet to scan crops and gather data. Although the agriculture industry has experimented with satellite technology since the 1970s, issues such as the high cost, cloud cover, and the lag between image capture and delivery have been consistent problems. Owing to these challenges, only 18 percent of U.S. crop area is managed with satellite or aerial imagery. Microsatellites may accelerate that trend.

For example, an Argentina-based company plans to put 300 microsatellites into orbit that would provide high-resolution images of every spot on Earth every five minutes. This type of consistent and instantaneous data delivery over the internet would lower costs and increase the chances of regularly obtaining some cloud-free images even in cloudy environments.

Finally, the technology that is likely to transform farming the most is robotics. While still in its early stages industrywide, at least 8,000 dairy farms worldwide use robotic milking systems. When a cow feels the need to be milked, she is trained to enter a stall where robotic arms wash her udder, attach the milking suction cups, and detach them when she has been milked.

One of the most interesting aspects of robotic milking is that so far it tends to be used by medium-sized family farms, which adopt robotics instead of hiring and managing employees. They use robotics to leverage family labor and avoid the complexities of managing people. By contrast, very large dairy farms already have human resources departments and typically grow their production by adding more employees. Robotic milking might be one of the forces tipping the economic balance away from mega dairies toward more modest-sized family operations.

GPS also has allowed the possibility of autonomous farm equipment—just as driverless cars appear soon in the offing, manufacturers are testing tractors that don't require people. Removing human drivers brings other changes, too, since it modifies the design criteria for farm equipment, allowing it to be much smaller.

Alternatives to conventional mechanization may be especially important for smaller farms in developing countries in Africa, Asia, and Latin America, where farm labor is increasingly scarce and expensive because young people are moving to the cities, but conventional mechanization disrupts agricultural landscapes and the communities that live in them. Creating the large fields needed for conventional mechanization often requires removing trees and hedges from fields, rerouting water courses, and sometimes relocating villages.

So imagine if a farmer in a developing country could buy a basic robot capable of planting, weeding, and harvesting for the cost of a motorbike. That robot might be a cost-effective alternative to conventional mechanization. The rapid and widespread adoption of mobile phone technology in the developing world suggests that if precision agriculture companies and researchers can develop technologies that solve smallholder farmer problems at a low cost, there is a tremendous market waiting.

NOT OLD MACDONALD'S FARM ANYMORE

The classic image of conventional mechanized agriculture is one of large rectangular fields with a minimum of trees, ponds, rocks, or other obstacles—picture the U.S. Midwest and Great Plains. And today there are even larger fields in the Australian Outback, Argentine Pampas, Brazilian Cerrado, or the Russian, Ukrainian, or Kazakh steppe.

The most successful of these converted from extensive grazing lands, managed either by nomads or large ranches. Large rectangular fields could be carved out with little disturbance of villages, and the number of people affected was relatively small.

In the future, precision agriculture will reduce the competitive advantage of these large rectangular fields, and other factors such as reliability of rainfall and distance to market may be more important in the choice of where to produce agricultural products. Areas of the developing world that are now dominated by manual,

smallholder agriculture may not need to go through the difficult transition of combining fields, clearing trees and rocks, moving villages, and draining ponds and seasonal water courses. With GPS guidance and robotics, those smallholder farmers may be able to use the most advanced agricultural techniques in a landscape that will be nearly unchanged.

In the short run in the United States, precision agriculture for commodity crops means that even fewer workers will be needed for production. GPS guidance allows farmers to accomplish more and, by reducing fatigue, work longer hours, especially in peak periods. In the longer run, precision agriculture is creating a demand for more skilled workers. Already agricultural suppliers and farm equipment companies worldwide are competing for employees who understand GPS, sensors, drones, and spatial data analysis.

In the future, supervising, repairing, and maintaining robots will probably become key farmer skills. With robotics, the need for unskilled labor to weed and harvest crops should almost disappear. Because this unskilled labor is often provided by immigrants in the U.S. and other industrialized countries, there will be important implications for immigration policy and for the developing world economies that have come to rely on remittances from those workers.

In the longer run, precision agriculture will probably mean that grain and oilseed production in the U.S. will move east. In the 19th and 20th centuries, agricultural production moved west to take advantage of fertile soils with few rocks that could be organized in large rectangular fields suitable for mechanization. Fields in the east are often small, irregularly shaped, and rocky, so many were used for pasture and hay or simply abandoned. But with GPS guidance and related technologies, it becomes easier to farm those irregularly shaped fields, and the region's reliable rainfall and proximity to markets will make them even more attractive.

Since World War II, the small farms and irregularly shaped fields of Western Europe have limited the ability of nations there to take advantage of conventional mechanized technology in grain, oilseed, and other commodity crop production. For Europe, precision agriculture in general, and GPS guidance and robotics in particular, are likely to make farms more competitive and less dependent on politically troublesome subsidies, influencing the political dynamic of the European Union.

Perhaps most of all, precision agriculture has the potential to help make farm production more efficient and better for the environment at a time when there will be more mouths to feed on Earth.

FIND MORE ONLINE

LEARN: *Tour an automated dairy farm in Indiana with Jess Lowenberg-DeBoer at pewtrusts.org/trend/precisionagriculture.*

