12 BOOKS THAT CHANGED THE WORLD

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To
Vivien Green
a wonderful friend
and a great lover of books

INTRODUCTION

The idea for this book came from a single image. About nine years ago, when I was reading about Isaac Newton, I imagined this awkward, unhappy, driven young man, sitting alone and in silence in his home, a farmhouse, forcing his mind to construct theories which eventually changed the world and changed it radically. Out of the unlikely context of that Lincolnshire farmhouse would come revolutions in thought whose force and consequences re-ordered human life. The juxtaposition of the solitary figure working to produce such a modest and harmless-looking object as a book and the explosion this caused in the minds of men and women then and since led me to look for others whose intense preoccupation posted in placid pages had seized the story of our species. That a mere book should have such power!

We think of the world changing 65 million years ago when an asteroid hastened the death of the dinosaurs and allowed space for the growth of the mammals. We think of the upheavals in ancient ice ages and fear global warming to come. We know about the destructions of war and the inspirational energy which can bring about peace. There was the American Revolution, the French Revolution, perhaps most important of all the Industrial Revolution, the draining of populations from the countryside to the cities. There was the extension of the lifespan, the eruptive transformations brought by the advances of technology. The rise and rise of mass consumerism . . . A mere book seems a very unlikely contender as a world-changing catalyst.

Yet for those of us who love to read, the idea that a book can have an influence is not news. Our perceptions have been shaped through books, our store of information heaped up, our tastes extended, perhaps refined, our sense of humour tickled, our sense of well-being restored or reinforced; we have been excited, alerted, moved, consoled, felt less alone, even felt morally improved and inspired - at least for a while. We know that books can change us as individuals.

On a different level books have often been and still are the agents of creeds which have shaped and reshaped humanity. These generally religious books would, I think, have figured prominently in the reckoning for a list of the twelve most influential books in the world. At one stage I had a list dominated by the Ancient Greeks, books of God, Marx and Mao and two or three books of science. It felt unsatisfactory; too ambitious, and, despite the undoubted importance, not very lively as a selection. Out of the several lists that followed, I eventually saw that a number of books by British authors had a fair claim to have changed the world. Indeed it was difficult to cut down the number to twelve - James Clerk Maxwell, Tom Paine and Dr Johnson, for instance, were hard to omit. The British have produced and still do produce a high yield in key thoughts, inventions and proposals. By omitting the definite article - these are not the twelve books - I believed a case could be made for the twelve books from these islands and that is what I try to do. The British provide a surprisingly rich crop.

From the beginning I wanted to enjoy a range. Leisure and literature would, if I could make it work, figure alongside science and the constitution; changes in society as well as changes in technology would be addressed. This has meant taking a risk and, now and then, elasticating the strict meaning of the word ‘book’.

For instance, I thought it essential, given its key constitutional importance, to include Magna Carta, which, though produced by the royal chancery in 1215 as a formal royal grant, became in effect a vital and enduring book of reference, the basic book of our constitution and that of many others, most importantly, of America and India.

Certain books suggested themselves, most especially Newton’s Principia Mathematica (1687), Darwin’s The Origin of Species (1859), Adam Smith’s The Wealth of Nations (1776), Michael Faraday’s Experimental Researches in Electricity (1855) and William Tyndale’s massive contribution to the King James Bible (1611).

It was, I thought, impossible to ignore William Wilberforce’s successful campaign for the abolition of slavery. True, it began as a four-hours-long speech in the House of Commons in 1789, but it was reproduced in print immediately afterwards and it is in its book form that its revolutionary and lasting influence resides. Nor could the emergence of women as equals in every respect be neglected and in different ways Mary Wollstonecraft’s *A Vindication of the Rights of Woman* (1792) and Marie Stopes’s *Married Love* (1918) spoke authoritatively and with far-reaching influence on that.

The arts could not be omitted, I thought, and nor could leisure. William Shakespeare’s posthumously published First Folio in 1623 will be argued for as a book that has ever since changed and reshaped minds. The first Book of Rules of Association Football (1863) enabled the world to play a game which now commands a unique and previously uncharted, unimagined empire of followers, participants, fanatics and rich merchants.

