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SENSEMAKING:
The Diverse Roles Citizens Play in Change

HOW COULD CITIZENS HAVE CHANGED THE WORLD FOR SUSTAINABILITY BY 2050?

by Gemma Adams

When you take a peek at what the future might hold and the changing hands of power and influence that could shape our society, it's likely that one actor will stand out beyond all others as a remarkable agent of change. This actor – perhaps surprisingly – is the citizen. That's you and me.

Individuals as agents of system change

Believe it or not, we could have an enormous impact on systemic change towards a sustainable society; not necessarily in scale – though this can be the case – rather, by acting against the grain of conventional thought and 'the done thing' to create radical new narratives and ways of doing things. More than policy-makers, government institutions, established business, small entrepreneurs or media outfits, for example – citizens and civil society organisations have the motivation and means to break with the norms that keep society locked in unsustainable patterns. The key question is how we'll embrace this new power and the purposes we'll pursue with it.

Shift from passive consumers to citizens innovating for themselves and beyond

The idea of citizens acting to solve issues we care about or to improve our lifestyles or their context isn't new. Nor is it new that we'd do it without expectation of a commercial return or being compelled by rules and regulations. What's different is that this active, creative, empowered role explodes into whole new realms as individuals are liberated by fresh stories about their identity and agency to participate in society beyond being a 'consumer', enabled by digital technologies to create whatever and whenever we want, and supported to act in more informed and sophisticated ways through new forms of learning and organising – sometimes alone, sometimes as part of formal and informal networks and as part of civil society organisations.

Change starts with ourselves: our own motivations will determine the role we play in change

In a fast-changing world that's impossible to predict, our motivations, beliefs and philosophies are something that citizens and communities can exercise some influence over and use to navigate by.

What's more, the values, mindset and ethos that guide individuals' creative experiences have a strong bearing on the role they play in change and the impact they have over their lifetimes. The most systemic shifts needed for a sustainable society are cultural rather than technological – for example, we need more sophisticated decision-making processes for picking up and responding to the state of living systems and new forms of leadership and ways of organising to make that response happen. As these

are formed by social processes that generate new ideas, meanings and modes of operating, rather than through invention, this puts a lot of emphasis on the purpose and qualities of the people doing the innovating – embodying the change we want to see in the world in order to bring it to reality.

Some of us will resist and subvert change while others will contribute and advocate for it. In the midst of all this, it's who we are – and how we are – that will shape the innovations we're part of.

With new power and possibilities citizens innovate against a much wider canvas

The potential for what can be innovated, and by whom, diversifies enormously into the future and this calls for a new set of understandings and a new language to describe how and what we innovate.

Digital data, platforms and services mean everyone has the tools to communicate their ideas, forge collaborations, build prototypes and develop them – and can use them to create not just new services and new ways of organising, living, producing and consuming, but new patterns of beliefs. This means that while markets concentrate on intellectual property and technological innovation and while public offices work towards political consensus, citizens are increasingly free and innovate in the gaps above and between to respond to the sustainability challenges that are affecting their lives.

What are the innovations that maverick citizens bring to reality on the pathway to the 2050 scenarios – and why do they have a big effect on society?

Citizens introduce four, broad types of innovation along the scenario pathways. These innovations often don't have an impact until a wider change of circumstances creates the conditions to enter – and alter – the mainstream. The significance of these types of innovation in influencing change along the four scenario pathways varies a lot; according to what else is going on in society and the evolution of events over time.

These different types of innovation are not discrete. They can blur and/or lead on to one another. So, for example, a community that initially embarks on an energy-related service innovation to serve a need in their locality might, through working together on an initiative that develops a different business model, inadvertently forge new narratives about the role of communities in the future of the energy system, that have a knock on effect to other communities and, ultimately, to policy.

