MEGATECH

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TECHNOLOGY IN 2050

edited by

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Introduction: meet megatech

Daniel Franklin

THIS BOOK IS BASED ON the idea that it can be useful to consider the long view. Setting our sights on 2050 is an invitation to identify the fundamental forces likely to shape the world between now and then. This volume's predecessor, *Megachange: The World in 2050*, published in 2012, provided an overview of such trends, from demography and religion to the economy and culture. Here the focus is narrower – on technology alone – but *Megatech* still ranges widely. For technology influences pretty much everything.

Clearly, it is impossible to know for sure what the technologies of 2050 will be, just as, 30 years ago, nobody could have envisaged today's world of Apple, Amazon, Facebook and Google. However, it is interesting and mind-stretching to make educated guesses. To do so, *Megatech* draws on the expertise of scientists, entrepreneurs, academics and sci-fi writers, as well as journalists from *The Economist*. The result is a rich variety of perspectives on how technology will evolve and affect us in the decades ahead.

Tools and platforms

We start with the basics. The first six chapters, in Part 1, address fundamental questions about the future of technology and what is likely to drive or constrain change. Where should we look for signs of what lies ahead? What will advances in science – physics and biology, in particular – make possible, and where might technology bump up against limits? How do investors spot emerging technologies and where are they putting their money now? Will change really be as fast and dramatic as is commonly supposed, or will it pale by comparison with the technology revolution of the last century?

To set about predicting the tech future, it helps to have a toolkit. Tom Standage provides one. He suggests that clues can be found in the patterns of the past, in the "edge cases" of the present and in the "imagined futures" of science fiction. He then tests these tools on four promising areas: virtual reality, self-driving cars, private spaceflight and gene editing. These examples suggest that a fertile period for discovery lies ahead (two science-fiction writers have dubbed the coming period of rapid change "the Accelerando"), which could echo the scientific revolution of the mid-17th century.

Advances in science make an Accelerando seem plausible. In his masterful overview of the state of fundamental physics (many readers will find themselves wishing the subject had been explained so clearly when they were at school), Frank Wilczek makes a striking claim:

> *We have, today, accurate, complete equations adequate to provide the foundation of nuclear physics, materials science, chemistry and all plausible forms of engineering.*

As a result, calculation can increasingly replace experimentation in developing technology, allowing far faster progress. This offers "brilliant opportunities for creativity in the service of human ends", and opens up "inspiring prospects for achieving new levels of material wealth and spiritual enrichment". Yet it also presents profound perils (or "failure modes"), the most worrying being nuclear war, ecological collapse and artificial-intelligence warfare.

If physics has reached a creative level of maturity, biology bubbles with youthful excitement. In the decades to 2050 we will learn how all the parts and systems underlying life fit together, predicts Robert Carlson. The sorts of things we can expect in the years to come include our brains being plugged into the internet and our used body parts being swapped out for new ones. All this will raise searching ethical questions. Meanwhile whole industries (from food to pharmaceuticals) will be transformed by bioengineering, as it becomes a platform to "build just about anything we see in nature", and much more besides.

Behind biotechnology's formidable potential lies the "hyper-exponential" increase in the productivity of DNA sequencing. A decade ago *The Economist* called this soaring efficiency "Carlson's curve", comparing it to a similar relentless improvement in microchips, known

as "Moore's law", which has driven digital development. But Moore's law is running out of steam. Does this mean that the massive demands for computing power – needed to do many of the wondrous things described elsewhere in this book – will bump up against physical limits in future? The short answer, according to Tim Cross, is: probably not. Other technologies will come to the rescue. Progress will be less regular and predictable without the "master metronome" of Moore's law, but a combination of 3D chips, quantum computers and having more of the processing work done in big data centres (hidden away in the "cloud") will enable the computing revolution to continue.

It will take the form of a succession of technology "waves", judging from the experience of recent decades. Half a dozen such waves have rolled in since the 1950s, from the early mainframes to today's smart machines and the "internet of things". In each wave a crowd of companies emerge, but only a few make it to the shore. And each successive wave is stronger than the last, boosted by the force of its predecessors. Silicon Valley investors are already riding the newest (seventh) wave, still in the early stages of formation: it carries artificial-intelligence (AI) companies. Early-stage venture capitalists began investing in AI around 2010, and billions of dollars are now pouring into firms developing AI software tools and applications. Ann Winblad reckons that "a rapid, virtuous and competitive cycle of innovation has picked up invisible momentum as the seventh wave builds". Its force will be felt in the decades ahead.