Which leaves the Patent Specification for Arkwright's Spinning Machine (1769). I was being shown over his now-derelict mills in Derbyshire and learned then how crucially important this invention was to an industrial revolution which has never stopped. This was made possible by a patent cunningly and skilfully put on paper by Richard Arkwright. A patent, I thought, could be called an entrepreneur-inventor's book.

What I wanted these books to have in common was that they changed the world to that in which we now live. They could be reduced to plausible snapshots. You could walk into a pub or an airport, go on an outing or just stay in your house, and be aware of what these books had delivered to the lives you daily led and saw. Newton took us to the Moon; Faraday gave us electricity; Darwin took away God and the gods who had been there since civilisation began; Mary Wollstonecraft started the struggle for the equality of women and Marie Stopes for their right to control and enjoy their sex and family lives. After Wilberforce the equality of the races was on the march and Magna Carta is the keystone of opposition to the exercise of tyrannic power. Our markets operate through the laws of Adam Smith, our imaginations are most exercised by Shakespeare, our work organised by Arkwright, our language and religious thought by the King James Bible and our world-dominating sport by the FA Book of Rules. Of course, with 'our' I take a licence. This is the case in the whole book. Many authors know much more about individual writers and subjects than I do, which I acknowledge in the course of this book. I thought, however, that the juxtapositions, the chance to look around different fields in a single book might be as entertaining for you to read as it has been for me to write.

On much the same principle, I decided not to order the book chronologically. I thought it would imply an historical evolution which is only partly true. More importantly, though, as I had come across these books randomly I think the higgledy-piggledy is more honest and appropriate than the chronological.

It seems to me all but miraculous that amid the tumult of events and the mêlée of competing dramas, despite the uproars of wars and politics and all the bombast of the daily news, these British voices began, all of them, with the quiet strokes of a quill or a pen and were formed in seclusion to be sent out into the world, where a fuse was lit. There then followed a conceptual chain reaction, sometimes of awesome proportions, which changed the way all of us lead and experience our lives.

PRINCIPIA MATHEMATICA

1687 by Isaac Newton

‘Nature, and Nature’s Laws lay hid in night:/God said “Let Newton be!” and all was light.’ In that brilliant couplet Alexander Pope, the supreme poet of his day, summed up the awe felt by everyone who could grasp what Newton had done. Voltaire, the most famous philosopher in Europe, witnessed Newton’s state funeral in Westminster Abbey and praised an England which honoured a mathematician as other countries honoured a monarch. The great scholar Laplace, who was extremely sparing with his praise, makes Newton the one exception, and he laid out reasons still held to be valid which prove that Newton’s most famous book Principia Mathematica will ‘always have a pre-eminence above all the other works of human genius’.

There were those who were prepared to call Newton a god, and indeed, as well as bringing him, in his own lifetime and since, the support of the most accomplished minds in science, his work also gathered flocks of followers who saw him as the source of solutions to the meaning of life. It might be appropriate to note here that Newton, though an unorthodox Anglican, was a true believer. ‘Gravity is God,’ he said. Newton’s fame and importance are still as strong today, and despite his disclaimer that ‘if I have seen further it is by standing on the shoulders of giants’, there are those, not least Einstein, whose ideas refined and extended but by no means diminished the achievement of Newton, who still see him as unique. Einstein wrote, ‘Nature to him was an open book. He stands before us, strong, certain and alone.’

And it was by thought alone that he achieved this pre-eminence. Newton made the most telling remark on the process of thought that I have ever encountered. It is also the simplest. When asked how he had come upon his theory of gravity, he said, ‘By thinking on it continuously.’

Isaac Newton was the first man to reveal the true properties of light, just as he was the first to discover and examine the laws of motion. He discovered and proved mathematically the laws of gravity which frame and dictate our life on Earth. He defined space and time and unlocked the secrets of the planets and their movements. He gave man the knowledge that would enable him to leave our planet and explore the others. He enabled the establishment of new technologies that still shape and reshape our lives. He codified and exemplified the scientific method that is with us to this day. Even listed in that bare outline, this one man's achievement has something of the heroic about it. He did this by working in solitude. Through the inexplicable magnificence of the human brain he distilled his thought into a few books, most importantly Philosophiae Naturalis Principia Mathematica - usually known as the Principia - published in 1687.