ENGAGE: *#PewTrend*

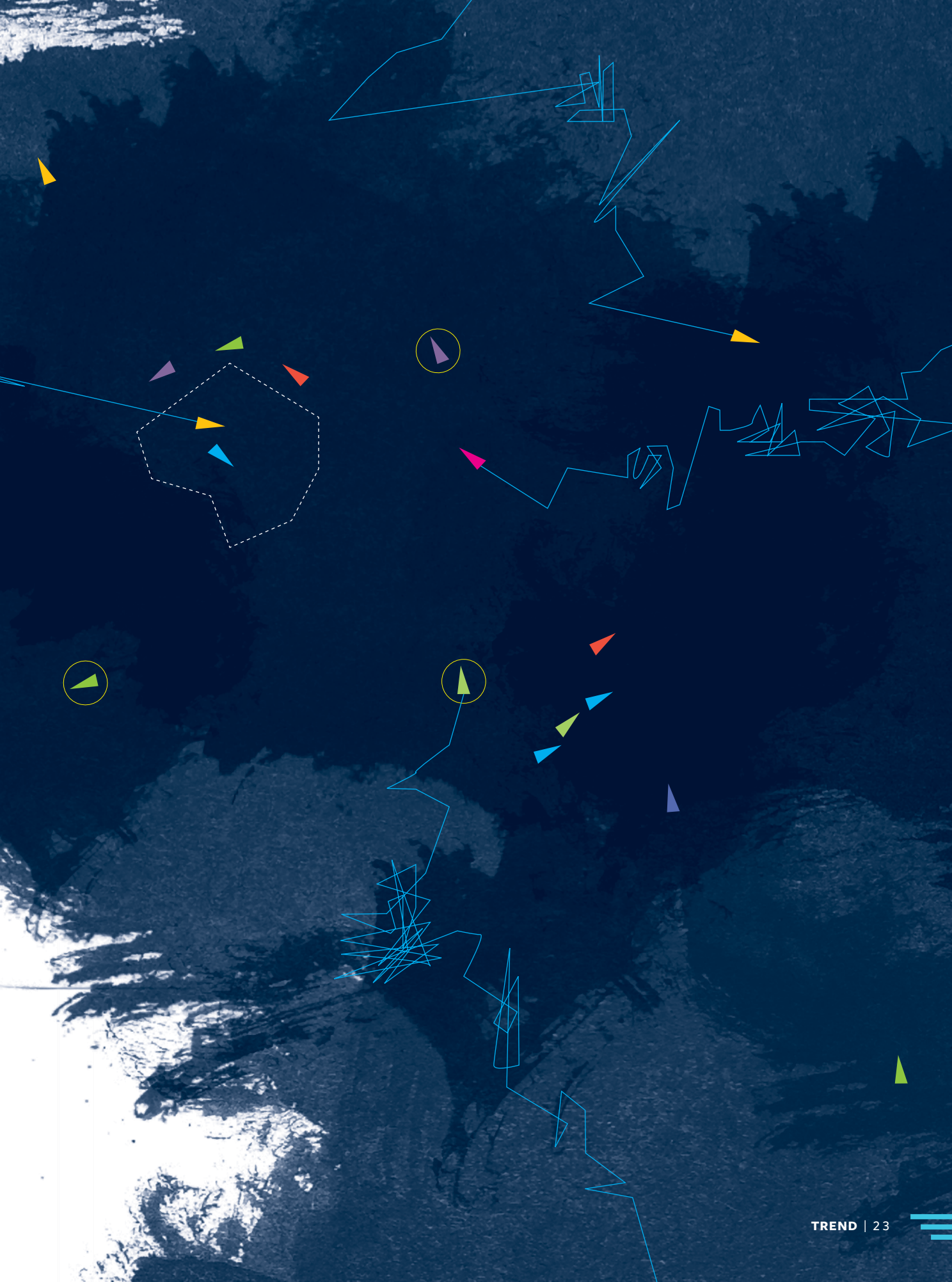
THE TAKEAWAY

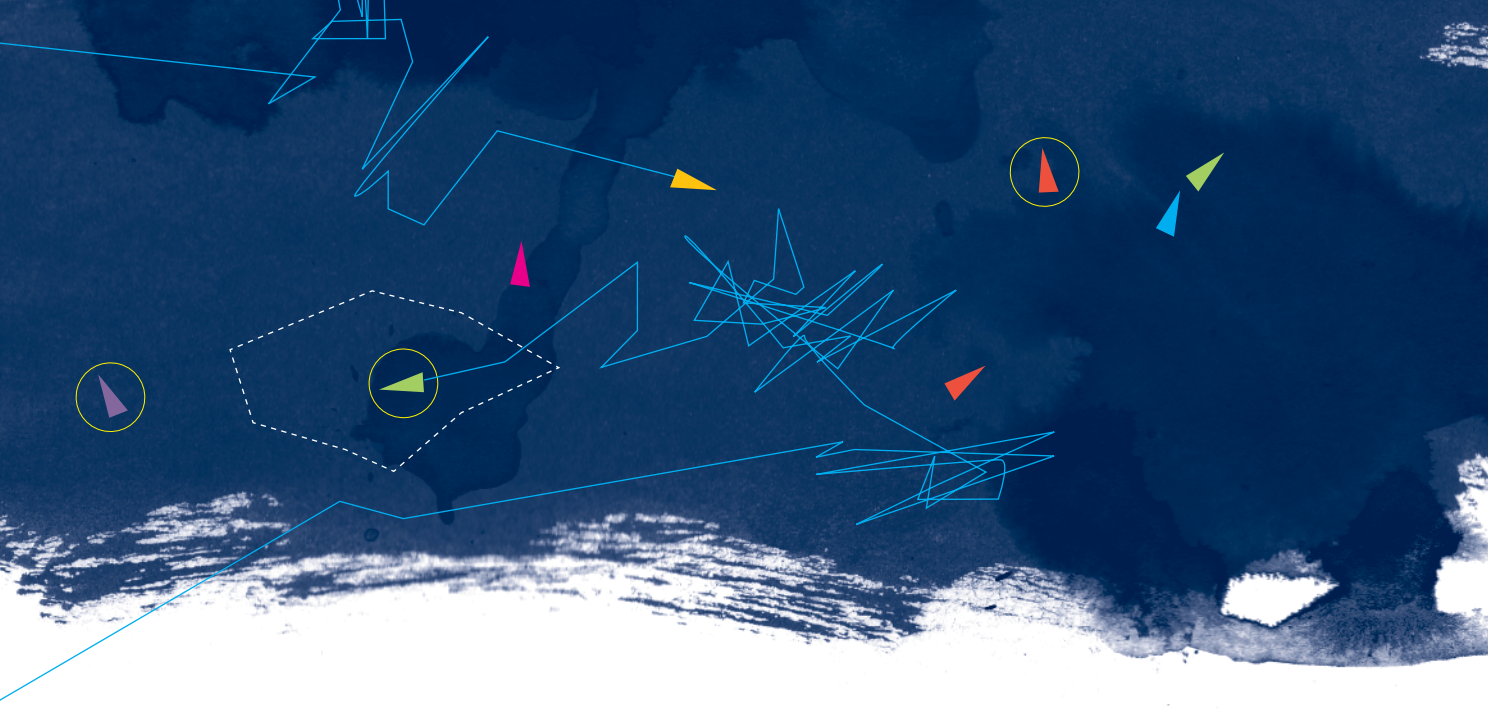
Using new technology, we can transform farming and increase food, feed, fiber, and fuel production while reducing the pollution and other environmental footprints of agriculture.

As criminals become more ingenious, law enforcement also has to become more inventive.

Environmental Crime Requires High-Tech Solutions

BY DAVID HIGGINS





Over recent decades, technological invention has allowed us to see more of the world, and its breathtaking biodiversity, than we ever imagined. Anyone with a good internet connection can now virtually visit the endangered gorillas in the Democratic Republic of Congo, the elephants of Kenya's Maasai Mara, and the rainforest of the Amazon. Yet these same technologies that bring our eyes to nearly every corner of the planet also provide capacity to criminals who seek the high profit and low-risk nature of environmental crime. In fact, illicit environmental activities, such as wildlife crime, illegal exploitation of the world's wild flora and fauna, and even new methods such as carbon trade and water management crime, have grown and are currently estimated to be worth up to $258 billion annually. And there is evidence that environmental crimes frequently converge with other serious crimes, such as human and drug trafficking, counterfeiting, cybercrime, and corruption. Environmental crime therefore presents a challenge that requires both high-tech invention and highly collaborative coordination. Global policymakers, law enforcement, and local communities must partner across multiple means and methods to put knowledge to purpose in order to strengthen environmental security worldwide. In short, as criminals become more ingenious, law enforcement also has to become more inventive.

EVERY MEANINGFUL EFFORT TO FIGHT ENVIRONMENTAL CRIME BEGINS WITH MONITORING AND COMMUNICATIONS, AND TECHNOLOGY HAS ENHANCED BOTH THE TECHNIQUES AND THE TOOLS AVAILABLE TO THE GLOBAL COMMUNITY.

Every meaningful effort to fight environmental crime begins with monitoring and communications, and technology has enhanced both the techniques and the tools available to the global community in this domain. A wide range of technology now allows us to scan across land and sea by using satellites, aerial drones, remote trigger systems

Environmental crimes frequently converge with other serious crimes, such as human and drug trafficking, counterfeiting, cybercrime, and corruption … and present a challenge that requires both high-tech invention and highly collaborative coordination.

that initiate cameras or other monitoring and security measures, thermal imaging cameras, and radio frequency identification. All this data can be collected and shared via secure information networks that allow local, national, and international law enforcement teams to analyze, communicate, and act to generate leads and disrupt the organized networks that profit from environmental crime.

