

To Explain the World: the Discovery of Modern Science

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Reviewer: Thomas Colville

'I am a physicist, not a historian' (p. ix). This is how Steven Weinberg, one of the most eminent scientists of our time, has chosen to begin his effort to encapsulate the historical development of the scientific method. Starting in the ancient world with a guided tour of Greek physics, and then Greek astronomy, Weinberg touches briefly on the Middle Ages before delving into the Scientific Revolution, finally tying together his grand narrative with an epilogue that takes us forward from Newton to the world of modern science. This is a fluent and scientifically rich book, but it unfortunately fails to engage with the consensus among historians – offering an unabashedly Whig account of the history of science instead.

Weinberg's opening salvo (declaring his field of expertise) may sound modest, but it is also entirely accurate. Weinberg is not a historian and, in many senses, this is not a history of science. *To Explain the World* is an exercise in judging philosophers and natural philosophers of the past by the standards of modern science. Weinberg offers praise when the great men of philosophy observe from nature and write with logic, and he is also not afraid of criticising when Galileo was not 'at his best' (p. 185) or of declaring that 'although often wrong Aristotle is not silly, in the way that Plato sometimes is' (p. 23). In fact the book as a whole is saturated with Weinberg's own personality. The reader will find that the author moves from Tycho Brahe to the multiverse theory (p. 164) simply because the latter clearly interests Weinberg. Similarly, his argument that 'there *was* a scientific revolution' (p. 146) is primarily based on the fact that from the 16th century onwards 'from the perspective of a contemporary working scientist' (p. 146) Weinberg recognises the philosophical methods to be more like his own. *To Explain the World* is short on historiography, or even historical method, but it is rich in personality and impressive in the way that it simplifies potentially difficult historic and modern scientific issues for a wide audience.

For Weinberg, the history of modern science began in Europe, although he does recognise that the Babylonians, Chinese, and Egyptians also made contributions. The story therefore begins in part one, 'Greek physics', with Thales, the mysterious Milesian philosopher who may have predicted a solar eclipse in the year 585BC. From Thales we move to Anaximander, thence to Anaximenes, Xenophanes, Heraclitus, and Empedocles. The first chapter really gathers pace when the story progresses to Parmenides and Zeno of Elea. Weinberg accuses these two philosophers, not just of 'intellectual laziness', but also an 'intellectual snobbery' (p. 8) which persists for far too long in the history of science and held back thoroughgoing, unbiased

observation of nature. The pre-Socratic predilection for a-priori reasoning, rather than descriptions of what they saw with their own eyes, is presented as an example of bad scientific practice, which we have thankfully overcome. Moving into a discussion of Socrates and Plato, Weinberg's next criticism is that none of these philosophers genuinely explained how it was that they came to their conclusions about the fundamental constituents of nature (water, fire, ether, etc.). This is the real meat of the argument in chapter one: the lack of substantial explanation underlying the theories from Thales to Plato qualifies these men as poets, rather than physicists, according to Weinberg. They wrote ideas which were pleasing to the eye, the ear, or the mind, but they did not aim to test or verify.

Chapter two moves from theories of fundamental substances to the development of mathematics. Weinberg introduces the reader to the Pythagoreans, and suggests that the discovery (or perhaps invention) of some significant mathematical principles had its origin in the Greek appreciation of music, and the mathematical patterns of strings playing pleasantly or discordantly to the ear. Once again, this methodological development is not wholly praised, as Weinberg expresses concerns that the deductive style of mathematical theorising has impinged upon the natural sciences, leading many great men – at least up to the early modern period – to believe they could discover truths about the world from their unaided intellect. As in chapter one, chapter two closes with Weinberg's relief that modern science has drawn better and more distinct boundaries which isolate the natural sciences from these methodological landmines.

Chapter three makes the natural move from Plato to Aristotle, about whom Weinberg is more generous with his praise – at least 'it would be unfair to conclude that Aristotle was stupid' (p. 30). Weinberg is concerned to explain how Aristotle arrived at his theories of motion, but above all this chapter is a transition from the Classical era, to the far more scientifically promising Hellenistic era. Chapter four therefore delves into the mental world of men such as Archimedes and explains that the science of the Hellenistic era was partly driven forward by a greater ability to embrace technology and practical value in the world. Once again, however, Weinberg seems to need to end his chapter with a criticism of the past and an expression of relief that the present has progressed past it; he therefore offers a very brief interlude about medical practices in history and the way that they generally did not develop alongside any evidence of their efficacy.