Yet how big will the impact of AI and other new technologies really be? An American economist, Robert Gordon, is among those who argue that the digital revolution, however impressive, has relatively limited transformative potential when compared with the great innovations of the second half of the 19th century. Electricity, cars, indoor plumbing and modern medicine powered a century of rapid productivity growth; today, despite the spread of the internet, smartphones, apps and bots, productivity and pay are rising at disappointingly slow rates. If anything, technology is contributing to inequality and fuelling frustration. As Ryan Avent explains, however, there is a strong case for greater optimism about the decades ahead. Learning to make the most of new technologies takes time; that was equally true of electrification (indeed, the pattern of labour-productivity growth in

the information-technology era is remarkably similar so far to that seen in the electrification age). As with previous tech-driven spurts in economic growth, tomorrow's advances will come in new ways that are hard to imagine now. That is not to say the rapid change ahead will be easy to cope with. On the contrary, it will be difficult and disruptive – something the later chapters of this book grapple with in more depth.

Industrial revolutions

First, though, we look in Part 2 at the transformation technology will bring about in a number of critical industries. Of these, none is more important than farming. How do you feed a planet of nearly 10 billion people by 2050? Comfortably, argues Geoffrey Carr, provided consumers accept the sorts of food-production techniques that will become possible in the not-so-distant future. Such techniques include the application to plants of precise gene-editing tools that could, for example, turbo-boost photosynthesis to make crops grow faster and dramatically improve yields. Urban fish farms could in effect bring the ocean inland and make fish the dominant source of animal protein. Unless, that is, it is outdone by mass production of animal products – steak, milk and eggs without shells should be on the menu – grown from cell culture, without any actual animals.

If there is no reason for the world to go hungry, there is every reason to expect it to be healthier. Health care has in the past been relatively slow to adopt new technology. Yet the pace of change is accelerating. Disruption will come from many areas, including AI, big data and ever-cheaper genome sequencing. The field will start to look very different. New apps and ever more sophisticated AI tools will do jobs once performed by doctors; "targeted therapies", aimed at specific molecules or cells, will dominate drug development; and whole new sub-industries will emerge, around regenerative medicine, for example, and data aggregation. But in one key respect, suggests Gianrico Farrugia, the result will look rather familiar: health care will more closely resemble other industries, with the patient seen as the customer.

The energy industry needs (for the planet's sake) to look less familiar in future, moving away from reliance on fuels that contribute to climate change. Anne Schukat expects to see a great shift away from fossil fuels

in the next decades, and a rapid rise of renewable sources of energy, especially solar and wind power, the costs of which are tumbling. Big improvements in battery technology will help: "distributed" storage of energy, in homes as well as businesses, will spread. The world used to worry about energy scarcity. But with the rise of renewables, and with "fracking" technology unlocking stores of oil and gas, the prospect instead is of energy abundance.

New materials will help to make manufacturing a lot more energy-efficient, too. As Paul Markillie points out, the way the BMW i3 electric car is "knitted" together using carbon fibre gives a glimpse of the future: production of the i3 uses 50% less energy and 70% less water than would be the case in a factory using traditional processes and materials. This is part of a materials revolution that includes, beyond carbon fibre, possibilities such as "smart" materials capable of remembering their shape and assembling themselves into components, and molecular-level manipulation to create bespoke substances and to change the way materials respond to light, electricity, water and heat. Clever new materials will also help the spread of "additive manufacturing", popularly known as 3D printing. As materials and processes become critical elements of firms' competitive advantage, a lot of the manufacturing that went offshore will come home, to be closer to customers.

New materials will also have military applications – giving soldiers lighter and more flexible armour, for example. And other technologies, including laser guns and military robots, will be on the march. The US still leads in the making of defence kit, but potential rivals are catching up. By mid-century, says Benjamin Sutherland, the West's monopoly on precision warfare may well be long gone. One hope for the West is that it can keep an edge thanks to a cultural advantage: the freedom of thought that may allow its soldiers to make more effective use of intelligence delivered via smart devices, such as "augmented reality" (AR) displays.

