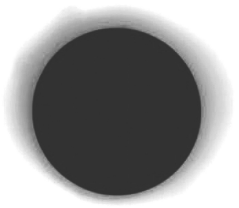
10

HOW DO WE SHAPE THE FUTURE?



A century ago, Albert Einstein revolutionised our understanding of space, time, energy and matter. We are still finding awesome confirmations of his predictions, like the gravitational waves observed in 2016 by the LIGO experiment. When I think about ingenuity, Einstein springs to mind. Where did his ingenious ideas come from? A blend of qualities, perhaps: intuition, originality, brilliance. Einstein had the ability to look beyond the surface to reveal the underlying structure. He was undaunted by common sense, the idea that things must be the way they seemed. He had the courage to pursue ideas that seemed absurd to others. And this set him free to be ingenious, a genius of his time and every other.

A key element for Einstein was imagination. Many of his discoveries came from his ability to reimagine the universe through thought experiments. At the age of sixteen, when he visualised riding on a beam of light, he realised that from this vantage light would appear as a frozen wave. That image ultimately led to the theory of special relativity.

One hundred years later, physicists know far more about the universe than Einstein did. Now we have greater tools for discovery, such as particle accelerators, supercomputers, space telescopes and experiments such as the LIGO lab’s work on gravitational waves. Yet imagination remains our most powerful attribute. With it, we can roam anywhere in space and time. We can witness nature’s most exotic phenomena while driving in a car, snoozing in bed or pretending to listen to someone boring at a party.

As a boy, I was passionately interested in how things worked. In those days, it was more straightforward to take something apart and figure out the mechanics. I was not always successful in reassembling toys I had pulled to pieces, but I

think I learned more than a boy or girl today would, if he or she tried the same trick on a smartphone.

My job now is still to figure out how things work, only the scale has changed. I don't destroy toy trains any more. Instead, I try to figure out how the universe works, using the laws of physics. If you know how something works, you can control it. It sounds so simple when I say it like that! It is an absorbing and complex endeavour that has fascinated and thrilled me throughout my adult life. I have worked with some of the greatest scientists in the world. I have been lucky to be alive through what has been a glorious time in my chosen field, cosmology, the study of the origins of the universe.

The human mind is an incredible thing. It can conceive of the magnificence of the heavens and the intricacies of the basic components of matter. Yet for each mind to achieve its full potential, it needs a spark. The spark of enquiry and wonder.

Often that spark comes from a teacher. Allow me to explain. I wasn't the easiest person to teach, I was slow to learn to read and my handwriting was untidy. But when I was fourteen my teacher at my school in St Albans, Dikran Tahta, showed me how to harness my energy and encouraged me to think creatively about mathematics. He opened my eyes to maths as the blueprint of the universe itself. If you look behind every exceptional person there is an exceptional teacher. When each of us thinks about what we can do in life, chances are we can do it because of a teacher.

However, education and science and technology research are endangered now more than ever before. Due to the recent global financial crisis and austerity measures, funding is being significantly cut to all areas of science, but in particular the fundamental sciences have been badly affected. We are also in danger of becoming culturally isolated and insular, and increasingly remote from where progress is being made. At the level of research, the exchange of people across borders enables skills to transfer more quickly and brings new people with different ideas, derived from their different backgrounds. This can easily make for progress where now this progress will be harder. Unfortunately, we cannot go back in time. With Brexit and Trump now exerting new forces in relation to immigration and the development of education, we are witnessing a global revolt against experts, which includes scientists. So what can we do to secure the future of science and technology education?

I return to my teacher, Mr Tahta. The basis for the future of education must lie

in schools and inspiring teachers. But schools can only offer an elementary framework where sometimes rote-learning, equations and examinations can alienate children from science. Most people respond to a qualitative, rather than a quantitative, understanding, without the need for complicated equations. Popular science books and articles can also put across ideas about the way we live. However, only a small percentage of the population read even the most successful books. Science documentaries and films reach a mass audience, but it is only one-way communication.

When I started out in the field in the 1960s, cosmology was an obscure and cranky branch of scientific study. Today, through theoretical work and experimental triumphs such as the Large Hadron Collider and the discovery of the Higgs boson, cosmology has opened the universe up to us. There are big questions still to answer and much work lies ahead. But we know more now and have achieved more in this relatively short space of time than anyone could have imagined.

But what lies ahead for those who are young now? I can say with confidence that their future will depend more on science and technology than any previous generation's has done. They need to know about science more than any before them because it is part of their daily lives in an unprecedented way.

Without speculating too wildly, there are trends we can see and emerging problems that we know must be dealt with, now and into the future. Among the problems I count global warming, finding space and resources for the massive increase in the Earth's human population, rapid extinction of other species, the need to develop renewable energy sources, the degradation of the oceans, deforestation and epidemic diseases—just to name a few.

