

مركز محمد بن راشد
لأبحاث المستقبل

MBR CENTER FOR ACCELERATED RESEARCH

FUTURE FORESIGHTS

TECHNOLOGY TRENDS HIGHLIGHTS

DUBAI FUTURE ACADEMY - 2018

A Report for Governments to Support Future Technologies

From brain-computer interfaces to the latest in battery technology, the "Future Foresights" report covers tech trends that could affect people and the cities they inhabit worldwide over the next 20 to 30 years. It lends special focus to how these trends might impact the seven sectors laid out in the UAE's National Innovation Strategy.

To draft this report, we picked the brains of world-renowned tech experts and collected valuable insight from people working in different Dubai government departments. The findings point us towards the vital role

that governments can play in supporting the technologies of the future and creating an economic and legislative environment that enables and stimulates the private sector. It's more than a compendium of interesting tech trends though; it also serves as a guide for governments to understand these new technologies as they look towards the future.

Bear in mind, however, that this report does not offer governments specific or sequential plans and work procedures they should follow. Instead it sheds light on a number of challenges that surround technology, and offers ideas on how to deal with these challenges. The goal is to build a government work system that is able to operate with the future in mind and empower the strategic sectors that support new technologies.

The main take-away from our interviews with tech experts is that governments can put in place the broad lines to create the change needed, to anticipate and support technology, and to identify the drivers that

motivate the private sector to invest in these sectors.

The "Future Foresights" report, published by the Dubai Future Academy, is a complement to the "State of the Future" Report, released at the World Economic Forum in Davos in January 2017.

Dubai Future Academy seeks to publish reports and provide comprehensive educational and training programs that look towards the future. This offers government officials and private sector partners from corporations and startups in the UAE and the entire region the opportunity to explore the future of strategic sectors, to enhance their decision-making abilities, and to set strategies and design scenarios for the future.



FUTURE FORESIGHTS



Foreword

In the UAE today, building the future is an industry and a science in itself. It is a curriculum we teach in our universities and academic centers. It is a discipline rooted in the long-term vision that our nation was built upon, which our wise leaders consistently bring to life in their initiatives and directives.

The science of building the future seeks, first and foremost, to draw a clear image of what human societies will look like in the future - an image based on a set of projections developed by leading experts in strategic sectors. Facts and data are the bedrock on which these forecasts are built, basing them in the realities of our world and the technological boom taking place all around us.

The industry of building the future cannot be a unilateral project. It calls on governments around the world to join hands and initiate change in their respective societies, and to strengthen partnership with the private sector to lay

strong foundations that allow them to steer global trends in humanity's favor.

In the UAE, we have fully embraced change and are already at work to meet the requirements of the future. Forging strong partnerships with companies and entrepreneurs, we set out to customize our government system and operations and tailor them to the challenges and opportunities of the future. Our ultimate goal is to achieve excellence across all departments and firmly place the UAE at the top of the charts in terms of future-readiness. With that in mind, we carefully weigh the challenges and opportunities ahead to develop innovative solutions that spread happiness and secure prosperity for our future generations.

The "Future Foresights" report is instrumental to Dubai Future Foundation's role in implementing the ambitious Dubai Future Agenda. The Foundation joins a legion of scientists, experts and specialists from the world's leading universities

and institutes on a mission to spread knowledge and promote future-readiness. We strive to be a catalyst for inspiration and creativity, as well as an ally in efforts to build a better future for our region and catapult the UAE to the forefront of cutting-edge science and technology.

Mohammed Abdullah Al Gergawi,

Minister of Cabinet Affairs and the Future,

Vice Chairman of the Board of Trustees, Managing Director of the Dubai Future Foundation

FUTURE

FORESIGHTS



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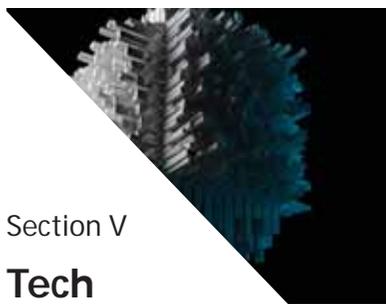
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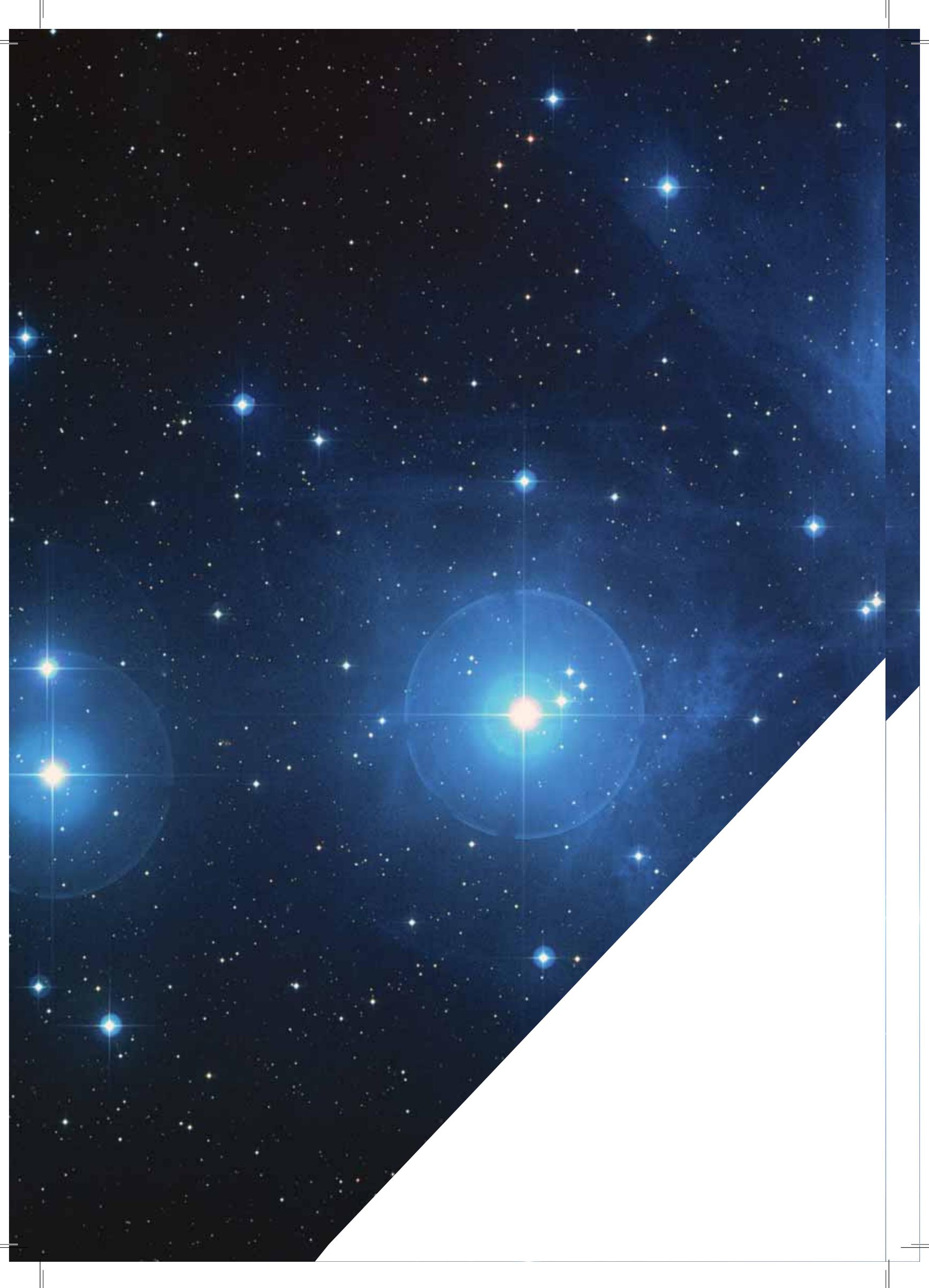
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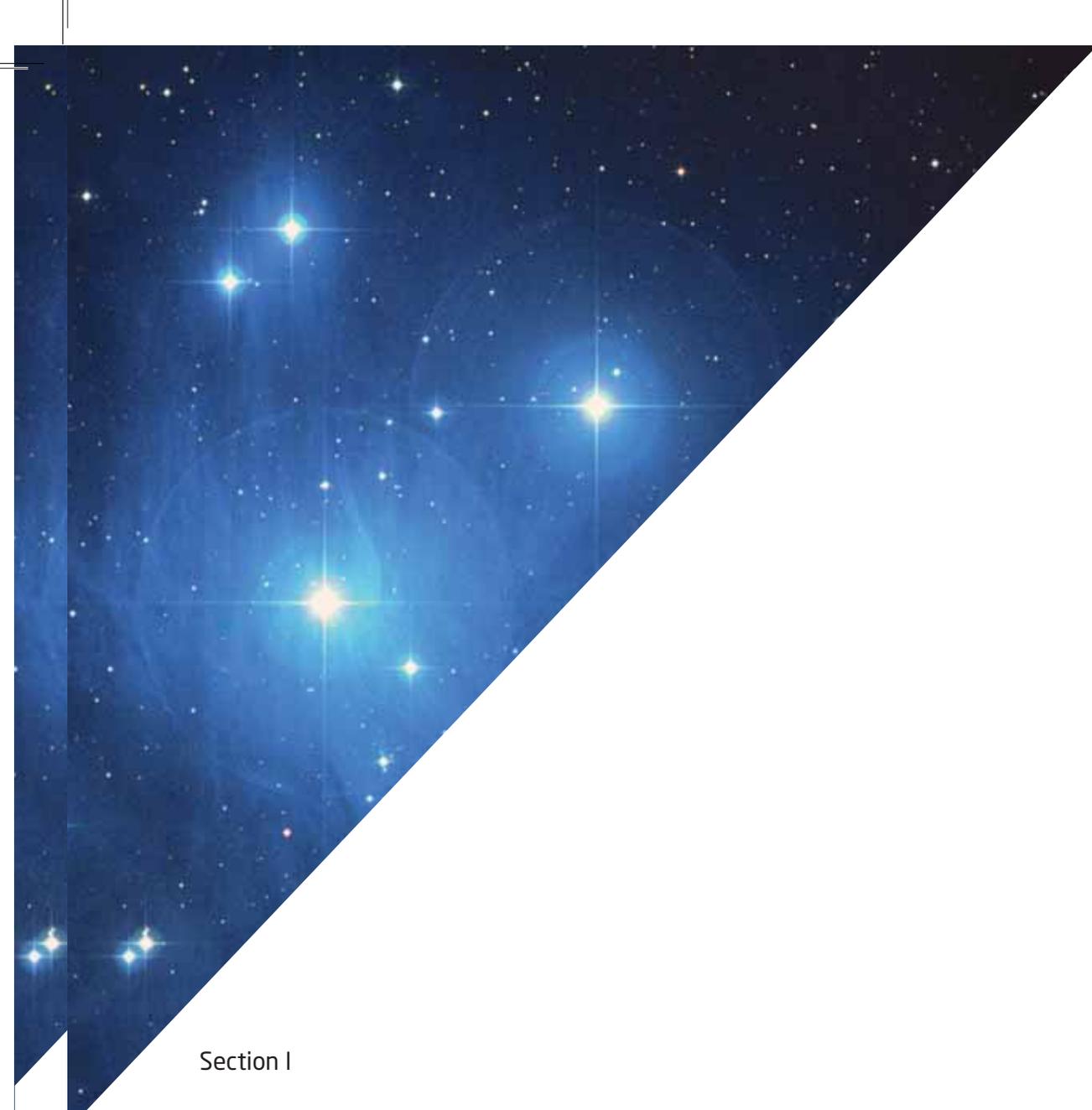
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Section I

Space

Our cities won't always be confined to Earth. Recent advances in private spaceflight reveal just how close we are to conquering the cosmos and establishing colonies on other worlds. In the next few decades, these efforts will come to fruition, and today's advances in manufacturing and research will make space travel affordable and ensure that our off-world colonies are safe. To become a multi-planetary species or even engage in space tourism, governments will need to invest in inventive propulsion systems, hibernation solutions, reusable rockets, and asteroid mining technology.

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- I** **Colonizing the Solar System**
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OUR EXPERTS

We returned to three commentators from our pool of experts to ask how changes in the space sector could affect cities in 20 or 30 years, summarizing their response in a series of articles.

Adrian Brown

**Research Scientist,
SETI Institute**

Adrian Brown is a planetary scientist working at the SETI Institute and NASA Ames Research Center. His fields of research include astrobiology and remote sensing spectroscopy. Brown's current research focuses on the analysis of data from the Mars Reconnaissance Orbiter.

Alan Stern

**Principal Investigator,
New Horizons Mission**

Alan Stern is a planetary scientist, space program executive, and aerospace consultant. He leads NASA's New Horizons mission to Pluto. In 2007, he was appointed NASA's chief of all science missions. Since 2009, he has been an Associate Vice President and Special Assistant to the President at the Southwest Research Institute.

Brian Koberlein

**Astrophysicist and Senior
Lecturer, Rochester Institute
of Technology**

Brian Koberlein is an astrophysicist at RIT and has written a textbook on computational astrophysics with Cambridge University Press. His articles on astronomy have appeared in a number of publications, such as Forbes, Futurism, and EarthSky.

Experts' highlights: **FUTURE FORESIGHTS**

Space

THE WORLD TODAY



How long it takes to reach Alpha Centauri today: 78,000 years at the speed of New Horizons, the fastest spacecraft to leave Earth.



How much it costs to launch the first stage of a rocket today: \$61.2 million (SpaceX Falcon 9).



How many active landers on Mars today: 2 (Curiosity and Opportunity rover missions).



How many private tourists have flown in space so far: 7.



How far humans have travelled from Earth: 400,000 km.

THE REALITY TOMORROW

- ▶ How long it will take to reach Alpha Centauri with Breakthrough Starshot: 20 years.
- ▶ How much it will cost to launch the first stage of a reusable rocket: \$48.3 million, assuming half of the savings are passed on to customers.
- ▶ Cost for a future flight into space on Virgin Galactic: US \$250,000.
- ▶ How many companies/nations plan to have humans on Mars by the 2040s: 6 (NASA, China, Dubai, Russia, SpaceX and Mars One).
- ▶ Distance humans will have to travel to get to Mars: 223 million km, on average.
- ▶ The UAE Mars mission aims to analyse the Martian climate in order for the scientists to better understand the Red Planet, the Earth in the future millions of years from now, and other planets that have yet to be discovered. It will allow us to analyze newly discovered planets far across the galaxy to be able to determine if there is life on it. - Sara Al Ameri, UAE Minister of State for Advanced Sciences and the Emirates Mars Mission Science Team Leader at the MBR Space Centre

BUILDING THE FUTURE



Before humans can travel the cosmos and establish permanent settlements off-world, we will need to determine exactly how the human body responds to long-term spaceflight. Ultimately, governing bodies will need to identify potential risks from radiation, microgravity, and similar threats and work with both physicians and innovators in order to mitigate these concerns and safeguard human colonists.



Reusable rockets dramatically reduce the cost of spaceflight and make exploration truly affordable. Beyond investing in the sector, governments need to streamline approval processes and encourage both collaboration and information sharing in order to assist companies who are innovating in this space and working to test these technologies.



One of the most expensive aspects of space explorations is launching material off Earth. Future missions will need to harvest material from the local environment (asteroids, moons, or planets) and use 3D-printing technologies to build habitats and necessary tools. This will require a strong investment in materials science and research related to how effective this printing tech is in different gravitational conditions.



In order to make long term colonies truly viable, governments will need to work together in order to create an international network of space stations, satellites, and Moon-based resource stations to bring cargo between the Earth and Mars (or any alternative off world colonies).

Space

Colonizing the Solar System

In the world of tomorrow, colonies will dot the local cosmos and extend humanity's reach beyond the bounds of Earth. But voyaging to other worlds will require a series of smaller scale projects, including developing better systems for supporting human health in space, before we start our full-scale launch.

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Number of cargo trips
Elon Musk estimates will
be needed for every hu-
man expedition to Mars.

In the coming decades, we will see the establishment of cities orbiting in space and situated on other worlds. Our first target for settlement, according to Adrian Brown, should be Mars. Because it is the planet that most closely resembles our own, Brown says that Mars is the most viable place for us to "make a human-looking city" in the next five to 30 years.

One of the first obstacles we must overcome when attempting to transport people throughout space is not technological, but biological. The human body reacts poorly to extended periods in microgravity. Despite exercising for roughly two hours a day, astronauts aboard the International Space Station (ISS) still experience muscle degradation. While

scientists have developed impact-bearing exercises to almost arrest bone loss, we can't completely eradicate it. Doctors are also concerned about the permanent degradation in eyesight astronauts experience after returning to Earth, the cause of which is still being investigated.

Another major health risk associated with space travel is radiation. Radiation can damage the central nervous system, resulting in reduced motor function and altered cognitive function. Astronauts on the ISS are exposed to 10 times as much radiation as they would be on Earth. However, an even stronger form of radiation, galactic cosmic radiation, comes from outer space. Therefore, a trip to Mars would result in exposure to 100 times more

radiation than experienced on Earth. To better understand these and other risks to human health, there needs to be more research than the tests done on the relatively small number of astronauts and limited kinds of journeys there have been so far. One way to achieve this is by investing and participating in long-term spaceflight missions, but those can be very time-consuming and costly. Thankfully, many alternative options exist. Already, scientists are using Earth-based facilities to study the impact of microgravity, and similar research on bone loss can be accomplished by studying various restrictive diets. Further studies on mammals aboard the International Space Station, such as mice, can help scientists glean valuable data on the effects of



In the most distant future; we'll see cities in space... but in the near future, we'll see cities that'll have their own spaceports. Space will blossom into a more everyday affair.

Alan Stern

radiation as well.

Sara Al Ameri, who is the UAE's first Minister of State for Advanced Sciences and the Emirates Mars Mission Science Team Leader at the Mohammad Bin Rashid Space Centre, notes the vast progress that has been made in the space industry, but asserts that there is still much that needs to be learned before we can send humans to permanently live on other worlds. "The UAE's Mars mission aims to analyse the Martian climate in order for the scientists to better understand the Red Planet, the Earth in the future millions of years from now, and other planets that have yet to be discovered. It will allow us to analyze newly discovered planets far across the galaxy to be able to determine if there is life on it."

To this end, before considering how we'd live once on the Red Planet, we must determine how humans would get there in the first place. The most logical plan is for governments to create a series of orbiting stations that can support spacecraft as they travel. The first step to this "deep space gateway" is a small space station that orbits Earth. This could serve as a spaceport, launch base, and staging location for deep space transport spacecraft.

Once humans do reach Mars, they will need to live off the land as much as possible to reduce the cost of transporting items from Earth. Governments should lead the charge in extracting the huge deposits of ice beneath the Martian surface and combining

them with the carbon in the atmosphere to produce life-supporting fluids, fuels, oxidizers, and plastics for equipment. Further, the dry ice that accumulates at the planet's poles can be turned into a gas to release energy that can be used to power turbines. Martian regolith may be repurposed for habitats or even for growing plants. In fact, in 2017, researchers at the International Potato Center in Peru sprouted spuds using simulated Martian dirt. Continued research in these areas is needed in order to determine where we can harvest minerals from Mars, what vegetation can grow in Mars' soil, and how we can support that growth.



Space

Out-of-This-World Tourism

If we need a break for a few days, today's citizens head to one of the seven natural wonders. In the future, individuals will unwind by taking day trips to the sky, orbiting around the Earth, or even vacationing for a few days on a space station. Reusable rockets and new types of manufacturing will be needed to bring the cost down from a one-off luxury to a regular trip.



At first, our voyages to space will not be long. "The earliest kind of space tourism is going to be day trips where people go up briefly into space and come back the same day," says Alan Stern. "That's what Virgin Galactic, Blue Origin, and a number of other companies are already planning."

While it's true that several companies are pursuing space tourism, Virgin Galactic likely has the lead with its SpaceShipTwo

system. Under development since 2003, the system's design involves a carrier aircraft, WhiteKnightTwo, bringing the spacecraft into the upper atmosphere. SpaceShipTwo will then light its engines for a brief, 15-minute suborbital flight before returning to Earth and landing on a conventional runway.

This 14 year development timeline, even for tourism spacecraft, illustrates the long

cycles of research required in the space sector - and the timeline that government space centers will need to operate under too. There are opportunities for better coordination between governments and private space companies, as well as between larger programs and the small companies moving into the space sector.

This kind of coordination could help reduce the costs of space tourism when offered

\$250K

Cost of a ticket on
Virgin Galactic's
SpaceShipTwo



by a company working by themselves. Few paying space tourists have ventured into space, and those who have all paid millions of dollars to the Russian government to spend time on the Mir space station or the ISS. Virgin Galactic already has hundreds of paying customers patiently waiting for their turn to travel into space, but the journey's US\$250,000 is still too high for many.

The primary cost of getting items into space is launch costs. Just reaching low Earth orbit costs several thousand dollars per kilogram via a typical rocket. To that end, governments should invest in reusable rocket technology. Gwynne Shotwell, president and chief operating officer of SpaceX, for example, suggested that launches with recycled boosters could take 30 percent off the usual \$62 million cost of building a new rocket each time. Reducing the costs of production by using less expensive materials, such as 3D-printed parts, will also play a role.

"The idea of reusable rockets is all about getting the price down. It's far too

expensive to go into space right now and to do it on a regular basis," says Brian Koberlein. This is because, after each mission, traditional rockets burn up in our atmosphere. The cost of manufacturing an entirely new rocket for each mission is prohibitive, but reusable rockets can fix this. "With reusable rockets, they hope to drop the cost of spaceflight by a factor of 100, which will just be huge," Alan Stern says.

As a way to increase interest in spaceflight and even potentially fund some of the necessary research, governments could work alongside companies that use balloons to transport passengers high into the atmosphere. This would provide more people with the opportunity to see the blackness of space for a fraction of the price.

Of course, short space voyages will just be the beginning. Companies like Bigelow Aerospace are already working on space habitats. Bigelow already has two space station modules in orbit to monitor the

long-term effects of radiation on inflatable structures. In 2016, the company added the first inflatable module to the International Space Station (ISS), and it's currently being used for testing purposes as well. Similar structures can be created for Earth-based testing, and partnerships can be formed with innovators currently working on these enterprises in order to expedite their realization.

With more people in space, there will be a greater need for legislation. At the moment, most space law assumes that vehicles travel must be registered, like boats on the ocean. New rules should be able to account for a craft constructed by two nations. They will also need to develop strict regulations about who can launch and carry people to space. Additionally, processes will need to be in place to inform passengers about the various risks and confirm that they meet basic health requirements.

Space

Satellites Go Mainstream

In the future, advances in quantum computing technologies will allow us to finally secure our satellite communications. At the same time, as space becomes more democratized, sophisticated technologies will be within the reach of ordinary individuals. This will usher in a new age in security and make satellite-based science more accessible than ever before.

At this very moment, approximately 1,400 operational satellites are in orbit. Launching a satellite into space used to be a complicated affair that cost millions, but today, even elementary school students can create their own satellites for space exploration. The most popular format is the CubeSat, and its usage has exploded since the first small cube (generally 10x10x10 centimeters in size) was launched into space in 2003. Since then, CubeSats have been used for applications ranging from telecommunication, weather monitoring, to scientific observations.

The relatively low cost of a CubeSat (US\$100,000 per unit) is due in part to the fact that several can be launched in one

payload. This opens up space for nations and governments with smaller budgets, giving them the ability to use satellites to observe their terrain for effects of climate change or to mitigate disasters, for example.

As satellites become ubiquitous, governments across the globe must establish rules to ensure they don't pose a threat to those on the ground. One way to do this is by supporting the implementation of artificial intelligence (AI) in the design of satellite technology. AI could play a key role in helping the satellites navigate safely. While today's AI is used mostly for bigger satellites and interstellar probes, governments should take advantage of



4,4325

Number of satellites SpaceX plans to put into orbit between 2019 and 2024 to improve global internet connectivity.

the technology for smaller and cheaper satellites. AI could reduce the need for communications that could be hacked or overheard and allow the tiny satellites to navigate in ways that avoid collisions and optimize flight.

CubeSats give us the ability to put more devices in orbit around the Earth, and they can provide us with more data than we ever imagined possible, making it easier to monitor changes to the earth's surface and weather in real-time.

Launching these types of satellites raises interesting legal questions. "You've got large countries who have already explored space and countries who already have a space program who probably want to keep their share of the pie," says Brian Koberlein. "At the same time, as costs come down, smaller and less dominant countries are going to be able to have their own space programs. What type of international treaties do you start imposing? It's a complex thing, and there's a limited amount of space." Governments must begin international collaborations today to protect the future of our planet and ensure their place in the space race of tomorrow.

For the most part, CubeSats have been limited to Earth's orbit, but in the next 20 years, they will be traveling across the solar system and beyond. NASA has design concepts for future missions to Mars and Europa (one of Jupiter's moons) that would

include CubeSat tag-alongs to a main mission. Experts agree that their low cost positions CubeSats as the technology most likely to dominate the future. However, the satellites do have limitations that need to be considered. While rare, they have been hacked in the past, with the hackers gaining the ability to access the devices' information or redirect their missions. When millions of these satellites are orbiting our planet and stretching out across the solar system, these breaches will become more frequent.

Governments must invest in encryption in order to stay one step ahead of hackers, which is where quantum-computing technologies for satellites could be useful. In 2016, China launched the first quantum satellite with an extra encryption for its communications. The information is encoded in a way that is, in theory, too complex for even the best computers to hack.

Satellites are likely to find new applications in the future. Someday, satellites could detect dark matter, provide details about the composition of the planets in other solar systems, or observe the far reaches of the galaxy. In order to keep up with the ever-changing field of space exploration, and shape the potential uses of new technologies, governments will need to be running the research programs that develop them.



Both asteroids and the Moon are going to be important for mining rare Earth metals. The key developments that we need are reusable rockets and robotic mining systems.

Alan Stern

Space

A Universe of Resources

The miners of tomorrow won't be confined to Earth; they will mine the universe itself. Asteroids could allow us to harvest precious minerals, obtain clean water, and make nearly all the elements on the periodic table plentiful and easily accessible at a time when the availability of rare elements is already affecting mobile phone and computer manufacturers.