I had the great good fortune to look closely at a first edition of Principia in the Wren Library in Trinity College, Newton's college, in Cambridge. It is an unprepossessing volume. While I looked around at the written splendour of ages on the shelves of that palatial room, I came across many grander, fatter, more gilded, more important-looking books. The Principia is about 6 by 8 inches. It is leather bound, weighs about 3 pounds, consists of 512 pages filled with mathematical problems, calculations and diagrams, and it is written in Latin. The material is arranged in three parts, and between the covers of the volume I was holding a scholar from Lincolnshire, only son of an illiterate farmer, figured out our world.

We are told that Newton had a difficult birth on the family farm at Woolsthorpe near Grantham. He was born on Christmas Day in 1642, three months after his father had died. When he was three his mother moved out to live with a wealthy rector in a parish near by and for the next eight years of his life he was brought up by Granny Ascough, his maternal grandmother. Very little is known about this period. It was believed that his mother was the only woman he ever loved. It is presumed that he hated his stepfather because at one stage he said he wanted to burn down his house with both his stepfather and his mother inside it. Later, in a written list of sins, he regrets having entertained such a thought.

Prompted by whatever impulse or guidance, this lonely, sickly boy began to make toys from a very young age. He made a working windmill driven by mice running around a treadmill; mice being easy to come by on a farm and windmills a feature of that part of the world. He made kites to which he attached lights which he flew at night, presumably scaring the wits out of the locals. Later he made clocks.

As a young adult, when it was intended that he become a farmer, he went, like a character in a Thomas Hardy novel, to Stourbridge Fair, a traditional English gathering of livestock, pedlars, young people on the gad, buyers and sellers of rare breeds and bargains, beer, an unusual concentration of noise and excitement in the silent, placid countryside; there, from a hawker of strange objects, he bought a rough-hewn glass prism. Back on the farm at

Woolsthorpe Newton constructed an experiment which shone white light through the glass. The spectrum of colours on the wall was to set him off on his profound thoughts about the properties of light, a subject which had engaged natural philosophers for centuries and a study he pursued with outstanding success throughout his life.

He was also unafraid to use himself as an experiment, rather as painters use their own faces as a cheap and testing way to develop the skills of portraiture. He wanted to know what pictures could be made by the eye, and so in one experiment he pushed a bodkin, an ivory toothpick, underneath his eyeball almost right to the back of the socket. He wrote: ‘I push a bodkin betwixt my eye and the bone as near to the backside of my eye as I can and pressing my eye with the end of it there appear several white, dark and coloured circles, which circles are plainest when I continue to rub my eye with the point of the bodkin.’

This is a most strange young man. After a few of these experiments he records that he was obliged to spend two weeks in bed with the curtains drawn.

There was an uncle educated at Cambridge who helped this clearly unusually clever, self-driven, solitary boy on his way by getting him, in his teens, to Grantham Grammar School, where the headmaster, Henry Stokes, was notable for raising the level of scholarship to that of a university. When Newton arrived at Trinity College, Cambridge, in 1661, he was well grounded in classics and mathematics. Despite the comfortable wealth of his mother and her second husband, he was poorly provided for. He was obliged to be a sub-sizar, that is to say a poor scholar who was forced to wait on other students and fellows and eat only after they had finished, his portion being their leavings.

The Cambridge that Newton came to in 1661 was not the dynamo of academic, especially scientific, enquiry and success it was to become - largely as a result of his Principia, which gave Cambridge its enduring reputation for high scholarship. It was here, very quickly, that he laid down his own laws of learning. In 1664 he wrote, ‘Amicus Plato, amicus Aristotelis, magis amica veritas’ (Plato is my friend, Aristotle is my friend, but my best friend is truth). His colours were nailed to the mast. It was as if he gave notice to himself that his great journey was begun.