There are also the great inventions of the future, which will revolutionise the ways we live, work, eat, communicate and travel. There is such enormous scope for innovation in every area of life. This is exciting. We could be mining rare metals on the Moon, establishing a human outpost on Mars and finding cures and treatments for conditions which currently offer no hope. The huge questions of existence still remain unanswered—how did life begin on Earth? What is consciousness? Is there anyone out there or are we alone in the universe? These are questions for the next generation to work on.

Some think that humanity today is the pinnacle of evolution, and that this is as good as it gets. I disagree. There ought to be something very special about the boundary conditions of our universe, and what can be more special than that

there is no boundary. And there should be no boundary to human endeavour. We have two options for the future of humanity as I see it: first, the exploration of space for alternative planets on which to live, and second, the positive use of artificial intelligence to improve our world.

The Earth is becoming too small for us. Our physical resources are being drained at an alarming rate. Mankind has presented our planet with the disastrous gifts of climate change, pollution, rising temperatures, reduction of the polar ice caps, deforestation and decimation of animal species. Our population, too, is increasing at an alarming rate. Faced with these figures, it is clear this near-exponential population growth cannot continue into the next millennium.

Another reason to consider colonising another planet is the possibility of nuclear war. There is a theory that says the reason we have not been contacted by extra-terrestrials is that when a civilisation reaches our stage of development it becomes unstable and destroys itself. We now have the technological power to destroy every living creature on Earth. As we have seen in recent events in North Korea, this is a sobering and worrying thought.

But I believe we can avoid this potential for Armageddon, and one of the best ways for us to do this is to move out into space and explore the potential for humans to live on other planets.

The second development which will impact on the future of humanity is the rise of artificial intelligence.

Artificial intelligence research is now progressing rapidly. Recent landmarks such as self-driving cars, a computer winning the game of Go and the arrival of digital personal assistants Siri, Google Now and Cortana are merely symptoms of an IT arms race, fuelled by unprecedented investments and building on an increasingly mature, theoretical foundation. Such achievements will probably pale against what the coming decades will bring.

But the advent of super-intelligent AI would be either the best or the worst thing ever to happen to humanity. We cannot know if we will be infinitely helped by AI, or ignored by it and sidelined, or conceivably destroyed by it. As an optimist, I believe that we can create AI for the good of the world, that it can work in harmony with us. We simply need to be aware of the dangers, identify them, employ the best possible practice and management and prepare for its consequences well in advance.

Technology has had a huge impact on my life. I speak through a computer. I

have benefited from assisted technology to give me a voice that my illness has taken away. I was lucky to lose my voice at the beginning of the personal computing age. Intel has been supporting me for over twenty-five years, allowing me to do what I love every day. Over these years the world, and technology's impact on it, has changed dramatically. Technology has changed the way we all live our lives, from communication to genetic research, to access to information, and much, much more. As technology has got smarter, it has opened doors to possibilities that I didn't ever predict. The technology that is now being developed to support the disabled is leading the way in breaking down the communication barriers which once stood in the way. It is often a proving ground for the technology of the future. Voice to text, text to voice, home automation, drive by wire, even the Segway, were developed for the disabled, years before they were in everyday use. These technological achievements are due to the spark of fire within ourselves, the creative force. This creativity can take many forms, from physical achievement to theoretical physics.

But so much more will happen. Brain interfaces could make this means of communication—used by more and more people—quicker and more expressive. I now use Facebook—it allows me to speak directly to my friends and followers worldwide so they can keep up with my latest theories and see pictures from my travels. It also means I can see what my children are really up to, rather than what they tell me they are doing.

In the same way that the internet, our mobile phones, medical imaging, satellite navigation and social networks would have been incomprehensible to the society of only a few generations ago, our future world will be equally transformed in ways we are only beginning to conceive. Information on its own will not take us there, but its intelligent and creative use will.

There is so much more to come and I hope that this prospect offers great inspiration to schoolchildren today. But we have a role to play in making sure this generation of children have not just the opportunity but the wish to engage fully with the study of science at an early level so that they can go on to fulfil their potential and create a better world for the whole human race. And I believe the future of learning and education is the internet. People can answer back and interact. In a way, the internet connects us all together like the neurons in a giant brain. And with such an IQ, what cannot we be capable of?

When I was growing up it was still acceptable—not to me but in social terms

—to say that one was not interested in science and did not see the point in bothering with it. This is no longer the case. Let me be clear. I am not promoting the idea that all young people should grow up to be scientists. I do not see that as an ideal situation, as the world needs people with a wide variety of skills. But I am advocating that all young people should be familiar with and confident around scientific subjects, whatever they choose to do. They need to be scientifically literate, and inspired to engage with developments in science and technology in order to learn more.