The strain on our planet's resources is increasing. One of the most promising places to mine new resources is actually in space – on comets, asteroids, and minor planetary bodies. The mineral wealth in the asteroid belt alone, which exists between the orbits of Mars and Jupiter, equates to about US\$100 billion for every person on Earth today.

"Asteroids and the Moon are going to be important for mining rare earth metals," Alan Stern notes. "I think the development of reusable rockets and robotic mining systems will be key. Humans will be relegated not to the digging, refining, or high grading of the materials, but to the repairing of the robots."

However, before humans can mine the universe, governments must pass regulations that clarify the rules of ownership of material from space. The Outer Space Treaty, for example, prohibits countries from establishing territorial claims. However, several private companies have joined the space industry over the last decade – Orbital Sciences Corp. and SpaceX offer regular cargo trips to the International Space Station, while others, such as Planetary Resources and Deep Space Industries, have begun ventures aimed at

mining asteroids. Since treaty laws do not include companies, answering questions such as whether asteroids can be mined or if parts of the Moon or Mars can be claimed is difficult.

The business case for traveling to asteroids relies on the reduction of space travel prices. "We still have to develop more powerful rockets and be able to go out for longer periods of time," Brian Koberlein notes. "We have to be able to get to the asteroids and bring stuff back if we want to do asteroid mining."

One such rocket is the Space Launch System (SLS), the most powerful rocket NASA has ever built. The launch vehicle is meant to transport astronauts beyond Earth's orbit and into deep space. As governments plan their space programs, they must consider rockets that open the door for larger payloads, including robotic scientific missions. The SLS offers the highest-ever payload mass and volume capability and energy, and therefore, it's a great example of a rocket that can meet a variety of crew and cargo mission needs.

Space

Thinking Interstellar

In the future, Alpha Centauri, the star system four light-years away from us, could be figuratively much closer than it is today. Already, we are working on nanosatellites that could make it to the system in just 20 years, and advances in hibernation pods could allow humans to travel to alien star systems without aging.

“The first glimmers of interstellar flight are already on the horizon,” says Alan Stern. “Yuri Milner and the Starshot project are looking at sending very small spacecrafts to the nearest star. Of course, those spacecrafts are too small to put people in.” While humans may not be wandering alien star systems in the next 20 years, nations could have tiny robotic explorers orbiting foreign suns.

The Breakthrough Starshot Initiative’s proposal to send nanosatellites to the Alpha Centauri system in the coming decades is promising, but it faces many hurdles. Batteries, power management, the design of a “lightsail” to capture photons

for propulsion, and other matters must be perfected on a very small scale. We’ll also need powerful telecommunication systems to allow us to stay in touch with our robotic explorers.

Leaps in interstellar flight for robots are probable in the next few decades, but bringing humans along for the ride will require much thought. Humans require resources such as air, water, and food that make it difficult to pack them into a compact ship. Additionally, the human lifespan is limited, and reaching other stars takes significant time when navigating in large vessels.

“If we want to send people, we have to have some way to stop their aging,” says Brian Koberlein. “There is no foreseeable technology that would get humans to other stars in a human lifetime. That’s just not happening. So the only way is to have some type of suspended animation that would allow that, unless we’re just going to send probes over generations of spaceship residents.”

We still don’t fully understand hibernation processes in mammals that engage in them regularly, but we have seen spectacular examples of temporary hibernation in humans. Induced comas or anesthetics for instance, as well as more strange

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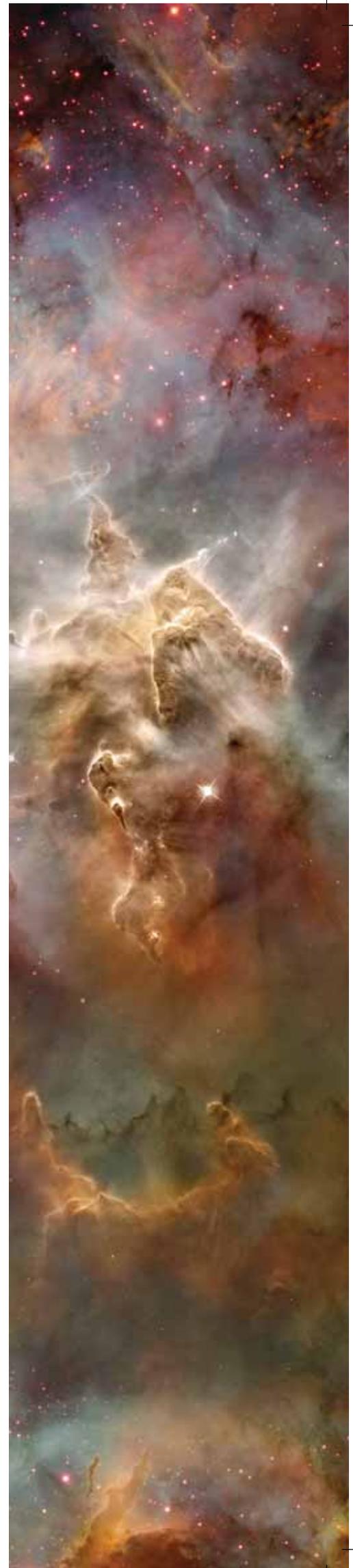
The number of years experts estimate it will take us to travel to Alpha Centauri, the closest star system to our own, using nanosatellites.

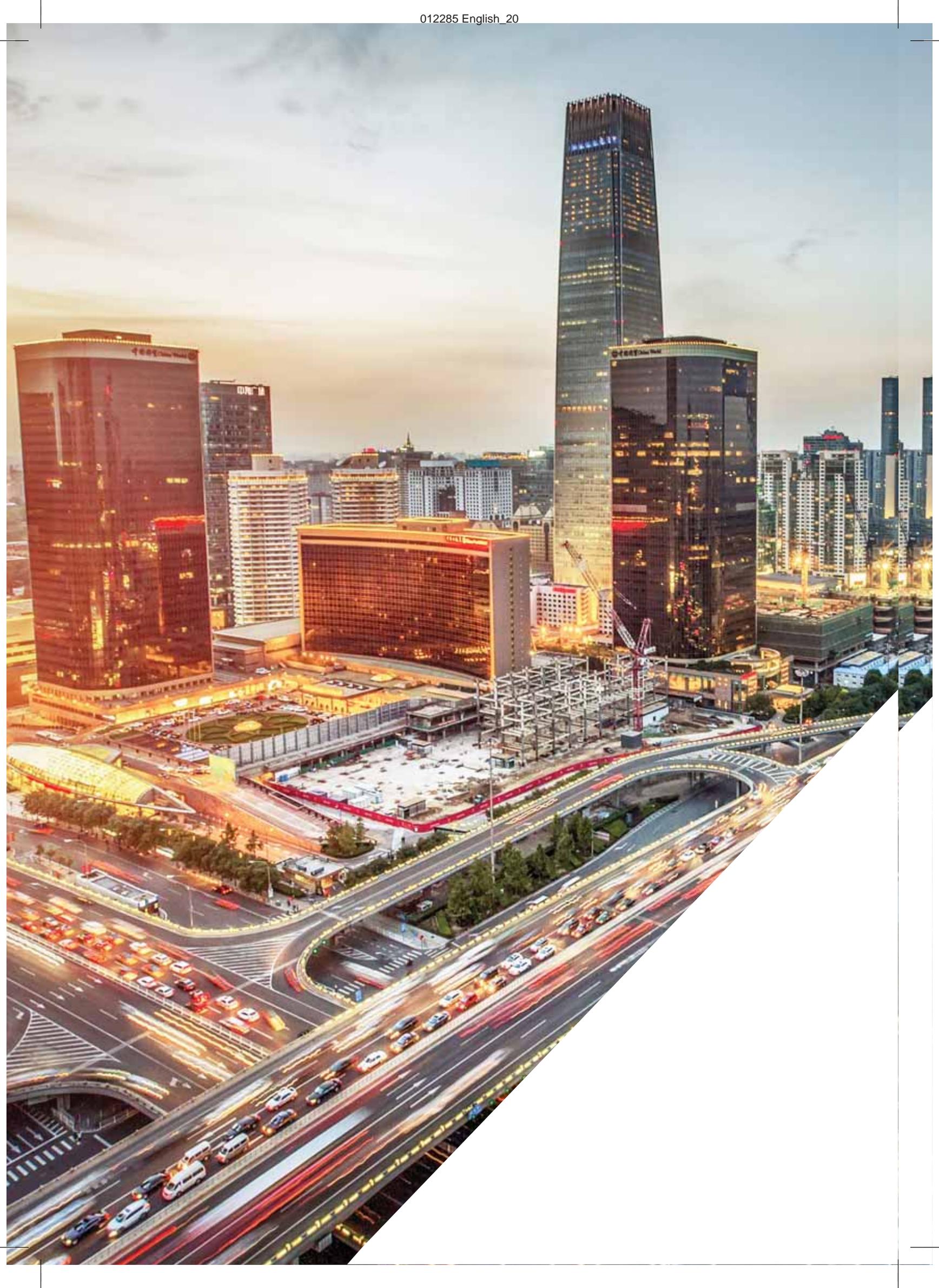
cases where young children have survived unharmed when their bodies are frozen after falling into icy water.

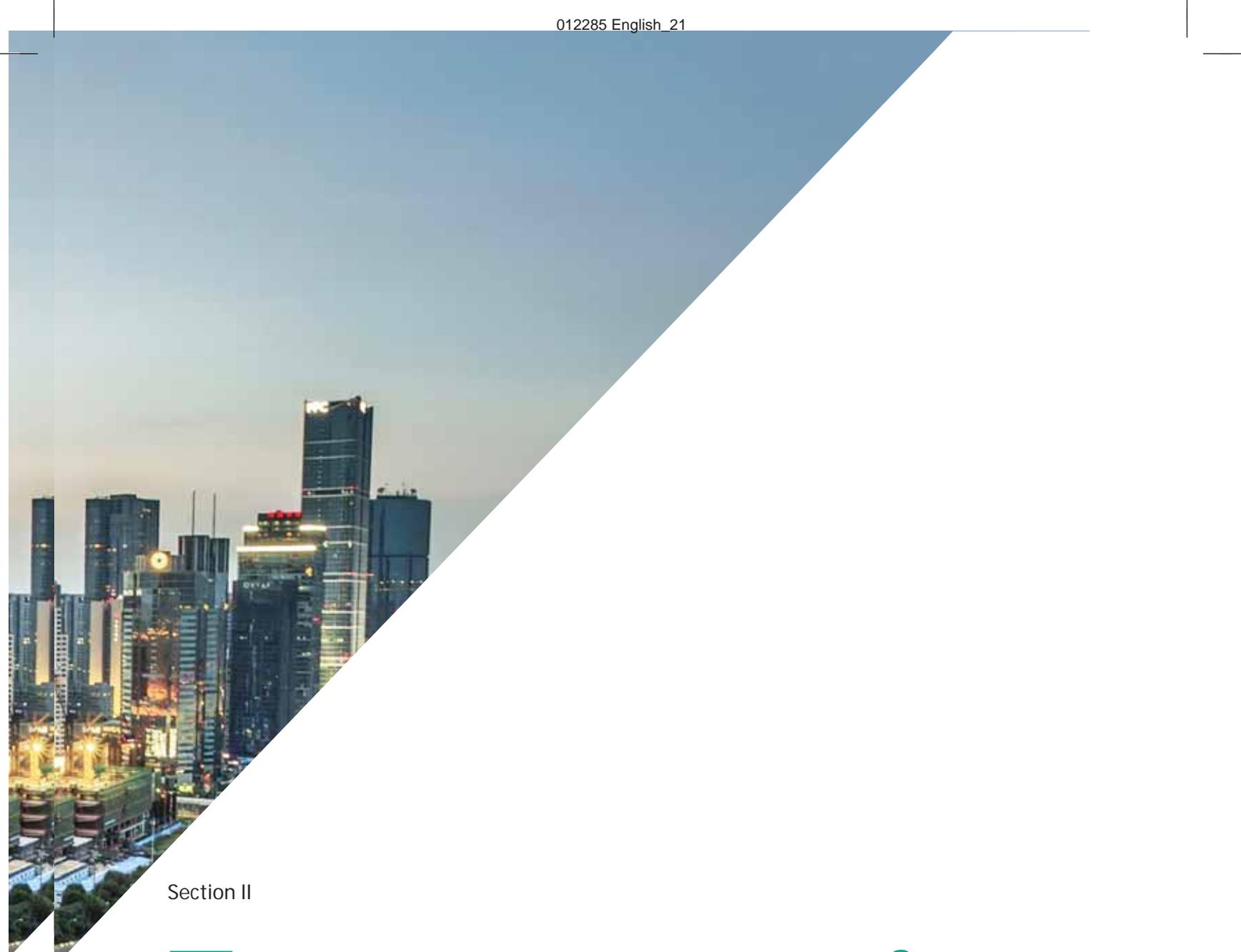
John A. Bradford from Spaceworks proposes a method called "therapeutic hypothermia" for forcing hibernation-like states for astronauts. This involves cooling the body a bit below 37 degrees Celsius (98.6 degrees Fahrenheit) to slow down a person's heart rate and lower blood pressure. This has been effective for as long as two weeks, and Spaceworks believes they can extend that duration to months. By investing in similar research on animals, both in microgravity and on the ground, governments can speed up the

development of methods that could support deep-space missions for humans.

If global collaborations will be helpful in the development of accessible space tourism and useful small satellite research, they will be vital in overcoming the long list of scientific challenges for human interstellar travel - and then helping to find a way to maximize its value for those back on Earth.







Section II

Transportation

Today's traffic congestion costs billions and pours massive amounts of fossil fuels into the atmosphere. As our population continues to grow, cities will need to find more efficient and sustainable solutions for transporting goods and people. The Hyperloop, flying cars, supersonic planes, and autonomous vehicles could make global travel much faster and easier.

SECTIONS

- I** **The Future of Commuting**
- II** **Super Speedy Shipping**
- III** **Accommodating Sustainable Infrastructure**
- IV** **Making a New Path to Travel**
- V** **Securing the Future of Transport**

OUR EXPERTS

We returned to four commentators from our pool of experts to ask how changes in transportation could affect cities in 20 or 30 years, summarizing their response in a series of articles.

Tony Robinson

CEO and Co-Founder, UKi
Media & Events

Tony Robinson co-founded the company behind The Future of Transportation World Conference, which brings together more than 160 automotive manufacturers, transportation authorities, and city planners to discuss how to provide safe, efficient, sustainable transportation for the world in 2030 and beyond.

Ari Teman

Co-Founder, FutureNYC

Ari Teman is an award-winning, patent-holding inventor and designer. He is a co-creator of FutureNYC, a plan for NYC to successfully incorporate autonomous cars and give roads back to humans, and his work has been recognized by The White House and Mayor Bloomberg's office.

Evan Saunders

Head of Sales and Marketing,
Urban626

Evan Saunders is helping lead a revolution in urban living through the development of mobile power sources and the creation of URB-E, a lightweight, foldable electric vehicle. URB-E is deployed in more than 20 countries and is the first vehicle with a built-in removable battery capable of charging multiple devices.

Experts' highlights: **FUTURE FORESIGHTS**

Transportation

THE WORLD TODAY



The world's first pilotless aerial vehicle (AAV) aircraft capable of carrying passengers is set to fly across Dubai.



Tesla will have 10,000 superchargers for high-speed electric cars by the end of 2017.



Almost 1.3 million people die in road crashes every year.



Millions of people spend at least two hours commuting per day.



Transportation contributes to more than half of the carbon monoxide and nitrogen oxides and almost a quarter of the hydrocarbons emitted into the air.

THE REALITY TOMORROW

- The Roads and Transport Authority, in partnership with Uber, will launch a passenger service of Vertical Take-Off and Landing Vehicles in Dubai in 2020.
- "The EHang184 pilotless craft will help Dubai achieve its goals of one in four journeys to be taken by driverless, autonomous transport by 2030." - Mattar Al Tayer, Director-General and Chairman, Road and Transport Authority (RTA) (Dubai).
- Electric Cars Adoption, could reduce annual greenhouse gas emissions by 1700 million metric tons by 2050 relative to 2015 levels, which equates to more than a 70% reduction.
- It will take about 30 minutes to travel from San Francisco to Los Angeles by Hyperloop.
- Vehicle-related fatalities will drop substantially when self-driving cars are available, as 90% of accidents are caused by human error.



BUILDING THE FUTURE



To reduce commutes and carbon emissions, governments must ensure that more advanced forms of transportation are supported and, eventually, overtake traditional cars. This includes supporting initiatives to back car-sharing services, high speed railways, autonomous vehicles, and passenger carrying drones. Each of these advances will require dedicated task forces to formulate new regulations to both govern the technologies and protect passengers.



Issues related to traffic congestion can be solved by having roads direct the traffic that flows over them (backed by sensors and artificial intelligence), self-healing roads that reduce the need for construction, and encouraging car-sharing.



City planners will need to begin preparing the grid to accommodate the influx of electric cars by initiating a comprehensive analysis of the current infrastructure, allocating the funds necessary to complete upgrades, and developing realistic projections that account for these new forms of transport.

Transportation

The Future of Commuting

Persistent science fiction about ways to improve our daily journeys are now being developed as real technologies. Prototypes are already being designed for the Hyperloop, consumer-based flying cars, supersonic planes and futuristic jetpacks.

The growth of car ownership and road networks has also brought new worries about safety, unsustainable congestion and air pollution. We've come to understand that the future will require far more efficient modes of transportation. The solution to congestion is not more roads, but better infrastructure management and more flexible forms of transport – forms that require less construction and maintenance.

Experts expect cars to still be a part of most cities in the next 20 to 30 years, but to create a truly viable transportation network, car ownership needs to decrease. Several car-sharing services have sprung up in recent years, including Uber, Lyft, and Rover Parking. Studies conducted by MIT reveal that carpooling apps could reduce congestion by a factor of three in the coming years while still serving the same number of people.

Cities should encourage these services, while at the same time ensuring they best serve the needs of citizens. This will mean working alongside established taxi services

to help the companies transition into these more technologically advanced and efficient modes of transportation.

Our cars are already smarter, but soon they could be smart enough to control themselves. Cars that drive themselves will be able to decrease accidents by analyzing information and responding to obstacles far faster than humans can. They'll also decrease pollution by navigating along the most efficient routes at the most efficient speeds. Several jurisdictions have already approved testing for autonomous vehicles, including buses and taxis, which will combine the benefits of smarter cars and shared vehicles.

Ari Teman argues that autonomous cars will be far better because they don't have any of the concerns that humans do: "Cars will drop you off and go on their way. Since they are autonomous, they don't rubberneck. They don't get into accidents. They don't stop to chat with a friend. They just go where they're supposed to go."

Governments should begin working

on the legislation that will govern autonomous cars today to ensure their ubiquity tomorrow. This legislation will need to include a comprehensive plan that outlines testing procedures for autonomous cars, rules regarding annual maintenance requirements and inspections, and clear laws that govern fault in relation to accidents. Governments will also have to consider how to phase out non-autonomous cars through a series of stages, navigating the diverse requirements of both manufacturers and the national infrastructure, which will need to be adapted to accommodate self-driving technologies.

The cities that flourish in the future will develop new forms of transport for long-distance travel. Hyperloop hopes to deliver fast travel between cities – especially for frequent commuters. First proposed by Tesla and SpaceX CEO Elon Musk, the concept consists of a high-speed train that uses magnetic levitation and vacuum tubes to propel small pods carrying people along a track at 1,200 km/h (745 mph).

In the coming years, cars will drop you off and go on their way. Since they are autonomous, they don't rubberneck. They don't get into accidents. They don't stop to chat with a friend. They just go where they're supposed to go.

Ari Teman

The most effective transportation networks will also need to be supplemented with versatile forms of individual transportation. "I don't actually see the future of transport in cities being expanded on the ground, and I don't see it expanded underground. Where I see it taking place, which is very exciting and in the very near term, is through developments in what we call 'personal airborne transportation systems,'" says Tony Robinson.

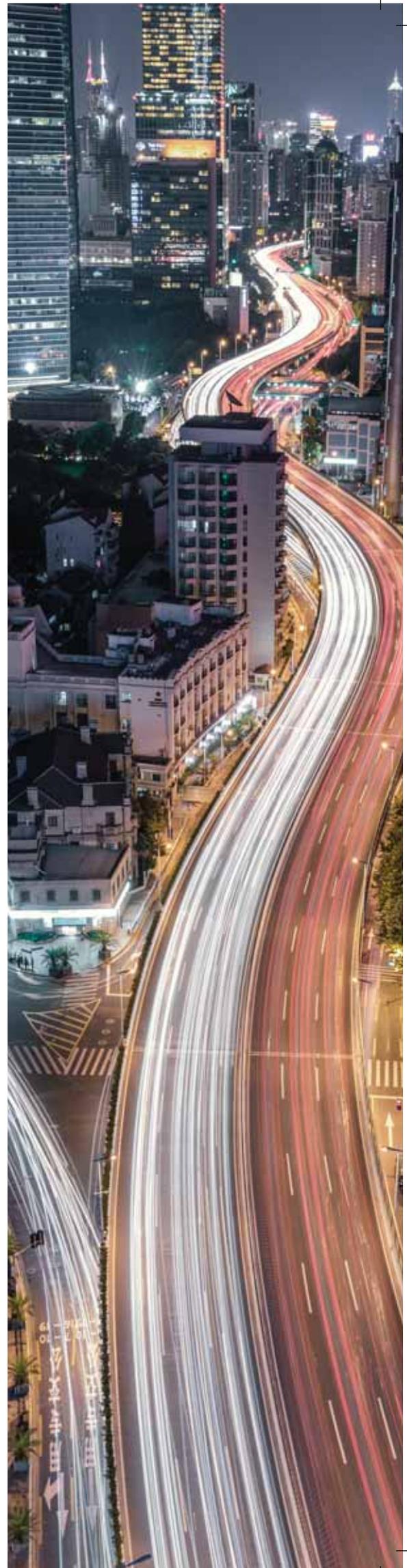
"At the moment, we see people talking about flying cars and flying taxis," he adds. "I think one needs to get rid of those images of things with wheels and think of a different sort of thing much more like a drone." Taking to the air will give individuals the ability to travel farther and faster across city landscapes, giving them a level of autonomy beyond anything we've seen before.

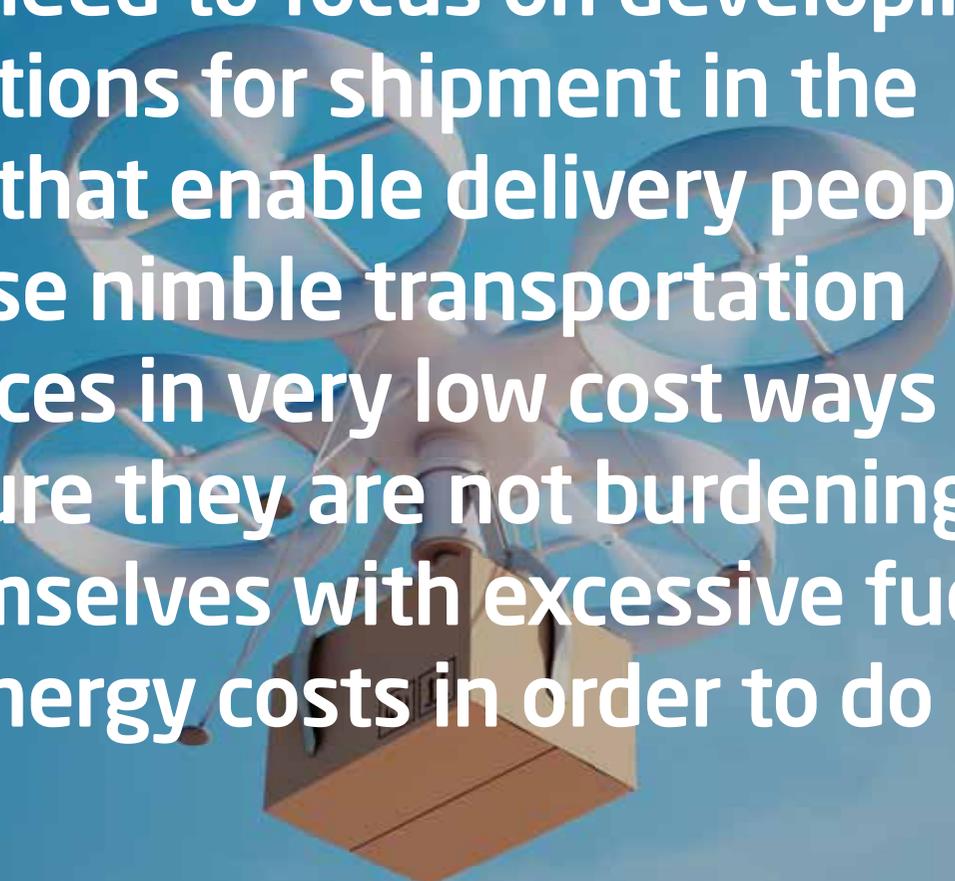
Before developing vacuum tubes or flying vehicles, there is still a lot of room for expanding existing transport between cities. As the world continues to globalize and cities become denser,

mass transportation by high-speed trains will provide residents with a faster, more efficient, and cleaner way to travel, giving them access to new job opportunities and cultural interactions, while increasing communication between cities.

Another possible solution is the development of small electric vehicles, such as the URB-E. This foldable, bike-like transportation device enables commuters or delivery persons to zip through the city and carry their transport with them – no need to worry about parking or theft. Cities can begin to encourage such modes of transportation by creating lanes dedicated to individuals using renewable forms of energy to transport goods and by expanding lanes for non-traditional methods of transport, such as drones and electric bikes.

Today's governments can help accelerate these developments by fostering collaborations between the researchers working on these systems and the legislative bodies charged with governing them.





We need to focus on developing solutions for shipment in the city that enable delivery people to use nimble transportation devices in very low cost ways and ensure they are not burdening themselves with excessive fuel or energy costs in order to do so.

