

Educating Newton

Rediscovering Science

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For my family

Introduction

At the entrance to the chapel of Trinity College, Cambridge, stands a life-size marble statue facing eastwards towards the high altar. It depicts an elderly man, richly draped with flowing robes, lost in thought. Before him stretches a chequered floor on which have stood many of the greatest men and women in the history of the human race.

There are others commemorated in stone around the edge of that ante-chapel, all of whom celebrated alumni of this revered place of learning. Among their number stand the intellectual elite of British history: Francis Bacon, a founder of the scientific method; Isaac Barrow, who was fundamental to the development of modern mathematics; Thomas, Baron Macaulay, a parliamentary reformer responsible for the legal system of much of the British empire; William Whewell, a highly accomplished scientist and philosopher; and Alfred, Lord Tennyson who is reputedly the second most quoted writer in the English language, surpassed only by William Shakespeare.

Yet even among these extraordinary superlatives in the field of human genius, only one titanic figure is granted a central place of honour, gazing pensively eastwards, past his contemporaries, towards the high altar.

Our understanding of the Universe around us perhaps owes more to Sir Isaac Newton than to any other human being before or since. He ranks among the greatest geniuses ever to set foot on this Earth, and his legacy has dominated scientific thought of all nations for three centuries. Newton's most profound discoveries, though they have since been embellished and extended, still lie at the very core of our understanding of the Cosmos.

Inscribed along the base of the statue commemorating this one man are the Latin words, '*qui genus humanum ingenio superavit*'. Loosely translated, "he surpassed the race of men in understanding." The deeper we look into the achievements that inspired those hyperbolic words, the harder it becomes to deny the accuracy of such an extraordinary, reverential epitaph.

Newton possessed a forceful intellect and he understood the natural world with an unparalleled clarity. He was a fierce and prodigious polymath who tirelessly focussed his energy towards an extraordinary range of diverse and distinct challenges, and excelled at them all. He was arguably the most influential founder of the entire global scientific endeavour and his works rank amongst the greatest ever achievements of the human mind.

However...

Despite this extravagant eulogy, it would not be overstepping to mark to say that Isaac Newton knew so little of the physical Universe by the standards that we might set today, that he would fail even the most basic high-school science examinations. Our world would seem as alien to him as his seventeenth century life would have appeared to a stone-age hunter-gatherer. Every aspect of human civilisation has evolved beyond recognition from that medieval world Newton knew, sometimes in giant and profound leaps, though usually through the slow but steady march of progress which, year after year, has built so extensively on the foundation that he himself provided.

In this book, I aim to show how our society has been shaped by the progress of science, not just through the gadgets and devices upon which it depends, but also by our understanding of the Universe in which we live. Each year we collectively advance one step further away from the world with which Newton would have been familiar, and we uncover yet more vital pieces of the puzzle of the natural world; a conundrum that Newton spent so long struggling to understand.

It is tempting in this age of technology to fall for the strangely seductive tendency to look back at previous generations with a degree of arrogance, laughing at the mistakes they made, ridiculing the beliefs they held dear and highlighting the extraordinary poverty of their knowledge of the Universe. I think we all, albeit with some understandable guilt, enjoy the feeling of superiority we get when reading of times gone by, when people were primitive enough to believe in such fantasies as witchcraft and bloodletting. It is tempting to think of our distant ancestors as our intellectual inferiors because they were unaware of so many things that we now consider second nature. Tempting, but false, because this picture doesn't even remotely hold up to a more thorough examination in the light of science or history. Although there are a great many things that were not known in the seventeenth century, the world into which Isaac Newton was born was hardly ignorant.

For example, I challenge any reader of this book to duplicate the feats that the great pioneers had already achieved by the year of Newton's birth. Medieval explorers knew much about the geography of the Earth and had mapped most of its surface; astronomers knew that our planet was not, as was previously believed, the centre of the Universe, but that it orbits around the Sun, together with the five other planets known at that time, the orbits for which were also accurately studied; engineers had developed the technology to manufacture enormous sailing vessels and to chart their progress accurately across the vast expanse of the open oceans; pioneers had circumnavigated the globe and built trade links spanning the continents, bridging all the distinct societies of the world in the ages before multinational corporations and cheap international travel brought the world to our doorstep; architects designed and built towering cathedrals that still dominate the skylines of twenty-first century cities; and last, but not least, creative minds had crafted fine works of art, literature and music which, in many cases, remain unparalleled to this day.