A world where only a tiny super-elite are capable of understanding advanced science and technology and its applications would be, to my mind, a dangerous and limited one. I seriously doubt whether long-range beneficial projects such as cleaning up the oceans or curing diseases in the developing world would be given priority. Worse, we could find that technology is used against us and that we might have no power to stop it.

I don’t believe in boundaries, either for what we can do in our personal lives or for what life and intelligence can accomplish in our universe. We stand at a threshold of important discoveries in all areas of science. Without doubt, our world will change enormously in the next fifty years. We will find out what happened at the Big Bang. We will come to understand how life began on Earth. We may even discover whether life exists elsewhere in the universe. While the chances of communicating with an intelligent extra-terrestrial species may be slim, the importance of such a discovery means we must not give up trying. We will continue to explore our cosmic habitat, sending robots and humans into space. We cannot continue to look inwards at ourselves on a small and increasingly polluted and overcrowded planet. Through scientific endeavour and technological innovation, we must look outwards to the wider universe, while also striving to fix the problems on Earth. And I am optimistic that we will ultimately create viable habitats for the human race on other planets. We will transcend the Earth and learn to exist in space.

This is not the end of the story, but just the beginning of what I hope will be billions of years of life flourishing in the cosmos.

And one final point—we never really know where the next great scientific discovery will come from, nor who will make it. Opening up the thrill and wonder of scientific discovery, creating innovative and accessible ways to reach out to the widest young audience possible, greatly increases the chances of finding and inspiring the new Einstein. Wherever she might be.

So remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don’t just give up. Unleash your imagination. Shape the future.

What world-changing idea, small or big, would you like to see implemented by humanity?

This is easy. I would like to see the development of fusion power to give an unlimited supply of clean energy, and a switch to electric cars. Nuclear fusion would become a practical power source and would provide us with an inexhaustible supply of energy, without pollution or global warming.



Afterword

Lucy Hawking

On the bleak greyness of a Cambridge spring day, we set off in a cortège of black cars towards Great St Mary's Church, the university church where distinguished academics by tradition have their funeral services. Out of term, the streets seemed muted. Cambridge looked empty, not even a wandering tourist in sight. The only spikes of colour came from the blue flashing lights of the police motorcycle outriders, guarding the hearse with my father's coffin in it, stopping the sparse traffic as we went.

And then we turned left. And saw the crowds, massed along one of the most recognisable streets in the world, King's Parade, the heart of Cambridge itself. I have never seen so many people so silent. With banners, flags, cameras and mobile phones held aloft, the huge numbers of people lining the streets stood in quiet respect as the head porter of Gonville and Caius, my father's Cambridge college, dressed ceremonially in his bowler hat and carrying an ebony cane, walked solemnly along the street to meet the hearse and walk it to the church.

My aunt squeezed my hand as we both burst into tears. "He would have loved this," she whispered to me.

Since my father died, there has been so much he would have loved, so much I wish he could have known. I wish he could have seen the extraordinary outpouring of affection towards him, coming from all around the world. I wish he could have known how dearly loved and respected he was by millions of people he had never met. I wish he had known he would be interred in Westminster Abbey, between two of his scientific heroes, Isaac Newton and Charles Darwin, and that as he was laid to rest in the earth his voice would be beamed by a radio telescope towards a black hole.

But he would also have wondered what all the fuss was about. He was a surprisingly modest man who, while adoring the limelight, seemed baffled by his

own fame. One phrase in this book jumped off the page at me as summing up his attitude to himself: “if I have made a contribution.” He is the only person who would have added the “if” to that sentence. I think everyone else felt pretty sure he had.

And what a contribution it is. Both in the overarching grandeur of his work in cosmology, exploring the structure and origins of the universe itself and in his completely human bravery and humour in the face of his challenges. He found a way to reach beyond the limits of knowledge while surpassing the limits of endurance at the same time. I believe it was this combination which made him so iconic yet also so reachable, so accessible. He suffered but he persevered. It was effortful for him to communicate—but he made that effort, constantly adapting his equipment as he further lost mobility. He selected his words precisely so that they would have maximum impact when spoken in that flat electronic voice which became so oddly expressive when used by him. When he spoke, people listened, whether it was his views on the NHS or on the expansion of the universe, never losing an opportunity to include a joke, delivered in the most deadpan fashion but with a knowing twinkle in his eyes.

My father was also a family man, a fact lost on most people until the film *The Theory of Everything* came out in 2014. It certainly was not usual, in the 1970s, to find a disabled person who had a spouse and children of his own nor one with such a strong sense of autonomy and independence. As a small child, I intensely disliked the way strangers felt free to stare at us, sometimes with open mouths, as my father piloted his wheelchair at insane speeds through Cambridge, accompanied by two mop-haired blond children, often running alongside while trying to eat an ice cream. I thought it was incredibly rude. I used to try to stare back but I don’t think my indignation ever hit the target, especially not from a childish face smeared with melted lolly.