Evan Saunders

Transportation

Super Speedy Shipping

From customized shipping solutions to underground transport tunnels, tomorrow's goods will travel in ways that are remarkably efficient and clean.

Shipping is one of the primary causes of today's traffic issues. One of the problems faced by port cities is transporting goods from the shore into the city without causing traffic congestion. Advances in automation will provide opportunities to improve this. "You will find automated pods going from warehouse to restaurant or warehouse to retail store – even to the aisle or to the shelf itself," says Ari Teman.

The rise of predictive shipping - where demand is predicted in advance and goods are moved to near where they are most likely to be purchased - will give consumers the ability to receive products as soon as they are needed. More precise delivery systems will make it feasible to have

city policies that specify when shipping vehicles should be on the roads, without affecting businesses delivering goods. Consumers and businesses will be able to get their goods without contributing to traffic congestion or noise pollution. "Cities will be able to say that major deliveries can only happen from two in the morning to six in the morning," predicts Evan Saunders. "You get a four-hour window to get your stuff into your store, and it's done electronically."

Not all cities are attached to ports, however, and long-distance solutions will need to be developed for larger shipments. One potential solution is to bore underground, particularly attractive

in areas which regularly suffer from hazardous weather conditions. This would require significant work as drilling long-distance tunnels is neither easy nor cheap. However, tunnels could significantly outlast traditional roads and decrease the cost of their repair and maintenance, which means that they would ultimately pay for themselves.

Governments would still need to complete cost analyses to determine how economically viable this kind of new system would be for their jurisdiction.

Transportation

Accommodating a Sustainable Infrastructure

In the coming decades, changes to our cities' electrical grids will allow us to accommodate electric vehicles, and a unique kind of car will take to the streets. This will form a new energy infrastructure, and traditional gas stations will quickly become relics of the past.



According to the World Health Organization, more than 3 million people die prematurely each year due to prolonged exposure to air pollution. Studies conducted by the U.S. government report that transportation causes more than half of the carbon monoxide and nitrogen oxides pumped into the atmosphere.

We must transition away from fossil fuel-

powered vehicles and toward those that use sustainable forms of fuel, such as electric cars. Some regions will be quicker to embrace electric vehicles than others. For example, people living in affluent areas are more likely to be able to afford the higher price tags that come along with emerging technologies. However, as the decades progress, the technology will become more economically viable for

the average citizen. Experts across the automotive industry, from Tesla to Volvo, assert that the majority of vehicles on the roads in the future will be electric.

The impact of an electric car on the electricity grid depends on how the vehicle is charged regularly. A slow charge at a standard 110-volt outlet makes little difference, nor does charging at a public

10,000

The number of high-speed electric car Superchargers that Tesla will have in operation by the end of the year.



station equipped with transformers. Creating a dedicated charging port at a house, however, could be the electrical equivalent of adding an extra dwelling to the grid. This could put strain on the grid in neighbourhoods with previously stable demand. Cities that create public charging stations will be able to cope better with the additional demand for electricity created by electric cars.

If a car is shared, presuming it moves between different areas of the city. "It won't need to park; it will be in operation continuously, going from sharer to sharer, from member to member," Tony Robinson says. "But it will, of course, need to stop. It will need to be recharged. It will need to be serviced and maintained." To this end, ride-sharing of electric vehicles should be encouraged in order to reduce both the

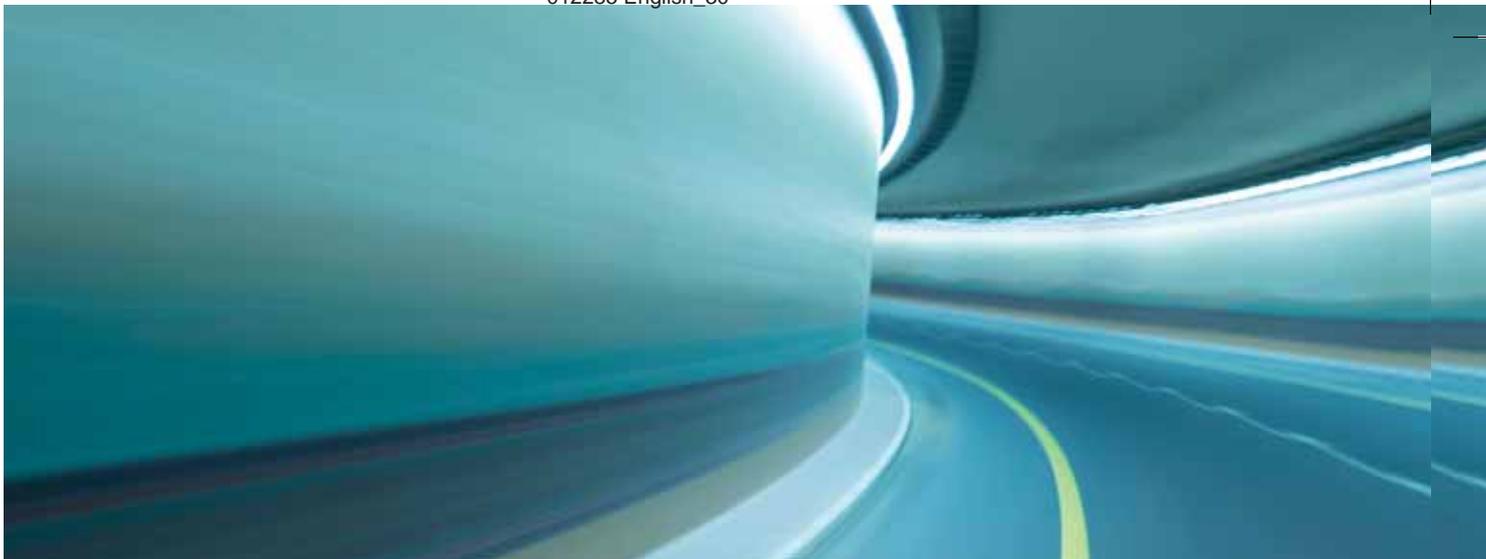
number of electric cars on the road and the number of charging ports required.

Another potential solution would be to regulate when electric vehicles can be charged. Some utilities may develop automatic shutoff systems that are enabled after the electric vehicle consumes a certain amount of electricity. Mandates that only allow maximum charging on an electric vehicle during off-peak hours (with some supplemental charging allowed during the day, if the car reaches a certain battery threshold) could also be a viable solution.

Advances in technology could eliminate this charging problem altogether. Redox flow batteries, currently under development, can convert between electrical and chemical energy or vice versa. This could lead to fully electric cars that can be charged in just

minutes by refilling their liquid chemical tanks the same way one would a gas tank in a traditional car. Alternatively, in sunny areas of the world, additional home solar panels could not only provide a boom for renewable energy, they could also help shoulder the demand for electric vehicle charging.

These solutions require cities to start working with vehicle manufacturers now in order to understand how to roll out widespread electric car use. There needs to be thorough analyses of how energy demand will change when cities transition to electric cars and how much it will cost to make this transition.



Transportation

Making a New Path to Travel

Tomorrow, our roads won't be simple slabs of pavement. Sensors will allow for the precise measurement of traffic volume, adaptive paving technologies will make potholes a thing of the past, and unused stretches of pavement will be adapted to generate power.

Twenty to 30 years from now, traffic won't be directed by humans standing in the middle of an intersection. In the cities of tomorrow, computers will take the lead in preventing congestion and getting us where we need to go. Artificial intelligence will enable machines to see traffic patterns on individual streets and reroute vehicles in real time in order to prevent traffic jams, help individuals avoid hazardous conditions or decrease wear and tear on our roads.

Roads will direct the traffic that flows over them. "When an emergency vehicle is coming, you want the road itself to light up, to blink red or green so pedestrians know to get out of the way," Ari Teman says. Ultimately, this system could redirect traffic

whenever the need arises, not just when an emergency vehicle approaches.

Traffic volume measurements could be based on sensors implanted in roads or on cameras embedded in traffic lights. These measurements could be used to redirect traffic to areas that experience a low volume of congestion. The effectiveness of road-based sensors and traffic cameras will vary depending on weather conditions, and each system provides a different kind of information, such as how much weight a road endures versus the number of vehicles using that route.

As the various different systems mature, the cities that continue to assess different

options, rather than following one provider, will be in a better position to make the most out of this technology.

A significant amount of traffic congestion is due to routine road maintenance and construction. Roads are frequently damaged by vehicle wear and tear, and in places that experience wide ranges of weather conditions, the extreme cold and heat forces roads to shrink and expand, causing further damage that workers must repair.

Ari Teman says that city planners must rethink how they conceive roads. Currently, old roads are repaired and new ones are created through on-site paving. However,



430 quintillion

Joules of energy from the Sun hit the Earth each hour.

Teman thinks we should create roads in modular pieces: "Once the piece gets ruined or destroyed, you only have to pick it up and replace that part of the road." This process of repairing the road would be more like tiling it than traditional paving, he explains. Ultimately, this will dramatically reduce the amount of time it takes to repair our roads, and the modular construction will enable cities to more quickly and easily incorporate new sensing technologies into them.

Another solution, one that will require cities to begin investing in materials science research today, is self-repairing roads. Though they may sound like extreme science, work is already being done in this

area. For example, Erik Schlangen, a civil engineer and innovator who deals with experimental micromechanics, created a new type of porous asphalt that, when cracked, can be "healed" through the use of induction heating. The roads of tomorrow may, quite literally, never require repair.

Of course, repaving all of our roads with these pioneering materials will be costly. Money-saving solutions can be incorporated in order to help finance the cost of the upgrades. For example, roadways can incorporate energy-generating features, such as solar panels or technologies that harvest kinetic energy, in order to produce energy. This energy can be used to power traffic lights and electric cars or simply be

fed back into the grid. Millions of joules of energy hit our roads each hour. As a result, their energy generating capacity is enormous, and this energy could be harnessed to help cities afford such advanced, self-healing smart roads.

These recommendations don't apply to just our roads, but to all walkways and transportation paths. In the ideal city – a city that is truly optimized and efficient – all surfaces will be self-healing and energy-generating.

Transportation

Securing the Future of Transport

As AI continues to advance, machine learning capabilities will prevent transport for individuals who fail to pass facial recognition tests, and artificial intelligence will lead us into an age when road accidents are uncommon enough to make newspaper headlines.

As more and more people take part in the rideshare economy, companies have recognized a need to incorporate new technologies to help ensure that the right driver connects with the right passenger. Rather than relying on information on the make and model of a driver's car, which can be difficult to determine, especially at night, riders in some areas can now just keep an eye out for a light. As Ari Teman explains, "Uber now uses a color-coded light on the front of the car in order to tell you 'you're going to the car with the green light,' 'you're going to the car with the red light,' so people can recognize if they're getting into the wrong vehicle."

As society begins to incorporate automated taxis and automated rental cars, humans will disappear from the driver's seat, and we'll need a new way to verify that the right person has reached the right vehicle. Advanced facial recognition technology could ensure that a car's door only unlocks for the person entitled to the vehicle.

These smart technologies can also be used to pull background information on individuals to determine if they have certain routes they prefer to travel. The car could suggest stops they frequently make along the intended route, and automatically adjust the car's temperature, radio, interior lighting, and other settings to suit the rider's preferences.

The greatest advantage to incorporating artificial intelligence into vehicles is a reduction in accidents. "Zero fatalities may be difficult to achieve, but very close to zero will definitely be a possibility," says Tony Robinson. While intelligent vehicles will keep us safer, their use will lead to the emergence of different kinds of challenges. "Unfortunately, as these things change, new problems come along, and one of the things to look at and consider is cyberattacks," Robinson explains. Vehicles that incorporate AI will be subject to hacking, meaning that an unauthorized individual could access and ultimately take



Zero fatalities may be difficult to achieve, but very close to zero will definitely be a possibility.

Tony Robinson

over an autonomous car.

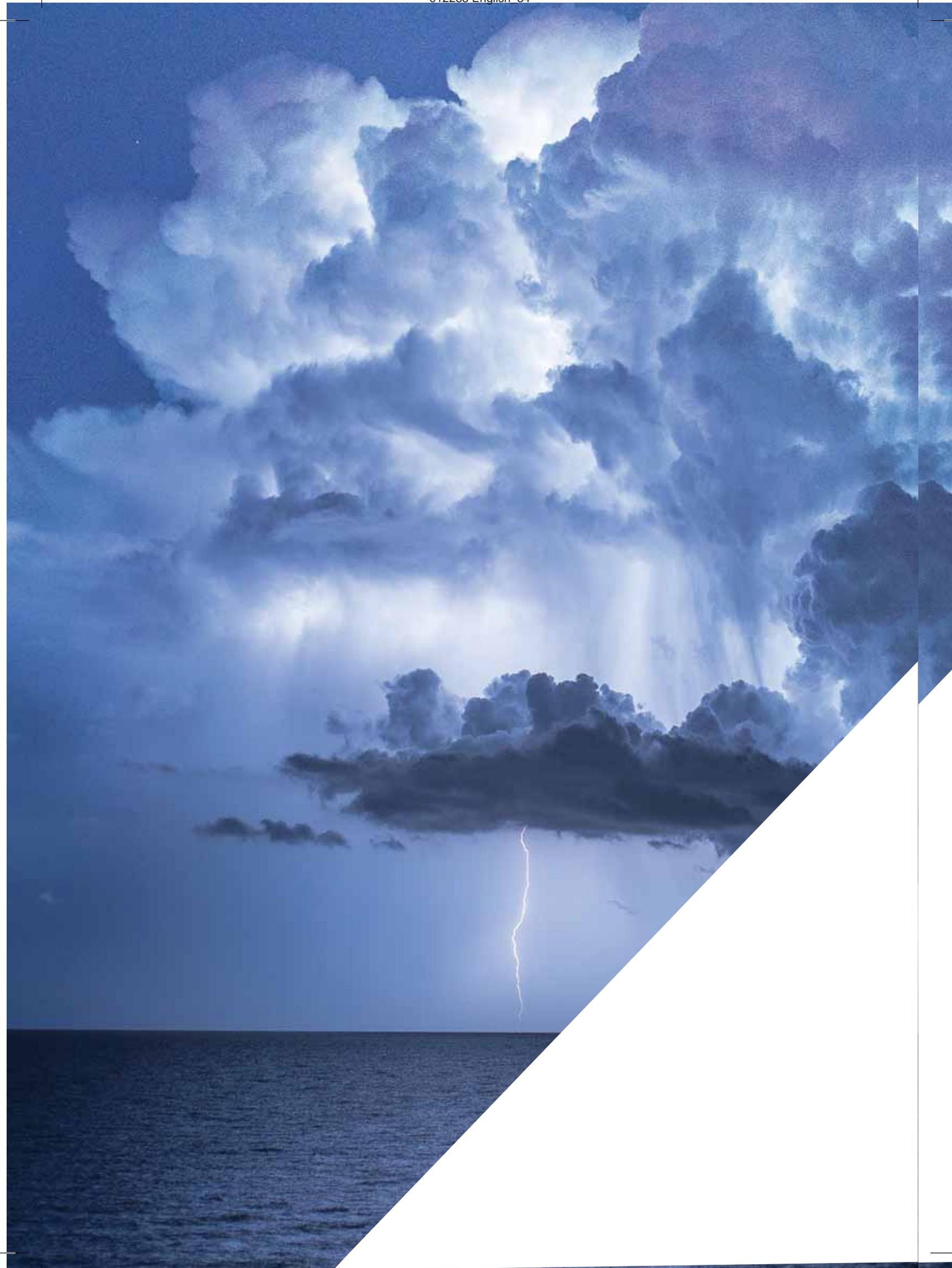
New kinds of tests and standards will be needed to ensure that a vehicle is able to navigate roads safely and protect itself from outsiders. Automatic “kill switches” that allow law enforcement officials or passengers to cut off outside access to cars could improve the chances of avoiding dangerous hacks.

Of course, transportation security concerns extend well beyond the vehicles on our roads. Checkpoints are currently a major bottleneck at airports. In future cities, advanced scanning technology can look at and identify passengers as they are walking through security. Rather than forcing individuals to hand over their passports to security officials, automated, artificially intelligent systems can do the registration work. These same systems can be used to check individuals into flights and ensure they are boarding the correct plane at the correct gate. Indeed, in the future,

automation will take over much of the work of today's airport staff. Already, Dubai's Department of Economic Development has signed an agreement with ObjectTech Group Ltd to build digital passports that will enable seamless entry to Dubai using ObjectTech's identity system.

“The dread of going through security at an airport will be an old-fashioned feeling that humans living 20 to 30 years from now will laugh about,” Evan Saunders says, adding that, when most people go to the airport, security will be expedited and efficient. This will lead to very different kinds of jobs in airports. Instead of spending all their time glancing up and down at tickets, tomorrow's airport staff will need to focus on addressing issues when they arise and completing more advanced checks.





Section III

Water

Global demand for fresh water could be 40% greater than supply by 2030. In many areas of the world, it's already difficult to access water for growing crops, let alone drinking water. This challenge is made worse by today's methods for managing water which lead to contamination and unnecessary waste. Cities of tomorrow will need to rely on the desalination and decontamination efforts that have already begun. Coupled with conservation efforts and weather modification, there are clear paths towards global water security.

SECTIONS

- I** **Cleaner Water for the World**
- II** **The Salt of the Sea**
- III** **Capturing Clouds**
- IV** **Reducing Water Waste**
- V** **Preventing Pollution**

OUR EXPERTS

We returned to four commentators from our pool of experts to ask how changes in water treatment could affect cities in 20 or 30 years, summarizing their response in a series of articles.

Steve Maxwell

Managing Director, TSG

Steve Maxwell obtained his master's degree in Geology and Public Policy from Harvard. He serves as the managing director of TSG, a management consulting firm focused on commercial water and environmental services. He is the author of "The Future of Water" and has 30 years of experience in environmental and resource management.

Kalanithy Vairavamoorthy

**Deputy Director General,
International Water
Management Institute**

Kalanithy Vairavamoorthy is an internationally recognized expert on urban water systems and sustainable urban resource management. Vairavamoorthy is co-chair of the International Water Association's "Cities of the Future" program and is the founding Dean of the Patel College of Global Sustainability.

Emily Tow

Mechanical Engineer, MIT

Emily Tow is a Ph.D. candidate in Mechanical Engineering at MIT. Her research addresses heat and mass transfer processes in desalination with the goal of reducing energy consumption and improving sustainability. Tow is an NSF Graduate Research Fellow and a member of the Lienhard Research Group within the Rohsenow Kendall Heat Transfer Lab.

Experts' highlights: FUTURE FORESIGHTS

Water

THE WORLD TODAY



The UAE Water Aid Foundation, in cooperation with the Dubai Electricity and Water Authority, is completing a reverse osmosis water desalination plant to produce 50 cubic meters (50,000 liters) of fresh water a day.



As of February 2017, the UAE National Centre of Meteorology and Seismology carried out 58 cloud-seeding operations in that year alone.



"Cloud seeding is a way to enhance the amount of precipitation that falls from the clouds, and it helps generate 10 to 30 percent more rain. We started testing this method back in 2002 and went until 2006, and that's when we officially began to carry out cloud-seeding operations." --H.E. Saeed Mohammed Al Tayar



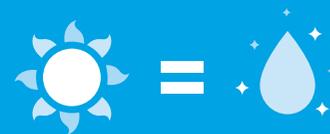
It is estimated that eight million metric tons of plastic waste enter the ocean each year.



2.4 billion people worldwide lack access to clean water.

THE REALITY TOMORROW

- The Dubai Electricity and Water Authority plans to generate 1.1 billion liters of water a day by 2030 using desalination facilities that are powered by the Sun.



- Technological advances are expected to reduce the cost of desalinated water by 60% in the next 20 years.



- The Ocean Cleanup project plans to remove an estimated 50 percent of the Great Pacific Garbage Patch in 5 years using advanced technologies, paving the way to a plastic free ocean in the next thirty years.



BUILDING THE FUTURE



"We need to find sustainable and effective solutions to serve drought-stricken areas and to highlight the role of renewable energy in achieving sustainable development." - H.E. Saeed Mohammed Al Tayar, MD & CEO of DEWA and Chairman of the Board of Trustees of Suqia



Future research on cloud seeding includes a three pronged approach that focuses on learning more about ice production processes in cumulus clouds, obtaining a comprehensive understanding of the role of atmospheric aerosols in precipitation management, and modifying electrical properties of clouds.



In order to optimize efficiency, future desalination plants will require investment in materials science, as early work shows that new nanomaterials and biomaterials could be used to allow water to more easily pass through the system.



Lowering water usage will come from several areas: advancements in engineering, the fabrication of more efficient technologies, ensuring that individuals are informed about proper water use, and creating denser communities that make more efficient use of water than traditional suburbs and rural regions.



Making clean water accessible to all individuals will require massive governmental data collection and analysis. This will allow city planners to identify the communities that need targeting and where technology needs to be deployed to make "grey water" available for common uses, which will conserve clean drinking water for its intended purpose.

Water

Cleaner Water for the World

Health issues that stem from water contamination are still too common. Advanced sanitization and innovative portable technologies will be key to answering this challenge.

The first step to cleaner water is considering the way that we manage the water cycle, according to Kalanithy Vairavamoorthy. "Traditionally, you would have a group of people managing the water supply, a different group managing the wastewater side, and a third group managing stormwater," he explains. "Now, what we're starting to do is look at it in a more holistic way." By securing a comprehensive understanding of where water is wasted, where it is available in excess, and what areas need what kind of water, we can begin to develop solutions that incorporate all areas of our infrastructure.

Under this new way of thinking, the supply

of different types of water can be changed according to the demand. Vairavamoorthy clarifies how this would work: "So, if I have an increase in drinking water demand, I might try to extract more groundwater or surface water to meet that or invest in leakage management depending on what caused the need. If I wanted water to flush my toilet or water the gardens, then I would add gray water within the system and move that gray water to meet those demands."

People in areas where clean water is difficult to access have many potential ways to attack their problem. Communities can also use membranes, desalination, or chemical treatments to increase the

supply of water available for agriculture. Oxidization techniques remove contaminants in water by forcing oxygen to react with hydroxyl radicals. This process breaks down the contaminants into smaller, harmless components, rendering the water drinkable.

While technology plays a role in providing communities with clean water, microfinancing can put that tech to work where it's most needed. Organizations such as Water.org and WaterCredit encourage philanthropic donations to create water infrastructure in developing countries. The funds are used to build wells, latrines, water connections, and other items that a community may need.

But wells frequently break down a couple of years after installation because they are not properly maintained. Public health campaigns about the importance of clean water and training for communities on how to manage water-cleaning technology will go a long way toward ensuring that, once a technology is installed, it remains functional.

There needs to be better and more accessible government data about water usage, so that policymakers can reach informed decisions about how water is used, which types of water are appropriate for which uses, and whether more water is needed in a particular area. Smartphone apps, drones, and other easily accessible

technologies can help local officials survey communities, and the data gathered can then be provided to the central government for review.

One of the simplest steps that governments can take is to avoid contamination in the first place. In 2012, the winner of the California Institute of Technology's Reinvent the Toilet Challenge used solar energy to transform wastewater into fertilizer and hydrogen. This eliminated the need to flush it into a system for storage and filtration, which creates a risk for leakage and the spread of disease.

Researchers at the University of Michigan developed a technology that turns cow

manure into filtered water that can be used for fertilizer or as drinking water for the cows themselves. While the water it produces doesn't meet the standards necessary for human consumption, the process could reduce the cost of caring for livestock in developing countries.

As our population continues to increase and more forms of waste enter the system, enterprises like the aforementioned will ensure that everything is reused, which will ultimately make our cities and their populations, both human and animal, sustainable.



Water

The Salt of the Sea

Seventy percent of our planet is covered in water. Unfortunately, most of it is salt water in our oceans, so only a small fraction is drinkable. But that's fast changing. Breakthrough innovations will ensure that all of Earth's water is fit for human consumption.

In the future, coastal cities and even some areas farther inland will use desalination to provide their populations with drinking water, most especially after other sources of raw water have been exhausted. While desalination technology is currently expensive and energy intensive, by investing in new materials and incorporating renewable energy solutions, we can make the tech cost effective.

For example, the Masdar renewable energy initiative piloted desalination plants in Ghantoot, Abu Dhabi that run on solar power rather than fossil fuels. Efforts in Dubai and Abu Dhabi are underway to make these energy-intensive processes more efficient.

Moreover, the Dubai Electricity and Water Authority plans to use solar power for its desalination water plants, which is expected to generate 305 million gallons per day by 2030, saving \$13 billion between 2017 and 2030. Additionally, this year, DEWA agreed to work with the UAE Water Aid Foundation (Suqia) to finish a reverse osmosis water plant that would also use solar power.

The importance of such efforts cannot be overstated. "This cooperation, between Suqia and DEWA, is keen to raise awareness on the importance of finding sustainable and effective solutions to serve drought-stricken areas and to highlight the role of renewable energy in achieving sustainable development," notes His Excellency Saeed Mohammed Al Tayer, Chairman of the Board of Trustees of the UAE Water Aid Foundation and MD & CEO of DEWA.

"This is part of Suqia's commitment towards strengthening the global role of our leadership in addressing the challenges facing humanity, and providing support and humanitarian assistance throughout the world, in line with the 2030 agenda of the 17 United Nations Sustainable Development Goals."

Usually distillation - boiling water to remove the salt - is used in desalination plants. But there are more and more reverse osmosis pilot projects. The process uses high pressure to push water through a semipermeable membrane - made of very thin materials like graphene - to remove salt, dangerous particles and bacteria from drinking water.

Nanomaterials like graphene promise a new generation of reverse osmosis desalination that uses much less energy. These new materials are still being developed and there is an opportunity for governments to work with researchers to expedite their development and secure their implementation.

To make desalination viable, governments will need to regulate, incentivize, and educate the population on the use of this water. Emily Tow states that, ultimately, it will be up to individual countries to develop laws around their water use. "Regulation is one area, and public education and outreach is another area, that cities will need to focus on because people don't like the idea of drinking seawater and often think that the water isn't safe," Tow explains. She suggests that education begin with children so that citizens are acclimated to the idea that the water is drinkable from a young age. That education should be supplemented by online information showing that the water coming out of the plants meets high quality standards.

