

Introduction: the Old World and the New

If we had been born a couple or more centuries ago, there is a good chance that we would have been poor, very poor indeed. Our lives would have been spent working on the land, with little or no prospect of change. We would produce large families, but few of our children would outlive us. In any case, we ourselves wouldn't expect to live much beyond about 45. We would call a hovel our home, and heat it in winter with whatever sticks of wood that we were able to collect. Other comforts would have to be paid for either in kind or with the few pennies we had managed to save. Apart from everyday conversation, crying children and the noise of poultry and livestock, we would have lived amidst silence, interrupted on occasion by a thunderclap, communal song, the drums and trumpets of passing soldiers, maybe a lonely church bell tolling every so often. Most of us would have believed without question in the literal existence of spirits or gods or one God as the guiding or even the all-determining power in life and even more so after death.

In short, we would have been living in what is sometimes called the Old World, as distinct from the modern New World which you and I inhabit and which has made us rich and next year may make us richer still. Ours is a world where goods are readily available everywhere; however many we may own today we can always obtain newer and more up-to-date versions of them tomorrow. We are living longer and we are dying of mostly different diseases. Noise surrounds us wherever we go. We are parents of a few carefully planned and properly vaccinated children, who are likely to live even longer than we will. Many of those among us who still regularly go to church are no longer inclined to take the texts recited there in their literal sense. Our everyday behaviour is oriented towards this life – however hard

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we may try we find it difficult to imagine what life after death might possibly be like. When we travel we usually reach our destination by air, rail or motor car within hours instead of after days or weeks on horseback or on board a pitching barque, more concerned about tailbacks or punctures than ambush by pirates or robbers.

The modern way of life outlined above is everyday reality for most of us in the West. For the majority of the world's population it is a different matter or, rather, it is still a different matter. The minority for whom the picture of the modern world just sketched has already become a reality is growing by the day. And the diminishing majority who hardly take part in it yet do not just aspire to the material advantages that we may call ours: their aspiration has become perfectly realistic. Even if the world's poor do not expect it for themselves, they do so for their children or their children's children. Within a few generations the leap from the Old to the New World seems to be attainable for all.

This of course raises the question of what made the leap possible. When, where, how and due to what was it first made?

When and where it all started are easy to answer: indeed, the modern world has its roots in the West, and the first signs manifested themselves in Britain around 1780. As a result, within a century, the face of Europe and the United States changed beyond recognition.

Precisely how the process of modernisation developed and in particular how a New World was actually able to detach itself from the Old, and why this turning point in history took place specifically in European civilisation rather than in China or India or the Islamic world – these are for a historian the truly big questions. The past hundred years or so have seen a succession of studies devoted to untying this tangled knot which, in its full complexity, I shall leave tied here. In this book I confine myself to resolving one specific aspect of the question – an aspect that is often overlooked or cut short but is nevertheless crucial. Directly or indirectly, at every point in the range of contrasts that I listed above, we encountered modern science.

Take the contrast between modern unbelief and the pre-modern literal belief in a quite vividly imagined hereafter. What is at issue here is our irreversible awareness of abstract natural laws, operating according to fixed rules, in precisely defined circumstances – laws of the kind that have continued to characterise nature-knowledge ever since Newton. These laws have made the notion of a deity concerned with our personal welfare highly problematic. Whether modern science actually *imposes* some ‘scientific world-view’ is a doubtful matter. It is nonetheless fairly obvious that modern science is at odds in important ways with the broad conception of the world that comes with the traditional world religions.

Another contrast listed above, between pre-modern silence and modern noise, does not so much reflect the tension between a pre-scientific world-view and one formed at least in part by modern science. Here the contrast is between pre-modern craftsmanship, based on hands-on experience, and our modern science-based technology. From my first visit to the Archeon archaeological theme park in the Netherlands I remember in particular the pre-history area, then directly behind the main building. I recall the unearthly silence on entering it, the sensation of being completely out of earshot of radio stations, muzak, the beeping of reversing lorries or the neighbour’s power drill, and the relaxing sensation of not being semi-consciously occupied with blotting them out. And therefore: silence, pre-modern silence.

Loud noise, obviously, has always been with us; in ancient Kaifeng or Rome the racket must have been considerable, and probably round-the-clock. But it was easy to escape from it; you only had to walk out of the city gate. More importantly, pre-modern noise was not intended to numb the brain through automated drumming or the electronic amplification of mindless babbling. Our modern urban world is not only full of inescapable cacophony, but for the first time in history the (in principle) pleasing sound that we call music has become part and parcel of that noisy background. How could our daily experience of sound change so radically? What or more importantly

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who was behind it? Who brought about the disruption of a centuries-old pattern, which all over the globe may have varied somewhat from place to place, but whose underlying features were the same everywhere?