This may sound like a Hollywood version of a military campaign until you consider how common it has become for global agencies and organizations to work together using technological inventions to pursue environmental criminals.

Take the challenge of tracking illegally sourced timber, which makes up the biggest portion of the annual cost of environmental crime at an estimated $152 billion. Years ago, this type of

environmental crime was incredibly difficult to detect unless someone witnessed illegal forestry activity and monitored the supply chain. Today, tactics such as DNA analysis and stable isotope analysis—which helps identify the geographic origin of trees—have given rise to more sophisticated approaches and successful seizes of illegally sourced timber.

ILLEGALLY SOURCED TIMBER MAKES UP THE BIGGEST PORTION OF THE ANNUAL COST OF ENVIRONMENTAL CRIME AT AN ESTIMATED $152 BILLION.

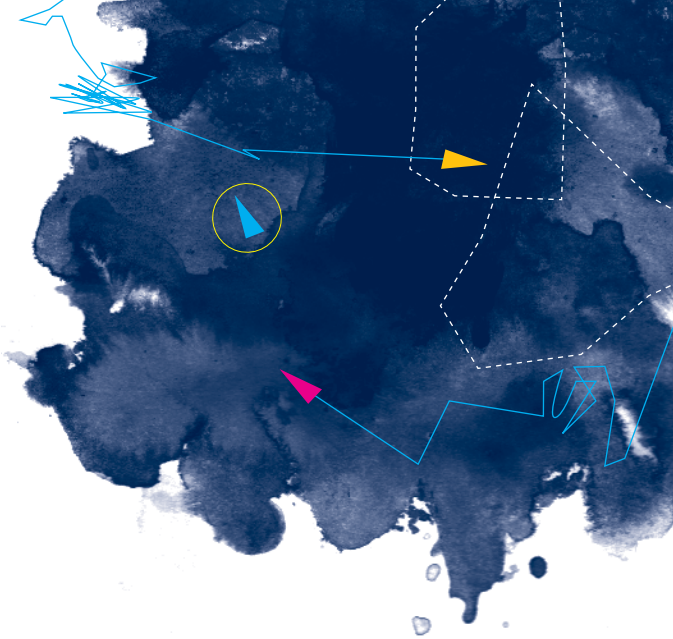
The story of the Yacu Kallpa cargo ship is a good example. The Yacu Kallpa routinely traveled with timber from Iquitos, in the Peruvian Amazon, to Houston, often making multiple trips each year. In 2016, following a detainment by United States authorities of 71 shipping containers from the vessel, which contained more than 3.8 million pounds of potentially illegally sourced timber, law enforcement agencies in multiple countries, and at international organizations such as Interpol and the World Customs Organization, began monitoring the ship. An investigation by Peru's authorities determined that 90 percent of the load of timber—1.2 million cubic meters—leaving Iquitos on the vessel was harvested illegally. Law enforcement efforts began. Authorities monitored signals from the ship's Automatic Identification System (AIS) to track its progress, and Brazilian authorities confirmed that the illegal timber was onboard after briefly detaining the ship. When it reached Tampico, Mexico, local authorities confiscated some of the timber, which they confirmed was illegal.

Another example is the Hua Li 8, a Chinese-flagged vessel that was suspected of illegal fishing within the Argentine Exclusive Economic Zone in February 2016. When confronted by the Argentine authorities, the vessel ignored authorities and refused to stop, fleeing into neighboring waters and onto the high seas. Interpol issued a "Purple Notice," which asks member countries to seek or provide information on the methods and activities of a criminal, and other countries helped track the vessel as it traveled across the Atlantic and Indian Oceans.

The AIS, which helps ships avoid collisions through the electronic exchange of data with nearby vessels, coast guard stations, and satellites, also allowed international officials monitoring the Hua Li 8 to track it across the high seas. In collaboration with The Pew Charitable Trusts' project to end illegal fishing and Satellite Applications Catapult's "Eyes on the Seas" technology, the Hua Li 8's signal was tracked until the ship was intercepted by the Indonesian Navy. Technology also played a role in ensuring evidence was available to document the Hua Li's illegal fishing. National enforcement agents, with the support of Interpol, were able to collect digital evidence from the vast array of electronic devices onboard, which led to a treasure trove of data on the ship's movements and communications that will undoubtedly lead law enforcement to other potential criminal networks that operate in a similar fashion.

In Kenya, another monitoring advancement can be seen in a project called tenBoma, which is led by the International Fund for Animal Welfare and the Kenya Wildlife Service. Taking its name from a Kenyan community policing philosophy, Nyumba Kumi, which means "10 houses" in Swahili, the project combines high-tech data analysis, Kenyan national security operations, and community anti-poaching initiatives to stop poachers who are hunting wildlife such as elephants and rhinos. This multifaceted approach and community-led effort taps technologies such as geographical tracking to identify routes, DNA analysis to determine origin, and chemical isotope analysis to establish the age of individual species.

While these technological advances are helping the global environmental community



strengthen communications and monitoring, technology cannot be considered in isolation from those who use it. It is important to identify the most effective and suitable tools for the wide range of threats dealt with by law enforcement, but these tools also require skilled officers and professionals to maximize their potential. Another key consideration is to ensure that all legal aspects, including protection of human rights, are addressed before a new technology or equipment is introduced to the law enforcement arena.

In that regard, enforcement technologies and tactics have evolved considerably, but we need to ensure that the right tools are in the hands of those who need it most. Front-line tactical level officers require access to tools that provide the right information so they can make safe enforcement interventions and harvest the evidence that is ever increasingly electronic in nature.

ILLICIT ENVIRONMENTAL ACTIVITIES HAVE GROWN AND ARE CURRENTLY ESTIMATED TO BE WORTH UP TO $258 BILLION ANNUALLY.

Front-line tactical responses might mean providing support to rangers and law enforcement officers working in difficult or dangerous areas, such as the jungle, through the use of drones with thermal imaging cameras, range finders, or light-intensifying binoculars. Poachers are likely to have access to these modern technologies, and we need to equip those fighting crime with the same tools to effectively enforce the rule of law and protect vulnerable areas and species.

When it comes to the front-line fight against environmental crime, training remains a fundamental element of effective enforcement. While digital forensics, drones, and databases are the inventions that receive attention, it is the ranger, operator, or officer who must be able to connect the digital dots to capture environmental criminals with the right evidence to shut down an operation or network.

Today, training takes many forms: from basic computer training to help front-line officers use new technologies, to training in digital forensics, evidence removal, and handling. The international community works together to harness the expertise of the private sector and governments to strengthen our response to environmental crime and help protect the planet.

Likewise, other international policy, development, and non-governmental organizations play vital roles, offering on-the-ground training and support to local communities, providing funding for countries to strengthen their internal resources and capacity, and developing networks of partners who work together to monitor and enforce environmental rule of law.

In fact, global partnerships are where the fight against environmental crime turns from high tech to highly personal. Good communication and collaboration between global agencies and policymakers are vital but equally so are the relationships between country and local representatives, including tribal leaders and elected officials, and the public. Regular and sustained communication and information sharing are essential so that policymakers can inform and interest their constituents—ensuring public support and aiding monitoring and enforcement.