UAE Water Aid will not differentiate between one person and another, so are all of our humanitarian works, such as the UAE's humanitarian mission that lies in helping the afflicted, the needy and disadvantaged people all over the world without any distinction.

Mohammed bin Rashid Al Maktoum

Technological advances are expected to reduce the cost of desalinated water by

60%

in the next 20 years.

Water

Capturing Clouds

Already, we are investigating the possibility of using techniques inspired by nature to modify our weather and produce rainwater. In the future, stimulating rainfall on demand will be more effective.

The Earth's biosphere is a very complex and very fragile ecological system. As a result, modifying weather on our planet is a risky task. We may be able to do it in a way that is both responsible and economically viable in the next 20 to 30 years if cities begin to invest in potential methods today. Some innovative cities have already begun to experiment with weather modification, including Abu Dhabi and Dubai.

The most viable practice used today is cloud seeding. The process can be best understood by comparing it to traditional rainfall. Rain forms when atmospheric water vapor condenses and becomes too heavy to remain suspended in the air. The water then falls under the natural influence

of gravity. Cloud seeding encourages rain to form by creating "seeds" from chemical compounds like silver iodide, around which the water vapor can form crystals, which turns into rain.

The problem with this method is that it's extremely difficult to directly measure human effects on large-scale weather systems. As a result, scientists are divided on the effectiveness of cloud seeding. That said, the technology is being used more and more frequently, particularly in dry areas of the western United States and the United Arab Emirates where climate change is exacerbating the effects of drought.

There is work currently underway to

determine exactly how effective the method is. By February 2017, for example, the UAE National Centre of Meteorology and Seismology had already carried out nearly 60 cloud-seeding operations in that year.

Noting the long term planning that went into these operations, and how this "longterm look" ultimately allowed the project to succeed, Dr. Ahmed Habeeb, meteorologist at the UAE National Centre of Meteorology and Seismology, asserts, "We started testing this method back in 2002 and went all the way until 2006. That's when we officially began to carry out cloud-seeding operations. Cloud seeding is a way to enhance the amount of precipitation that



falls from the clouds and helps generate 10 to 30 percent more rain.”

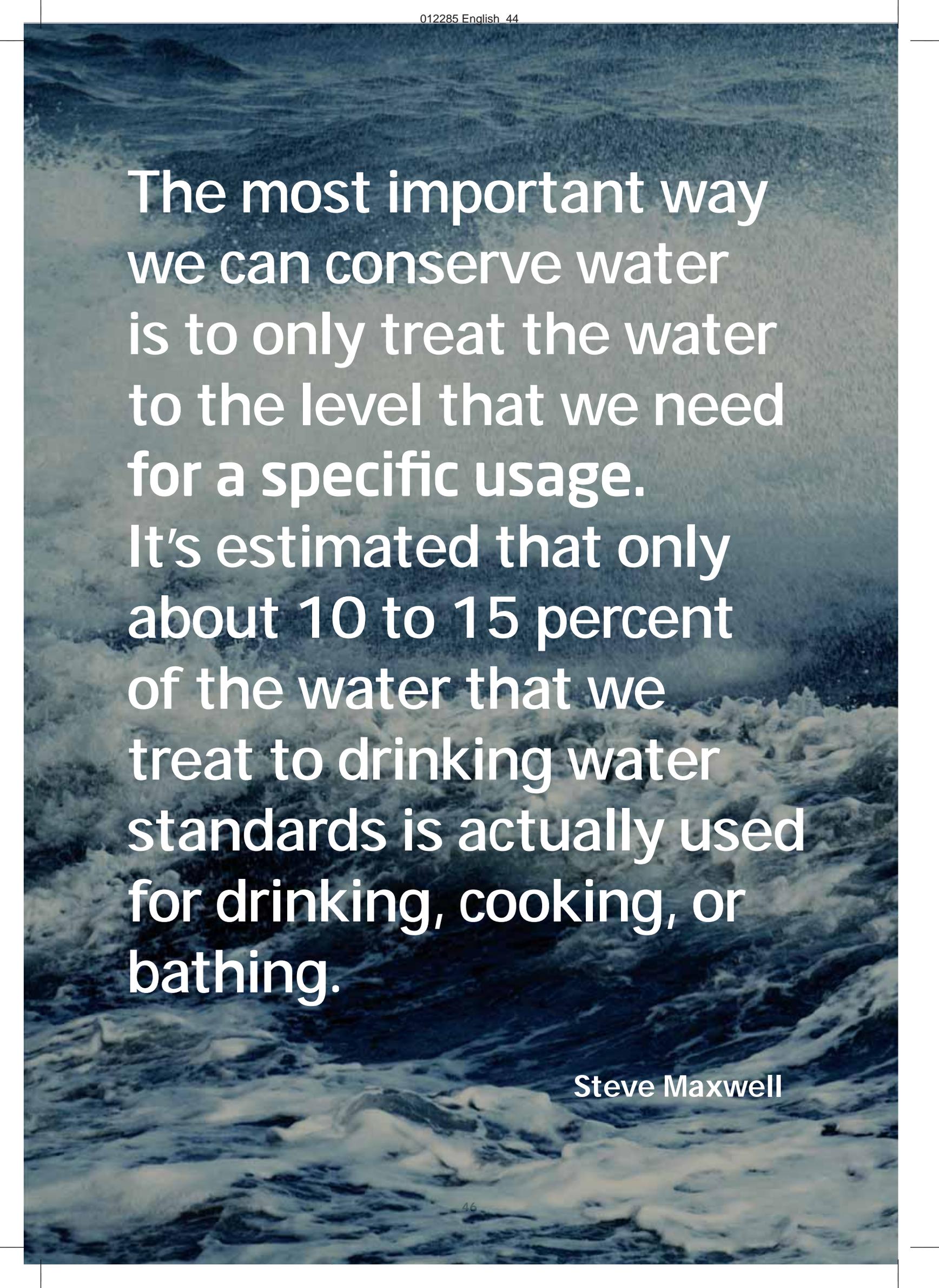
Traditionally, cloud seeding has involved expensive flights, but today, we can use drones to take to the air more easily. Drones don't use combustion engines, so they would reduce our environmental impact while still allowing us to scatter water. There are also some ground-based projects, where cloud seeds travel up into the clouds with the other particles in the air that are heated on a hot day.

Before drones could be used for cloud seeding, however, government restrictions on the devices would have to be revised to allow them to be flown at the same altitudes at which clouds can form. This would put them in the way of flight paths, requiring better detection systems to avoid collisions. But this legislation would mean more researchers could work on cloud seeding projects as they would be cheaper to run.

Other concerns with cloud seeding will need to be addressed as well. Some scientists worry that areas surrounding the cloud-seeded zone will experience increased evaporation, as the water is attracted away from there to the seeded clouds. This may require a strictly regulated program of cloud seeding that tries to ensure that it does not create drought in one area for the sake of seeding clouds in another.

Silver iodide is toxic to the environment. Finding alternatives will be vital for the sustainability of cloud seeding - making sure one environmental solution does not cause another. Other techniques, such as using dry ice, must be tested to determine their effectiveness.

Even with the use of drones, cloud seeding is expensive, requiring huge investments on the parts of governments and scientific institutions. Methods for exporting the technology affordably to poor but most water-strained communities will make the largest social impact. Longer-range or more lightweight drones could help.



The most important way we can conserve water is to only treat the water to the level that we need for a specific usage. It's estimated that only about 10 to 15 percent of the water that we treat to drinking water standards is actually used for drinking, cooking, or bathing.

Steve Maxwell

Water

Reducing Water Waste

Humanity wastes more than a trillion gallons of water each year. Tomorrow's technologies could bring an end to this, working in conjunction with government incentives and algorithms that dynamically alter water allocation.

In urbanized areas of developed countries, we frequently use drinking water for far more than just drinking. The water that we use to boil rice does not need to be chemically treated to the same degree as drinking water, yet it is. This wastes clean drinking water. Cities would save some of this excess by looking at the example of more isolated and rural communities, which are common users of what is known as "gray water". This water is not safe for drinking, but it is adequate for other everyday uses, such as watering a garden or using the toilet.

"What you're seeing now is this changing perspective where people are starting to think more of the productive use of water," says Kalanithy Vairavamoorthy. "So, for drinking, we need a certain water quality, but for flushing, do we need water at all? And if we do, what quality of water would be appropriate? What type of water would be appropriate for gardening?" Vairavamoorthy argues that cities need to start working with different grades of water in order to prevent waste. He continues, "No longer are we thinking of using one quality of water, which is essentially drinking water, for everything.

We're starting to think about different grades of water for different intended uses".

City design also plays a major role in water consumption. The traditional dream of buying a house in the suburbs is costly in terms of electricity, transportation and water as well. Government incentives to encourage residential buildings in downtown areas will help residents to take advantage of urban living and its comparably compact environmental footprint.

These changes could include giving tax breaks to developers, improving education and parks for families considering the move with children, and replacing aging apartment buildings with more environmentally friendly dwellings that will reduce water usage through more efficient toilets, showers, and sinks.

Water will no longer have to be piped between houses, but can be shared by residents in apartment buildings or densely packed dwellings where there will be less potential for leaks and subsequent waste.

"A major component of the capital expenditure for water production today is in the distribution infrastructure and moving that water around. Because water is a heavy substance, it's not like moving electricity. It's much more expensive," Steve Maxwell says. "A lot of the energy consumption that is utilized by the water industry is actually energy that goes into pumping water from one place to another." By limiting the distance that water needs to be transported, cities can save money, which can be fed back into our water systems to implement more advanced technologies that measure leaks or identify areas of excessive water use.

In concert, governments need to encourage people to think carefully about their water usage, especially in water-stressed areas. Offering incentives for people to replace lawns with more drought-friendly plants or renovate their houses to remove water-hungry older appliances are among the measures that governments can take to encourage citizens to conserve water through everyday actions.

Water

Preventing Pollution

Our oceans are dying. They are filled with oil, plastic, and the toxic runoff from our cities. But clean fuels and new-age biodegradables will allow us to save our aquatic ecosystems and, in so doing, safeguard the long-term habitability of our planet.

Oceans are our planet's largest ecosystems. They are also the largest source of water. If cost-effective desalination techniques are implemented, they could provide us with a near endless supply of drinking water. But we are ruining them with our pollution. The same is true of our sources of fresh water. Each year, they become more and more clogged with our debris.

One large part of the problem is limited access to recycling. Only a small fraction of the world's population – even in urban areas – has access to facilities to recycle plastic and other commonly used products. If plastic is thrown away, it tends to end

up in one of two places: a landfill or a water system. This has led to the creation of the Great Pacific Garbage Patch and other polluted waterways. Even worse, most of the particles are microscopic, making it difficult to track the exact level of contamination from satellites or even through close methods of analysis.

Recycling facilities tend to be large, costly, and difficult to construct. Again, encouraging individuals to move to urban areas will help. "A lot of these systems, whether water treatment or recycling systems, come with high capital costs or initial outlays, so they tend not to be

economical or adopted in areas where it's more difficult to afford them," explains Steve Maxwell. "But when you have a highly condensed population in a smaller area, those costs can be spread over a much larger base, so it's easier to make those sorts of capital investments."

However, automated and more localised facilities could encourage communities to take more ownership of the process. This might also generate money in depressed local economies. Recycling plants provide opportunities for employment and the materials they produce will be cheaper for local firms when they don't have to pay for



The Ocean Cleanup project plans to clean up an estimated

50%

of the Great Pacific Garbage Patch in only five years.

transporting them from further away.

Governments can play a significant role in reducing use of plastics, especially for food containers. Plastic bags in grocery stores have been banned in some jurisdictions, but those account for only a fraction of the plastic in a typical market. Cities could also consider using additives that force plastic to break down over time and biodegrade in a way that is not harmful to the environment.

Another major risk to our water is pollution from oil spills, devastating to both marine wildlife and human populations. Several

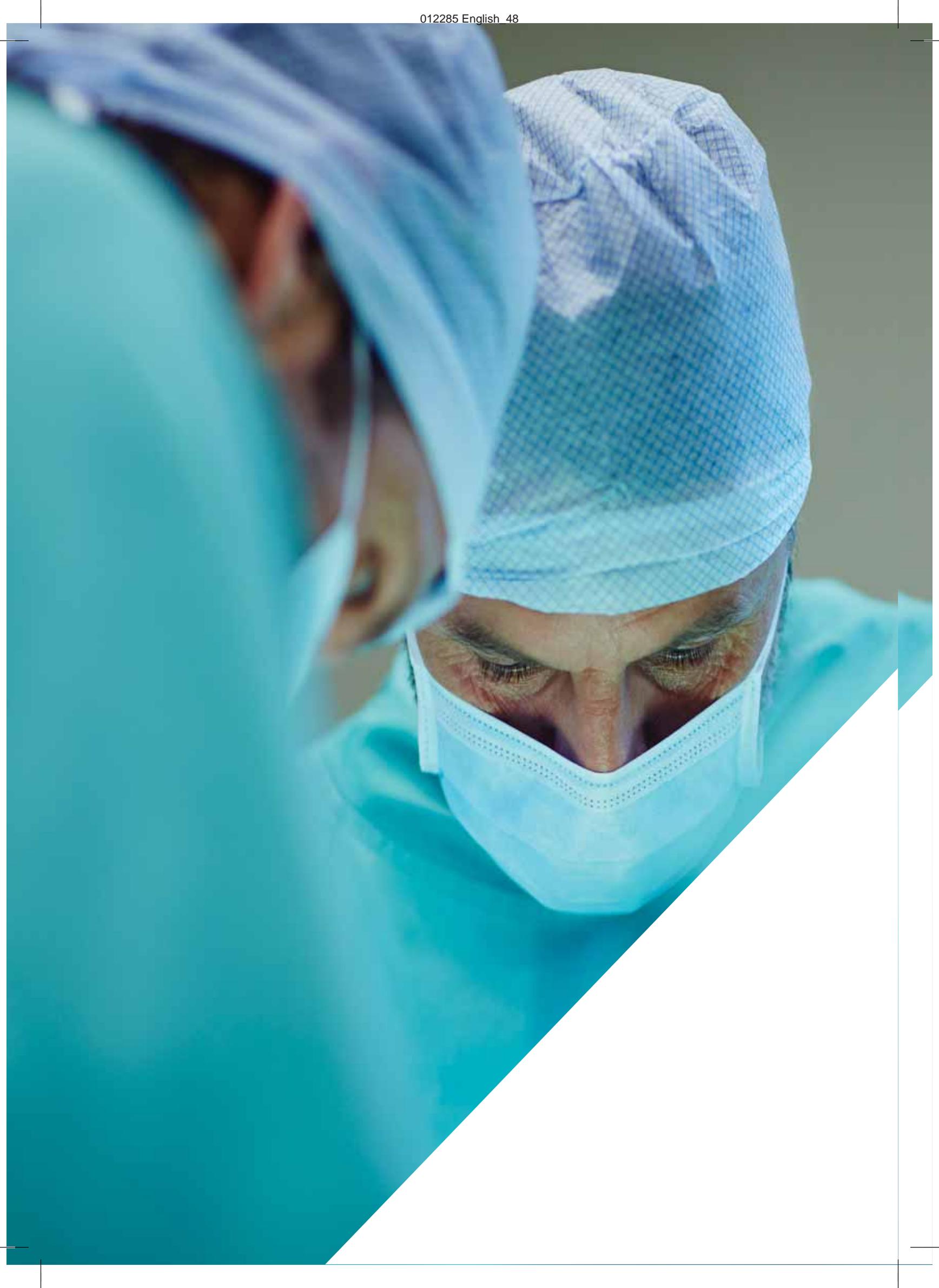
technologies can now contain the problem after it occurs, such as a material that soaks up oil like a sponge. Others are in various stages of development: filters that use gravity to separate oil from water, an MIT invention that uses magnets to pull oil from water, and polymers that can absorb oil.

Some scientists are also considering bio-inspired solutions. Surprisingly, milkweed is quite useful in filtering out oil because it is extremely absorbent. Clams are another possibility, since they are naturally designed to filter out contaminants while feeding along the bottom of oceans.

But the most effective solution is ensuring that oil isn't released into the environment even if a ship is grounded or a pipe encounters significant stresses. Smarter technologies, such as an in-development robot that helps prevent spills from occurring

Ultimately, governments will need to promote the research being done in these sectors in order to find solutions that are both effective and economically viable. In doing so, they can help to ensure that humans have access to clean, healthy aquatic ecosystems for generations to come.





Section IV

Health

Each year, there are roughly 15 million new cases of cancer and nearly 20 million people die of cardiovascular disease. This number can be drastically reduced in the coming decades, but first, we must invest in the research to make it happen. New kinds of health informatics and DNA analysis could allow doctors to anticipate disease and illness before symptoms even emerge, making emergency room visits obsolete. Bionic eyes, synthetic organs, and robotic skeletons will take us from superhumans to cyborgs. If we begin work today, humans inhabiting the cities of the future will do more than just live longer, they will live healthier lives too.

SECTIONS

- I** **Bringing an End to Hospitals**
- II** **Rolling Back the Clock**
- III** **A New Way to Fight Disease**
- IV** **A New Kind of Skeleton**
- V** **Becoming a Cyborg**

OUR EXPERTS

We returned to four commentators from our pool of experts to ask how changes in the health sector could affect cities in 20 or 30 years, summarizing their response in a series of articles.

Arthur Caplan

**Founding Director of the
Division of Medical Ethics,
New York University**

Arthur Caplan has made numerous contributions to public health policy, including helping to found the National Marrow Donor Program, helping create the system for distributing organs in the U.S., and advising on legislation and regulation in many other areas of healthcare, such as blood safety.

Aubrey de Grey

**Chief Science Officer, The SENS
Research Foundation**

Aubrey de Grey is a biomedical gerontologist who founded the SENS Research Foundation. He is Editor-in-Chief of Rejuvenation Research and is a Fellow of both the Gerontological Society of America and the American Aging Association.

Vadim Cherdak

CEO and President, eCare21

Vadim Cherdak is an award-winning mathematician and innovator. He started eCare21 to form partnerships with big data analytics services that enable the company to collect, compare, and analyze real-time information about a person's health and wellness.

Basil Harris

**Co-Leader, Final Frontier
Medical Devices**

Basil Harris is a physician with a PhD in engineering. He has been actively practicing emergency medicine for over 15 years, spending the last 12 years at Lankenau Medical Center of Main Line Health.

Experts' highlights: **FUTURE FORESIGHTS**

Health



THE WORLD TODAY

Vadim Cherdak's company, eCare21, utilizes roughly 200 different wearables and monitoring devices to help individuals obtain information on their medical conditions. "We collect information, analyze it, and provide physicians with the ability to get this information, find patterns, and use it in their preventive treatment for patients."



Worldwide, there are approximately 14 million new cases of cancer each year.



The average human lifespan is currently 79 years old.

THE REALITY TOMORROW

- More information-collecting will help monitor and prevent medical conditions in the coming decades. "By collecting large amounts of vital information, by managing medication intake, by keeping track of a care plan for every individual, we can drastically improve the quality of life of a patient."
- AI software will be deployed that can interpret cancer screenings 30 times more quickly than doctors and with 99 percent accuracy.
- Medical technologies may allow humans to have an "indefinite" lifespan, thanks to things like nanobots that protect every cell in the human body.



BUILDING THE FUTURE



Preventing illnesses requires investing in and developing technologies that can predict diseases and read signs of early symptoms. This will require a close collaboration between engineers and primary care physicians in order to ensure that the tech is being deployed where it is most needed and can be best utilized.



In order to prevent diseases before they happen, genetic testing and DNA analysis services must be made affordable and governments must bring physicians and testing facilities together in order to deploy strategies to decrease the amount of time it takes to complete an analysis.



Exoskeletons require more basic government investment to overcome problems related to bulkiness, stiffness, and flexibility. This will require, first and foremost, investment in the materials sciences.



Our greatest shortcoming related to combating disease is currently a lack of real-world data - structured, longitudinal data related to patients who develop different forms of a disease at a variety of junctures. Governments need to assist doctors with the collection, synthesis, and distribution of this data to improve outcomes and disease research.

Health

Bringing an End to Hospitals

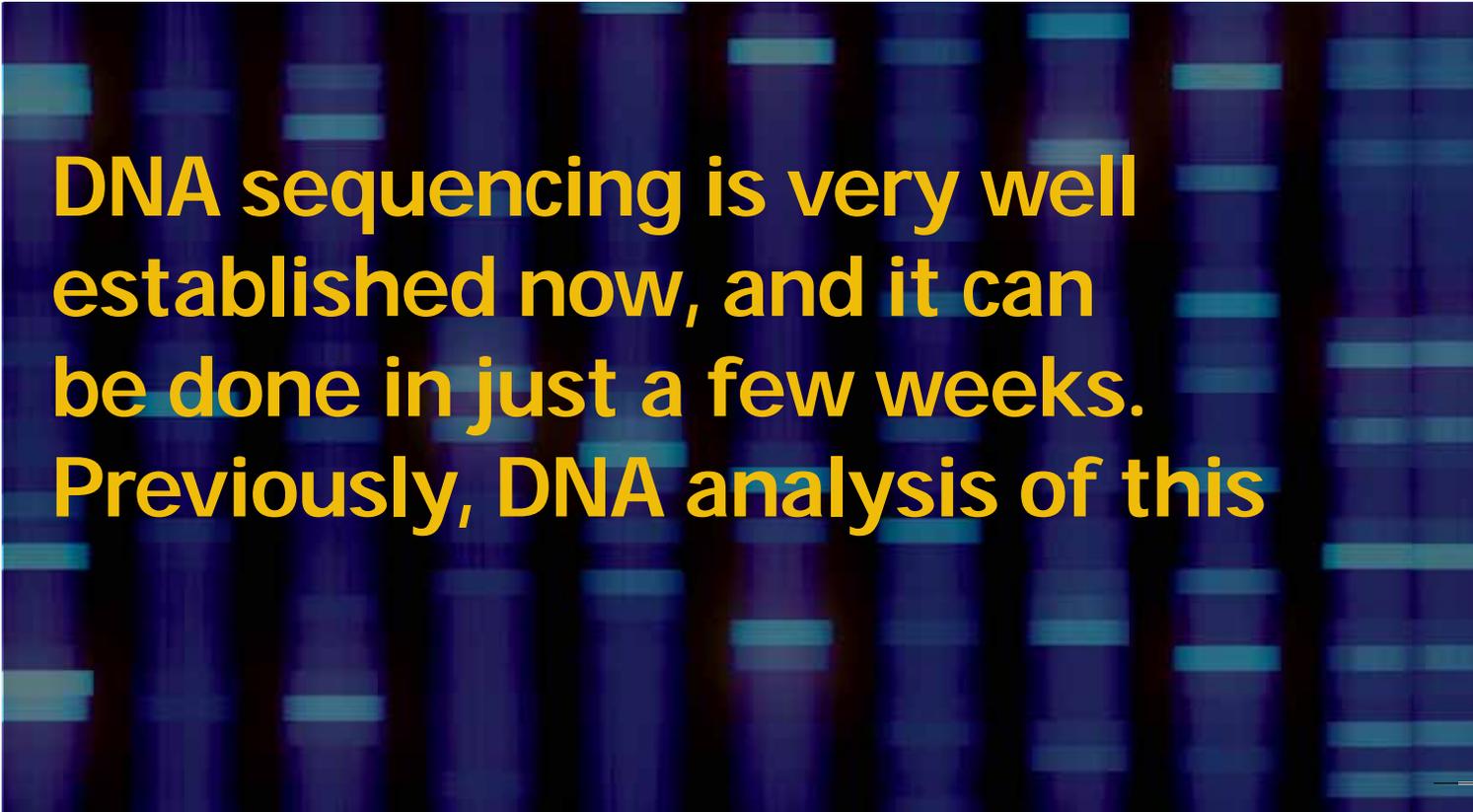
Today, we are often only able to identify and treat diseases after individuals have started experiencing symptoms. Increasingly, advances in DNA analysis and machine learning allow us to predict diseases before any signs of illness emerge, ultimately leading to a world in which emergency hospital visits, and perhaps even doctors, are a thing of the past.

Today, the internet already equips patients with the tools they need to better understand illness. Often, before ever seeing a doctor, a person will research their symptoms in an attempt to identify the cause. Advanced software is increasingly able to provide not just information about a disease but also predict illnesses before they ever arrive, shifting the focus of

medical care from treatment to prevention.

Small stepping stones on the path to this future are already in place in some of today's homes and hospitals. For example, the XPRIZE Foundation recently held a competition to create a "tricorder," a device inspired by the futuristic all-in-one medical tool featured in many episodes of the sci-fi television series Star Trek. Basil Harris

created the winning entry, which is smart enough to detect such medical conditions as whooping cough, hypertension, and diabetes. It can also monitor vital signs, such as blood pressure, body temperature, and oxygen saturation. These technologies take some of the pressure off self-diagnosis, creating a more objective system for diagnosis.



DNA sequencing is very well established now, and it can be done in just a few weeks. Previously, DNA analysis of this

Basil Harris suggests that the next step will be to integrate the data from these devices into smarter systems, that are updated with the latest clinical knowledge. Then, that information will be incorporated into a patient's medical record, allowing doctors to look at their current condition, compare it with the past, and make informed decisions about how to help.

The Dubai Health Authority recently implemented an electronic medical record system called Salama in Rashid Hospital, Barsha Health Center, Airport Medical Center, the Dermatology Center, and the Dubai Physiotherapy and Rehabilitation Center.

"The system is so efficient that it has multiple core applications. It integrates 25 applications through a single interface. Now the patient's appointment, queue management, radiology, pharmacy, laboratory information system, dental records, information about the patient on biomedical devices such as dialysis machine, ventilator, cardiac machine etc., will all be integrated," notes Amani Al Jassmi, Director of Information Technology at the Dubai Health Authority.

But we can go even further. DNA analysis will allow doctors to track conditions, such as breast cancer or heart disease, through

entire families. Eventually, gene editing technology – pioneered today through measures such as CRISPR – could enable medical professionals to edit out the genes before they have a chance to impact your health.