Newton knew and understood all of this; he had studied in great detail the achievements of generations before him right the way back to the great thinkers of antiquity, which dominated most learned thought at the time. He was an accomplished theoretician but was also a talented and thorough experimenter. He was not content merely to build mathematical models of the physical world, but also insisted on testing their accuracy with equal zeal and vigour. In his time, and purely by virtue of his great mind, extraordinary dedication and stubborn perseverance, he became one of the most important men in England, amassed a considerable personal wealth and earned the near-worshipful admiration of many otherwise excellent, well-regarded scholars.

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I often find myself day-dreaming, imagining how it would feel to meet the greatest minds of human civilisation, long since departed. What would happen if I were to bring them into the modern world – a world which they helped to create but which has now far surpassed anything that they could ever have imagined? Our way of life is certainly profoundly different to theirs, but that's not purely because of tablet computers and high-definition televisions. There's much more to the picture that we inevitably miss if we focus only on the technological marvels of the information age.

Our world differs from that of Sir Isaac Newton, and all those scientific pioneers before him, by far more than just the physical manifestations of three hundred years of scientific progress. An increased scientific understanding in society has delivered numerous fundamental shifts in the way we think. We no longer suffer the same fears, foster the same beliefs, or nourish the same hopes as did our medieval ancestors. We see things in a different way to the greatest minds of distant generations, and we're able to do that because of the insights that we, as a society, have gathered for ourselves; Insights that have radically reinvented our relationship with the natural world, with manifestations of technology, and with each other. The accumulated knowledge of

mankind has surged relentlessly forwards, and that same learning has stealthily filtered into the consciousness of every individual human mind.

When we look out at the sky, we see the same Sun whose light has warmed our ancestors since our species first arose on the African savannah. Yet we no longer marvel at an anthropomorphic god driving celestial horses from a blazing chariot of fire, but rather a giant ball of gas a million times the size of our Earth, four hundred times further away than the moon, burning at unimaginable temperatures through the power of nuclear fusion. When we watch a chimpanzee gazing towards us with its wistful eyes, we marvel at the extraordinary physiological similarities that we now know to be far more than just mere coincidence. When we feel unwell, we talk about germs, viruses and white blood cells, not about witches' curses, divine wrath and unbalanced humours. The difference between our world and that of ages past is not just one of technology, it is one of perception. We, as a species, have embraced countless shifts in the frame of reference from which we see and interpret the world around us, radically reshaping our everyday experience to such a degree that we are unaware that it would even be possible to understand it differently.

Perception doesn't just cover our direct physical encounters with the external world. After all, nobody alive has ever seen the structure of an atom with the naked eye, and our understanding of the stars and planets in the Milky Way is based on observations taken with sophisticated telescopes and not merely the wide-eyed night time stargazing that inspired our ancestors to weave an intricate pantheon of fictional beasts in the heavens above. Our understanding of mankind's place in the cosmos is not based on our own senses, nor on our own direct experiences, but rather on the knowledge that we have gained together as a species, searching for the hidden secrets of the Universe with sophisticated apparatus and theoretical techniques.

The birth and development of science, largely ignited by the work of Sir Isaac Newton, has heralded an entirely new era in human experience. Our interaction with the world is no longer based on what we, as individuals, experience during our lifetimes, but we now understand together as one single organism. Our individual experience of life is inescapably moulded and amplified by the discoveries made by those thousands of intellectual pioneers who went before us to prepare the way.

The greatest gift that humanity possesses is the ability to benefit and to learn collectively from the work of others. Our inquisitive, highly adaptive minds coupled with our unique innate ability to express ourselves through language, have served to elevate us high above all other animals. This remarkable division of labour, not purely through space but also through time, is what has taken us from the Stone Age to the Information Age. Moreover, it is what has allowed us to develop the whole spectrum of human technological achievements, from flint axes and spears to vaccines, digital computers and nuclear-powered robots on Mars.

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This is a book about science, but it is not a science book; nor is it even about Sir Isaac Newton – at least not at its heart. I apologise if you are expecting a detailed and scholarly historical tome. There are plenty of good biographies out there that give you the facts about every intricate detail of Newton’s life – I have consulted many of them to enhance my storytelling, but it was never my plan to write another. There are also vastly many science texts that could tell you all you could ever realistically want to know about the law of gravitation and the mathematical laws that come with it, but I kept this book deliberately free of complicated terminology for a very good reason: My aim for this modest work is something very different. I hope to show how the human race owes a debt to science that stretches far deeper than you may ever have suspected, and I hope to teach you what Science really is

- not a list of facts and theories, but a powerful set of techniques that enable us to probe the natural world with unprecedented clarity.