Type of innovation	What is it and how does it contribute to systemic change?	Example of this type of innovation led by citizens in the scenarios
Product and service innovations	New products, services and virtual and real experiences that de-materialise systems of production and consumption, improving resource efficiency and the social and environmental impacts of the economy, while enabling growth.	In the *Governing the Commons* scenario, households' enthusiasm for distributed, digital fabrication introduces **radical new processes for product-service design**, consumption and production that disrupt supply chains. Against a backdrop of commodity price volatility, consumers start experimenting with reclaiming and remanufacturing waste and this drives a **rapid shift to a circular materials economy**. In the *Singular Super Champions* scenario, innovative consumers work with well-known brands to develop service experiences that are so **personalised, empathetic and desirable** that they diffuse quickly into the mainstream. This is a turning point in the materials intensity of the economy, and in citizens' trust in business.
Place and network-related innovation	A diverse range of activities shaping how whole places develop and behave, and affecting people and organisations within them. They might reconfigure the design of energy, food, mobility, housing and materials systems in a geography - offering comprehensive responses to systemic challenges, such as resource shortages and climate change.	In the *Local Loops* scenario, a long period of economic stagnation in Europe and supply disruptions in resources leads pioneering artisans to **forge new associations for living** and working to enable them to better-compete with global corporations in their area. Called 'Modern Guilds', they become thriving hubs of inter-regional trade; making use of locally-available materials. They **re-energise local pride and identity, rebuild social capital and final informal ways of servicing Guilds' interests** in the absence of public funds. Over time, the Guild model is picked up by policy-makers looking for ways of reigniting domestic economies and protecting the EU from growing global resource insecurity. They are the catalyst for an EU 'Local Loops' policy framework and lead to hyper-local lifestyles and carefully managed, circular, regional bio-economies. In the *Empathetic Communities* scenario network-related innovation is chaotic: a reaction a second financial crisis that society can't seem to bounce back from. City-neighbourhoods form cooperatives to secure their access to food, energy and other basic resources. Over time, **digitally-enabled cooperative platforms, urban farming and local microgrids** allow people to find alternative ways of subsisting that offer stability amidst economic uncertainty. This stops consumerism in its tracks and produces a massive drop in resource use and climate change impacts.

Type of innovation	What is it and how does it contribute to systemic change?	Example of this type of innovation led by citizens in the scenarios
Governance, decision-making and participation in society	A diverse range of activities affecting the overall governance or management of society: its constitution, legislature, executive and judiciary functions. They affect decision-making, accountability and all forms of social relations.	In the *Governing the Commons* scenario, government institutions' inability to usher nation states through the uncertainty of the twenty-first century leaves individuals so disillusioned with democracy that they create new, **platforms for dialogue and processes for community building, conflict resolution and decision making** for themselves. These new forms of citizen-to-citizen democracy implement a comprehensive and globally accountable approach to managing carbon emissions that succeeds where all other attempts had failed. Individuals' identities shift from being attached to national borders to being attached to personal values and interests. These more **fluid and global identities** lead to forms of democracy that transcend traditional borders and geographies of trust; improving the speed and agility with which society can respond to planetary scale issues. In the *Singular Super* Champions scenario the need to compete on the global stage gives rise to a new education system that identifies and nurtures individuals to realise their greatest potential as productive participants in the economy. People follow development tracks that match their aptitudes with economic priorities. While, in 2050, the entrenched inequalities of this system are straining social relations, it plays a vital role in creating reducing resource consumption. It instills a **civic duty in people to optimise their personal performance** and entrust their data to smart devices to allow the government to make the materials economy ever more efficiently.
Paradigm innovation	Activities that affect culture: everything we do and how we do it. These activities reform our most fundamental beliefs, our accepted wisdoms and assumptions and the language we use to understand the world - including our perception of 'self', of humanity and our attitudes towards the future.	In the *Empathetic Communities* scenario an extended period of social and economic turmoil follows a second financial collapse in which millions of people lost their life savings. This brings capitalism into question and, in response, Transhumanism enters the mainstream. Citizens embark on a **project of self-transformation** as a route to transforming the human condition and reaching for a better way of living and being. With help from advanced technologies, they **experiment with how to find empathy with each other**. In the *Local Loops* scenario, there's a gradual, less profound paradigm change, but it plays just as important a role in realising the eventual 2050 scenario and its dramatic reductions in resource use. Spurred by the need to build local resilience, the first 'Modern Guilds' were intrinsically **embedded with regional bio-economies** in order to manage access to resources and adaptation to compete with global conglomerates. As Guilds scale across Europe, their story of local resilience and needing to better **attune human systems with living systems** spreads with them. Instituted by an EU-wide framework, a guiding philosophy of renewal, and equilibrium eventually replaces that of economic growth.

They play diverse roles in processes of innovation that play to their own and others' strengths

The more complex and uncertain the challenges we want to tackle, the more collaborative and creative our response must be. This calls for new understandings and a new language for innovation that replaces the idea of the lone hero battling the odds with a more holistic view of the contributions needed to bring ideas that challenge norms into reality, and to create impact at scale.

Here are some of the roles that we identified through EU-Innovate. They can be – and often are –// held by different people and organisations working together. Have you held or come across any of them?