In many cases, preventative medicine will emerge from monitoring equipment. For example, Vadim Cherdak's company, eCare21, utilizes roughly 200 different wearables and monitoring devices to help individuals obtain information on their medical conditions. "We collect information, analyze it, and provide physicians with the ability to get this information, find patterns, and use it in their preventive treatment for patients," explains Cherdak.

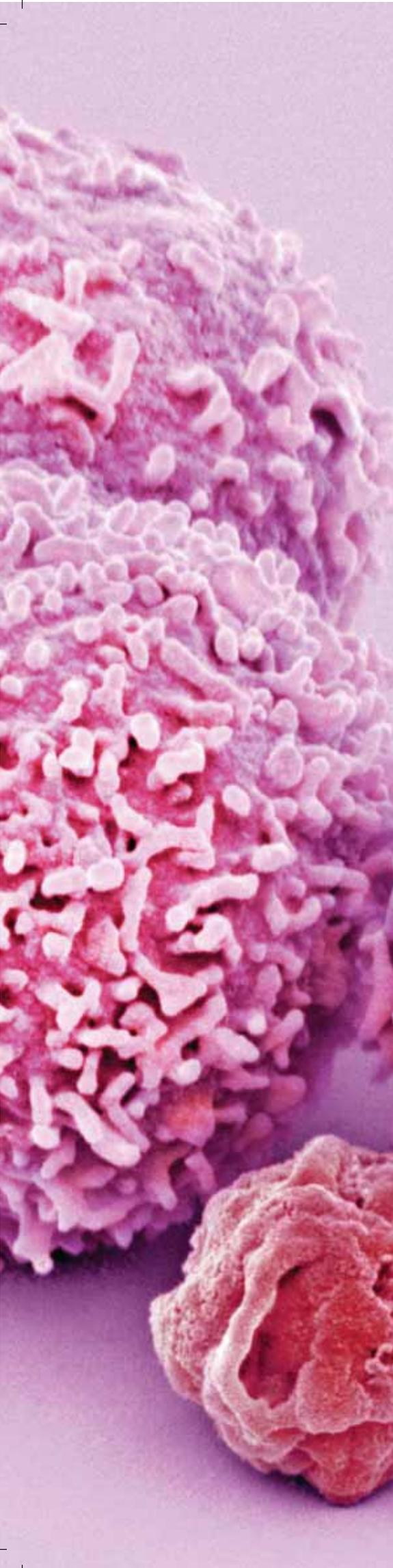
In the future, Cherdak anticipates that artificial intelligence systems will be trained to analyze health information, resulting in quicker interactions with patients and, ultimately, fewer acute situations. Hospitals, he adds, will then allow "more home treatment for patients who need more health attention and much more support for different telecommunication systems for health intervention." In this respect, he says that we will begin to "talk about the unbounding of medicine from hospitals and doctor's offices, toward homes and potential patients".

In many cases, says Aubrey de Grey, medical professionals already know the steps to preventative medicine, but they lack the funds to implement these strategies. He suggests that governments should look closely at "the industry that works in vaccine development, then detection of new pathogens, and help them get on with their work, with larger amounts of manpower than they have now".

It is far cheaper and far easier to prevent an illness than to treat it. So the first step in safeguarding the lives of tomorrow is investing in and developing technologies that are able to predict illnesses and read signs of early symptoms. As these technologies advance, doctors will need to focus less on hospital and emergency room work. This will require close collaboration between the engineers developing future medical technologies and primary care physicians in order to ensure that not only are we developing the products that are most beneficial to both doctors and patients, but that doctors are ready and willing to use them.

**magnitude would've taken
months, years, or decades to
sequence.**

Aubrey de Grey



The next 20 to 30 years will be all about quality of life and learning to extend biological processes...wear and tear stuff. After that, we will start getting into discussions of extending the human lifespan.

Arthur Caplan

Health

Rolling Back the Clock

Future generations will be living longer than ever before. As scientists move closer to stopping the basic processes that cause cell loss and figuring out how we can live healthier lives, we will begin to extend the human lifespan.

In previous generations, aging was closely associated with deterioration and rapid death. However, today's seniors are living much longer than before, and in many cases, they are far healthier and more able-bodied. However, more research needs to be done to ensure the improve later years.

"People don't just want to live longer – they want to live well," says Arthur Caplan. "There's a certain fantasy of extending the human lifespan 200 or 300 years or more, but it's really about living better and having a good quality of life. After all, you start to deteriorate in your 60s, no matter how far you're jogging, no matter what you're eating. If your body is wearing out, that has to be solved before we get into any serious discussion about life extension."

Another challenge of the coming generation, Caplan says, is to provide all populations equal access to healthcare for improving quality of life - treatment that is often confined to richer countries today.

Vadim Cherdak believes personalized medicine will go a long way, as access to information about an individual's life history

will help inform future decisions about their medical care. Outlining the simplest steps that can be immediately taken, he states, "By collecting large amounts of vital information, by managing medication intake, by keeping track of a care plan for every individual, we can drastically improve the quality of life of a patient".

Improving quality of life is the first step. Many experts, including Aubrey de Grey, say that it's also possible to extend the human lifespan. The methods currently under consideration that seem to hold the most promise involve altering the metabolism of the organism in some way, such as via hibernation or by reducing food consumption. "Essentially, all organisms respond to famine in the wild by altering their metabolic priorities so as to essentially hunker down, rather than do what they normally do, which is try to reproduce as much as possible," say de Grey.

He acknowledges that the phenomenon has a much less quantitative impact in humans, a long-life species, than other species, but it provides a good starting

point. "The rejuvenation side of things, where we're trying to turn back the clock, is a much more complicated approach," he adds. "It's really a 'divide and conquer' approach, where we need to identify the different types of molecular and cellular damage in the body, and then figure out ways to repair that damage so as to restore the structure of the body as it was in young adulthood." De Grey's group, the SENS Foundation, has identified seven targets in aging prevention that already have potential cures. For example, for cell loss and tissue atrophy – a phenomenon identified in the 1950s – a possible solution could include stem cells and tissue engineering.

As well as funding this kind of research, Governments will need to focus on formulating rules and regulations to ensure that stem cell and gene editing research is deployed responsibly.

Health

A New Way to Fight Disease

Today's research into DNA will allow us to combat disease in tomorrow's citizens. And advances in gene editing will enable us to truly fight back against the harmful organisms that have been plaguing humanity since the dawn of time.

Today, our understanding of our genetic makeup is still in its nascent stage, but we are quickly advancing. For example, a patient undergoing breast cancer treatments can have the sequence of their cancer genome analyzed to help their doctor best decide which treatment plan is best suited for the individual patient. This level of detail was difficult to achieve even a decade ago.

For society to reap the benefits of DNA analysis, it must be affordable for all individuals. We will need to both decrease the amount of time that it takes to complete such an analysis and increase the abilities of our computer systems so that they can readily identify issues in an individual's genome. To this end, governments must begin to formulate programs that will ensure that all citizens have access to DNA analysis, ideally from the time of childhood, so that the necessary preventative measures can be put in place and intervention can occur as soon as possible.

Of course, many people have concerns about privacy, as insurance agencies, employers, or other individuals who gain access to this health information

could use it improperly. There is a role for government to act as a trustworthy gatekeeper for this information, as well to help the public understand the benefits of DNA analysis and convince them to trust that their information will be kept private.

However, genome sequencing is just the beginning. With the advent of commercially available gene editing, cancerous cells could be altered and corrected before mutations even occur, making common cancers, such as prostate cancer and breast cancer, things of the past.

CRISPR is one of the most promising gene editing technologies. It is still in its infancy; the number of off-target edits that occur as a result of its use are still being studied. But CRISPR is most exciting due to its accessibility. The Journal Science named CRISPR as the breakthrough of the year in 2015, and just two years later, the most basic form of the technology costs US\$150. This extends the reach of CRISPR testing beyond traditional laboratory environments to community colleges, school classrooms, and the labs of curious self-taught scientists.

"Sometimes the modification does what

you want, and sometimes it does something that you didn't want," notes Aubrey de Grey. "You'd need to be able to test what things happen before you administer the modified cells to the patient. As time goes on, these technologies will need to become more controllable. Only then will it become possible to inject the engineered construct, the DNA, into the body and have it do what you want it to do without the risk of, for example, inducing cancer."

Access to gene editing technology also brings with it a challenge for regulators to govern its use in many different contexts. Like with the biobricks given to students of synthetic biology, providing students with these cutting-edge tools will help them be better prepared for the rapid pace of change in medical technology in the next 20 to 30 years. This hands-on experience will also help surface ethical debates early in clinical or scientific careers, improving the chances for good self-governance among professionals using gene editing techniques.

In 20 to 30 years, gene editing is going to be used to battle diseases. Most of these diseases are due to our urban lifestyle – coping with stress by smoking, overeating, drinking too much, vehicular accidents that take place with pedestrians, and so on. Research will focus on repairs, treatments, and prevention.

Arthur Caplan

Health

A New Kind of Skeleton

NASA is already studying how to help humans move more efficiently by experimenting with robotic harnesses. Manufacturing companies are investigating similar technologies to improve worker safety, and militaries around the world are working on tech that makes their soldiers faster and stronger.

The fantasy of Iron Man is alive and well, with a number of companies and agencies working on devices that augment the human body from the outside. For astronauts, the benefits of such systems are obvious. An exoskeleton that restricts motion could be used to help prevent bone and muscle loss caused by exposure to microgravity for months at a time. Workers on Earth could benefit from exoskeletons as well. The devices could take physical burdens off of people who work in environments that require a lot of lifting and thereby prevent work-related injuries.

Exoskeletons have a host of applications

in relation to health and medicine, also. People who can't walk due to disabilities or injuries can use the systems to regain their mobility. Such devices have advanced significantly over the past few years, with each new generation more flexible, lighter, and more affordable than the one before.

The Hybrid Assistive Limb (HAL) device was created in Japan by the University of Tsukuba's Yoshiyuki Sankai. This mechanical clothing fits around the human body, making advantage of human biology to deliver a more seamless locomotive experience. To move, a person first thinks about the action, which sends electrical

impulses from their brain to the leg or other limb expected to carry out the action. Because these impulses are detectable on the skin, HAL can pick up and process them to determine the desired action before helping the wearer carry it out. The suit received a global safety certification in 2013 and is in trial use around the world, with medical applications and in high risk situations such as disaster response.

Because they include cutting-edge technology and must be custom-tailored to each patient, exoskeletons are currently extremely expensive. Mass manufacturing would cut down on the per-device cost,



Experts predict that
exoskeleton demand may reach
\$3.3 billion USD
by 2025.

but not enough people need these devices for medical reasons to warrant large production runs. Larger orders from military contracts could help reduce the price. The U.S. Defense Advanced Research Projects Agency (DARPA) is leading the production of exoskeletons that will allow the military's soldiers to run faster and travel farther. This kind of program provides researchers with the resources to create devices that could eventually be used to assist non-military personnel.

Governments can play a role in this kind of cross- sector support: identifying where technologies developed for one purpose

can serve another, increasing their social and economic impact. This particularly valuable when both purposes - in this case military and healthcare - relate to government goals.

Whether designed via government partnerships or by private companies, the next generation of exoskeletons will need to be more flexible than the current generation. Exoskeletons still suffer from problems of bulkiness and stiffness, making it difficult for companies to justify investing in the technology. Outside of the most straightforward urban settings, exoskeletons still perform poorly as they

aren't yet capable of assisting people in walking over uneven ground.

A better understanding of human mechanics will greatly help in improving the benefits of these devices, and in the next 20 to 30 years, several technological advances should lead to exoskeletons that are both more functional and more affordable. Nanomaterials are sure to make the devices stronger and lighter, while 3D-printed parts will drive down the cost of manufacturing.

Health

Becoming a Cyborg

Today, we have pacemakers and hearing aids. Tomorrow, we will have bionic eyes, synthetic organs, and regenerating tissue. These advances will allow us to incorporate entirely new senses into our bodies and heal serious injuries that, in previous eras, would have required major surgery.

Cyborgs already walk among us, and they include surprisingly young people. The United Kingdom's Neil Harbisson grew up with severe color blindness and can only see in grayscale. After deciding he wanted another way to experience color, he developed a sensor that can translate color frequencies into sound frequencies, which he memorized. Then, he created an antenna that attaches to his head, and now, he can use the sound frequencies generated by his device to better differentiate the colors he encounters throughout his daily life.

Harbisson's device is just one example of a cyborg-like technology, and while some may seem ordinary, such as pacemakers and hearing aids, far more futuristic ones are on the horizon.

As machines get smaller and smarter, mini-cyborgs inside of our bodies will be even more common. Imagine machines that can automatically clear clots from your blood or artificial hearts made from a mixture of novel materials and your own cells.

For hospitals, investments in regenerative organs could cut down on many risks that patients face. For example, even in sterile conditions, patients with burns or open wounds face numerous risks to their health simply because their skin cannot keep contaminants out of the body. Artificially

generating tissue technology would allow the skin to "knit up" faster and thus keep the rest of the body safe.

Arthur Caplan anticipates more people using cyborg technologies for enhancement purposes than for basic body functions and health. A significant segment of any city's population, he points out, works at night, and he suggests that we could create artificial eyes "so that they'd be able to see a little bit more of the light spectrum". Such investments would have health and economic benefits, as they would allow workers to work more efficiently and likely cut down on accidents caused by visibility issues.

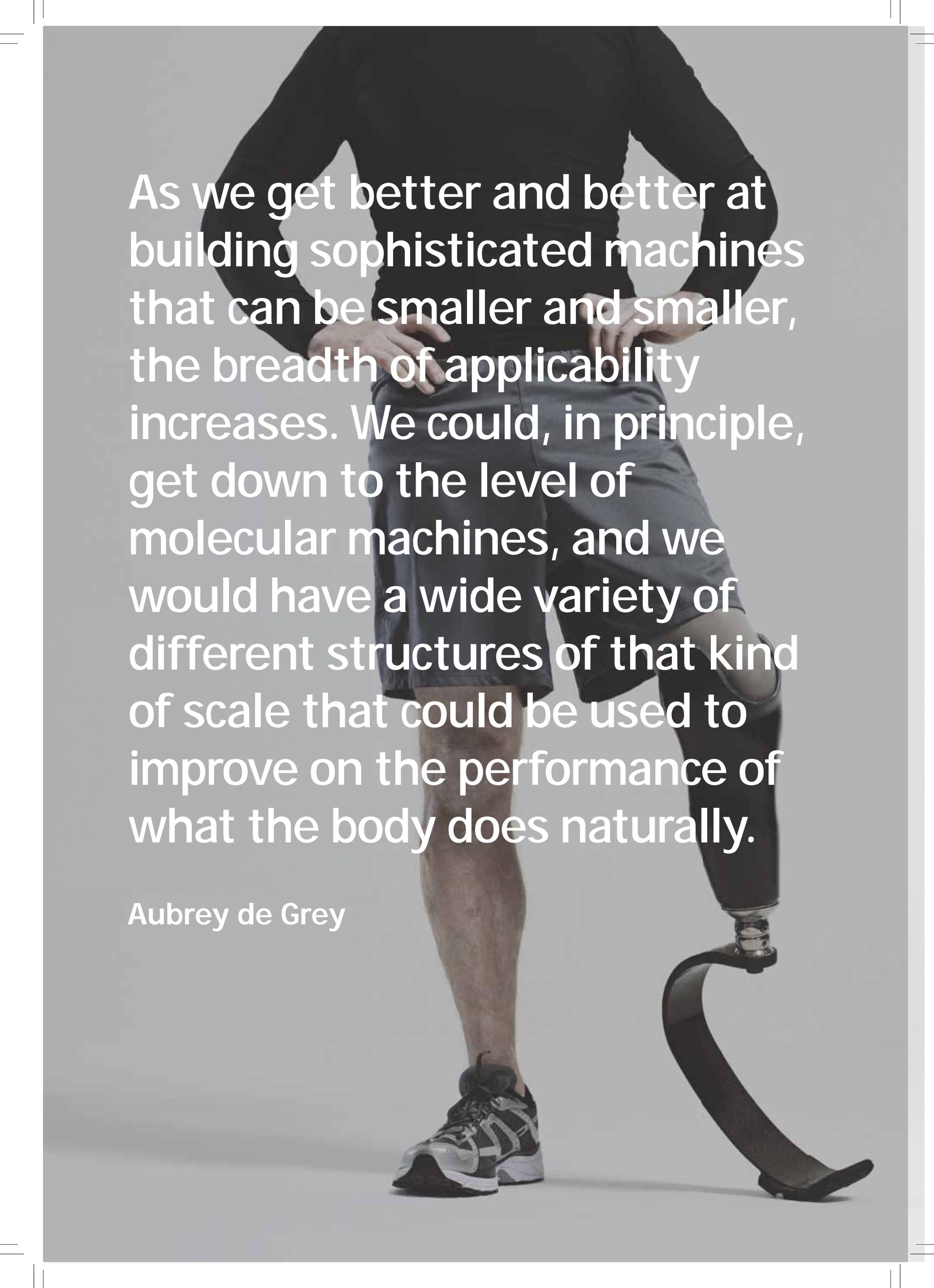
Today, we tend to draw a distinction between natural and artificial enhancements to the human body. However, Aubrey de Grey suggests that instead of focusing on how the enhancement is done, focus on the fact that an enhancement has taken place. In this philosophical context, "cyborg" would have less meaning.

And this is an issue that we need to address today. Case in point, a resident of Dubai recently received the first-ever fully 3-D printed prosthetic leg. This was made possible through a collaboration between the Dubai Health Authority

and Arab Health. "This is a truly unique collaboration that allows us to see the most modern technology emerge and become a reality. This is a learning curve for everyone engaged, and part of the foundation of future 3D printing research and development work in the UAE," said Dr Mohammad Al Redha, the Director of the Executive Office for Organisational Transformation at DHA.

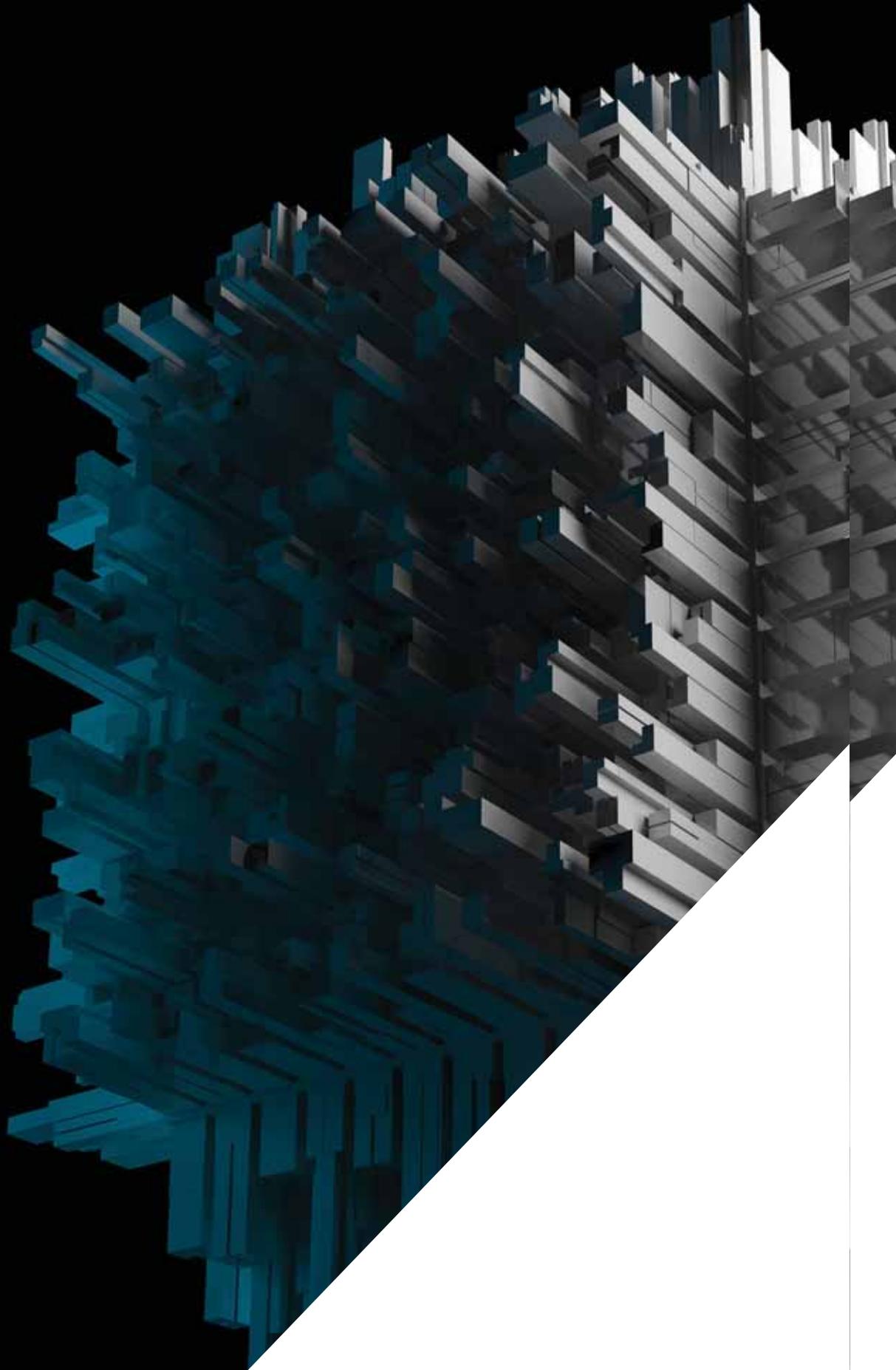
de Grey notes the questions that come along with such advancements, questions that we must start to answer today: "Does it really make much difference if you wear glasses or if you have Lasik surgery? Does it really make a difference if you have a cellphone in your hand or implanted in your brain or under your skin?" he asks. "To me, these things are functionally equivalent, and it's really just a matter of taste and take-up. It'll be determined more by the market than the technology."

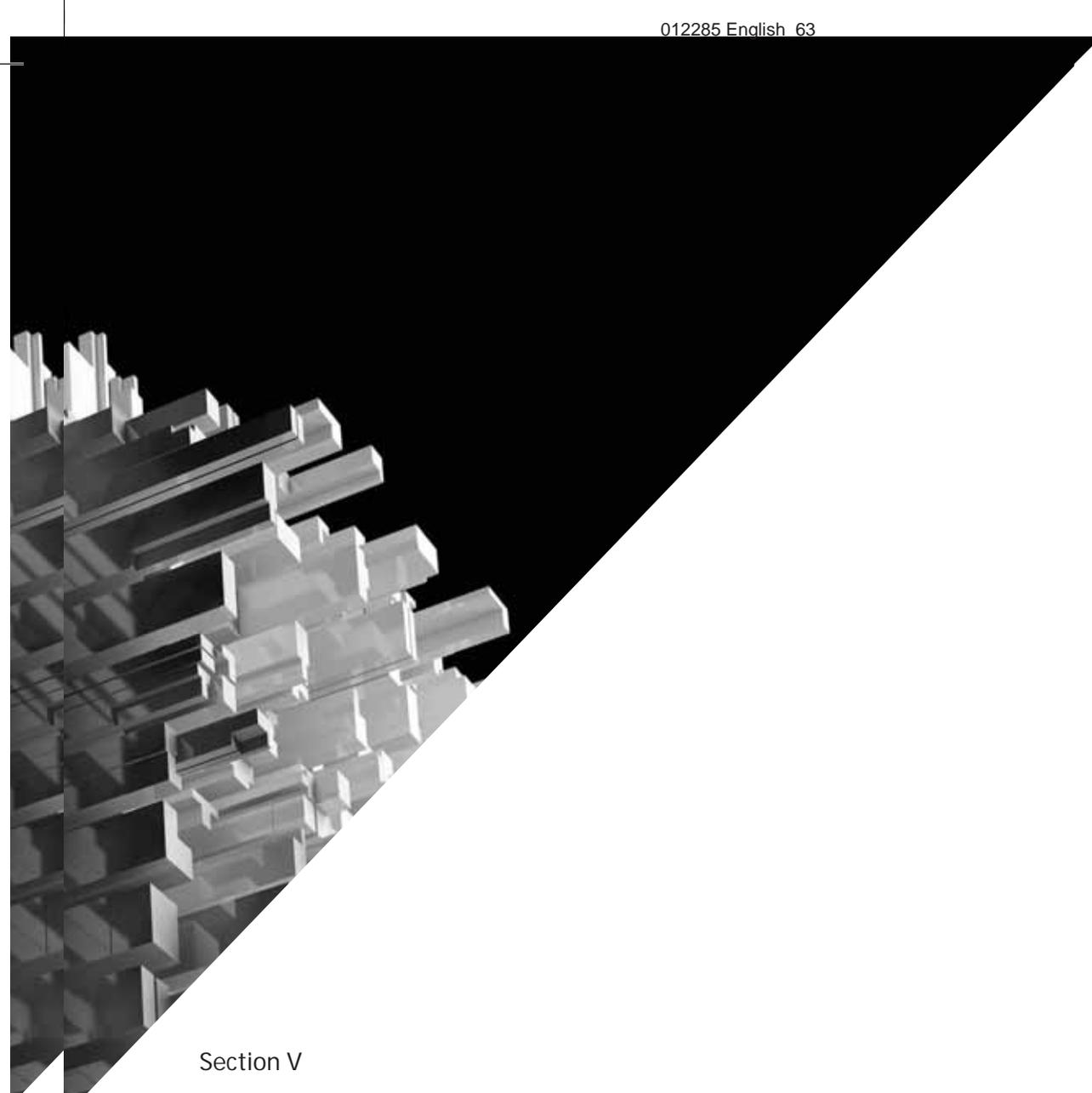
In the more distant future, better mapping of the brain would allow for even more advanced cyber-like technologies. Thanks to brain-computer interfaces, students may be able to act like a "cyborg" and implant a tough algebra lesson or foreign language inside their head (more in Education section).

A person wearing a black long-sleeved shirt and grey shorts stands with their hands on their hips. They have a prosthetic right leg, which is black and curved, resembling a running blade. They are wearing a grey and black athletic shoe on their natural left leg. The background is a plain, light grey color.