This is a book about human wonder and perception, and how we see the world through the lens of knowledge and understanding. My overriding aim was to show how our interaction with our environment has been crucially shaped by several monumental shifts in understanding that have taken place during the last three centuries. And I will take you through those discoveries in order, introducing you to them as we might introduce them to Isaac Newton in his imaginary journey through time to the present day.

Our journey begins by examining the world as Newton left it. I start this tale by investigating a set of discoveries that remain, even today, as Newton's best known achievements. I will describe how they provided a shift in perception so enormous that it is a testament to the human mind that it goes unnoticed by almost all of us almost all of the time.

I find that this is the case with many of the most important discoveries ever made. The most influential theories in all science have permeated so deep into our subconscious minds that we don't even realise that there was once a time before they were known. The greatest compliment anyone could ever pay to any scientific theory is not just to refuse to doubt it, but to refuse to accept that doubt were even possible. To ask, with incredulous surprise, how things could ever be otherwise.

I have chosen to spend just the first chapter of this book introducing the world of science as it was when Isaac Newton departed this world in the early eighteenth century. To dedicate merely one chapter on arguably the greatest scientist who ever lived (and after whom the book is named) might seem a debatable use of resources, I freely admit. However, the pioneering achievement of Isaac Newton's life was not in creating a great many advancements in a wide diversity of fields - for one thing, there really were no individual scientific disciplines to speak of at the time. On the contrary, Newton's great contribution was that he

brought together all the disparate threads of learning that had recently been crafted by such great figures as Galileo, Kepler and Copernicus. He built a theoretical foundation with which to express them, and then he wove those threads together into a stunning, coherent and powerful whole.

Newton was not the only one to realise that the few tentative forays that humankind had made into a new, undiscovered world of knowledge were the first shoots of a scientific renaissance. Even so, he was arguably the only man of the time capable of constructing the apparatus by which that renaissance could proceed. He spent his life building the foundations on which scientific theory would be constructed for centuries after his death. His most celebrated works brought together the sciences of astronomy, mechanics and optics empowered by new mathematical tools developed by the greatest minds across Europe.

What Newton did, in essence, was to bridge the gap between folk science - that is, the science that human beings had so far managed to invent purely through intuition and anecdote - and a rigorous system of learning that would facilitate all the discoveries that followed.

Until the late seventeenth century, humanity had mainly been wandering around in the darkness, grasping at truths and falsehoods with equal enthusiasm and without any means by which to distinguish between the two. The Newtonian revolution provided a light of reason which gave us the opportunity to discard nonsense and superstition, to identify essential laws of nature, and to begin a steady and unfaltering progress away from our humble origins.

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Newton was hardly a modest man, though in a letter to a fellow scientist he once remarked, "If I have seen further, it is by standing on the shoulders of giants." I don't subscribe to the media-friendly cliché that isolated geniuses are responsible for all scientific progress. Not only is

that viewpoint patently untrue, but it's also an insult to the millions of men and women who have worked tirelessly over the history of civilisation to build up this great edifice of human knowledge. However, it is often those few great minds who give us that first flash of inspiration, the courageous declaration, or the painstaking and obsessive investigation that brings about the birth of a new and exciting insight into the world around us.

This book, I have said, is not about science – it is about the human experience of knowledge. It is, as Newton himself might perhaps have put it, the view from the giants' shoulders.

Dr Colin Frayn,
London,
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Thank you for reading this Introduction to my book “Educating Newton”. If you enjoyed what you read, then please find out more on my website:

<http://www.frayn.net/books/newton/>

If you feel like the message of my book is worth spreading then I encourage you to send it to anyone else who might benefit from it. If you work for a publisher and are interested in publishing my work then please contact me directly on colin@frayn.net.

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If you would like to learn more about science, please take a look at my online lectures at this location:

<https://www.youtube.com/user/ColinFrayn>

My series on Understanding Science covers some of the material from Educating Newton, and goes into far more detail about the mechanisms behind the scientific method, and how we can use these powerful techniques in our day-to-day lives.