It wasn’t, by any stretch of the imagination, a normal childhood. I knew that—and yet at the same time I didn’t. I thought it was perfectly normal to ask grown-ups lots of challenging questions because this is what we did at home. It was only when I allegedly reduced a vicar to tears with my close examination of his proof of the existence of God that it started to dawn on me that this was unexpected.

As a child, I didn’t think of myself as the questioning type—I believed that was my elder brother, who in the manner of elder brothers outsmarted me at every turn (and indeed still does). I remember one family holiday—which, like

so many family holidays, mysteriously coincided with an overseas physics conference. My brother and I attended some of the lectures—presumably to give my mother a break from her wraparound caring duties. In those days, physics lectures were not popular and definitely not for kids. I sat there, doodling on my notepad, but my brother put his skinny little-boy arm in the air and asked a question of the distinguished academic presenter while my father glowed with pride.

I am often asked, “What is it like to be Stephen Hawking’s daughter?” and inevitably, there is no brief answer that fits the bill. I can say that the highs were very high, the lows were profound and that in between existed a place which we used to call “normal—for us,” an acceptance as adults that what we found normal wouldn’t count as such for anyone else. As time dulls the raw grief, I have reflected that it could take me for ever to process our experiences. In a way, I’m not even sure I want to. Sometimes, I just want to hold on to the last words my father said to me, that I had been a lovely daughter and that I should be unafraid. I will never be as brave as him—I’m not by nature a particularly courageous person—but he showed me that I could try. And that trying might turn out to be the most important part of courage.

My father never gave up, he never shied away from the fight. At the age of seventy-five, completely paralysed and able to move only a few facial muscles, he still got up every day, put on a suit and went to work. He had stuff to do and was not going to let a few trivialities get in his way. But I have to say, had he known about the police motorcycle outriders who were present at his funeral, he would have requested them each day to navigate him through the morning traffic from his home in Cambridge to his office.

Happily, he did know about this book. It was one of the projects he worked on in what would turn out to be his last year on Earth. His idea was to bring his contemporary writings together into one volume. Like so many things that have happened since he died, I wish he could have seen the final version. I think he would have been very proud of this book and even he might have had to admit, in the end, that he had made a contribution after all.

Lucy Hawking
July 2018

Acknowledgements

The Stephen Hawking estate would like to thank Kip Thorne, Eddie Redmayne, Paul Davies, Seth Shostak, Dame Stephanie Shirley, Tom Nabarro, Martin Rees, Malcolm Perry, Paul Shellard, Robert Kirby, Nick Davies, Kate Craigie, Chris Simms, Doug Abrams, Jennifer Hershey, Anne Speyer, Anthea Bain, Jonathan Wood, Elizabeth Forrester, Yuri Milner, Thomas Hertog, Ma Hauteng, Ben Bowie and Fay Dowker for their help in compiling this book.

Stephen Hawking was well known for his scientific and creative collaborations throughout his career, from working with colleagues on ground-breaking science papers to collaborating with script writers, such as the team from *The Simpsons*. In his later years, Stephen needed increasing levels of support from those around him both technically and in terms of communication assistance. The estate would like to thank all those who helped Stephen to keep communicating with the world.

By Stephen Hawking

A Brief History of Time
Black Holes and Baby Universes and Other Essays
The Illustrated A Brief History of Time
The Universe in a Nutshell
A Briefer History of Time *(with Leonard Mlodinow)*
The Grand Design *(with Leonard Mlodinow)*
My Brief History
Brief Answers to the Big Questions

FOR CHILDREN

George's Secret Key to the Universe *(with Lucy Hawking)*
George's Cosmic Treasure Hunt *(with Lucy Hawking)*
George and the Big Bang *(with Lucy Hawking)*
George and the Unbreakable Code *(with Lucy Hawking)*
George and the Blue Moon *(with Lucy Hawking)*

About the Author

STEPHEN HAWKING was the Lucasian Professor of Mathematics at the University of Cambridge for thirty years and the recipient of numerous awards and honors including the Presidential Medal of Freedom. His books for the general reader include *My Brief History,* the classic *A Brief History of Time*, the essay collection *Black Holes and Baby Universes, The Universe in a Nutshell,* and, with Leonard Mlodinow, *A Briefer History of Time* and *The Grand Design.* He also co-authored a series of children's books with his daughter, beginning with *George's Secret Key to the Universe.* Stephen Hawking died in 2018.

hawking.org.uk



Penguin
Random
House

What's next on your reading list?

Discover your next great read!

Get personalized book picks and up-to-date news about this author.

Sign up now.