As we get better and better at building sophisticated machines that can be smaller and smaller, the breadth of applicability increases. We could, in principle, get down to the level of molecular machines, and we would have a wide variety of different structures of that kind of scale that could be used to improve on the performance of what the body does naturally.

Aubrey de Grey





Section V

Technology

With responsible planning, technological advances will help future cities meet a myriad of demands. 3D-printing technology, for example, will allow citizens to print homes, businesses, and goods in record time. Artificial intelligence will change the nature of work; humans will find themselves working alongside machines in new ways. But future cities won't be limited to the physical world. Blockchain, for instance, will lead to innovations in banking and politics. Virtual and augmented reality will assist citizens with urban planning, education, entertainment, and training, and we will literally enter a new kind of (digital) world.

SECTIONS

- I Securing the Future**
- II On-Demand Construction**
- III Living a Virtual Life**
- IV A Robo-Revolution**
- V A New Kind of Intelligence**

OUR EXPERTS

We returned to four commentators from our pool of experts to ask how changes in the technology sector could affect cities in 20 or 30 years, summarizing their response in a series of articles.

Amir Benifatemi

Prize Lead, XPRIZE

Amir Benifatemi has more than 25 years of experience in the development and growth of emerging and transformative technologies. Benifatemi previously worked as a design engineer at the European Space Agency and contributed to the formation of more than 10 startups focusing on predictive technologies, IoT, and healthcare. At XPRIZE, he is the Prize Lead of the IBM Watson AI XPRIZE.

Robert Morgan

VR/AR Narrative Consultant

Rob Morgan is a game writer, narrative designer, and voice director. He has written and designed interactive narratives for platinum-selling console titles and award-winning browser, mobile, and ARG projects. Morgan just finished writing the script for The Assembly for PlayStation VR, Oculus Rift, and HTC Vive.

Amanda Gutterman

CMO, ConsenSys

Amanda Gutterman is the CMO at ConsenSys, a venture production studio and custom software development consultancy building decentralized applications, enterprise solutions, and developer tools for blockchain ecosystems focused primarily on Ethereum.

David Orban

Founder, Network Society Research

David Orban is a faculty member and advisor at Singularity University and the founder of Network Society Research, a London-based company creating an analytical tool to allow enterprises to confront decentralized exponential technologies disrupting the centralized and hierarchical functions of governments and corporations.

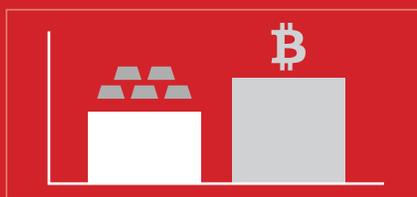
Experts' highlights: **FUTURE FORESIGHTS**

Technology

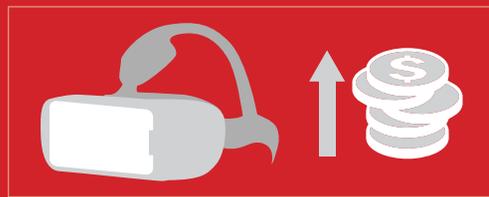
THE WORLD TODAY



One of the world's first 3D-printed homes, a house that spans 38-square-meters, was created in just 24 hours for \$10,000.



For the first time in history, Bitcoin (**\$1,271**) surpassed the price of gold (\$1,235).



Worldwide spending in the augmented reality and virtual reality market is forecasted to reach \$6.2 billion by the end of the year.

THE REALITY TOMORROW

- Governing officials assert that 25% of Dubai's buildings will be **3D-printed by 2030**.
- Experts predict that Bitcoin will be worth **\$500,000 by 2030**.
- In 2016, His Highness Sheikh Hamdan Bin Mohammad Al Maktoum, Crown Prince of Dubai announced the Blockchain 2020 strategy. Dubai has committed to be first city fully-powered by blockchain by 2020.
- Worldwide spending for the augmented reality and virtual reality market is forecasted to reach **\$143.3 billion by 2020**.
- AI will be all around and embedded in everything we do, and 3D-printing will not be called "3D-printing" anymore. It will just be called "**printing**."
- His Excellency Wesam Al Abbas Lootah.

BUILDING THE FUTURE



Blockchain technologies will allow us to more easily exchange money and share information. In order to make this happen, governments will need to inform the general population about their utility, ensure there is universal access to the Internet, and form initiatives to protect companies and economies that may suffer as a result of these developments.



"One of the pillars of our strategy is industry creation - or, as we like to say, becoming the global capital of blockchain. We want to become the place with the right technology and regulation ecosystem for new nascent technology to flourish: for it to move from a new to a mature idea." - His Excellency Wesam Al Abbas Lootah, CEO, Smart Dubai Government Establishment (the technology arm of Smart Dubai).



3D-printing will revolutionize building and fashion, offering new tools to fabricate the future. Artisans and engineers will need to begin training today in order to ensure they know how to incorporate these new technologies into their work and best utilize them in their designs.



Virtual and augmented reality will make it easier for individuals to wayfind or access information on the go. Governments, will have to enact legislation to enhance individual privacy, educate users on how to best to protect themselves, and ensure the screens we interact with don't erroneously track information or personal data.



While automation will make future workplaces more affordable for companies and safer for workers, infrastructure must be upgraded to accommodate their use and ensure that these technologies can be deployed to their maximum reach.



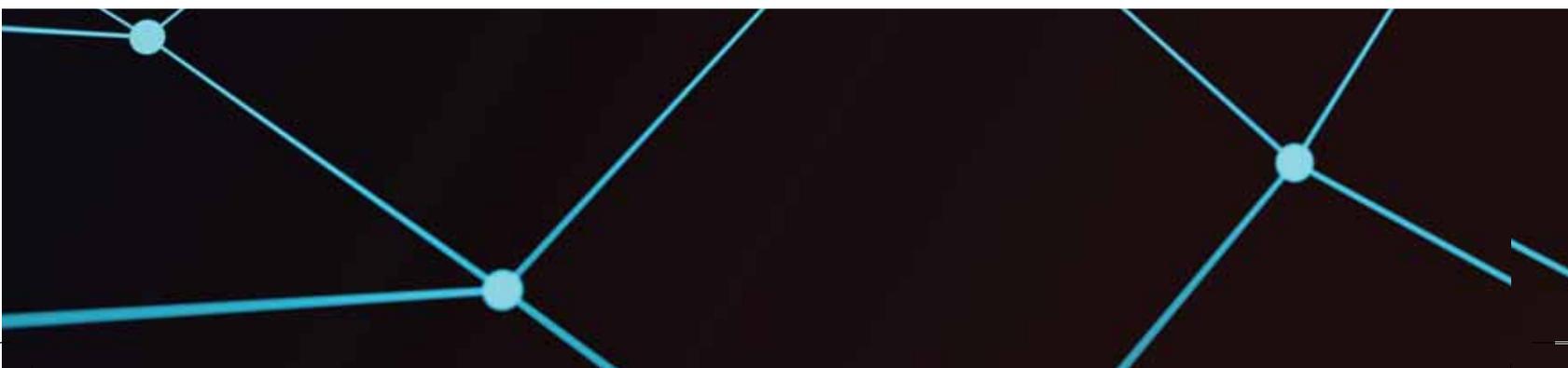
Artificial intelligence will make industries more efficient, but there is a risk of massive-scale job disruption. Governments need to create the legal framework to govern AI research and deployment and also collaborate with city planners to make sure the technologies are implemented in ways that complement human labor.



Technology

Securing the Future

Blockchain technologies are already leading a revolution in banking. In the world of tomorrow, this software platform will allow us to secure and complete a host of diverse transactions. At the same time, the technology will democratize the world and help create a more equal society.



Blockchain is a way to distribute information digitally without copying it. Its most well-known application is in support of Bitcoin, a digital currency used for direct peer-to-peer transactions. These transactions require verifications, which is where blockchain comes in. Since blockchain is a decentralized, distributed database, it allows users to transact in Bitcoins without the need for an intermediary.

Governments around the world have already launched initiatives in order to accelerate the use of blockchain into other sectors. "Back in 2016, His Highness Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum, Crown Prince of Dubai, Chairman of the Board of Trustees at Dubai Future Foundation, announced the Dubai Blockchain Strategy 2020" notes His Excellency Wesam Al Abbas Lootah, who is the CEO of Smart Dubai Government Establishment. "Dubai has committed to be first city fully-powered by blockchain by 2020. One of the pillars of our strategy is industry creation. We want to become the place with the right technology and regulation ecosystem for new nascent technology to flourish: for it to move from a new to a mature idea ... We have already brought onboard IBM as the Blockchain Lead Strategic Partner and ConsenSys as Blockchain City Advisor to help us with implementation."

Similar partnerships between governments and innovate companies operating in this space would be beneficial, as they would identify more issues and areas for both improvement and expansion.

The distributed nature of blockchain has many advantages over traditional ledgers in relation to security. Since identical copies

of the information are available across the network, there is no central point of control or potential central point of failure. As a result, blockchain could allow cities of the future to secure transactions as never before.

"Blockchain is about resource allocation in an open environment where trust is taken out of the equation," notes David Orban. "We are accustomed to having to build trust before we can transact. What blockchain allows is a vast increase in the speed of frictionless transactions, making trust computable – trust is now a feature of the network. As a consequence, in the coming decades, when the technology is in widespread use, we will be able to have a much higher granularity than is possible today."

For example, users' individual identities could be stored and accessed in the cloud, making identity theft, and other identity issues, a problem of the past. As Amanda Gutterman notes, blockchain can solve a number of systemic issues in this sector: "According to institutions like the United Nations, World Bank, and ID2020 project, over 2.5 billion people lack access to basic identity provided by a central government. This usually means they lack even the most basic inclusion in the global economy, since they are unable to get bank accounts. With uPort identity on the Ethereum blockchain, individuals in emerging economies that lack central government infrastructure can create blockchain-based identities that allow them to build reputation, become eligible for a loan on the strength of that reputation, and create and execute smart contracts."

Along these same lines, documents could

be more securely stored and modified in the network, simplifying contracts, the buying and selling of goods, and anything else that requires records. The blockchain can also be searched quickly, and it could give us a universal form of document storage that cities worldwide can access – much like the internet of today, but more secure and better cataloged.

Gutterman clarifies, "Instead of relying upon paper documentation or centralized digital representations of information—which are protected only by perimeter security and are vulnerable to human errors, hacking, and manipulation—documentation can exist on blockchains where they can be granularly authenticated by each necessary body in order to be official. This prevents loss and error, and adds efficiency to the system."

Of course, blockchain has a myriad of uses outside of basic documentation, such as tracing food distribution, connecting smart appliances, and even improving the copyright system in the music industry. As blockchain becomes more popular, it could even allow people to vote from their own residences and partake in the political process from home, something that would be remarkably useful for individuals who cannot travel due to age, disability, or remote lodging.

But many innovators and investors aren't operating in this space because it is unfamiliar and difficult to explain. Local governments can play a role in changing this. They can act as intermediaries between companies building blockchain ecosystems and the individuals or organizations that could benefit from those innovations.

It's relatively easy to imagine an office building that gradually optimizes itself so that it changes its own layout—even day to day, contextually, or as required by people who are using it—in real time.

Robert Morgan



24

Hours it took Apis Cor, a San Francisco-based startup, to 3D print an entire 400-square-foot home.

Technology

On-Demand Construction

As the population of cities increases, new tech will help future societies meet their ever-growing construction demands. 3D printing will let us literally print businesses and dwellings on demand. Meanwhile, consumer-level 3D printers will give individuals the ability to print everything from clothing to furniture, bringing an end to stores as we know them.

3D printing was first made possible in the 1980s, but only in the past decade have we begun to understand its full potential. And thanks to advances in materials and manufacturing, the technology is more accessible than ever before. Cities worldwide are now hosting makerspaces where residents can 3D print their own goods. 3D printing is even available to astronauts on the International Space Station where, eventually, they will be able to print their own tools for repairs or scientific experiments.

As Amir Benifatemi notes, we already have the necessary knowledge to make 3D printing ubiquitous. However, cities largely have yet to reap its benefits. "Today, 3D printing and on-demand fabrication are already available because of material science and robotics technology," Benifatemi says, but to become truly universal, technology and materials will need to be "distributed in strategic places to avoid the cost of transportation." Only then will they make their way into the majority of homes.

3D printing could be especially useful for

clothing because fashion change several times a year, and clothing tends to wear out quickly as a result of frequent use. As the technology becomes cheaper, haute couture could come right to our homes. Fashion could even be tailored to each consumer's individual sizes, giving people who are taller, larger, shorter, or smaller easy access to beautiful clothing – all without leaving the house.

This ambitious enterprise will have a dramatic impact on designers who create clothing and companies involved in shipping them. Although some may fear the job loss that could result from widely distributed 3D-printing technologies, we will still need artists in the cities of tomorrow – they will just need to be trained to create using these new platforms. Governments can help by introducing 3D printing into educational institutions.

Smart robots could 3D print modular housing or offices to reduce the costs of construction. Today, small companies struggle to adapt their office spaces to a rapidly changing workforce, but that will change. In the next few decades, robotic

technology will be able to alter offices by repurposing materials. Robert Morgan says 3D printing will eventually give us the ability to "reconstruct automatically". "It's relatively easy to imagine an office building that gradually optimizes itself so that it may change its own layout day-to-day or even contextually based on the people who are using it," he claims.

People employed as architects and construction workers will obviously be impacted by these advances. Those workers will remain an important part of the creation process as we will need their expertise to create safe and structurally sound designs. However, they will need to be prepared to work with new materials instead of the traditional brick and mortar, as well as new kinds of software that can model these kinds of structures accurately.

Again, government can play a significant role in ensuring that the latest technologies are integrated into training for professionals in this sector.



Technology

Living a Virtual Life

The next generation of screens will be right inside your head(set). Along with advancements in gaming and entertainment, virtual reality and augmented reality will offer us customized worlds where we can experience breaking news from the front line or learn a new skill with a tutor on the other side of the globe.

Virtual reality (VR) – a computer-generated simulation of an environment – and augmented reality (AR) – a computer-generated image that is superimposed onto the real world – are on the cusp of mainstream integration. For decades, VR has been used for educational purposes, such as to train pilots via simulated landings. However, until very recently, the technology required full-room simulators. Today, consumers have easy access to virtual reality through commercially available headsets, such as PlayStation VR and Oculus Rift, and a host of augmented reality tech is on the way to market thanks to innovative companies like Magic Leap.

In the future, headsets will be less bulky and less reliant on computers for processing, allowing people to use virtual reality on-the-go. Virtual reality could be used by urban planners who want to see a new bridge, building or roadway in context

before building it. The virtual design will make it easier to receive input from local citizens prior to construction.

In the coming decades, city-wide use of AR will transform how we experience the world around us, giving individuals and organizations the ability to create custom realities that adapt to their needs and wants. For example, today we can look at our phones for directions to the nearest store. In the future, augmented reality could create a virtual pathway to lead us there.

“While walking down the street, you might be able to see a data billboard updated in real-time,” notes Robert Morgan. Your AR glasses could even project individuals’ names and biographical information over their heads as you approach them.

This raises concerns, both for the individual

using the VR/AR device and for those around them. For example, hackers could interrupt signals and alter what is displayed in individual devices. Up-to-date security systems and contingency plans in the event that technology is compromised could help this generation of technology from repeating the history of consumer database breaches.

This will go some way to securing individual privacy and freedoms in an augmented world. But new protections will be needed, too. Regulation will need to cover what information can be taken from users and what is displayed on VR/AR devices. It should be easy for individuals to access and control information stored about them by companies. Lack of this kind of control causes users to leave existing digital services, and so is likely to cause more of an issue when those services can directly affect our experiences.



Virtual reality will allow everyone to be understanding of, and privy to, situations in life that are not theirs.

Amir Benifatemi



Technology

A Robo-Revolution

Autonomous robots will eventually perform our most dangerous and physically demanding jobs. Everything from cleaning to rescue work may soon be done by steel and plastic.

In Silicon Valley, Savioke's robots are upending the hotel industry. Botlr is able to respond to requests from hotel guests, delivering food or towels to their doors using an internal mapping system to navigate around the hotel and avoid obstacles. Once Botlr arrives at its destination, it calls the guest via the hotel phone. When the guest opens their door, the locked tray containing their items springs open. Botlr asks how the guest's stay has been and gives them time to take a selfie before returning to its charging station.

The robot, we are assured, is not taking away hospitality jobs. Instead, it reduces the workload of existing staff members, who are still needed to run the robot: putting items into its tray, cleaning it and helping it out if it is stuck. However, as robots advance, they will be able to complete increasingly complicated tasks, such as cleaning hotel rooms and even preparing food for room service.

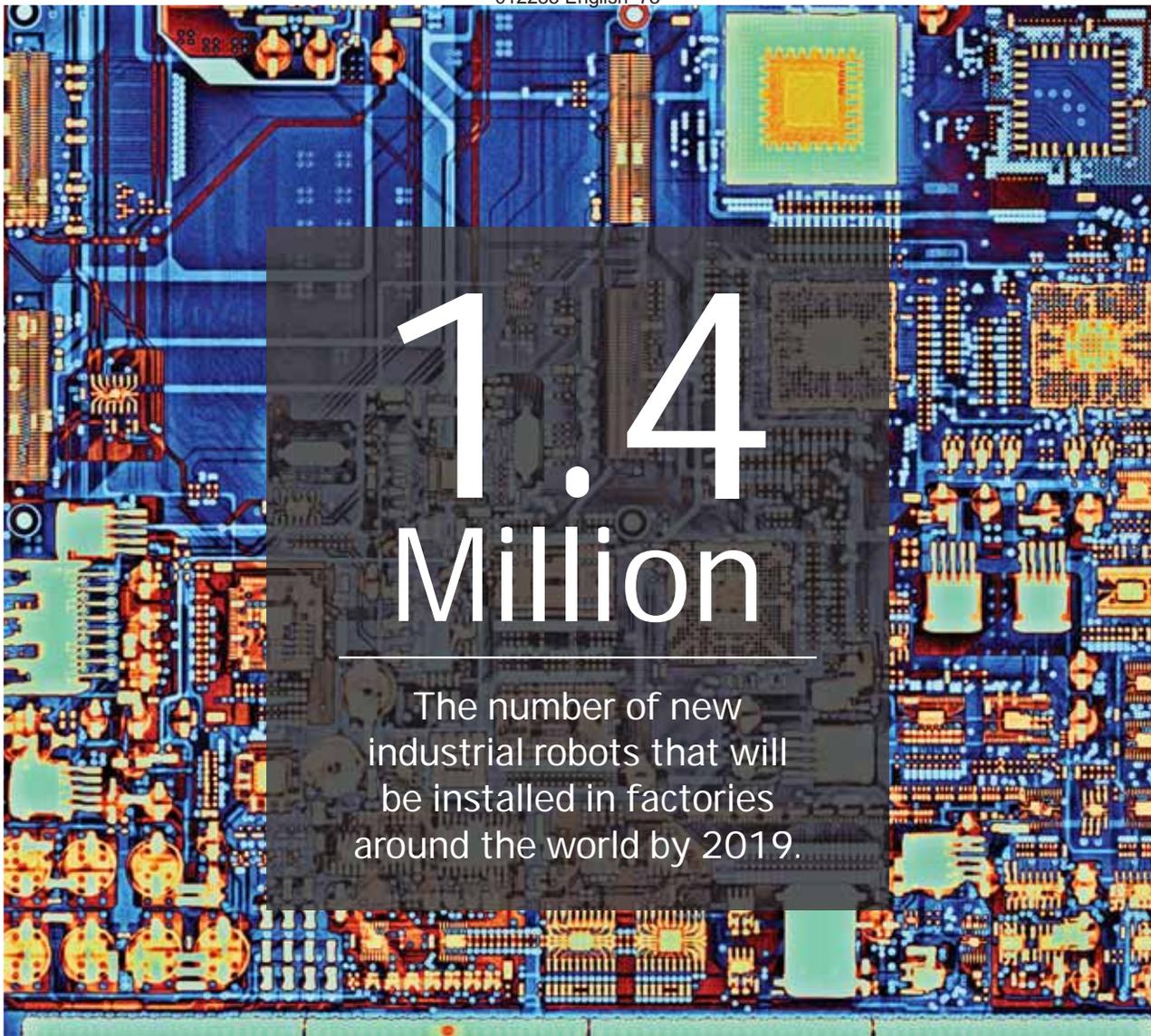
"Robots help a lot in situations of hardship, situations of disaster recovery, situations of difficult access," says Amir Benifatemi. For example, robots helped repair the Fukushima disaster site, and in the future, experts could use robots to fix broken machinery or free trapped people – all without risking rescue workers' lives. We will still need rescue workers in the future, but those workers will need to be trained to properly use the advanced robotics technology at their disposal.

As this shows, fears about job losses associated with advancing robot technology might be better aimed at how robotics are changing jobs rather than replacing them. Governments can help by providing retraining for people to take on tasks that complement those that can be automated.

We cannot deploy robots, however, without upgrading infrastructure to accommodate them. The hallways of hospitals and hotels

are crowded and unpredictable, so robots will need advanced obstacle recognition capabilities to move around safely without endangering the lives of patients, staff or visitors. If we plan to put cleaning robots on the road, special hours or lanes for cleaning may be necessary. Urban centers will also need to include facilities for storing, charging and repairing robotic workers.

Today, most individuals would be reluctant to put their health and safety, or even just the safety of their possessions, in the hands of a machine. Some of this fear can be overcome by ensuring that people have ready access to information about the safety testing of each product, and this testing will need to be carefully regulated. But some of this fear is about handing over control to non-human systems. It's likely this basic human response will affect the success of some robotic systems over others.



1.4 Million

The number of new industrial robots that will be installed in factories around the world by 2019.

Once we put aside our fear of robots, their benefit will be tremendous: hardship, disaster recovery, care, transportation....

Amir Benifatemi

Technology

A New Kind of Intelligence

Machine learning algorithms build their own models of the world from the data they are given. The blueprint for this kind of intelligent system has been around since the 1960s. In the last few years, access to large amounts of data and cheap computing power has led to a surge in real world applications --from speech recognition to interpreting medical scans. But synthetic intelligence could do far more than revolutionize how we govern our cities--it could leave humanity in the dust.



In the coming decades, advances in quantum computing will increase the speed and security of communications, calculations and predictions made by machines. Coupled with advances in machine learning, computers will be able to analyze information and make decisions at a pace that we cannot imagine.

The impact of this will be widespread. For example, AI and machine learning could save the medical sector billions of dollars annually by efficiently processing complex data sets during clinical trials and R&D.

From energy use to waste management, most of the systems running our city infrastructure could be parsed and managed

by computers in the coming decades.

Predictive text will allow robots to rewrite press releases as news reports. The routine work of paralegals and junior academics will change, as computers will quickly hunt down relevant case law or reference papers within huge databases. Call center agents and fast-food workers will be replaced by customer-serving robots, and traditional classroom tasks, such as grading papers and other assessments, will be outsourced to AI.

"The intelligence that AI provides to software or machines will surpass our natural ability to understand certain issues," Amir Benifatemi argues. "AI will

have more memory and more processing capabilities, surpassing the average level of human intelligence.

Already, there are governmental efforts into the existential benefits and risks posed by advancing artificial intelligence. H.H. Sheikh Mohammed bin Rashid Al Maktoum, Vice-President and Prime Minister of the UAE and Ruler of Dubai, announced the UAE Strategy for Artificial Intelligence, an initiative within the UAE Centennial 2071 objectives, and appointed the first Minister of State for Artificial Intelligence. The US White House have formed their own task forces to develop legal frameworks to govern AI research and deployment.



"In 2016, we launched the first AI-powered city service in the Middle East in collaboration with Dubai Economy," notes His Excellency Wesam Al Abbas Lootah. This collaboration resulted in the creation of "RASHID", an IBM Watson-powered service that allows investors, entrepreneurs, and business owners to ask questions and get answers based on the latest real-time information. This works because the system is able to understand natural language, rapidly analyse and verify massive data stores, interpret data, and provide answers.