Part one concludes with chapter five – which marks an unexpected break from the simple chronology which guided the first four chapters. Titled 'Ancient science and religion', Weinberg uses this chapter to set science and religion up as opposing mental forces. One which seeks to explain the world based on testable observation, and the other which describes the world around human values and supernatural intervention. The adoption of Christianity, according to this view, retarded the progress of natural science.

Part two takes 'Greek astronomy' as its topic, anchored around the basic premise that this was the area of science in the ancient world which progressed most effectively towards Weinberg's notion of successful observation. Chapter six seeks to explain why this might be, by running through the practical value that accurate astronomical observation entailed (timekeeping and navigation for example). Weinberg celebrates the fact that 'perhaps under the pressure of practical needs, astronomers learned not to rely on intellect alone' (p. 62). Chapter seven details how this happened in the case of measuring the Sun, Moon, and Earth. Aristarchus of Samos features as a leading light here, although his inability to examine his own experimental uncertainty holds back his accuracy. And Eratosthenes, although he was 'lucky' (p. 76), breaks Weinberg's habit of ending chapters with wholehearted criticism – the reader is informed that the philosopher 'had done quite well' (p. 76).

Chapter eight is the longest chapter about the ancient world in this book, but this is largely due to the number of excursions and deviations into modern physics. Ostensibly about 'The problem of the planets' for ancient Greek observers, Weinberg really uses this chapter to ask what these philosophers observed in the night sky, and suggests where they could have made better scientific progress with their theories. This leads Weinberg to discuss problems in modern science, such as fine-tuning evidence to fit theories. Introducing these asides is symptomatic of the passionate interest that Weinberg clearly holds for the history of Greek astronomy; this chapter truly reveals his desire to make himself a part of this story and to do the story

justice. As a result, he refrains from ending the chapter on a 'sour note' (p. 100), instead quoting Ptolemy on the pleasure he feels when discovering astronomical facts.

This evident passion for Greek astronomy does not seem to be repeated in part three: 'The Middle Ages'. Comprising of just two chapters, this small middle part certainly gives the impression that most developments in the scientific method took place in either the Classical and Hellenistic eras, or in the Scientific Revolution of the early modern period. Chapter nine, 'The Arabs,' surveys a number of influential names and their works, including al-Razi, Ibn Rushd, and Moses ben Maimon. Despite covering a number of interesting and influential men and their ideas, the narrative of this chapter is very much one of eventual decline – which leads Weinberg to ask the same question he posed at the end of the Hellenistic era of science: did religion's prominence cause the decline in scientific observation? By weighing up the complex questions of what religion said about science, and what scientists thought about their religion, Weinberg seems to suggest that no decisive answer can be found. However, a general impression, once again, that religion and science are mutually exclusive (if not opposing) forces pervades his conclusions which draw in comparisons with 21st-century Islam, and personal anecdotes about the suppression of science. Chapter ten continues this debate about the importance of religion as a scientific retardant, but in medieval Western and Central Europe. Weinberg portrays the waxing and waning of Aristotle and Ptolemy's popularity, but the essential purpose of this chapter is to set up the reader for the next important development: the Scientific Revolution.

As the introduction to part four, 'The Scientific Revolution', makes clear, Weinberg thoroughly believes that a Scientific Revolution did take place, and, as becomes apparent in chapter 11, he believes that it was caused by the breakthroughs that took place in the minds of a series of great men. This is a familiar story: Copernicus to Brahe, Kepler to Galileo. By this point in the book it becomes very clear that although *To Explain the World* angles itself as a description of the scientific method in general, the reader will find very little (if anything) about chemistry, alchemy, medicine, biology, zoology, psychiatry, or many other subdivisions of scientific and proto-scientific endeavour. The focus in this book is very firmly on astronomy and physics. It covers the traditional story of the early modern development of astronomy very effectively and with a real flair for explaining scientific concepts, but the reader may be left wondering whether or not similar achievements were developing in other strands of 'science'.