At Cambridge Newton took up another study - that of alchemy - which he was to pursue as zealously as he pursued his physics. His writings on this ancient, occult and erudite subject are voluminous and, it is said even by experts, largely in code and impenetrable. For example, one entry reads, ‘Today I made Jupiter fly on his eagle’. For long periods he had a furnace which burned continuously in which he developed, according to Dr Robert Iliffe, ‘a whole series of amalgams and elements which we simply cannot replicate today. It is impossible’, he goes on, ‘to know whether various impurities entered the chemical material and made Newton develop various things that we will simply never be able to recover. Alchemy was . . . the province of adepts, gifted people touched by God. On a number of occasions in the 1670s and 1680s, he uses alchemical terms and language to shed light on aspects of what we would now call his science.’

As the influence of alchemy, called the Hermetic Tradition, grew stronger, Newton’s concept of nature underwent a crucial change. He had been entirely what could be termed a mechanical philosopher in the accepted seventeenth-century style, one who explained natural phenomena by the motions of particles of matter. So, for instance, he held that the physical reality of light is a stream of tiny corpuscles diverted from its course by the presence of denser or rarer media.

Influenced by the Hermetic Tradition, he began to use the language of alchemists to describe puzzling phenomena such as chemical affinities. Unlikely as it seems, this combination proved fruitful: a match between the ‘magical’ and the mechanical. The words ‘attractions and repulsions’ and the ideas which flowed from them have been called ‘direct transpositions of the occult sympathies and antipathies of Hermetic philosophy’. Newton ignored the protests of other mechanical philosophers and claimed an important place for these supplements to the merely mechanical theories.

By combining these two apparently irreconcilable states of knowledge and reconciling them through the concept of force, it has been said that Newton ‘made his ultimate contribution to science’.

In order to stress the importance to Newton’s mind and work of his alchemical studies, which for years were little known about and when first known little regarded, I have got ahead of myself in telling his story. What the pursuit of alchemy reveals to me, however, is that nothing intellectually demanding or mysterious was alien to him. He was rigorous in his examination of religious texts, especially those concerning the Trinity, in which, dangerously for his career, he did not believe; he was rigorous in the many branches of natural-philosophical or scientific enquiry that he inherited and developed and often reinvented; rigorous with Aristotle, with Plato, and equally with an antique study - alchemy - thought irrelevant and even rather ridiculous by gentleman scholars of the Enlightenment which Newton did so much to establish.

He sought out sources of knowledge everywhere he could. Robert Boyle, the seventeenth-century chemist, was to give Newton the basis for his work in chemistry. A study of Descartes set him off on the latest mathematics. He learned about algebraic techniques which could be applied to geometry. Typically he sought confirmation for the new geometry in classical geometry. Again and again Newton seems to be reaching out for a Theory of Everything. Perhaps this is a natural consequence of his belief in One God the Maker of All Things Visible and Invisible. Perhaps it is evidence of a mind incapable of accepting partial explanations and unafraid to seek out connections even when to others there appeared to be none at all.

In 1665 the plague came back to England in force. Those who could fled the towns and cities, seeking out isolated spots thought to be safest from the fatal infection. The University of Cambridge closed down and at the age of twenty-three Newton returned to his home, to Woolsthorpe. Out of the next two years grew the legend and to a certain extent a myth of the making of Newton's unique genius.

He himself said of that time: 'In the two plague years I was in the prime of my age for invention and minded mathematics and philosophy more than at any time since.' We also know that he said that he would sometimes work eighteen or even twenty hours a day. This gargantuan capacity for work continued for another quarter of a century.

There is often argument and unease about the word 'genius', especially when applied to scientists. A genius for centuries was a god or inspired by God or fed with the fire of that which had no name. In the nineteenth century Kant said that Goethe and Homer could be called men of genius but not Newton because Newton could explain how he arrived at his theories and conclusions. True genius came out of 'nothing' or out of total darkness. I think Kant was mistaken about Newton or genius or both. Goethe and Homer both came out of a tradition: as did Newton. All three transformed it.

In these two years at Woolsthorpe and for some time afterwards, with powers as gifted and strong as those of any artist, Newton imagined himself into the world as it is. He did it in the language of mathematics. There are those who believe that this language can bring us nearer to the truth of the world as it is than any other, that mathematics can describe the world more illuminatingly and comprehensively than any other method. Proofs are also offered and it is surely tendentious to assert that one form of thought - the literary, for example - is in its very nature capable of delivering greater riches of understanding than another because proofs are not offered. Are 'proofs' below the salt? It smacks a little of intellectual snobbery. It smacks even more of a mistaken understanding of an act of creativity. Cézanne could have explained his intentions and methods in discovering Mont St-Victoire during the course of making his seventy paintings of it. Shakespeare could have given reasons for the order and selection of words he used, the juxtaposition of phrases. To explain how you arrive at your conclusions is not a bar to being called a genius: if anything it is cause for additional admiration.