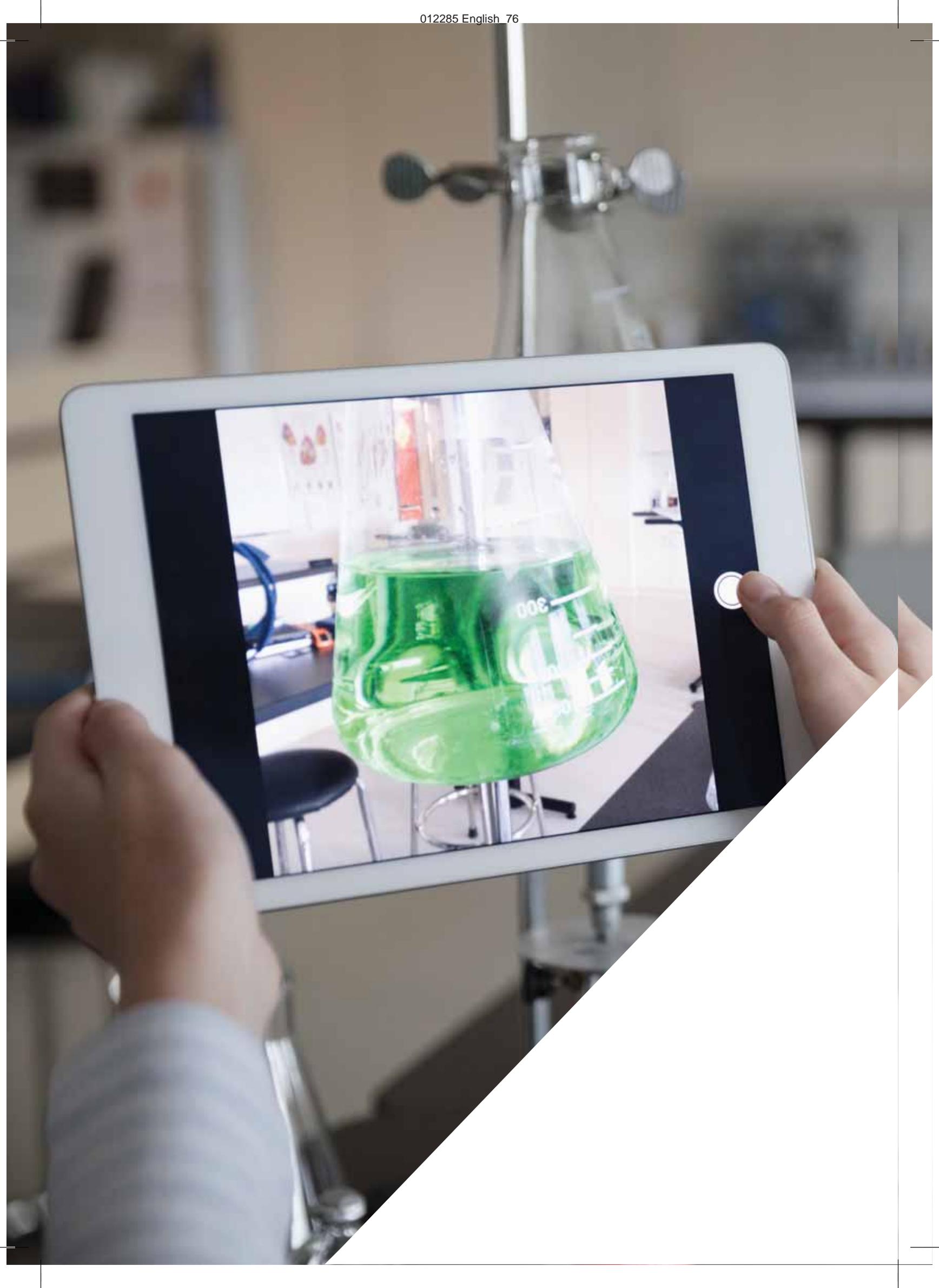
"RASHID" helps entrepreneurs by asking them: what kind of business do you want to start? What partners do you have? And

what kind of agreements do you already have? It helps to recommend the kind of legal entity they should set up and takes them all the way to the point where they can apply directly online to set up the company," His Excellency continues. In this respect, AI is already working to help industry, and in the coming years, improvements on these systems will take out a lot of the legwork in day-to-day work.

As with robotic developments, governments have a role to play in arming citizens with the skills and abilities that help them make the most of new synthetic intelligence. Machines can crunch the data while humans deal with concerns that cannot be readily analyzed by a computer. For

instance, a search algorithm can find relevant legal cases, but a human will determine the most effective way to present an argument to a jury.

Some tasks will prove difficult, if not impossible, for computers to replicate. Family ties, bonds of friendship, creativity – all of these are particular to the human experience, and elements of them can be utilized within the workforce. For some, synthetic intelligence could free them from repetitive labor and create a host of new, innovative opportunities.



Section VI

Education

For cities to thrive in the future, every citizen, especially those in our burgeoning youth populations, should benefit from good education. Fortunately, this will become easier as technology helps to provide bespoke learning programmes for individuals and many aspects of learning take place outside the classroom - virtually. There are also more disruptive changes on the horizon, from direct connections between the brain and computers to better understanding of how our environment affects human genetic condition and the capabilities we each have as a result.

SECTIONS

- I** **The Classroom Reimagined**
- II** **Teaching Rebooted**
- III** **Brains Wired for Education**
- IV** **Equalizing Intelligence**
- V** **A New Kind of Learning**

OUR EXPERTS

We returned to three commentators from our pool of experts to ask how changes in the education sector could affect cities in 20 or 30 years, summarising their response in a series of articles.

Reshma Patel

**Executive Director,
Impact Network**

Reshma Patel serves as the executive director of Impact Network to empower teachers across Zambia, providing them with daily lessons delivered through a tablet and projector. Impact Network serves over 2,100 students at a cost of only \$3 a month per student (a fraction of the cost of government schools).

Moshe Szyf

**Professor of Pharmacology and
Therapeutics, McGill University**

Moshe Szyf completed his postdoctoral fellowship in Genetics at Harvard Medical School and currently holds a James McGill Professorship and GlaxoSmithKline-CIHR Chair in Pharmacology. He is the founding co-director of the Sackler Institute for Epigenetics and Psychobiology at McGill.

Zach Sims

**Co-Founder and CEO,
Codecademy**

Zach Sims is the Co-Founder and CEO of Codecademy, which has taught millions of people how to program through its online portal. Ultimately, they hope to use their team to shape the online learning experience of the future.

Experts' highlights: **FUTURE FORESIGHTS**

Education

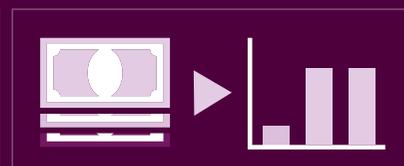
THE WORLD TODAY



CodeAcademy had 25 million active users as of January 2016.

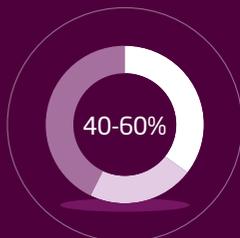


Over **58 million** students use massively open online courses (MOOCs) instead of traditional classrooms.



Salaries and benefits normally make up 80 percent of a school's expenses.

THE REALITY TOMORROW



By 2030, 40 to 60 percent of all jobs will be replaced by automation, a change that will dramatically reduce how much of a school's budget is devoted to staffing.



Virtual reality will take the place of class trips and replace many traditional classrooms.



Education action plans will ensure that all people are functionally literate by 2030.

BUILDING THE FUTURE



Virtual reality will be a requirement in tomorrow's classrooms to give students world-class education, which will require forming in-depth partnerships with private sector companies innovating in virtual reality and connecting them with school boards to ensure technologies are deployed and implemented effectively.



More artificial intelligence investment is required to predict students' learning needs, make changes to curricula in real-time, and to better prepare AI systems to takeover traditional forms of assessment.



Many jobs in the future will be replaced by automation. Combating this problem requires teaching students automation-proof skills (tailored to specific needs and circumstances), exposing students to multiple cultures and ideas, and fostering lifelong learning by teaching that is centered around curiosity, problem solving, and creativity.



"[We] must make sure that people aren't reticent to use technology and that, within a school district, there are people who are responsible for promoting these new technologies." - Zach Sims, Co-Founder and CEO, Codecademy



Education

The Classroom: Reimagined

Virtual reality can help students to step inside an organism, rather than read about it on a page. Augmented reality and holographic technology could open new frontiers in distance learning, allowing students to “see” each other and the teacher in virtual classrooms.

The classrooms of today are already undergoing a transformation. Recent research has revealed that self-directed learning is more effective than simply listening to a lecture or reading information from a textbook. Innovative educators are employing a “flipped classroom” model. This approach to education is focused on reducing (or even eliminating entirely) the time that a teacher stands at the front of the class and lectures the group. Instead, the students are asked to learn

facts through video tutorials at home and classroom sessions are used to for group activities aimed at developing problem solving skills.

In the future, these new models could go beyond asking students to think critically and solve problems. Teachers will also encourage their pupils to explore new worlds.

Reshma Patel, Executive Director of

Impact Network, recently created a virtual reality experience to “transport” learners to Zambia. This work allows people to do more than just learn facts and figures about a location; it enabled them to walk in someone else’s shoes. In the coming decades, she expects that virtual reality will become ubiquitous in our classrooms, ushering in a new age in understanding and critical thought. She says that such advances “will foster real understanding of where people that are different from you

come from" and ultimately "give students a better understanding of life without any of them ever having to leave their desks or maybe even their homes".

Moshe Szyf agrees, predicting that students in the most forward-thinking classrooms 20 years from now "will be faced with tasks and real learning experiences, instead of having information regurgitated to them by their teacher."

Ultimately, we will need to determine how to best prepare students and teachers to meet these changes. "We are now on the cusp of exponential change. The majority of children starting school today will go on to work in jobs that don't yet exist," said Hind Al Mualla, Chief of Creativity, Happiness and Innovation, Knowledge and Human Development Authority. "The way we understand work and learning will be different, as will be the ways we interact with each other. Understanding how education will fit into these changes, and then responding to them, is going to be the greatest challenge for educators and policy-makers in the coming years."

Today's governments can lay the groundwork for these classrooms by investing in more in-depth partnerships

with virtual reality companies. They should also implement software in the classroom in consultation with individual school boards. This will help tomorrow's teachers understand which technologies and experiences are most effective.

Zach Sims, the Co-Founder and CEO of Codecademy, says that the first step to guaranteeing that new technologies are successfully incorporated into the classroom is ensuring that "there's sufficient budget to make all of the necessary tools available": making sure the transition to a "technologically upgraded classrooms" is complete rather than partial.

The second step to integrating these new technologies, according to Sims, is ensuring that both parents and students understand their value. He says that governments "must make sure that people aren't reticent to using technology and that, within a school district, there are people who are responsible for promoting these new technologies".

As virtual reality becomes more present in our education system, it will also open up the possibility of remote learning. Students and teachers could put on headsets and be transported to a classroom anywhere in

the world – a classroom in which they see avatars of their classmates and teachers next to them even though they may be hundreds or thousands of miles away. This transition could save a significant amount of money, as it would make school buildings and student transportation services unnecessary. However, before reaching this point, there needs to be research into the impact remote learning will have on students.

Virtual reality could allow students to experience a new kind of classroom – one where they learn through exploration and discovery, where they see information instead of simply hearing about it, where they are challenged, where they are given the opportunity to solve the problems that they see before them. The potential benefits and novel risks of this kind of education require research and investigation today.



Education

Teaching Rebooted

In the world of tomorrow, a new kind of teacher will enter the arena – one with synthetic intelligence and armed with advanced forms of assessment and custom software that allow us to create a specific curriculum for each and every child.

Today, students greatly outnumber teachers. As a result, most schools have adopted a “one size fits all” approach to education. Regardless of what proclivities individual students may have, everyone in the classroom is taught the same thing at the same pace – we simply don’t have enough teachers to ensure that each learner has a curriculum that is tailored to their needs. However, in 20 years time, artificially intelligent teachers will rule our schools, and there will be millions of them.

“Everyone is on the same track, but the future will be defined by personalizing education to different types of student needs,” Zach Sims asserts. Thanks to these new artificial intelligences, he continues, “students will have an experience that is much more tailored to them to make sure that we can avoid holes in their education.”

To this end, an artificial intelligence backed by machine learning can make predictions about students’ learning needs, foreseeing

and anticipating areas of difficulty and enacting changes to their curriculum in real-time in order to ensure that each student has the resources and training needed to complete assignments and acquire the necessary knowledge.

In short, an AI teacher can pace itself with the students’ needs. For example, “you might see a question that comes up depending on how you answer a previous question,” says Reshma Patel. “If the

student is struggling to answer, the AI can suggest more systems or tutoring platforms to help out, and if the student is answering very quickly, the AI can skip ahead a little and then test the student's skills on a more advanced topic."

While we don't yet have millions of AI educators, the role of the teacher is already undergoing a shift.

A large part of a traditional teacher's job is presenting students with factual information, such as historical dates, mathematical formulas, and other concrete skills that can be learned through memorization. In recent years, as the internet made this information more accessible to students, the role of the teacher began to shift toward helping students learn the best ways to locate and evaluate information. However, as research into artificial intelligence continues to advance, AI will eventually be able to seek out information, evaluate it, and provide the most relevant bits to us all by itself, making

the roles of both teacher and student subject to change once again.

Will human teachers have a place in the coming decades? Can we ensure that an entire profession doesn't disappear due to advances in AI and automation?

Patel asserts that the world will still need human teachers, but that their focus will be on teaching "life skills" and helping to motivate students. Instead of imparting factual information, they will be teaching students about things like creating community ties and managing resources effectively in an increasingly environmentally strained world. Human teachers will focus more on teaching critical thinking, objective analysis, and how to synthesize and evaluate information related to topics that may not have an objective answer, such as philosophy and the arts.

Essentially, tomorrow's teachers will be tasked with ensuring that students have a "growth mindset" in which a shortcoming is

seen simply as a setback that will require the student to pursue a creative solution.

As such, school boards must ensure that teachers are trained in how to supplement the information taught by AI with "real-life information." This means that those in charge of developing the national curriculum will need to interact with companies creating AI-focused educational technologies in order to determine where machine learning and AI fall short and how human teachers can best fill in the gaps. For example, a traditional "job skills" course would teach students how to write a solid resume. AI and job simulations could help students figure out that information by themselves. Teachers, however, can speak to the real-life experiences of recruiters tasked with finding the perfect candidate.

AI won't really be replacing humans in the classroom, but more so augmenting teacher/student interactions and making them more meaningful, and ultimately beneficial, to the humans that are involved.

Zach Sims

Education

Brains Wired for Education

What could you accomplish if you could type or “speak” with your brain waves? What could you achieve if you could upload entire languages or add and remove memories at will? Tomorrow, brain-computer interfaces will allow students to learn at an unprecedented pace and in ways that, today, seem like science fiction.

Direct brain-computer interfaces (BCIs) sound like something out of a fantasy story, but over the past year, some of the world’s most renowned innovators – including Elon Musk, Bryan Johnson, and Mark Zuckerberg – have announced initiatives aimed at bringing BCIs to the commercial market. In the coming decades, the impact that BCIs

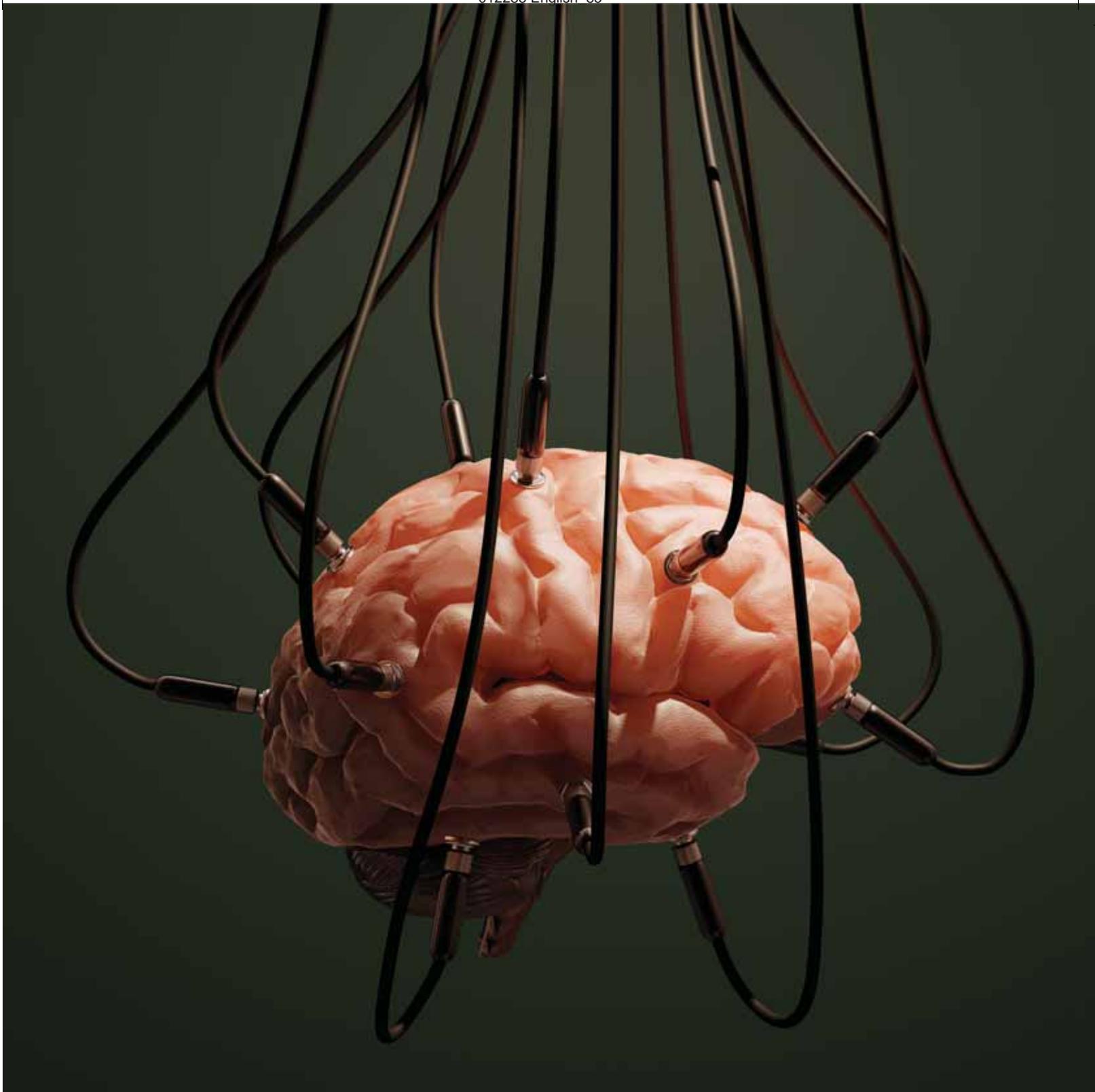
have on education could be astounding. Eventually, the technology could allow individuals to upload knowledge directly to their brain..

The first step to this remarkably advanced technology is a better understanding of how the brain functions. Investing in

neuroscience research could also reveal facts about the human brain that could, in themselves, revolutionize education. For example, we may discover how to stimulate the states that are most conducive to learning and uncover new information related to prolonging memory retention.

100

Number of words per minute
Facebook’s Brain Computer Interface will let users “type” using just their thoughts.



Governments can do more than just invest in research – they can ensure that education experts are involved in discussions about how to use the research from an early stage, as well as providing support for testing ideas that come out of those discussions.

Beyond this there is a role for government in supporting public engagement with this new technology. Exposing the public to each incremental advance as it is made

could help individuals discuss fears and hopes for the technology and support adequate regulation.

Some of this regulation will need to cover equality of access to the technology. When realised, BCIs could create a new standard for human intelligence. If the tech is not distributed equally, it could potentially create separate classes of humans. Ultimately, new legislation will need to guarantee that breakthrough technology

is treated like other public utilities and all students and learners have equal access to it.

It could seem like advances in brain-computer interfaces could render our schools and our teachers entirely obsolete. Technology may one day allow us to upload information into our brains. But we will still need teachers who can help students appraise and understand the qualitative value of the information they receive.

Education

Equalizing Intelligence

Emerging research into epigenetic effects could help enhance the intellectual capabilities of tomorrow's students. Such advances will help us create a more equal playing field by changing the environment around someone in order to modify gene expression, improving how they develop and learn.

Advances in artificial intelligence only allow us to make interventions based on a student's behavior. In the future, genetic testing could help schools see which interventions are needed based on a student's genome, and notably, institutions will be able to predict issues before they arise.

Genetics is about far more than a code inherited from one's ancestors. Moshe Szyf explains that genes are not only activated biologically, but also by their surrounding environment; lifestyle and physical

environment can cause changes in gene expression, affecting body functions and behavior.

The study of how the environment triggers molecular changes in the human body is known as behavioral epigenetics, and it could help us understand how to create the best possible environment for students.

"As genetic research advances, it will give us guidance on what enrichments [environmental changes] are the most effective and what kind of enrichments could improve learning," Szyf notes. These

enrichments could include things as diverse as social experiences, toxicological exposures, nutrition, and hormones, just to name a few. Notably, the molecular changes brought on by these enrichments can influence us prenatally, postnatally, and in adulthood, and the specific impact that they have will vary depending upon the age of the individual during exposure.

A number of companies already specialize in DNA analysis, and they can provide individuals with a complete breakdown of their genetic code. However, clear



As genetic research advances, it will give us guidance on what enrichments [through environmental changes] are the most effective, and what kind of enrichments could improve learning.

Moshe Szyf

relationships between genetics and human abilities have not been easy to find. This science would need to advance much further before this area of educational research can develop.

To support gene-level research, there will also need to be a better understanding of how environment influences impact individuals. This begins with investing in research focused on an exhaustive understanding of how enrichments impact animal models. From there, researchers can determine if there is a correlation between those models and children or adults who have been subject to comparable

environmental enrichments.

If we are able to make some direct links between environmental factors and particular genes, then practical testing of how changing environment affects an individual's development will be possible.

Epigenetics is a new field and so what it will show, and what it will mean for human development and education, are not clear yet. It could revolutionise the sector. But it also comes with legitimate fears about privacy and equality of access to the technology. Scientific developments in the interpretation of genetic information

will need to come hand-in-hand with an advanced security infrastructure that will prevent the release of sensitive information and ensure access is granted only on a need-to-know basis. These technologies will make the greatest difference if they are developed to meet the needs of the greatest number of people. Exclusive, personal DNA-testing services already point to a future where this might not be the case.



Education

A New Kind of Learning

As automation continues to increase, the work that we do will undergo a massive transformation. Lifelong learning will become more important—keeping step with the changing demand in the labor market—and automation-proof skills will become more and more in demand.

For a generation now, the internet has opened up what was previously specialist information to wide audiences. Moshe Szyf says that the amount of medical knowledge that people have today compared to 20 years ago is astounding: "Technology not only allows people to access information, it gives them more accessible ways to evaluate information."

This technology has already changed the way we work; in the U.S. demand for jobs including analytic but non-routine tasks - like software developers, designers and architects - have increased much more than jobs that require more basic information retrieval and routine processes that computers can now take on.

"The purpose of education is to 'bring out from within' - that is, for each child to have access to the skills and knowledge that will enable them to be the best they can be," said Hind Al Mualla. "This relies on cooperation and trust between all those involved in educating a child - parents, teachers, policy makers, the wider community, and of course children themselves - and would go far beyond

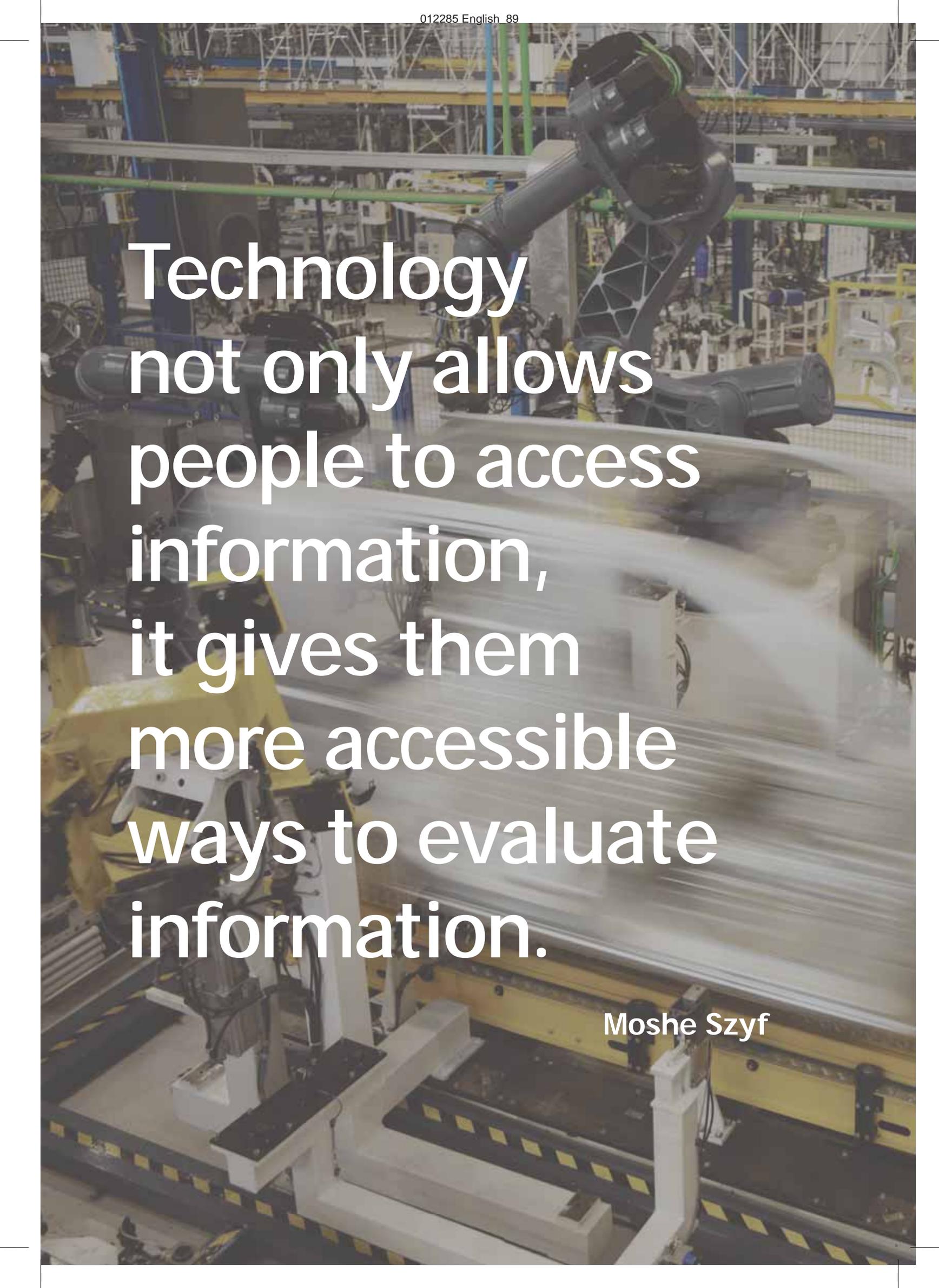
academic achievement as a measure of success. An ideal education would first recognise each child's individual talents and abilities, and bring the whole education community together to help bring out the best from within."

Zach Sims argues that today's students should be learning skills that cannot be easily reproduced by automated systems. For example, although it is possible to automate the technical work that is currently done by nurses, a large part of their job is providing comfort to those in their care. A robot, by its very nature, cannot possess these "humanitarian" skills. Other jobs that cannot be easily overtaken by robots and automation include those focused on providing specialized advice tailored to specific needs and circumstances. Such positions include things like social workers, nutritionists, legal counselors, and dental hygienists. By ensuring that individuals are learning these skills, governments and educational boards can guarantee that today's students will have work tomorrow.