There are many strong examples of the power of partnership at play in fighting environmental crime today. Kenya's tenBoma is one, but there are many partnerships that Interpol and other international organizations have developed, including with private firms that provide cyber security and digital forensics solutions, which can be implemented globally.

As we look to the future, we know that advances in technology will act as a catalyst and have the potential to significantly contribute to progress toward global law enforcement goals and protect the rule of law. Yet we must marry technological invention and evolution with the fundamental elements of communication, partnership, and public education in order to be successful. No one tech tool can solve global environmental crime, just as no one country or organization can.

As environmental crime has grown, so has the recognition that nations must consider environmental security in line with national and economic security, and seek to protect environmental quality, natural resources, and biodiversity. Today, technological invention makes it possible for us to do more to protect the planet than ever before. We have the capacity and capability to thwart environmental crime, and working together, we can apply practical knowledge, innovation, and aspiration to solve global environmental challenges and strengthen security.

FIND MORE ONLINE

LEARN: *Read more about efforts to end illegal fishing at pewtrusts.org/endillegalfishing.*

FOLLOW: *@DavidHiggins101*

THE TAKEAWAY

Global policymakers, law enforcement, and local communities must partner across multiple means and methods to put knowledge to purpose in order to strengthen environmental security worldwide.

CAN PUBLIC POLICY BE INVENTIVE?

BY SUSAN URAHN

By infusing data into policymaking, lawmakers can determine the costs and benefits of their decisions. It's already starting to happen—with strong results for taxpayers.

Six years ago, the Iowa Department of Corrections had a problem. It didn't know what alternatives to incarceration might reduce recidivism—and didn't have any data about what the real long-term costs and benefits of those alternatives might be.

So officials developed a new cost-benefit analysis system, tailored to their state, to help determine programs' effectiveness and provide policymakers with the hard data they need to make informed legislative and budget decisions.

Working with the Pew-MacArthur Results First Initiative, state officials began to gather information and establish a methodical system to evaluate several key programs. The good news: Some of the state's drug treatment programs already were returning $8 in savings for every taxpayer dollar invested. And cognitive therapy—a relatively inexpensive program for Iowa—was returning $35 for every dollar spent.

But there was bad news, too.

Iowa officials had thought that a long-running domestic abuse program was a model of success. Not true: The evaluation showed that the program was actually costing the state $3 for every dollar spent on it—"a waste of taxpayer dollars," in the words of a Department of Corrections report. Officials promptly scrapped the program and developed a new one.

There's no question that every program that went under the microscope in Iowa—the effective and the ineffective alike—was developed with the best of intentions. Policymaking is essentially a prospective enterprise, with public officials (especially elected ones) rightly looking ahead with the intention of making things better. For many lawmakers, the greatest challenge is simply getting legislation passed. No small feat, to be sure.

But some of those Iowa programs worked and some didn't. How to know which? Answering that question requires that policymaking be as retrospective as it is inventive: looking back to evaluate previous decisions and program performance while studying the experience of other policymaking groups to take innovative ideas forward. It requires that research be grounded in empirical evidence that provides useful information for policymakers. And it requires the use of evaluation tools to put the evidence through a cost-benefit prism.

These cost-benefit analyses naturally build on requirements in most states that lawmakers consider the fiscal impacts of proposed legislation. (Policymakers know this as the "fiscal note"—essentially, the price tag for a new piece of legislation.) And they have the potential to yield significant benefits to policymakers and taxpayers.

The benefits come from helping policymakers grapple with difficult budgetary decisions about current programs and providing background as they face new challenges. Political considerations and voter feedback will always be paramount in the policy arena. But with these evaluation tools, we will be able to reinvent how public policy can be developed in the modern digital world.

Rigorously conducted independent research is the heart of an evidence-based approach to policymaking. Without it, stakeholders can use opinions and ideology to argue without end. With it, they can develop policy that cuts through the ideological noise. This research must be timely

and relevant to the real-world choices that policymakers face.

While we now have powerful tools to compile and evaluate evidence, the idea of using research to inform policy is not new. We need only look to history to see the key role that research has played in inspiring important social change.

In the early 1900s, for example, medical schools in the United States were unregulated and nearly anyone could become a doctor, without rigorous study of medical science or hands-on practical experience. The potential—and real—risks seem obvious in retrospect. At the time, the Carnegie Foundation for the Advancement of Teaching commissioned a study that documented concerns in the U.S. and Canada; recommended higher admission and graduation standards in medical schools; and called on the schools to follow the protocols of mainstream science. The Flexner Report, as it came to be called, led to the adoption of professional standards that we take for granted today.

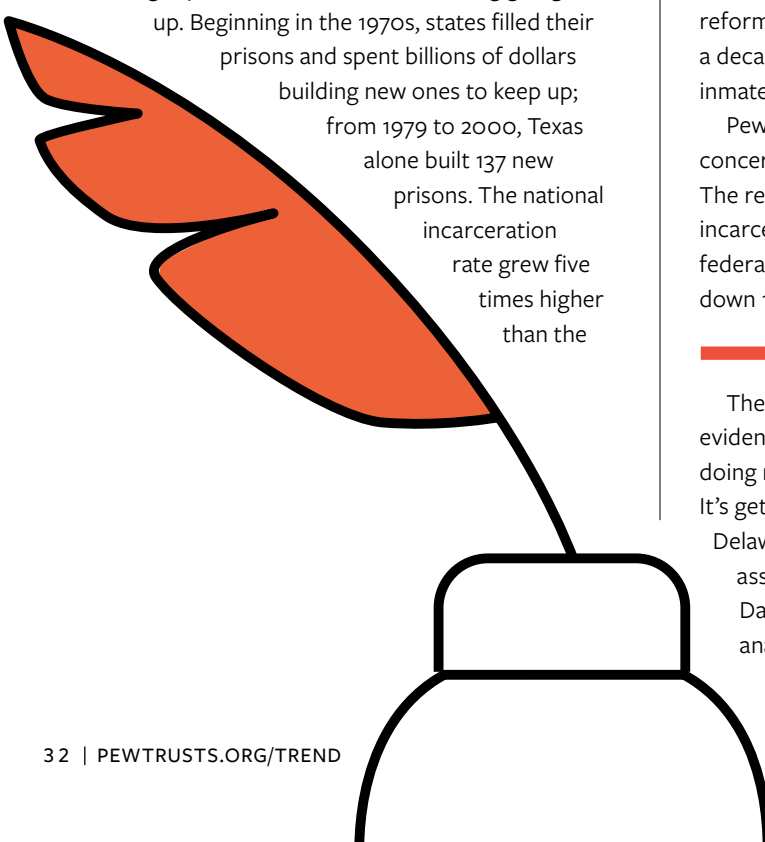
A more contemporary example comes from corrections policies in the states. For much of the 20th century, the national rates of incarceration stayed fairly constant. But after many states began passing laws that required longer prison terms, the rates starting going up. Beginning in the 1970s, states filled their prisons and spent billions of dollars building new ones to keep up; from 1979 to 2000, Texas alone built 137 new prisons. The national incarceration rate grew five times higher than the historic norm, with 1 out of every 100 Americans in prison.

Yet recidivism rates didn't drop.

With corrections costs consuming an exponentially growing portion of their budgets, policymakers in a number of states—and across the political spectrum—began to look for new solutions. Researchers at Pew went to states that asked for assistance to help determine what sorts of offenses were driving the biggest numbers of people into prison. They found that in many cases, offenders had committed nonviolent crimes or were being put back behind bars because of parole or probation violations, sometimes serving more time for those infractions than for their original crimes. In South Carolina, for example, initial data analysis showed that 60 percent of inmates in state prisons were nonviolent offenders.