What Newton set about thinking on in the time of plague, when, for most of his days, he was locked away with his closest, most loyal and only true friend, solitude, was to result in revelations, in ideas, which had not been there before in those forms. I can see no distinction between Newton thinking on the consequences of the fall of an apple and Homer thinking on the consequences of the taking of Helen or Shakespeare thinking out the consequences of the witches prophesying to Macbeth. Imagination flows to wherever the intensity of a profoundly well-prepared mind beckons it. When Einstein was asked what was most important to him in his work, he said, ‘Imagination. Above all else.’ Newton’s theories came every bit as much out of thin air as any of Goethe’s lines.

In those two years in his early twenties he laid the groundwork for many of his great contributions to knowledge. It was at this time that he experimented with the prism and decided that white light was composed of different-coloured lights and different properties. It was not that he merely saw this rainbow spectrum, as many had done before him: he proved why it was so and what the consequences were for the study of light itself, and proved it by an early example of what is now cutting edge - particle physics.

He developed a new and extraordinarily powerful form of mathematics which would enable him to define, compute and predict the workings of the natural world. The Greeks had uncovered an arithmetic and geometry adequate to compute their world, and remarkably durable and useful it had been. The Arabs introduced algebra, which offered a dimension for more variables and a more extensive employment of mathematical formulae. Descartes had brilliantly combined algebra and geometry in a system which allowed the introduction of values like time and distance to be plotted and expressed in graphs. Leibniz, working at the same time as Newton and independently of him, was engaged with the same mathematical problems Newton set himself to solve, especially the calculus. Newton invented a system he called ‘fluxions’, a system which allowed him to treat a curve not as something fixed and static but as created by a moving point. He did this by chopping up the moving point into an enormous number of minute points along the way. We know this system as ‘calculus’, and it allowed him to apply his laws to complex situations such as the effect of force on a moving body.

And then there was the apple tree. Still there, at Grantham, the tree itself or its direct heir, propped up and gnarled but defiant, as if it is damned if it will give in until everyone takes a careful look and agrees to believe its story. It was put about by Newton himself that it was the simple fall of an apple, an apple almost as famous as the apple in the Garden of Eden, that set him off and directed his mind to the thought which led to his stupendous theory of the force of gravity. Why did the apple fall down? Not up. Not sideways. It fell, he concluded, but infinitely more importantly he proved, because the Earth was exerting force on it. Newton realised that all objects are attracted to one another; the bigger the object, the bigger the attraction. Then the years followed in which he sought out and built the proofs.

Newton did not call it gravity yet, and initially he only speculated about its operation on or near the Earth. It would entail twenty years of work before his ideas would be set out in the Principia and Newton would prove how the Universal Law of Gravity shaped the cosmos and kept the planets in their orbits.

Newton returned to Cambridge in 1667 and in the next twenty years, besides thinking through his law of gravity, he engaged in many other investigations, had titanic and virulent quarrels with those who dared challenge or criticise him, turned friends into enemies overnight, damned publication, grew to be a monster and a myth and had a truly terrible nervous breakdown, after which he did less and less science in Cambridge and became more and more a national monument in the capital and a figure of international wonder.

At the age of twenty-seven, he became a professor of mathematics. He continued his passion for optics but he was also applying his ideas to the movement of the planets. By 1680 he was persuaded that the laws of attraction and repulsion dictated planetary movements also and he quantified the force involved.

In 1684, the wealthy, enterprising and talented British astronomer Edmund Halley (he of the comet) went to see Newton in Cambridge with a problem about a planet's orbit. In response, Newton wrote a short tract, 'De Motu' - 'On the Motion of Bodies in Orbit' - which revealed how far he had got in quantifying the movements of the planets. Halley was so impressed and excited when he read this that he raced down to Cambridge and urged Newton to publish immediately, a publication for which he would pay.