- Stimulator: Calls for ideas or offers initial funding to resolve a social or environmental challenge. Sets the process of innovation in motion; catalyses others to do it.
- Initiator: Inspires and/or generates ideas for innovation. Likely to be active throughout the innovation process.
- Broker/ mediator: Enables and facilitates meaningful collaboration between people and organisations in order to further the innovation. Involved in organising, negotiating and eliciting feedback.
- Concept refiner: Contributes expertise to the process of testing and developing ideas to form viable, feasible and desirable concepts. Their input increases the likelihood of successful implementation.
- Legitimator: Provides assistance by building credibility and trust in the process and in the innovation itself.
- Educator: 'Normalises' new ways of thinking and being. Sensitises, educates and prepares key players so that they are able to respond positively to the innovation and the social and environmental issues it addresses.
- Context creator: Create an enabling context to bring innovations into reality. Includes, not limited to, changing policies and the regulatory context. Scaling-up Impact: Promotes and enables adoption, engagement, growth, replication and the diffusion of innovation. Seeks to increase its sustainability impacts.

This article first appeared in Futures Centre in January 2017 and is reproduced with permission.

FUTURISTS IN ACTION

CITY FUTURES

by Shermon Cruz

Photo: Wilbert Quebral

Women & Futures
What would Philippine cities be like if they were designed by women?

Rarely do we frame city resilience and the future from a women and gender perspective. The default is, as some experts and analysts suggest, our ways of knowing the city have been informed by macho socio-politico and economic world-views. Symbols and shades of colour that adorn Philippine cities evoke strong and mannish narratives of city resilience and planning. Leadership, public service and nation-building is equated with "Dad" and community development as "brotherhood". There had been attempts to challenge and question the current patriarchal city futures narrative.

The Vigan City Futures Project attempted to deconstruct and question these frames. The project was a collaboration between the Center for Engaged Foresight and the WFSF World Futures Learning Lab (LEALA), funded by the UNESCO Participation Project in 2015.

Around 35 participants, of which 90% were women leaders, attended the work-shop. The learning lab introduced and combined creative, critical, interpretive and action-learning approaches and games to analyze, question and imagine alternative and preferred city futures from a woman's point of reference. Cesar Villanueva and I co-directed the course, with Mei-Mei Song, Janelle Marr and Ariana Lutterman facilitating.

Critical questions of the participants included: What would Philippine cities be like if they were designed by women? What would our streets, communities, priorities, festivals and neighborhood look like in a women and gender imagined alternative city futures? What might be their preferences? What narratives of resilience, planning, social innovations and city designs could surface or re-surface when the future of our cities are questioned, re-imagined and reconstructed by

Shermon organized and facilitated a series of action-learning city futures workshop and keynoted seminars and conferences to advance futures thinking and strategic foresight to engage and empower women of all ages to disrupt and imagine alternatives and transform city futures.

women? These questions helped the women identify the big issues and possibly some game changers essential to achieving long term sustainability and social transformation. Our game plan was to provide an avenue for women leaders to design their own strategic pathways by deepening their foresight capacities.

Participants identified some big narratives that must be challenged in their communities:

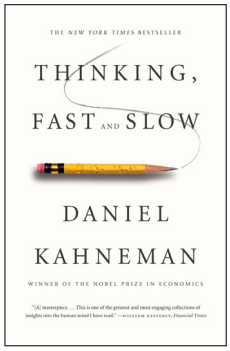
- Women perceived as sexual objects
- Growing incidence of early/ teen pregnancy
- Violence against women – discrimination in the workplace, sexual harassment, etc.
- Increasing number of single mothers unsupported by government and workplaces
- Age and gender gap in the work- place, political arena and society
- Gap between how younger and elder women view their roles in society and governance
- Consumption and competition-driven societal culture
- Prohibitive costs and limited access to health infrastructures (women, elders children)
- Problematic social value orientation (e.g. preference for male babies as a first child)
- Vulnerability of females of all ages to disasters and conflict, social media, technology
- Implicit and explicit masculinity in design of cities, social rules, income, organizational structure and dynamics, infrastructure and urban planning.

The women shared compelling personal stories of power relationships in the workplace (family, children, home are disowned in existing labor, workplace narratives and contexts) and society (male-female interaction and social dynamics). They spoke of income gaps and social narratives on how history, systems and trends favored and institutionalized patriarchal ways of knowing. A refocusing and reframing (with nature and mothers in mind) are needed and a strong action from the women sector is imperative if they are to disrupt the status quo and create a woman informed/narrative of sustainability and society.

Building on the research questions, emerging issues and drivers mapped, including the insights that emerged from the workshop, the preferred and transformed city future was the nurturing and gender equitable city. This vision offers access to resources and wealth opportunities to women; peace, safe and non-violent free roads; organic and plant based industries and lifestyles as well as food diversity; and systems would be open source, advocacy-driven, participatory and health-driven. Elders, children and mothers are prioritized. The underlying narrative was the Lungsod ng Buhay or the City of Life. The transformed future Philippine city would have playgrounds that are sensitive and responsive to the needs of children, elderlies and mothers.