The research was expanded to examine what sort of programs—especially drug treatment efforts—could help keep nonviolent offenders from returning to prison (and save the state's taxpayers the expense of jailing them). In South Carolina, officials looked back to see how their laws were performing and looked around to learn from the experiences of other jurisdictions. Armed with evidence-based information, legislators passed a series of reforms to the state's criminal justice system; a decade later, the percentage of nonviolent inmates in state prisons is down to 40.

Pew has worked in 33 states that are concerned about growing prison populations. The results are promising: Today, the national incarceration rate—which includes adults in federal and state prisons and local jails—is down 13 percent from its peak in 2007.



The innovative—and common-sense—evidence-based approach to policymaking is doing more than keeping people out of prison: It's getting people into college as well. In 2012, Delaware's Department of Education, with the assistance of Harvard University's Strategic Data Project, conducted an extensive analysis of data measuring the performance

Rigorously conducted independent research is the heart of an evidence-based approach to policymaking.

of the state's high school students. The conclusion? A large number of students whose SAT scores indicated they were capable of obtaining a college education nonetheless were not enrolled in college. From 2008 to 2011, for example, 18 percent of Delaware students who scored at least 1550 out of 2400 on the SAT did not enroll in college.

With these data in hand, the state began its Getting to Zero campaign, designed to take that 18 percent down to zero by having every college-ready student in Delaware apply for and enroll in postsecondary education. The campaign includes better training for school counselors on how to assist students and their families in completing the Free Application for Federal Student Aid; the designation of October and November as college application months, during which students receive help with their applications; and a texting system that families can use to access real-time information on financial aid and other concerns.

The campaign is proving to be a success. Ninety-eight percent of the state's college-ready applicants from the high school classes of 2014 and 2015 (the first two years of Getting to Zero) enrolled in an institution of higher learning.

On the fiscal front, most states offer tax incentives to encourage businesses to make investments that create or retain jobs. For the most part, policymakers have rarely looked back to see whether these incentives—which cost billions of dollars in forgone tax revenue—produce stronger local economies. But the District of Columbia and 22 states have passed legislation requiring regular, rigorous, and independent evaluations of their tax incentives—a clear example of how a data-based cost-benefit analysis can guide policymaking.

The Results First Initiative, which looked at Iowa's alternatives to incarceration, is now in place in 21 states and four counties, providing policymakers with accurate assessments of the true costs and benefits of public programs. These analyses calculate the returns on investment in alternative programs, rank programs based on cost and benefit, and help predict the impact of different policy options.

The project grew out of the pioneering efforts of the Washington State Institute for Public Policy (WSIPP), which created a sophisticated cost-benefit model to analyze programs in the Evergreen State. It helped make the state a national leader in incorporating an evidence-based approach into the legislative process and producing bipartisan policies that have saved billions of dollars. An early example came in 1997, when the Washington State Legislature passed the Community Juvenile Justice Act—one of the first in the nation to require that state-funded programs for juveniles be "compatible with research." The law directed WSIPP to develop methods for measuring the effectiveness of juvenile justice programs and helped to standardize the definition of what works in reducing recidivism among young offenders.

POLICYMAKING IS ESSENTIALLY A PROSPECTIVE ENTERPRISE, WITH PUBLIC OFFICIALS (ESPECIALLY ELECTED ONES) RIGHTLY LOOKING AHEAD WITH THE INTENTION OF MAKING THINGS BETTER.

State leaders have since mandated similar evaluations in human services programs, with the WSIPP analysis showing the cost benefits of these programs and ranking them for policymakers. A recent report, for example, showed that cognitive behavioral therapy for adult depression can produce up to $50 in taxpayer and societal benefits for every dollar invested.

On the other side of the country, Connecticut also has emerged as a leader in evidence-based policymaking with what it calls results-based accountability: a budgeting technique, now incorporated into the appropriations process, that helps policymakers use data on program outcomes to inform their funding decisions. Agencies study performance scorecards to highlight which programs are most effective at achieving desired outcomes and consider the information in spending decisions.

From Iowa to South Carolina, Delaware to Washington state, and Connecticut and other jurisdictions around the country, lawmakers are learning that building data into the policymaking process means they don't need to rely on anecdotal information. A significant reinvention of the way policymakers make decisions is underway as more state and local governments see the potential of using evidence to expand successful programs and eliminate those that aren't working. Not only will citizens benefit from these evidence-based programs, but every taxpayer will profit by seeing a better return on public expenditures.

FIND MORE ONLINE

LEARN: *Read more about the Pew-MacArthur Results First Initiative at pewtrusts.org/resultsfirst.*

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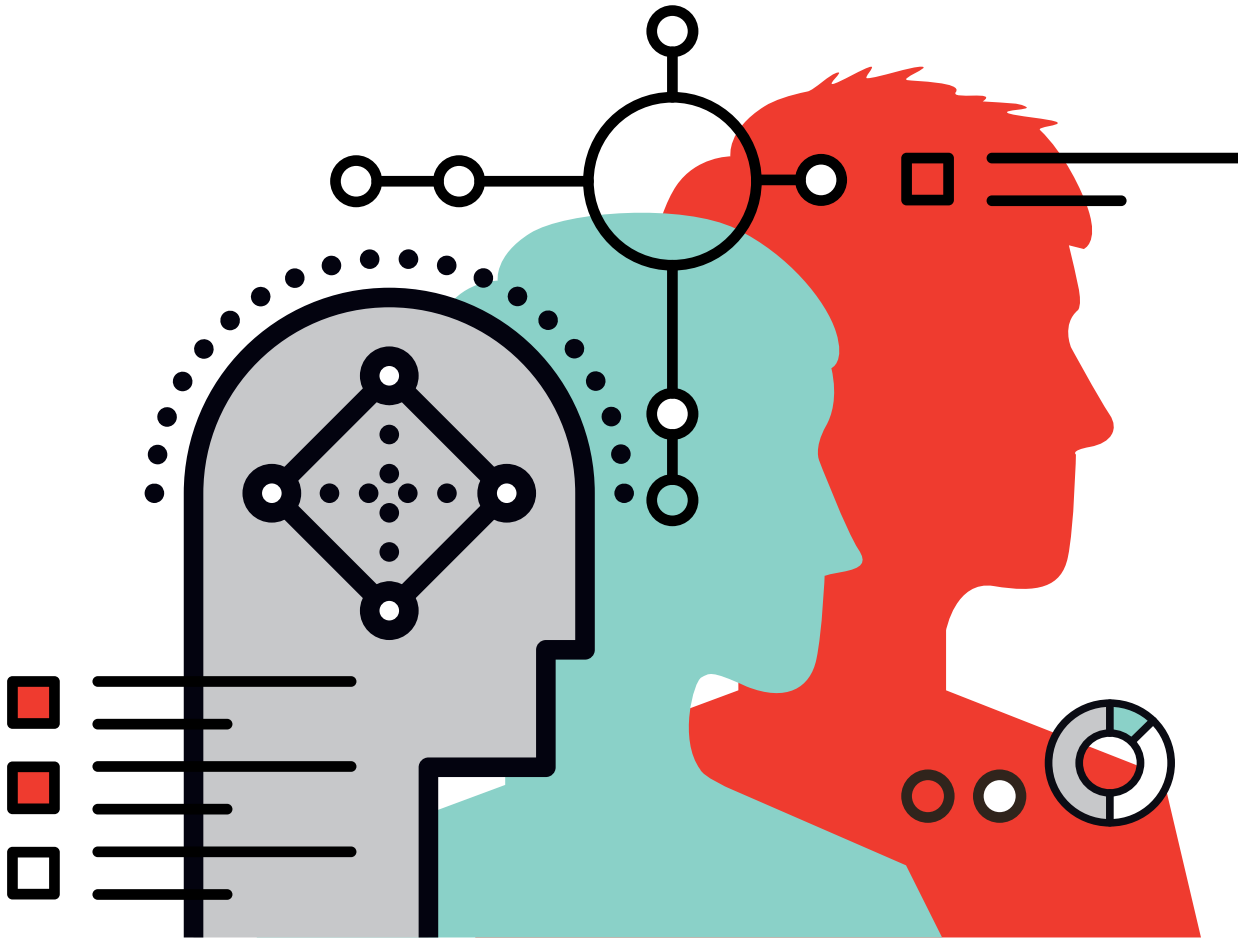