Chapter 12 moves from Galileo to Huygens and from there to Pascal, Torricelli, and Robert Boyle. By the time Boyle was experimenting with an air pump in the early Royal Society it is suggested that natural philosophers had decided to force Mother Nature to reveal her secrets. One feels that Weinberg's narrative could have been lent more depth by engaging with some of the vast historiography relating to these developments – but perhaps that is to wish that Weinberg had written an entirely different book. As a history of science for historians *To Explain the World* is insubstantial, but a broader audience will not fail to be engaged by the modernising narrative. Those historians of science who do choose to read Weinberg's book will no doubt have their focus drawn to chapter 13, in which he assesses Francis Bacon's and Rene Descartes' models for doing science. Both men are found wanting in Weinberg's judgement. Bacon is depicted as a holder of extreme views who in fact had little, if any, real influence on the development of science. And although Descartes is held in higher regard by Weinberg, he was ultimately doomed to fail because of his overreliance on the mathematical method and the fact that science does not develop through rules, but through the experience of doing it again and again. These are interesting arguments, but (for example) Weinberg will need far more than the one and half pages which he devotes to Francis Bacon to convince many historians of science that Bacon had zero impact on the scientific methods of Newton or Boyle.

The conclusion to this book is contained in chapters 14 and 15. Chapter 14 takes the reader through a survey of Newton's life, theories, and experiments, as well as pointing the reader forwards in time towards General Relativity. Newton is explained to be an oddball but nevertheless his thought is seen as the culmination of the scientific revolution. As with all historical figures in *To Explain the World*, Isaac Newton is described with his limitations and shortcomings but the author of 'doubtless the greatest book in the history of physical

science' (p. 231) is clearly somewhat of a hero for Weinberg. Chapter 15 is labelled the epilogue; it concludes Weinberg's 'grand story' (p. 268) and indicates the progress from Newton towards increasingly unified and reduced scientific theories. In the final few words Weinberg admits that there may be aspects of nature which the human mind cannot or will not ever fully understand, however the tone is unquestionably positive. The general thesis of *To Explain the World* is that the scientific method has gradually improved, through a trial and error process, to the point where we are now able to at least ask the right questions – questions which, for so much of history, were simply not posed.

I am a historian, not a scientist; but Weinberg's narrative of the development of the scientific method left me asking where and when other aspects of 'modern science' were discovered. Experiment and observation take centre stage in Weinberg's story. But if this book is to achieve its goal of telling the reader how modern science was discovered then there are other aspects of modern science, as I perceive it (admittedly as an outsider), which deserve explanation. Where and when did collaboration enter the story? With whom did peer review – surely one of the defining features of the modern scientific process – become expected practice?

One of Weinberg's fundamental aims in writing this book, beyond his own fascination with the subject, was surely to encourage that same fascination in other people. As the media furore over the infamous comments of Nobel Prize-winning biologist Tim Hunt have recently highlighted, one of the most contested, complex, and engaging aspects of the development of modern science is the participation of women. However, there is no place for women in Weinberg's history of science. Although I'm sure it is not his intention to write women out of history, the history of science told entirely through the thoughts and words of famous men (as it appears in *To Explain the World*) propagates a narrative in which women have had no effect on the development of scientific method. The reader engaged with any recent development in the history of science will be left wondering where certain social aspects of the history of science fall into Weinberg's chronology.

To Explain the World is engaging, and has clearly been written by a man with excellent grasp of scientific principles and an unparalleled ability to simplify those for the reader without a scientific background. The nearly 100 pages of technical notes also offer the reader with interest in the mathematics and physics in question the opportunity to gain a deeper understanding of the processes at work. This is a book which will therefore have a wide popular appeal. As a *longue durée* history of science for historians *To Explain the World* feels thin on argument and method, and heavy on Whiggish narrative. Weinberg's book will split opinions, some will be engrossed by the personality leaping from the page, others will argue that simply understanding modern science is not a sufficient qualification for writing a history of this sort. It is fascinating to see how a working (and highly prestigious) scientist views the history of his discipline, yet from the perspective of a historian this book offers nothing new to the field. Anachronistic judgements get in the way of seeing historical characters in their contemporary social contexts, and fail to do justice to the fact that the mental worlds of Plato and Bacon were not the same as one another, nor the same as Stephen Weinberg's. This approach, therefore, does not genuinely reveal how these philosophers thought, but how the author wishes they had thought.

Other reviews:

Guardian

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Telegraph

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Financial Times

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New York Times

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Times Higher Education

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