Shermon Cruz is a professional futurist, a certified business continuity professional and founder of the Center for Engaged Foresight. Cruz specializes on futures education and research, strategic foresight facilitation, planning, governance and policy management. For more about my city futures work, check www.engagedforesight.com

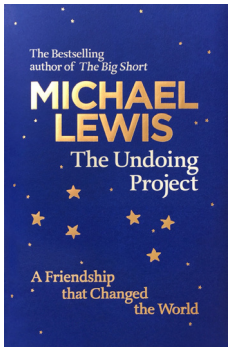
Thinking Fast and Slow
by Daniel Kahneman



Book Review

by Charles Brass – Chair, futures foundation

The Undoing Project
by Michael Lewis



One of the quotations on the back cover of "Thinking Fast and Slow" is from the Economist Magazine:

> "As Copernicus removed the Earth from the centre of the universe and Darwin knocked humans off their biological perch, Kahneman has shown that we are not the paragons of reason we assume ourselves to be."

Perhaps Kahneman is not as well known as Copernicus or Darwin, but the Economist is right to describe his work as equally earth-shattering. Kahneman (and his long-time collaborator Amos Tversky, to whose memory this book is dedicated) are heroes in the field of behavioural psychology. Beginning in the 1950s they devoted their professional lives to studying the judgements people make and why they make the decisions they do.

Their work is particularly important because it questions the conventional assumptions that human beings normally act rationally and logically and that their thinking is usually sound. Through a large number of cleverly designed experiments, Kahneman and Tversky conclusively demonstrate that this is not always the case – our minds can, and do, easily confuse us and get things wrong. We all too often act irrationally and, if pushed to justify our behaviour, can come up with very convincing sounding explanations.

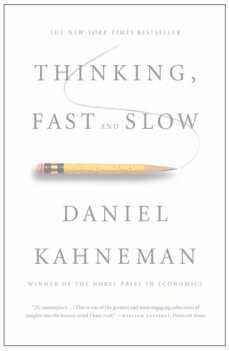
This may not sound all that earth-shattering, but the view that human beings are fundamentally rational has dominated economic and political thinking for as long as anyone can remember. Economic markets are supposed to work because people act rationally to decide what they want and what they are prepared to pay. Governments are told to get out of the way and allow the rationality of their individual citizens to collectively unleash the 'invisible hand' of the marketplace.

Kahneman, Tversky and a large number of their students and collaborators have spent the past 60 years questioning this economic wisdom, often facing great resistance from economists and even from other psychologists. Their work was vindicated when Kahneman received the Nobel Prize for Economics in 2002. Tversky would certainly have shared this honour, but he died in 1996 and Nobel Prizes are only awarded to living researchers.

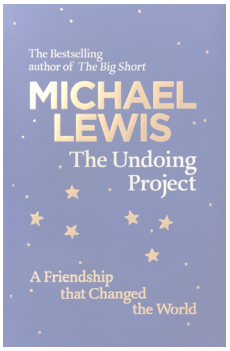
Thinking Fast and Slow is a 400 page summary of their research and its findings written in 2011. Kahneman says in the introduction that he wrote it to inform gossip and discussion at proverbial office water coolers. He would like people to be more aware of their decision making processes and why they think the way they do.

This paragraph, also from the introduction, neatly summarises his intentions:

> "Much of the discussion in this book is about biases of intuition. However, the focus on error does not denigrate human intelligence, any more than the attention to diseases in medical texts denies good health. Most of us are healthy most of the time, and most of our judgements and actions are appropriate most of the time. As we navigate our lives, we normally allow ourselves to be guided by impressions and feelings, and the confidence we have in our intuitive beliefs and preferences is usually justified. But not always. We are often confident even when we are wrong, and an objective observer is more likely to detect our errors than we are." (p4)



Kahneman's research shows humans are endowed with two distinct, but overlapping, ways of thinking – the fast and slow thinking of the title. He teases out how and why these two systems operate, and points out that most of the time our thinking is dominated by so-called fast thinking. There is a strong evolutionary dimension to this understanding. Humans share a fast, intuitive thinking system with many other species, and even our slower cognitive thinking system is only an extension of similar systems found in many of our closest animal cousins.



The middle part of this book is devoted to exploring why theorists have assumed the so-called 'rational man' hypothesis when our real-world behaviours can differ widely from this ideal. Many of these pages explore just how psychologists gradually overcame the objections of economists who fought hard to protect their simplistic models.