Your Next Co-Worker May Be a Robot

Technological advances are changing the very nature of labor and moving robots beyond rote, automated tasks into industries that once required the human touch.

BY ALEC ROSS

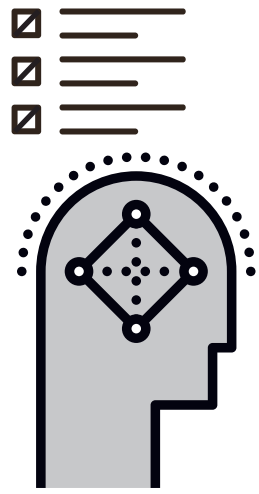
One of my first jobs was working as a midnight janitor. I pushed a mop around a concert venue with a handful of other men, cleaning up the aftermath of country music concerts. Forty years earlier, the middle-aged men mopping alongside me would have had better-paying jobs in the coal mines or factories that had since been taken over by automated labor. What was left for them was pushing a mop after midnight. I thought of them recently when I first observed the use of robot janitors at an airport in England. The boxy little machines use laser scanners and ultrasonic detectors to navigate while cleaning the floors. When the robot encounters a human obstacle, it says in a proper English accent, "Excuse me, I am cleaning," and then navigates around the person.

The last wave of labor substitution from automation and robotics came in jobs that were often dangerous, dirty, and dreary and involved little personal interaction. Initially the affected jobs were in industrial spaces like ports, factories, mines, and mills. Now, as with the janitorial crew, the move is to nonindustrial spaces such as restaurants and hotels. Jobs in the service sector that were largely safe from loss during the last stage of globalization will be at risk because advances in robotics have accelerated in recent years. With breakthroughs in the field itself (as well as advancements in information management), computing and high-end engineering tasks once thought to be the exclusive domain of humans—those that require personalized skills, situational awareness, spatial reasoning and dexterity, contextual understanding, and human judgment—are opening up to robots.

Two key developments dovetailed to make this possible: improvements in modeling belief space and the uplink of robots to the cloud. "Belief space" refers to a mathematical framework that allows us to model a given environment statistically and develop probabilistic outcomes. It is basically the application of algorithms to make sense of new or messy contexts. For robots, modeling belief space opens the way for greater situational awareness. It has led to breakthroughs in areas such as grasping, once a difficult robot task. Until recently, belief space was far too complex to sufficiently compute, a task made all the more difficult by the limited sets of robot experience available to analyze. But advances in data analytics have combined with exponentially greater sets of experiential robot data to enable programmers to develop robots that can now intelligently interact with their environment.

The recent exponential growth of robot data is due largely to the development of cloud robotics, a term coined by Google researcher James Kuffner. Linked to the cloud, robots can access vast troves of data and shared experience to enhance the understanding of their belief space. Before being hooked up to the cloud, robots had access to very limited data—either their own experience or that of a narrow cluster of robots. They were stand-alone pieces of electronics with capabilities that were limited to the hardware and software inside their units. But by becoming a networked device, constantly connected to the cloud, each robot can now incorporate the experiences of every other robot of its kind, "learning" at an accelerating rate. Imagine the kind of quantum leap that human culture would undertake if we were all suddenly given a direct link to the knowledge and experience of everyone else on the planet—if, when we made a decision, we were drawing not from just our own limited experience and expertise but from those of billions of other people. Big data has enabled this quantum leap for the cognitive development of robots.

THOSE WITH JOBS THAT ARE HARD TO AUTOMATE—LAWYERS, FOR EXAMPLE—MAY BE SAFE FOR NOW, BUT THOSE WITH MORE EASILY AUTOMATED WHITE-COLLAR JOBS, SUCH AS PARALEGALS, ARE AT HIGH RISK.



Another major development in robotics arrived through the material sciences, which have allowed robots to be constructed of new materials. Robots no longer have to be housed in the aluminum bodies of armor that characterized C-3Po or R2-D2. Today's robots can have bodies made of silicone, or even spider silk, that are eerily natural looking. Highly flexible components—such as air muscles (which distribute power through tubes holding highly concentrated pressurized air), electroactive polymers (which change a robot's size and shape when stimulated by an electric field), and ferrofluids (basically magnetic fluids that facilitate more humanlike movement)—have created robots that you might not even recognize as being artificial, almost like the Arnold Schwarzenegger cyborg in "The Terminator." An imitation caterpillar robot designed by researchers at Tufts University to perform tasks as varied as finding land mines and diagnosing diseases is even biodegradable—just like us.

Robots are now being built both bigger and smaller than ever before. Nanorobots, still in the early phases of development, promise a future in which autonomous machines at the scale of 10^{-9} meters (far, far smaller than a grain of sand) can diagnose and treat human diseases at the cellular levels. On the other end of the spectrum, the world's largest walking robot is a German-made fire-breathing dragon that stands 51 feet, weighs 11 tons, and is filled with 80 liters of fake blood for the staging of a folk play.

Indeed, the term "robot" was coined in a 1920 play, "R.U.R. (Rossum's Universal Robots)," by the Czech science fiction writer Karel Čapek. But its name boasts a deeper history. "Robot" derives its etymological roots from two Czech words, *rabota* ("obligatory work") and *robotnik* ("serf"), to describe, in Čapek's conception,

a new class of "artificial people" that would be created to serve humans. Although robots are doing certain things that humans could never do, their main use continues to be work that humans have been doing occupationally for centuries.

The next generation of robots will be mass-produced at declining costs that will make them increasingly competitive with even the lowest-wage workers, such as my co-workers on the janitorial crew. They will dramatically affect employment patterns as well as broader economic, political, and social trends. An example can be seen with Foxconn, the Taiwanese company that manufactures iPhones along with many other gadgets developed by companies such as Apple, Microsoft, and Samsung. Its largest factory complex, in the Shenzhen manufacturing zone near Hong Kong, employs workers in 15 separate factories. The company has announced plans to purchase 1 million robots over three years to supplement its workforce of 1 million.

Right now, the robots are slated to take over routine jobs such as painting, welding, and basic assembly. In May 2016, Foxconn laid off 60,000 employees in one day and announced that they would be replaced by robots. The company hopes to have the first fully automated plant in operation in the next five to 10 years.