But Newton was not ready. More than that, the writing of 'De Motu' had somehow nudged forward the progress of a Big Idea. 'De Motu' was just Book

One. He put all other work aside, scarcely went out, barely ate and settled to it with that astonishing concentration and stamina that made him able to 'think on it continuously' for up to twenty hours a day. He covered hundreds of sheets of manuscript with new calculations, which became the Principia with a Book Two and a Book Three. The reservoir built up with so much application and genius and over such a span of work-time was now released into a river of verifiable proofs which was to sweep all before it.

By publication in 1687 it was all there in the book I had been allowed to pick up in the Wren Library: the Laws of Motion, the Observations on the Movement of the Moon and the Planets, and the force holding it all together known as gravitas or gravity.

The Universal Law of Gravity was now revealed. It defined how all bodies, terrestrial and celestial, heavy and light, of whatever materials, were bound together through the laws of repulsion and attraction. Never before and never since had one mind discovered so much that was new and made such a profound and unending difference to our knowledge and to the way we would live our lives.

What was extraordinary enough was that these principles were expressed in geometrical form. What was most remarkable of all is that even though initially they may have been imagined, after twenty years of concentration, it could be seen by all who could understand, quite astonishingly to his contemporaries and to scientists ever since, that they were proved.

So how did the Principia change the world?

Perhaps we should begin with the world of Isaac Newton himself. He did not, like Byron, wake up to find himself famous, but when his fame rolled in it came from Mount Olympus, and it has rolled through the intellectual life of mankind ever since. Sir Edmund Halley, who had been a useful goad to Newton, said, in a poem he wrote as a kind of foreword to the Principia: 'No mortal may approach nearer to the gods', and that judgement, restated in the terms of the day, has never been overturned. Lord Rees, the Astronomer Royal, believes, as do the great majority of scientists and scientific historians today, that science is fundamentally an art of accretion rather than one of individuality, that scientists 'in the long run, if their ideas survive scrutiny . . . become just part of the corpus of public knowledge as it were, and their individuality fades'. But he felt compelled to add, 'I think most scientists would probably say that Newton may well be the most outstanding scientific intellect of all time.'

Initially only a few people could understand the book, but those who did, the savants of Europe (save France, which was reluctant to join in the acclaim and came in later, whipped into line by the authority and wit of Voltaire), began to spread the word and his reputation took wing. He was knighted, the first scientist (the word was not to be introduced until 1831, so more accurately 'natural philosopher') ever to be knighted. He became influential at court, first with Queen Anne, then with George I. He was made Warden of the Mint in 1696 (where he was the terror of all counterfeiters), then he became Master of the Bank of England. In 1703 he was elected president of the Royal Society.

Friendships came and went, with John Locke and Samuel Pepys and others on the metropolitan stage on which Newton, it seems rather clumsily, took his place, spending much of his time in London. Before his death he published Opticks and Arithmetica Universalis, seen once again as seminal in their fields, but the bulk and the truly great part of his work had been done before the end of the seventeenth century. The first quarter of the eighteenth century was a time of triumph. Rather like a Roman emperor, Newton inspired portraits, statues and poetry - especially by the most popular poet of the day, James Thomson, in his work The Seasons - influenced by the words Newton used as much as by the man he was. A whole generation of aspiring intelligences became Newtonians; mathematics, thanks to the Principia and the man who wrote it, became fashionable, its ideas socially exciting. Aristocrats were moved to build laboratories in their country houses, impoverished graduates gave lessons to refined young ladies on the wonders of Newton. He became a climate of opinion. In 1727 his death and burial were an occasion for official national mourning. Two years later the Principia was translated into English.

The chief way in which the Principia changed the world was to add so much and so majestically to our knowledge of the universe. 'Man is what he eats' is true; 'Man becomes what he knows' is another truth. Newton extended the boundaries of thought dramatically. Subsequently, often standing on his shoulders, almost three centuries of scientific investigation has been launched.

His fame and the excitement generated by his mind also made him an ideal to be followed by men and women, of the greatest intelligence. Newton was out there, he inspired and by the knock-on effect of history still does inspire young people to give their minds to science. He became the heroic example.