Finally Kahneman looks at two aspects of the self – what he calls the 'experiencing self' and the 'remembering self'. The neatest examples of the differences between these two occur at the times when major life decisions are made – for example, getting married or starting a new business. Our remembering selves know that many marriages and most new businesses fail, but our experiencing selves say this time It will be different

Kahneman takes his readers on a methodical journey through a lifetime of careful research in the hope that future generations will better understand when their decisions and judgements can be relied upon, and how to deal with situations when they can't.

As indication of the importance of Kahneman and Tversky's work is that in 2017 author Michael Lewis chose to write the story of their collaboration in "The Undoing Project".

Lewis introduces his book by describing a dilemma causing many modern thinkers quite some angst – when are human decisions better than those made by computer algorithms? This is a theme that obviously interests Lewis since he has explored it in different ways in many of his previous books. In fact, he begins this book by describing how one of his previous books – "Moneyball" – about one baseball team owner who built a successful team by ignoring human opinion about who were better baseball players and buying only those a computer algorithm judged to be the best – introduced him to the work of Kahneman and Tversky[1] .

Lewis traces their early lives – coincidentally both were Israelis – how they met and how they collaborated (this is a fascinating story in its own right, they were apparently very different types of people). He also provides an excellent overview of their research methodologies and findings, though I would recommend that anyone seriously interested also read "Thinking Fast and Slow".

Lewis tells Kahneman and Tversky's story with the flair of a journalist. It reads like and engaging story while never ignoring the crucial message that (as the sub-title suggests) this is a friendship that changed the world.

As human beings create ever more sophisticated (some say intelligent) computer systems on whose thinking we increasingly rely, it is very much worth pausing to consider carefully both how these artificial agents, and those who create them, think. Working out the place of human beings in a future world may just depend on deciding how these thinking systems differ, and where, if anywhere, human thinking is superior.

[1]This introduction was facilitated by one of Kahneman's collaborators – Richard Thaler – whose book "Nudge" on similar themes is also well worth reading

Signals in the Noise

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These technologies all have staying power. They will affect the economy and our politics, improve medicine, or influence our culture. Some are unfolding now; others will take a decade or more to develop. But you should know about all of them right now.

REVERSING PARALYSIS

Scientists are making remarkable progress at using brain implants to restore the freedom of movement that spinal cord injuries take away.

"Go, go!" was the thought racing through Grégoire Courtine's mind. The French neuroscientist was watching a macaque monkey as it hunched aggressively at one end of a treadmill. His team had used a blade to slice halfway through the animal's spinal cord, paralyzing its right leg. Now Courtine wanted to prove he could get the monkey walking again. To do it, he and colleagues had installed a recording device beneath its skull, touching its motor cortex, and sutured a pad of flexible electrodes around the animal's spinal cord, below the injury. A wireless connection joined the two electronic devices.

Grégoire Courtine holds the two main parts of the brain-spine interface. PHOTOGRAPH BY HILLARY SANCTUARY | EPFL

The result: a system that read the monkey's intention to move and then transmitted it immediately in the form of bursts of electrical stimulation to its spine. Soon enough, the monkey's right leg began to move. Extend and flex. Extend and flex. It hobbled forward. "The monkey was thinking, and then boom, it was walking," recalls an exultant Courtine, a professor with Switzerland's École Polytechnique Fédérale de Lausanne.

In recent years, lab animals and a few people have controlled computer cursors or robotic arms with their thoughts, thanks to a brain implant wired to machines. Now researchers are taking a significant next step toward reversing paralysis once and for all. They are wirelessly connecting the brain-reading technology directly to electrical stimulators on the body, creating what Courtine calls a "neural bypass" so that people's thoughts can again move their limbs.

SELF-DRIVING TRUCKS

Tractor-trailers without a human at the wheel will soon barrel onto highways near you. What will this mean for the nation's 1.7 million truck drivers?

Roman Mugriyev was driving his long-haul 18-wheeler down a two-lane Texas highway when he saw an oncoming car drift into his lane just a few hundred feet ahead. There was a ditch to his right and more oncoming cars to his left, so there was little for him to do but hit his horn and brake. "I could hear the man who taught me to drive telling me what he always said was rule number one: 'Don't hurt anybody,'" Mugriyev recalls.

But it wasn't going to work out that way. The errant car collided with the front of Mugriyev's truck. It shattered his front axle, and he struggled to keep his truck and the wrecked car now fused to it from hitting anyone else as it barreled down the road. After Mugriyev finally came to a stop, he learned that the woman driving the car had been killed in the collision.