Market forces are at least partly behind these developments. For the past 10 years, Foxconn was able to amass such a large workforce because labor in China has been so cheap. But wages in China have risen along with its overall economic growth—wages for manufacturing jobs have soared between fivefold and ninefold in the past decade—making it increasingly expensive to maintain a large Chinese labor force.

Boiled down to economic terms, the choice between employing humans versus buying and operating robots involves a trade-off in terms of expenditures. Human labor involves very little "capex," or capital expenditures—upfront payments for buildings, machinery, and equipment—but high "opex," or operational expenditures, the day-to-day costs such as salary and employee benefits. Robots come with a diametrically opposed cost structure: Their upfront capital costs are high, but their operating costs are minor—robots don't get a salary. As the capex of robots continues to go down, the opex of humans becomes comparatively more expensive and therefore less attractive for employers.

In industrialized countries, what we have witnessed in terms of manufacturing job loss is repeating itself across the economy. During the recent recession, 1 in 12 people working in sales in the United States was laid off. Two Oxford University professors who studied more than 700 detailed occupational types have published a study making the case that over half of U.S. jobs could be at risk of computerization in the next two decades. Forty-seven percent of American jobs are at high risk for robot takeover, and 19 percent face a medium level of risk. Those with jobs that are hard to automate—lawyers, for example—may be safe for now, but those with more easily

BY BECOMING A NETWORKED DEVICE, CONSTANTLY CONNECTED TO THE CLOUD, EACH ROBOT CAN NOW INCORPORATE THE EXPERIENCES OF EVERY OTHER ROBOT OF ITS KIND, "LEARNING" AT AN ACCELERATING RATE.

automated white-collar jobs, such as paralegals, are at high risk. In the greatest peril is the 60 percent of the U.S. workforce whose main job function is to aggregate and apply information.

So what to do about this? For starters, we must ensure that the outputs of our education systems map to the inputs of those fields where there will be human job growth. A report by the World Economic Forum estimates that the next wave of labor automation will eliminate 7.1 million jobs while producing 2.1 million new jobs. Although there is no feeling good about a net decrease in employment, the savvier stakeholders will focus on developing skills that are not dependent upon artificial intelligence or a part of the actual advancement of these technologies. An irony is that in a world growing more suffused with computer code and artificial intelligence, those things that make us most human become increasingly important in the workforce: emotional intelligence, creativity, critical thinking, communications, and teaching.

The most resilient people in the workplace will be those with interdisciplinary skills, a combination of technical and scientific skills alongside attributes we associate with the humanities. The distance between the humanities and more technical skills needs to narrow.

THE NEXT WAVE OF LABOR AUTOMATION WILL ELIMINATE 7.1 MILLION JOBS WHILE PRODUCING 2.1 MILLION NEW JOBS.

As technology continues to advance, robots will kill many jobs. They will also create and preserve others, and they will create immense value as well—although as we have seen time and again, this value won't be shared evenly. Overall, robots can be a boon, freeing up humans to do more productive things, but only so long as humans create the systems to adapt their workforces, economies, and societies to the inevitable disruption. The dangers to societies that don't handle these transitions properly are clear.

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THE TAKEAWAY

The next generation of robots will be mass-produced at declining costs that will make them increasingly competitive with even the lowest-wage workers.

Alfred Sommer: Inventing Public Health Research

As a medical researcher in Indonesia in the 1970s, Alfred Sommer discovered that vitamin A deficiencies were more common than generally known and that they dramatically increased childhood mortality rates. He found that these deficiencies could be treated with small, inexpensive vitamin doses, a development that the World Bank has lauded as one of the most cost-effective health treatments in history. Sommer, an ophthalmologist and epidemiologist, won the Albert Lasker Award for Clinical Medical Research and went on to serve as dean of the Johns Hopkins Bloomberg School of Public Health, where he remains on the faculty. He is also a Pew distinguished fellow and spoke with Trend *about how invention plays out in public health research.*

SPECIFIC DISCOVERIES OF NEW VACCINES, ANTIBIOTICS, AND ARTIFICIAL JOINTS HAVE TRANSFORMED PUBLIC HEALTH. BUT YOU HAVE POINTED OUT THAT SOME OF THE MOST DRAMATIC CHANGES OVER TIME HAVE RESULTED FROM US PUTTING KNOWLEDGE TO PURPOSE IN OTHER WAYS. WHAT DO YOU MEAN?

Our understanding of microbes and germ theory is the most obvious example. Sanitation—getting rid of abattoirs, developing waste treatment plants—has been responsible for 90 percent of the doubling of life expectancy since the late 1800s. The next advancement was water purification. It used to be people got water wherever they could. It was a professor at Johns Hopkins, Abel Wolman, who helped develop systems for water chlorination that had a huge impact in the United States and around the world. Social interventions have also played an important role, like child labor laws. They made a huge difference in allowing children to be educated, to be able to grow, and to be more productive and healthy members of society.

WHAT IS THE ROLE OF THE RESEARCHER, THE DISCOVERER, IN BRINGING HIS OR HER FINDINGS INTO SOCIETY?

When you discover something that is potentially an important observation or discovery, you have a moral obligation to pursue it and show either you are wrong, so you'll be the first person to show that you are wrong, or to show that you are right—because most people may not initially believe these discoveries, because they are such right-angle turns from current understandings. My vitamin A work was like that. At first nobody believed it; even after our clinical trials, there was skepticism. Eventually, other studies duplicated our results. But it took 15 years of persistence before it gained consensus. And here's an

interesting thing: We later found a study from London in 1930 showing that cod liver oil—rich in vitamin A—reduced measles mortality in youngsters by 50 percent. But nobody believed the connection, it did not change clinical practice, and the research was never pursued. So persistence pays.

ARE THERE ANY SHARED ATTRIBUTES ABOUT THESE SORTS OF SUCCESSFUL INNOVATIONS?

It's the need for data and observations that lead to successful innovations, as well as the fact that almost every major discovery is made by following up an unanticipated observation. The classic example of having data that leads to a "eureka" experience was the discovery of penicillin. For years, Alexander Fleming, like every other budding young microbiologist, had been growing bacteria on agar plates. Occasionally, the bacteria wouldn't grow because it was contaminated with a fungus. And for years, scientists, bright people, would look at it and say, "Oh, another contaminated plate," and throw it away. Then one day, Fleming looked at the plate and said, "I wonder why the bacteria don't grow when there's a fungus there." And that led to the observation that this fungus, penicillium, was producing a substance which was killing bacteria or inhibiting their growth.

WHAT ARE SOME CURRENT DEVELOPMENTS IN PUBLIC HEALTH RESEARCH THAT YOU'RE WATCHING THAT YOU BELIEVE SHOW PROMISE?

Being able to use new information in new ways is just as important as making a unique "eureka" observation, and that's the promise that big data offer. Here's an example: In medical school, you learn to write unintelligibly, and when I would fill out a chart on a patient, I would put in whatever was of interest and importance to me at that time. If another doctor came back three months later, he probably would not be able to read it, if he could even find it. Now, with the advent of electronic medical records, essential patient information is always there. That record can be linked with that patient if she returns to the hospital, or it can be linked with other people with similar illnesses or similar presenting signs. That not only serves the patient but allows us to make sure that money spent on health care is being spent well, and providing the benefits we expect.

YOU WROTE A MEMOIR ABOUT YOUR CAREER IN PUBLIC HEALTH. ITS SUBTITLE IS *INSPIRATION FOR TOMORROW'S LEADERS*. ARE WE IN NEED OF INSPIRATION?