Reshma Patel adds that technology will

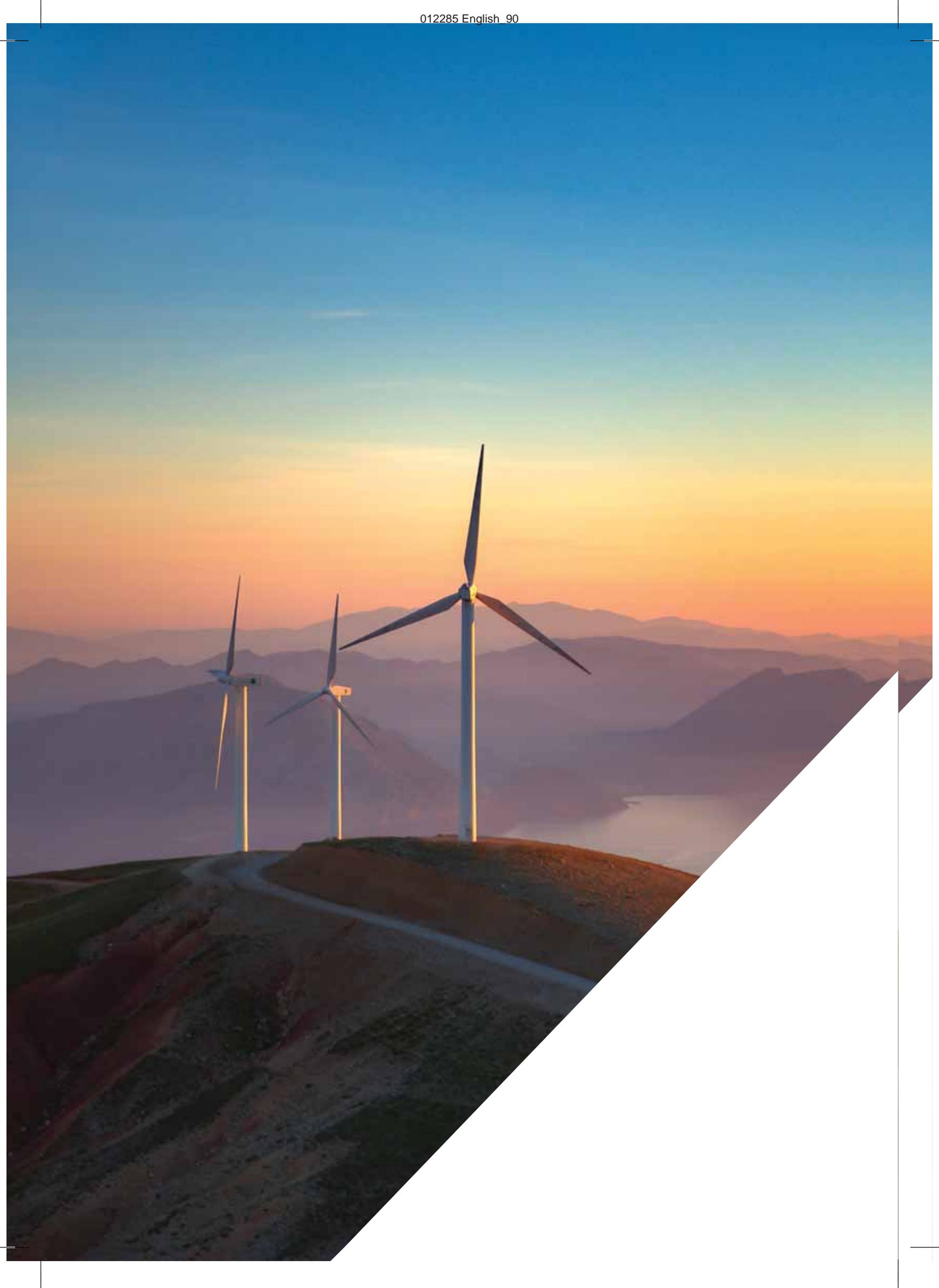
do more than just dictate the things that we need to learn — it will influence which things we want to learn. "I really feel like, in 20 years, our understanding of the world is going to change drastically," she says, asserting that people will be exposed to more of the world than ever before thanks to advances in technology. As a result of regular exposures to other cultures and novel ideas, we will likely be motivated to investigate a number of things we never considered previously. She says that this will help people "become curious about the world and find out more about the world," ultimately leading us into a new age in "creative energy".

Patel states that this creative energy will encourage people to become lifelong learners, driving their curiosity and, subsequently, their desire to know and understand. To this end, opportunities to learn from the very best institutions will increase, as platforms such as Coursera, TedX, and Codecademy already offer individuals a world-class education over the internet cheaply or even for free.



Technology
not only allows
people to access
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ways to evaluate
information.

Moshe Szyf



Section VII

Renewables

To avoid further increases in global average temperatures, cities in 20 years time will need to maximise their use of existing renewable energy solutions, as well as find new alternatives for generating energy and managing its use. Decades of work in nuclear fusion, coal pollution mitigation, and novel kinetic (movement) and solar energy-generation are likely to be part of the solution. These sustainable generation methods – together with innovative ideas such as carbon capture – will help us grow our urban centres without risking the stability of the global climate.

SECTIONS

- I** **Optimizing Energy**
- II** **Harnessing Energy From Everything**
- III** **Capturing Carbon**
- IV** **Plasma Power**
- V** **Harnessing Energy From Space**

OUR EXPERTS

We returned to three commentators from our pool of experts to ask how changes in the energy sector could affect cities in 20 or 30 years time, summarising their response in a series of articles.

Laurence Kemball-Cook

CEO, Pavegen

Laurence Kemball-Cook is the founder and CEO of Pavegen, a clean-tech company that has pioneered a technology that generates electricity from kinetic energy. His TEDx talk was featured amongst TED's top talks on envisioning the cities of the future and changing attitudes toward fossil fuels.

Jules Kortenhorst

Chief Executive Officer, Rocky Mountain Institute

Jules Kortenhorst works with the Rocky Mountain Institute to conduct research and analysis that helps businesses and communities shift from fossil fuels to efficiency and renewables. Kortenhorst was the founding CEO of the European Climate Foundation and currently serves on the Energy Transition Commission and the World Economic Forum Future Council on Energy.

Senthil Balasubramanian

Co-Founder, Sistine Solar

Senthil Balasubramanian's co-founded Sistine Solar, a company that designs and installs solar systems. Previously, he worked with Astonfield Renewables, a startup utility-scale PV power plant developer, and helped raise \$15M to build one of India's earliest solar power plants under the country's National Solar Policy.

Experts' highlights: FUTURE FORESIGHTS

Renewables

THE WORLD TODAY



More than 90 percent of UAE's energy needs are met by natural gas.



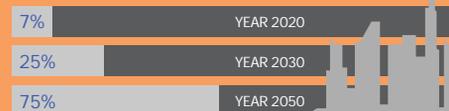
According to the World Health Organization, more than 3 million people die prematurely each year due to prolonged exposure to air pollution.



Newly installed capacity from renewable sources totaled 61.5 percent worldwide, surpassing that of natural gas, nuclear power, oil, and coal combined.

THE REALITY TOMORROW

■ The Dubai Clean Energy Strategy 2050 aims to provide 7% of Dubai's total power output from clean energy by 2020. This target will increase to 25% by 2030 and 75% by 2050.



■ Projections state that doubling the world's renewable energy capacity by 2030 could save the global economy between \$1.2 and \$4.2 trillion each year.



■ "Our reliance on sustainable energy is a guaranteed step towards a better future for us and for future generations." - Dr. Thani Al Zeyoudi, Minister of Climate Change and Environment.



BUILDING THE FUTURE



The first step to optimizing energy includes doing an energy audit of older buildings and integrating renewable technologies in these locations, where possible. Incremental upgrades to infrastructure will ultimately prepare cities for more sweeping, energy related technological changes down the road.



Reducing carbon emissions is predicated on encouraging businesses to shift to renewables; however, commercial carbon capture plants will need to be installed in order to prevent future damage to the biosphere and help to draw existing CO₂ out of the air. City planners should consider grants or other incentives that can be given to companies for including carbon capture into their technology or infrastructure.



One major barrier to solar power is the panels not receiving enough sunlight on their surfaces. This can be overcome by incorporating panels into a variety of buildings and surfaces, from roofs to transparent solar panels that function as windows on homes and businesses.



Renewables

Optimizing Energy

We waste a vast amount of the energy that we produce. In the world of tomorrow, advanced computer technologies will monitor how we use energy and allocate resources across the grid, while smarter city planning will allow us to eliminate waste and usher in a new age of sustainability.

Today's cities use an incredible amount of energy for electricity, heating, air conditioning, and even personal transportation. While alternative technologies, such as wind and solar, are becoming more widely adopted, the rapid increase in urban population will require that we think bigger and approach city construction (or reconstruction) in entirely new ways.

Not only do today's cities waste enormous

amounts of power by lighting or heating areas without any people, cities around the globe are often hampered by older, inefficient infrastructure. The best way to begin upgrading older neighborhoods is to first understand the amount of energy being consumed. This will require a thorough analysis of where energy is needed and where it goes. With this information, cities can start to reduce this waste, for example, by reducing an area's lighting or heating and cooling during off-

peak hours.

Jules Kortenhorst recommends integrating renewable technologies, such as solar power and, in flatter areas, wind power, in older buildings as they can be accommodated by existing systems without much disruption. Kortenhorst argues that such developments are the future of the most innovative cities: "We already see that emerging in the next decade in Europe, and we will see this emerging in developing

countries, such as China and India, as they build up their cities.”

Already, a number of cities around the world are beginning to incorporate similar advanced technologies into their systems in order to reduce waste. For example, the Dubai Energy and Water Authority uses the Microsoft HoloLens to give a real-time, 3-D view of data in their plants. This also provides the opportunity for remote expert assistance and maintenance of the plants.

“DEWA’s core mission is to provide people in Dubai with a continuous and reliable supply of energy and water,” notes His Excellency Saeed Mohammed Al Tayer, Managing Director & CEO, DEWA. He

continues by emphasizing the importance of innovation in solving the problems of today in the cities of tomorrow: “DEWA works on developing its processes by adopting state-of-the-art technologies in all fields. DEWA seeks to take the lead by adopting innovative ideas and solutions, to sustain its position as a role model for other local, regional and international entities in technological development and digital transformation.”

In the long term, advanced artificial intelligence systems can be put in place to monitor buildings, block by block and floor by floor, and allocate energy as needed based on predicted use. Cities can then make this information available to

individuals so that they can improve their own energy efficiency, saving both time and power on a smaller scale.

“In relation to the whole wearables movement, the more people can measure, the more they can take control of their health,” notes Senthil Balasubramanian. “Likewise, when it comes to optimizing energy, the more a homeowner in a city knows about where they are using energy and what devices are using energy, the more they are likely to question, ‘Is it really necessary for me to leave the AC on for the extra half hour?’”

Beyond this, the Internet of Things, coupled with artificial intelligence, can be used to

In future cities, we will control all devices using renewable energy, and we’ll make it far more efficient. Every street would know you’re walking down it, and the lights come on only if you’re there.

Laurence Kembball-Cook

implement innovative strategies for smart energy usage. For example, as Laurence Kembball-Cook notes, an AI-supported phone app could be used to control every streetlight in a city, saving energy and making cities safer. “Practical applications of that include accidents, where lights can automatically turn themselves much brighter. In other instances, systems can even switch the lights to pink, as pink lights have been proven to reduce the amount of street crime and fighting, especially after people have consumed alcohol.”

These solutions require highly skilled technicians, new hardware and expensive

computing power. But as advanced intelligence systems and renewable sources of energy continue to make their way to mass market, their costs will continue to decline.

Cities today use a number of strategies to decrease the amount of energy used for transportation, from bike lanes to electric car charging points, and supporting the increased use of public transportation.

Another way to reduce transportation energy usage is by designing neighborhoods around people rather than vehicles, says Kortzenhorst. This means

creating neighborhoods in which parking is not the dominant feature and walkways and bike paths connect various areas.

Pickup zones should be available at the city perimeter to support travel over longer distances, while the streets themselves are designed to be more accommodating to pedestrians. This would also reduce the number of car accidents and improve health through reduced pollution and increased exercise.



Renewables

Harnessing Energy From Everything

Wearable technology will enable tomorrow's citizens to generate energy from their bodies and movements, eliminating worries about our devices running out of power. Meanwhile, everything from our roads to our roofs will be used to harness solar and kinetic energy.

The most resilient cities in 20 to 30 years will need to harness energy from every source available to them. Jules Kortenhorst argues that a typical city of the future will harness energy from multiple sources, but the dominant one will be solar because it is abundant, ubiquitous, and cheap – every country in the world has access to it, although some obviously have more sunny days than others. Wind energy will also prove to be beneficial, with turbines positioned atop buildings and at the perimeters of cities.

Today, we think of solar and other forms of renewable energy primarily as a way to power buildings and houses. But companies are already thinking of ways to power our mobile devices using solar energy collected via our clothing or through a small, portable device. For example, Tommy Hilfiger has developed a line of jackets that come with solar panels that can charge a number of devices, and Kate Spade previously sold phone-charging handbags. In a similar way, instead of forcing us to find an electrical outlet every few hours, tablets could be

designed to harness solar energy, just as calculators once were, allowing for continuous use.

Convincing people to adopt portable energy sources, particularly when they attach to their body or clothes, could be a significant hurdle. Senthil Balasubramanian thinks we will be able to accomplish that through proper design and transportability: "Design holds a big key in achieving renewable energy use. The more you make it aesthetic, the more it captivates



people's emotions, not just their minds, and the technology will proliferate. Battery technology is also a big component. The moment you can truly have a fully off-grid solution, you are independent."

Solar and wind will remain the major players in future power generation, but in a city, people can generate energy all by themselves. A "smart road" could harness some of the kinetic energy of passing vehicles at a busy hub, powering a nearby streetlight or store sign. Alternatively, on an individual level, we could use the kinetic energy produced by movements as pedestrians walk down the sidewalk. As Pavegen's Laurence Kemball-Cook notes, to make this a reality, we simply need to invest in kinetic energy the same way that we invest in solar: "Solar has taken hundreds of billions in investment, millions of people have worked on solar panels—and what we're doing at Pavegen is really pioneering the area of kinetic energy." Kemball-Cook continues by outlining what fruits we stand to gain from such an investment, "in the future, when anyone builds a property, not only will they get something that looks like a normal floor and feels good, they will get one that provides energy to power the building." Other possible sources of power generation include the motion of revolving doors.

Ultimately, the key to managing the increasing energy demand of future cities is being open to any opportunity for energy generation, from something as simple as a flexible structure that moves in the wind or our own body heat.

Governments can support the adoption of these various energy-generation technologies in a number of ways beyond simply investing in solar and wind. Creating incubation hubs for energy-generation technologies would allow governments to identify missed opportunities for energy generation and capitalize them in partnership with companies already starting to develop these technologies. For example, the Dubai Future Accelerators is an intensive program established by the Dubai Future Foundation that seeks to solve some of today's most pressing problems by bringing together innovators and governing officials. As the website notes, the program uses "the city as a living testbed for creating solutions to the global challenges of tomorrow." DEWA works with the accelerator program to discover, and ultimately implement, new technologies that transform traditional models of generating, transmitting, and distributing water and electricity. Similar initiatives in other cities would vastly accelerate global solutions.

For the first time in human history, we have the opportunity for every individual to become a producer of energy.

Senthil Balasubramanian



Renewables

Capturing Carbon

Transitioning to renewables is the first step in addressing our climate issues, but to end global warming, we will need to remove the pollutants that we already put into the atmosphere. In the future, carbon capture will need to become a reality.

Nuclear, solar, wind, and other forms of energy do not produce the dangerous greenhouse gases that have been a fixture of our factories, buildings, and vehicles in the past, and they are quickly taking over. However, we still have decades worth of damage to undo.

To halt and reverse global warming, we are going to have to find a way to undo the mistakes of the past.

Some of the greenhouse gases in the atmosphere are there naturally; Earth needs a small amount of greenhouse gases to be a habitable planet. However, too many greenhouse gases have been pumped into the atmosphere too quickly, leading to extreme weather events and melting ice caps. Carbon dioxide (CO₂) capture and storage could be one of the most effective methods to remove these gases and restore that balance. It could also stabilize the concentration of greenhouse gases in the atmosphere more than 30 percent cheaper than other alternatives.

This year, the first commercial carbon capture plant went into operation near Zurich, Switzerland. The system draws CO₂ out of the air and compresses it. Climeworks, the Swiss company that developed it, plans to capture 1 percent of the carbon dioxide emissions emitted

worldwide by 2025.

The key to any carbon capture system is not simply storing the carbon, but using it. Climeworks has suggested it plans to transform the carbon it captures into products such as fertilizers or plastics. Meanwhile, at the Carbon XPrize test center in Wyoming, researchers are looking into ways to use captured carbon to create common materials such as concrete. By using the carbon they capture to make products that are needed for everyday life, cities can recoup the costs of building and maintaining their carbon capture plants.

Renewable thinking needn't be limited to renewable energy providers, either. A new generation of carbon capture mechanisms for power stations is being funded by the U.S. Department of Energy. These aim to reduce the cost and energy of removing carbon that would be otherwise pumped into the air by coal-fired electricity plants. These developments are still at an early stage, but if successful could further increase the U.S. government's motivation for transitioning from coal or gas to renewables.

In Australia, the government is looking to encourage more traditional energy providers to investigate carbon capture and storage. The government-backed Clean

Energy Finance Corp. currently provides loans to companies involved in renewable energy projects, such as solar or bioenergy. However, the government has indicated it could amend the corporation's policies if a coal- or gas-fired power plant wanted funding to build its own carbon capture system.

Critics of carbon storage note that the systems may produce unforeseen side effects. For example, storing carbon underground could harm local ecosystems. More funding for biological systems research and close collaboration with environmental scientists is needed to accurately determine the effects.



CO₂ capture and storage could reduce the cost of stabilizing the concentration of greenhouse gasses in the atmosphere by

30% or more.



Renewables

Plasma Power

Nuclear fusion has long promised us a limitless, clean source of energy. If incorporated into our future cities, it will utterly transform our world, bringing an end to many of the things threatening our continued existence on this planet.

Nuclear fusion is a pure, atomic release of energy. It occurs when two nuclei of atoms come together and form a heavier nucleus, releasing a massive amount of energy in the process. This fusion happens all the time in the Sun, and soon humans could make it possible on Earth.

Fusion doesn't come with any of the harmful radiation produced by current nuclear fission plants. But engineering challenges have, for a long time, delayed the development of fusion energy.

The problem largely rests on the amount of heat that is required for sustained nuclear fusion. For fusion to work, scientists need to heat a hydrogen atom to hundreds of

millions of degrees. Strong magnetic fields or high-powered lasers are required to confine the plasma that is created within a controlled region where fusion can happen. Ultimately, fusion technologies cost billions of dollars, requiring large collaborations often with multiple nations involved.

Because of the scale of the research involved, continuous investment in nuclear fusion over many decades will be necessary to deliver viable new energy systems. That payoff may be coming in the next few decades. Construction of the International Thermonuclear Experimental Reactor currently being built in southern France is expected to finish in 2021. The goal of that reactor is to produce roughly 10 times

the amount of energy it consumes, which would be a first among fusion processes. Other nations have come together to work on similar projects, which mostly aim to complete in the 2020s and 2030s.

There are shared challenges that all global efforts will face over the coming decades. For example, we need to find ways to make fusion possible on an industrial level, learn how to sustain plasma for an extended period, and experiment with new designs to determine if there are more effective and economical ways of creating and maintaining plasma. Each of these issues will take decades of work to overcome, so researchers will need to work collaboratively to find solutions.

People have been talking about fusion for 20 years, but I think the next 10 years are going to be the most transformative in that kind of journey.

Laurence Kemball-Cook

Renewables

Harnessing Energy From Space

Solar power depends entirely on weather conditions. However, future cities will be able to overcome issues that stem from cloud coverage by installing solar panels on the Moon and harvesting power from space-based orbiting tech.

Solar appears poised to be the dominant renewable technology of the future, but not all countries have equal access to it. For cities by the world's oceans, such as Seattle, cloudy days can outnumber sunny ones. Meanwhile, other locations, such as the north of Scotland, are often beset by stormy weather. However, we do have a way to help these more disadvantaged locations receive solar energy, and it involves beaming it down from space.

Above the Earth's atmosphere, there are a multitude of nearby locations that offer opportunity for solar generation. For example, we could construct a space station that harvests solar power to send back to Earth, although a network of stations would produce a better supply.

The Moon's flat planes would be ideal for arrays of solar panels. The Moon receives

full sunlight 24 hours a day for about half of every month, and with one side permanently facing the Earth, beaming energy from the Moon to our planet is a viable possibility.

After solar energy is collected on the Moon, it could be beamed back to Earth via microwaves, which are harmless to our planet's lifeforms. These microwaves can penetrate clouds, making it possible to deliver the energy to even the most overcast locations.

In 2016, Justin Lewis-Weber, published a paper about a smart solution for building these panels. Instead of sending humans to do it, which would be expensive, robots could assemble the panels. The more-advanced space companies are already thinking of ways to use resources found in the local environment to decrease costs.

The Moon's regolith could be used as a strut material for the solar panels, for example.

Of course, solutions exist that do not necessarily involve going all the way to space. Senthil Balasubramanian suggests that advanced means of weather pattern prediction – based on satellite data from space or drone technology from high altitudes, coupled with artificial intelligence – could improve the efficiency of technology that harvests solar energy from Earth's surface.

"The first step that we need to take is to get an estimate of how much energy our system can generate, and a lot of that is dependent on historical weather in a particular location. The more accurate that weather data can be, the more accurate our estimates are," Balasubramanian notes. "When you think about everything that's

Some variants of solar arrays
could see as much as

1 GW

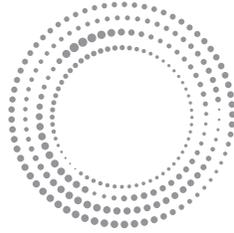
of energy beamed to receivers on
Earth – enough to power a larger city.

happening in drone technology, where they can gather very precise data that can be used to model weather behavior in the future, that's going to support the solar industry as a whole," he adds.

Solar energy will also help us explore the solar system. Laurence Kemball-Cook says solar will be an inevitable part of this future: "With companies like SpaceX exploring the furthest depths of our galaxy, we will be pioneering new forms of renewables – we'll be doing that until the day we die. These astronauts will need these capabilities to survive. We'll need extra budget and the determination of technical teams around the world to make this kind of stuff happen."



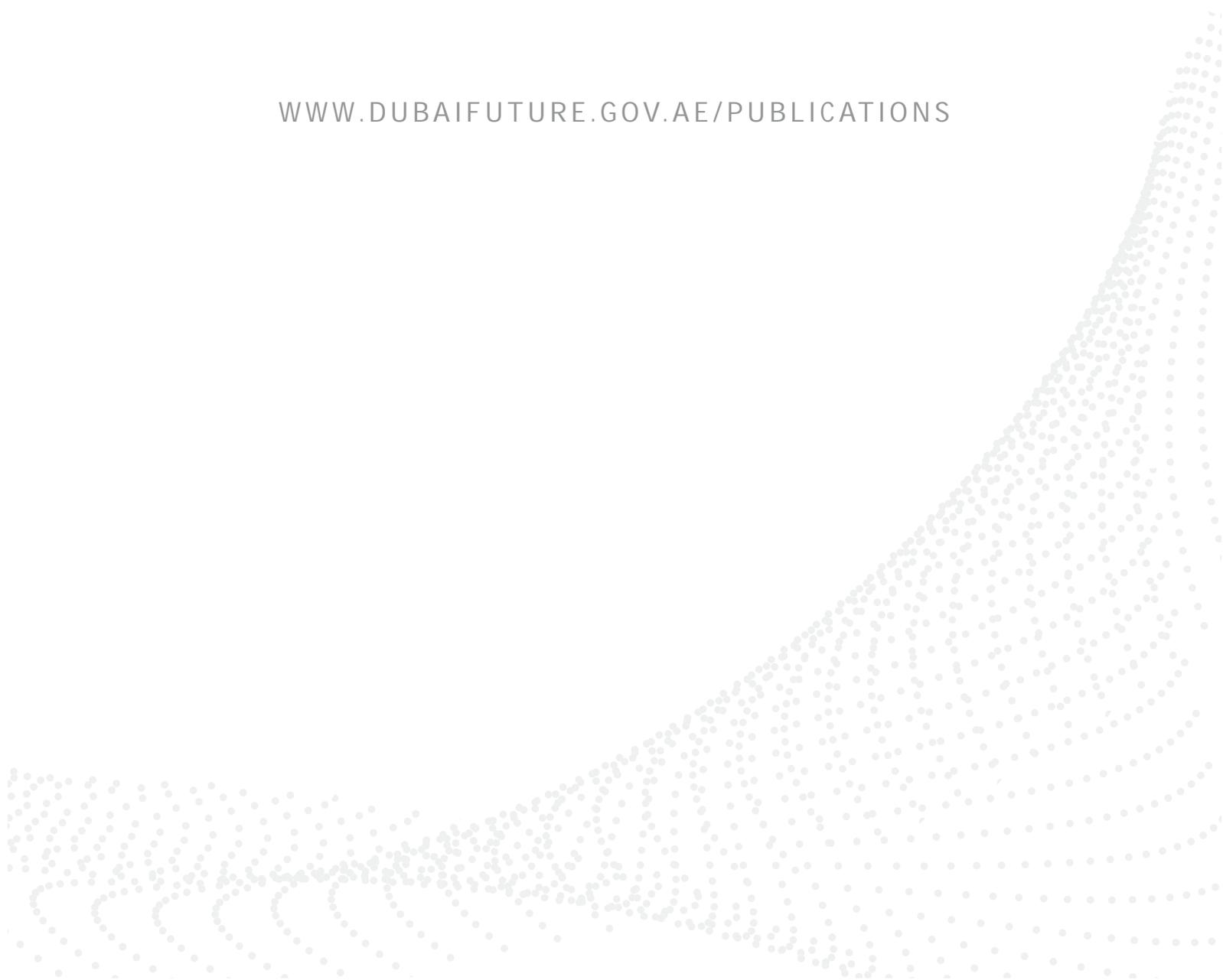
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