Could a computer have done better at the wheel? Or would it have done worse? We will probably find out in the next few years, because multiple companies are now testing self-driving trucks. Although many technical problems are still unresolved, proponents claim that self-driving trucks will be safer and less costly. "This system often drives better than I do," says Greg Murphy, who's been a professional truck driver for 40 years. He now serves as a safety backup driver during

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tests of self-driving trucks by Otto, a San Francisco company that outfits trucks with the equipment needed to drive themselves.

PAYING WITH YOUR FACE

Face-detecting systems in China now authorize payments, provide access to facilities, and track down criminals. Will other countries follow?

Shortly after walking through the door at Face++, a Chinese startup valued at roughly a billion dollars, I see my face, unshaven and looking a bit jet-lagged, flash up on a large screen near the entrance.

Having been added to a database, my face now provides automatic access to the building. It can also be used to monitor my movements through each room inside. As I tour the offices of Face++ (pronounced "face plus plus"), located in a suburb of Beijing, I see it appear on several more screens, automatically captured from countless angles by the company's software. On one screen a video shows the software tracking 83 different points on my face simultaneously. It's a little creepy, but undeniably impressive.

Over the past few years, computers have become incredibly good at recognizing faces, and the technology is expanding quickly in China in the interest of both surveillance and convenience. Face recognition might transform everything from policing to the way people interact every day with banks, stores, and transportation services.

Technology from Face++ is already being used in several popular apps. It is possible to transfer money through Alipay, a mobile payment app used by more than 120 million people in China, using only your face as credentials. Meanwhile, Didi, China's dominant ride-hailing company, uses the Face++ software to let passengers confirm that the person behind the wheel is a legitimate driver. (A "liveness" test, designed to prevent anyone from duping the system with a photo, requires people being scanned to move their head or speak while the app scans them.)

PRACTICAL QUANTUM COMPUTERS

Advances at Google, Intel, and several research groups indicate that computers with previously unimaginable power are finally within reach.

One of the labs at QuTech, a Dutch research institute, is responsible for some of the world's most advanced work on quantum computing, but it looks like an HVAC testing facility. Tucked away in a quiet corner of the applied sciences building at Delft University of Technology, the space is devoid of people. Buzzing with resonant waves as if occupied by a swarm of electric katydids, it is cluttered by tangles of insulated tubes, wires, and control hardware erupting from big blue cylinders on three and four legs.

Inside the blue cylinders—essentially supercharged refrigerators—spooky quantum-mechanical things are happening where nanowires, semiconductors, and superconductors meet at just a hair above absolute zero. It's here, down at the limits of physics, that solid materials give rise to so-called quasiparticles, whose unusual behavior gives them the potential to serve as the key components of quantum computers. And this lab in particular has taken big steps toward finally bringing those computers to fruition. In a few years they could rewrite encryption, materials science, pharmaceutical research, and artificial intelligence.

Every year quantum computing comes up as a candidate for this Breakthrough Technologies list, and every year we reach the same conclusion:

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not yet. Indeed, for years qubits and quantum computers existed mainly on paper, or in fragile experiments to determine their feasibility. (The Canadian company D-Wave Systems has been selling machines it calls quantum computers for a while, using a specialized technology called quantum annealing. The approach, sceptics say, is at best applicable to a very constrained set of computations and might offer no speed advantage over classical systems.) This year, however, a raft of previously theoretical designs are actually being built. Also new this year is the increased availability of corporate funding—from Google, IBM, Intel, and Microsoft, among others—for both research and the development of assorted technologies needed to actually build a working machine: microelectronics, complex circuits, and control software.

THE 360-DEGREE SELFIE

Inexpensive cameras that make spherical images are opening a new era in photography and changing the way people share stories.

Seasonal changes to vegetation fascinate Koen Hufkens. So last fall Hufkens, an ecological researcher at Harvard, devised a system to continuously broadcast images from a Massachusetts forest to a website called VirtualForest.io. And because he used a camera that creates 360°pictures, visitors can do more than just watch the feed; they can use their mouse cursor (on a computer) or finger (on a smartphone or tablet) to pan around the image in a circle or scroll up to view the forest canopy and down to see the ground. If they look at the image through a virtual-reality headset they can rotate the photo by moving their head, intensifying the illusion that they are in the woods.

Hufkens says the project will allow him to document how climate change is affecting leaf development in New England. The total cost? About $550, including $350 for the Ricoh Theta S camera that takes the photos.

Today, anyone can buy a decent 360°camera for less than $500, record a video within minutes, and upload it to Facebook or YouTube. Much of this amateur 360° content is blurry; some of it captures 360 degrees horizontally but not vertically; and most of it is mundane. (Watching footage of a stranger's vacation is almost as boring in spherical view as it is in regular mode.) But the best user-generated 360° photos and videos—such as the Virtual Forest—deepen the viewer's appreciation of a place or an event.