You can never have enough inspiration to get things going. Today, a lot of smart people are working on terrifically important problems. But all too often, those issues are actually quite plebeian. One reason is spending constraints. When funds are less available, there is risk avoidance. Something that is going to move our understanding an inch forward is much more likely to be funded than something that nobody else is considering, which is where breakthroughs actually occur. After all, they're breakthroughs because nobody ever thought of them before. The studies that are funded are safer, but they are rarely going to blaze new pathways to extraordinary insights that then lead us to a new understanding and new interventions.

You can never have enough inspiration to get things going.

Accelerating Innovation With Leadership

By Bill Gates

Innovation is the reason our lives have improved over the last century. From electricity and cars to medicine and planes, innovation has made the world better. Today, we are far more productive because of the IT revolution. The most successful economies are driven by innovative industries that evolve to meet the needs of a changing world. From the advances that put a computer on every desk to the discoveries that led to lifesaving vaccines, major innovations are the result of both government investments in basic research and the private sector creativity and investments that turn them into transformative products.

I've heard some people argue that life-changing innovations come exclusively from the private sector. But innovation starts with government support for the research labs and universities working on new insights that entrepreneurs can turn into companies that change the world. The public sector's investments unlock the private sector's ingenuity.

I was lucky enough to be a student when computers came along in the 1960s. At first they were very expensive, so it was hard to get access to them. But the twin miracles of the microchip revolution and the internet—both made possible by U.S. government research—

completely changed that. It's no wonder that today most of the leading hardware and software companies are based in the U.S.

Accelerating innovation requires both political leadership and private sector leadership. The best leaders have the ability to do both the urgent things that demand attention today and at the same time lay the groundwork for innovation that will pay dividends for decades.

When we innovate, we create millions of jobs, we build the companies that lead the world, we are healthier, and we make our lives more productive. And these benefits transcend borders, powering improvements in lives around the world. Our global culture of innovation has been most successful at those moments when science, technology, and great leadership come together to create miracles that improve modern life. I believe we are in one of those moments.

One of the most indelible examples of a world leader unleashing innovation from both public and private sectors came in 1961 when President John F. Kennedy spoke to the U.S. Congress and challenged the country to put a man on the moon within the decade. That speech came at a time of cultural and political turmoil, when national and economic security dominated the headlines. President Kennedy believed looking to the skies would inspire the country to dream big and accomplish huge things.

That speech didn't just launch humankind on a successful journey to the moon. It also inspired America to build a satellite network that changed the way we communicate across the globe and produced new forms of weather mapping which made farmers far more productive. In the face of fear, President Kennedy successfully summoned our country to harness American ingenuity and advance human progress.

It's important to remember what made the moonshot the moonshot—that is, what transforms political rhetoric into game-changing breakthroughs. A moonshot challenge requires a clear, measurable objective that captures the imagination of the nation and fundamentally changes how we view what's possible. And it requires marshaling the resources and intellect of both the public and private sectors. When we do that, we chart a course for a future that is safer, healthier, and stronger.

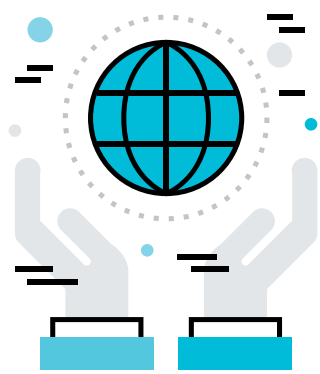
Because we are at a pivotal moment when the conditions are ripe for transformative innovations, there are many important things that national leaders can accomplish over the next decade. There are four objectives I think we should prioritize:

1

PROVIDE EVERYONE ON EARTH WITH AFFORDABLE ENERGY WITHOUT CONTRIBUTING TO CLIMATE CHANGE

There is enormous potential to develop technologies that will make energy cheaper and reduce our energy imports without contributing to climate change or air pollution. In the next eight years, we could start the transition to a new type of clean fuel that doesn't emit carbon, deploy batteries that let electric cars run far longer on a single charge, and produce dramatic drops in the total cost of renewables.

Last year, the U.S. and 20 other countries committed to doubling their energy R&D budgets, and 28 investors pledged to invest in the output of that research. This is only the start. By increasing government support for clean-energy research, presidents and prime ministers could attract more private investors to the field. As early-stage ideas progress, private capital will pour in to build the companies that will deliver those ideas to market.



2

DEVELOP A VACCINE FOR HIV AND A CURE FOR NEURODEGENERATIVE DISEASES

With the right leadership and investments over the next decade, we can discover and deliver a vaccine for HIV. Many have forgotten about the scourge of AIDS, treating it like a disease that can be managed instead of the deadly virus that kills more than 1 million people worldwide every year. Based on recent progress, I believe world leaders could help make an effective AIDS vaccine a reality within the next decade. And with a vaccine, we would be on the path to ending the disease altogether.

We can also make tremendous progress on ending neurodegenerative diseases like Alzheimer's. These diseases are devastating for the people and families that they affect. They are also huge drivers of out-of-control health care costs, which deplete government budgets that could be used for other critical functions. New digital tools and the rapid advancement of science are providing new momentum and hope in the search for cures.

When we innovate, we create millions of jobs, we build the companies that lead the world, and we make our lives more productive.

3

PROTECT THE WORLD FROM FUTURE HEALTH EPIDEMICS

Global leaders should be proud of their role in bringing the Ebola crisis to an end and helping the affected countries recover. Many agencies, including the Centers for Disease Control and Prevention (CDC) and the U.S. military, did exemplary work in the face of significant risks to their own safety. Other leaders around the world mobilized their infrastructures as well. But the Ebola epidemic and the rise of the Zika virus also highlight the need for new advances. There is a significant chance that a substantially more infectious epidemic will come along during the next decade. If one does, we will need to be able to detect it, develop a test for it, and produce cures very quickly. Using advances in biology, scientists are developing these capabilities. With vision and support, we will be able to identify and prevent epidemics before they devastate families, communities, and economies.

4

GIVE EVERY STUDENT AND TEACHER NEW TOOLS SO ALL STUDENTS GET A WORLD-CLASS EDUCATION

Education is one of the areas in R&D that is often overlooked and can have immediate payoff. The world can develop technologies that can help students learn in ways that are more tailored to their needs. But that is just one part of the equation for educational success. High-quality online courses are still in their infancy. So is personalized learning, which combines classroom time with digital tools to let students move at their own pace. Technology can make teachers' jobs easier and their work more effective by letting them upload videos of themselves in the classroom, connect with other teachers, watch the best educators at work, and get real-time feedback from their students. The private sector has started work on these ideas, but funding for government research budgets would boost the market and help identify the most effective approaches, giving teachers and students new tools that empower them to do their best work.

I hope our leaders seize these world-changing opportunities by investing in great research institutions, which translate into big opportunities for innovators.

When these ideas help shape a future that is healthier, more productive, and more powerful, it will be because world leaders stepped up to do the urgent and the important at the same time.

This piece originally appeared on Bill Gates' personal blog, GatesNotes.com, on Oct. 6, 2016, and was republished with permission.

A THOUSAND WORDS

REINVENTING THE SUN—Scientists in Germany have created what they call "the world's largest artificial sun" with 149 xenon short-arc lamps and are testing it to make hydrogen, which some consider the fuel of the future because it doesn't emit carbon when burned.

Picture-Alliance/Barcroft Images/Getty Images

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