Yet such technologies will be spreading far and wide, anyway. They will, predicts Leo Mirani, change human behaviour even more than the advent of smartphones and the web has done. He describes a 2050 world in which AR glasses have replaced smartphones, conversations with people who speak other languages will be simultaneously translated,

and you need never forget a name as everything you know about a person will appear as you talk to them. He imagines technology moving ever closer to our bodies, and even inside them. As this happens, concerns about the amount of data collected about us, and what the companies that gather the information might do with it, will intensify.

Nigh society

By now it should be obvious that the social and policy implications of the technologies on the horizon are huge. This is the focus of the contributions in Part 3, starting with a mind-clearing look at an area that has drawn sombre warnings from the likes of Stephen Hawking and Elon Musk: artificial intelligence. Might ultra-intelligent machines pose an existential threat to the human race? Luciano Floridi argues that the machines won't be the problem, but the humans who create the environment for them could be.

Despite the pitfalls there is enormous scope for progress. In a data-driven world, Kenneth Cukier points out, things that are currently hard to do will become easier, things that are expensive will become cheaper and things that are scarce will become more abundant. So doctors will use big-data systems to help them make better decisions, teachers will use data to tailor the pace of instruction to individual students, lawyers will be able to find relevant evidence and precedents faster and more cheaply. These and other professions won't be swept away by technology – we may even want more doctors, teachers and lawyers, not fewer – but they will need to change their ways and learn new skills.

If the coming digital dynamics mean upheaval in developed economies, this is not the only way that technology can bring dramatic change. Just as significant, if not more so, is the spread to poorer countries of what is already common in rich ones. Melinda Gates imagines a world in which every woman has a smartphone. The effect – from health to farming and banking – would be transformational. And by 2050 it is surely possible.

This is one example of how technology could reduce inequality in the world. Adrian Wooldridge suggests others – making the case that, having been responsible for much of the rise in inequality in recent years, technology could in future help to reverse it. For instance, it

can help to detect and select talented youngsters regardless of social background, giving those who might otherwise languish a chance to shine. Whether in education and health, in tackling corruption or in making poorer neighbourhoods safer, it offers a powerful tool for policymakers.

With so much disruption on the horizon, worries are growing about what it will mean for the world of work. Will machines hollow out industries or create more employment? And will new jobs come fast enough to avoid mass misery for those displaced? Lynda Gratton identifies the questions that businesses and policymakers should be asking as they contemplate an uncertain future for work, and concludes that successful organisations will have adaptability at their core. This means creativity in designing career ladders, imagination in nurturing talent, flexibility in training and a fresh attitude to machines-as-partners: "what great feats can be accomplished by workers with their robotic co-workers?"

Imagination, remember, was (in the form of science fiction) part of Tom Standage's toolkit for looking at the tech future. So we include some "imagined futures" in these pages, inviting two sci-fi writers to contribute short stories set in 2050. Alastair Reynolds and Nancy Kress responded splendidly, bringing technological possibilities to life, along with the moral issues they raise. Their works of fiction feel remarkably real.

Risky bigness

Three strands run through *Megatech*, intertwining in intriguing ways from beginning to end. The first reflects the quality suggested by the title: a sense of bigness. The possibilities opened up by the technologies envisaged for 2050 are huge. It is hard not to feel excited about the extraordinary advances that will be within reach. Here is the tantalising prospect of a world where services are delivered faster, cheaper and better; where access to them is widened, reducing inequality; where food is abundant, energy cleaner and transport safer; where people are healthier and have more opportunities.

Yet a lot could go wrong, as Oliver Morton emphasises in his thought-provoking concluding chapter. There will be unintended

consequences, potentially dangerous disruption and misuse of technology's power. A wariness of the risks ahead is the second thread weaving its way through these chapters: megatech could become negatech. Frank Wilczek warns of "failure modes", others caution that policymakers will struggle to keep up with the questions posed by what technology makes possible, industry after industry faces upheaval – with all that implies for jobs and the lives of those that work in them. Luciano Floridi puts the pace of change pithily in perspective:

> *The agricultural revolution took millennia to exert its full impact on society, the industrial revolution took centuries, but the digital one only a few decades. No wonder we feel confused and wrong-footed.*

An Accelerando is hard as well as exciting.

Interlaced with the idea of bigness and risk, however, is a third theme: a recurrent notion that there is nothing inevitable about what lies ahead. The impact of technology is only partly a matter of the innovations of scientists, geeks and entrepreneurs. The outcome by 2050 will also be shaped by the decisions of governments, the strategies of companies and the choices of individuals. It is up to all of us to make the most of megatech.