HOT SOLAR CELLS

By converting heat to focused beams of light, a new solar device could create cheap and continuous power.

Solar panels cover a growing number of rooftops, but even decades after they were first developed, the slabs of silicon remain bulky, expensive, and inefficient. Fundamental limitations prevent these conventional photovoltaics from absorbing more than a fraction of the energy in sunlight.

But a team of MIT scientists has built a different sort of solar energy device that uses inventive engineering and advances in materials science to capture far more of the sun's energy. The trick is to first turn sunlight into heat and then convert it back into light, but now focused within the spectrum that solar cells can use. While various researchers have been working for years on so-called solar thermophotovoltaics, the MIT device is the first one to absorb more energy than its photovoltaic cell alone, demonstrating that the approach could dramatically increase efficiency.

Standard silicon solar cells mainly capture

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the visual light from violet to red. That and other factors mean that they can never turn more than around 32 percent of the energy in sunlight into electricity. The MIT device is still a crude prototype, operating at just 6.8 percent efficiency—but with various enhancements it could be roughly twice as efficient as conventional photovoltaics.

GENE THERAPY 2.0

Scientists have solved fundamental problems that were holding back cures for rare hereditary disorders. Next we'll see if the same approach can take on cancer, heart disease, and other common illnesses.

When Kala Looks gave birth to fraternal twin boys in January 2015, she and her husband, Philip, had no idea that one of them was harboring a deadly mutation in his genes.

At three months old, their son Levi was diagnosed with severe combined immune deficiency, or SCID, which renders the body defenseless against infections. Levi's blood had only a few immune cells essential to fighting disease. Soon he would lose them and have no immune system at all.

Kala and Philip frantically began sanitizing their home to keep Levi alive. They got rid of the family cat, sprayed every surface with Lysol, and boiled the twins' toys in hot water. Philip would strap on a surgical mask when he came home from work.

At first, Kala and Philip thought their only option was to get Levi a bone marrow transplant, but they couldn't find a match for him. Then they learned about an experimental gene therapy at Boston Children's Hospital. It was attempting to treat children like Levi by replacing the gene responsible for destroying his immune system.

"I thought, this isn't real," Kala says. "There's no way this could work."

Nonetheless, the Lookses flew from their home in Michigan to Boston in May 2015. Days later, Levi got an infusion of the therapy into his veins. He has been a normal boy ever since—and he has even grown larger than his twin brother. Babies born with SCID typically didn't survive past two years old. Now, a one-time treatment offers a cure for patients like Levi Looks.

THE CELL ATLAS

Biology's next mega-project will find out what we're really made of.

In 1665, Robert Hooke peered down his microscope at a piece of cork and discovered little boxes that reminded him of rooms in a monastery. Being the first scientist to describe cells, Hooke would be amazed by biology's next mega-project: a scheme to individually capture and scrutinize millions of cells using the most powerful tools in modern genomics and cell biology.

The objective is to construct the first comprehensive "cell atlas," or map of human cells, a technological marvel that should comprehensively reveal, for the first time, what human bodies are actually made of and provide scientists a sophisticated new model of biology that could speed the search for drugs.

To perform the task of cataloguing the 37.2 trillion cells of the human body, an international consortium of scientists from the U.S., U.K., Sweden, Israel, the Netherlands, and Japan is being assembled to assign each a molecular signature and also give each type a zip code in the three-dimensional space of our bodies.

"We will see some things that we expect, things we know to exist, but I'm sure there will be completely novel things," says Mike Stubbington, head of the cell atlas team at the Sanger Institute in the U.K. "I think there will be surprises."

Signals in the Noise

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Previous attempts at describing cells, from the hairy neurons that populate the brain and spinal cord to the glutinous fat cells of the skin, suggest there are about 300 variations in total. But the true figure is undoubtedly larger. Analyzing molecular differences between cells has already revealed, for example, two new types of retinal cells that escaped decades of investigation of the eye; a cell that forms the first line of defense against pathogens and makes up four in every 10,000 blood cells; and a newly spotted immune cell that uniquely produces a steroid that appears to suppress the immune response.

Three technologies are coming together to make this new type of mapping possible. The first is known as "cellular microfluidics." Individual cells are separated, tagged with tiny beads, and manipulated in droplets of oil that are shunted like cars down the narrow, one-way streets of artificial capillaries etched into a tiny chip, so they can be corralled, cracked open, and studied one by one.