Professor Al Khalili, Head of the Theoretical Nuclear Physics group, University of Surrey, says that Volume One is the most important of the three because it is there that Newton virtually invented the calculus which is central to modern physics. This meant finding equations to describe the curve on a chart on the gradient of a line. It is absolutely central to understanding the world around you and all natural interactions that occur above the atomic level. To all intents and purposes 95 per cent of physics applied to daily life uses Newton's mechanics rather than Einstein's. Newton's equations, which Einstein refined, for instance on gravity, were accurate up to about the tenth decimal place, which was absolutely remarkable, Professor Khalili says, considering the paucity of research and equipment he had to rely on.

In terms of space, even after more than three centuries and the revelations of Einsteinian relativity and quantum mechanics, Newtonian physics continues to account for many of the phenomena in the observed world, and Newtonian celestial dynamics is used to determine the orbits of our space vehicles. In 1687 Newton laid out in mathematical terms the principles of time, force and motion that have guided the development of modern physics since. For instance, Newton regarded time as a kind of constant lying outside of space, which Einstein proved false, but in 99 per cent of instances it doesn't matter in practical terms and Newton's views hold.

In terms of scientific investigation, Newton's principles describe acceleration, deceleration and inertial movement, fluid dynamics and the motions of the Earth, Moon, planets and comets. The Principia also revolutionised the methods of scientific investigation.

With regard to light, ideas on which had moved on very little from Aristotle, Newton revised the notion that the separation of colours through a prism targeted with white light was due to the glass somehow modifying the beam and proved, yet again in mathematical terms, that the white light beam was made up of seven distinct types of moving particles, each with distinct properties that cannot be modified. These findings became the foundation of the science of physical optics.

The laws of motion seemed to be the critical issue in unlocking the secrets of 'natural law', and once again Aristotle's view still largely obtained before Newton. Galileo had challenged these ideas, for example that heavier objects fall faster than lighter ones. But it was Newton whose experiments uncovered the organising principle.

He introduced the notion that everything in the universe can be explained by mathematical laws. By the nineteenth century this idea had taken root to such an extent that 'scientific explanations' were, and largely still are, accepted as the best and liable to be the most accurate. Natural philosophers became 'the Priests of Nature'. To some natural philosophers, especially physicists, Newton's Principia stood not against but alongside the Bible, proving by the new scientific method what God had revealed in His words.

Newton says that if you are rolling a ball down a plane, or if you are firing a cannon ball on a trajectory or working out how a sailing ship moves in accordance with the wind and the waves and the tides, all of these things come back to these very basic rules.

The first rule is that things keep moving in a straight line unless something pushes them or pulls them. This applies to the orbit of the moon. It tries to go in a straight line. Gravity stops it. The second, that action and reaction are equal and opposite. Things bang together, they bounce off with equal force and this applies with rockets - you make it move by throwing things backwards and that moves you forward. The third law tells you how fast things move when you apply a force. When we think we understand the Big Bang it can all be traced back to Newton's Laws.

It might be useful to present as practical a list as I can, not comprehensive but, I think, indicative of the bewilderingly profound impact of one man's book.

In the communications industry, Newton's orbital mechanics are behind the workings of satellites and the multi-billion-pound satellite industry, which includes not only entertainment but defence, intelligence gathering and measuring changes in weather, crops and water.

His work on the propagation of waves, in particular their application to determine the velocity of sound, gave us the supersonic aircraft. Another important technology relying on the wave principle includes ultrasound, also called ultrasonic scanning, to obtain images from inside the human body.

Newton's invention of the reflecting telescope led to the periscope and the principles behind the reflective telescope can be traced through to the laser industry. Again, from his study of light come optical fibres which carry light for extremely long distances.

His celestial dynamics still determine the orbit of our space vehicles.

The breadth, depth and success of such later developments, according to Gribbin, gave the British an intellectual confidence in themselves across the board.

Yet it is, I think, useful to look at it from a rather different perspective.

In Simon Schaffer's opinion you did not need the Principia in the early days of the Industrial Revolution to build bridges, mills, guns, steam engines or anything technological. That kicked in later. But if you claimed Newtonian