The second is the ability to identify the genes active in single cells by decoding them in superfast and efficient sequencing machines at a cost of just a few cents per cell. One scientist can now process 10,000 cells in a single day.

The third technology uses novel labeling and staining techniques that can locate each type of cell—on the basis of its gene activity—at a specific zip code in a human organ or tissue.

BOTNETS OF THINGS

The relentless push to add connectivity to home gadgets is creating dangerous side effects that figure to get even worse.

Botnets have existed for at least a decade. As early as 2000, hackers were breaking into computers over the Internet and controlling them en masse from centralized systems. Among other things, the hackers used the combined computing power of these botnets to launch distributed denial-of-service attacks, which flood websites with traffic to take them down.

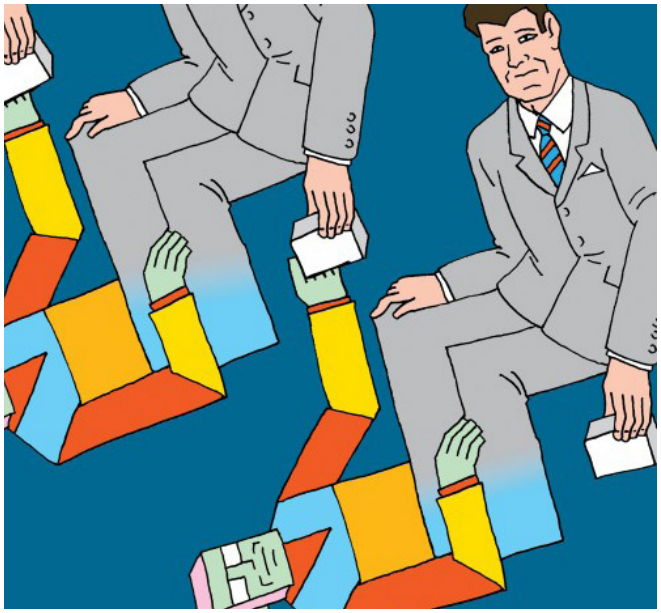
But now the problem is getting worse, thanks to a flood of cheap webcams, digital video recorders, and other gadgets in the "Internet of things." Because these devices typically have little or no security, hackers can take them over with little effort. And that makes it easier than ever to build huge botnets that take down much more than one site at a time.

In October, a botnet made up of 100,000 compromised gadgets knocked an Internet infrastructure provider partially offline. Taking down that provider, Dyn, resulted in a cascade of effects that ultimately caused a long list of high-profile websites, including Twitter and Netflix, to temporarily disappear from the Internet. More attacks are sure to follow: the botnet that attacked Dyn was created with publicly available malware called Mirai that largely automates the process of co-opting computers.

The best defense would be for everything online to run only secure software, so botnets couldn't be created in the first place. This isn't going to happen anytime soon. Internet of things devices are not designed with security in mind and often have no way of being patched. The things that have become part of Mirai botnets, for example, will be vulnerable until their owners throw them away. Botnets will get larger and more powerful simply because the number of vulnerable devices will go up by orders of magnitude over the next few years.

REINFORCEMENT LEARNING

By experimenting, computers are figuring out how to do things that no programmer could teach them.



Inside a simple computer simulation, a group of self-driving cars are performing a crazy-looking maneuver on a four-lane virtual highway. Half are trying to move from the right-hand lanes just as the other half try to merge from the left. It seems like just the sort of tricky thing that might flummox a robot vehicle, but they manage it with precision.

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I'm watching the driving simulation at the biggest artificial-intelligence conference of the year, held in Barcelona this past December. What's most amazing is that the software governing the cars' behavior wasn't programmed in the conventional sense at all. It learned how to merge, slickly and safely, simply by practicing. During training, the control software performed the maneuver over and over, altering its instructions a little with each attempt. Most of the time the merging happened way too slowly and cars interfered with each other. But whenever the merge went smoothly, the system would learn to favor the behavior that led up to it.

This approach, known as reinforcement learning, is largely how AlphaGo, a computer developed by a subsidiary of Alphabet called DeepMind, mastered the impossibly complex board game Go and beat one of the best human players in the world in a high-profile match last year. Now reinforcement learning may soon inject greater intelligence into much more than games. In addition to improving self-driving cars, the technology can get a robot to grasp objects it has never seen before, and it can figure out the optimal configuration for the equipment in a data center.

Reinforcement learning copies a very simple principle from nature. The psychologist Edward Thorndike documented it more than 100 years ago. Thorndike placed cats inside boxes from which they could escape only by pressing a lever. After a considerable amount of pacing around and meowing, the animals would eventually step on the lever by chance. After they learned to associate this behavior with the desired outcome, they eventually escaped with increasing speed.

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