Well, Hertz and Marconi brought it about. Though not alone, of course. The ingenious physicist and the clever engineer did not compose a single note of music and never deafened the neighbourhood with quadrasonic speakers blaring from their cars. They would have been staggered to find that any such thing could have resulted from the discovery made by the former and the invention of the latter. Yet, for all their stunned amazement, they would have had to concede that without the theoretical prediction of the radio wave and its concrete application in the 'wireless telegraph', modern electronic sound could not have happened as it did, or for that matter at all. At best they might point their finger at later scientists and engineers who built on their novel and, as such, still elementary insights and attainments. Or alternatively they might go back in time and single out Maxwell as the great theoretician of the electro-magnetic continuum, who in his turn might refer back to Faraday as the great investigator of electro-magnetic effects, who would then point at Newton as his role model, who in his turn would refer us back to Galileo as the great trail-blazer of an approach to nature that really holds water. Indeed, we can find such references in their collected works and letters. True, Galileo used to invoke at times the 'divine' Archimedes, but he was well aware that his own way of examining natural phenomena was not only in the right direction but also had no real precedent.

That is how we arrive at the years around 1600, which is when 'the re-creation of the world' (to use the original, Dutch title of this book) began. This beginning consisted first and foremost of new ways of thinking. For centuries Greeks but also Chinese, Europeans but also Arabs, monks but also laymen, lone thinkers but also philosophical schools, had reflected with great acumen and perseverance on how the natural world hangs together. But traditional thinking, though

often very ingenious, was, in retrospect, most often misdirected, and between the 1600s and the 1640s Galileo, Kepler, Descartes, Bacon and numerous others gave a decisive new twist to it. It was not just a theoretical twist but, inextricably bound up with it, a practical one as well. The kind of reasoning associated with the embryonic modern science emerging at that time has been called 'hands-on thinking' (literally 'thinking with the hands'). For the first time ever, room was created for testing systematically whether assertions about nature stood up to reality. All over the seventeenth century hands-on thinkers began to explore procedures and practices for checking whether a plausible-looking assertion was anything more than just a plausible assertion. In this book I seek to analyse how all this happened in the way it did and to explain what made it possible.

Expert historians of science have provided numerous accounts of the seemingly miraculous range of theoretical and practical breakthroughs from Galileo to Newton. My own introduction to the genre was E. J. Dijksterhuis' *The Mechanization of the World Picture: From Pythagoras to Newton*, published in Dutch sixty-five years ago but still in many ways an inspiring account. I myself drew up a comparative and critical inventory of all those dozens and dozens of interpretations and explanations in *The Scientific Revolution: A Historiographical Inquiry* (1994). But no systematic, source-based effort has yet been undertaken to explain why the decisive move towards modern science happened in, of all places, Europe, that late-comer among the great traditional civilisations. Why not in China, why not in the Islamic world, in both of which the knowledge of nature was at times pursued in quite advanced ways? There are enough clichés in circulation, and plenty of glib answers, but until recently there had been no sustained in-depth historical comparison of the pursuit of nature-knowledge in these three civilisations. In my *How Modern Science Came into the World: Four Civilizations, One Seventeenth-Century Breakthrough* (2010), which is just such a comparative study, I set out my research findings in full, complete with an account of the book's conceptual underpinnings and sources

Cambridge University Press

978-1-107-12006-8 - The Rise of Modern Science Explained: A Comparative History

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and references to the literature. In the present volume, which contains the same argument in shortened form, I am not primarily addressing my fellow historians of science, but a wider readership. I set myself up here as the reader's authoritative and reliable guide – a posture that I dare to assume only in view of the existence of that larger book, in which I instead invite the reader to join me on an adventurous voyage of discovery.

The wider readership of the present volume needs no special knowledge to follow the argument developed in it. I set forth in words, not formulas, the mathematical issues that arise from time to time. Far more important than the knowledge that the reader may or may not possess is a willingness to set that knowledge aside for the time being. I began this chapter with the contrast between the Old World and the New. We can only conjure up life in the Old World by looking around us and then, one by one, eliminating things. Let's pull out that plug, get rid of the gas oven, ditch your mobile phone. Hey, what's that plastic bin bag doing here? That bike in the wooden shed can go too. The shed can stay, though. In the same vein I am asking you, the reader, to delete several modern concepts from your brain. Say goodbye to evolutionary theory, abandon the law of universal gravitation, jettison the table of chemical elements. I must even beg you to suspend for now your own notions of how our knowledge of nature originated and how that knowledge advances over time. If you've read Kuhn, don't immediately see paradigm shifts everywhere; we'll find out in the course of the book whether they are of any use to us. If you prefer Popper, try abandoning your trusted criterion of falsifiability until the final pages. And if you are tacitly assuming that science in the past must really have been about the same as that of today, only much simpler and with weird errors that the great heroes of past science managed over time to weed out one by one, then please clear a space in your brain for a situation where there is no such thing as science at all. The natural world now lies before us unexplored and undiscovered; how can we, through thought and observation, come to grips with it?

I To begin at the beginning: nature-knowledge in Greece and China

The natural world around us looks both impressive and mysterious. In the past, controlling it in times of drought or plague required magical incantations, while real understanding came via the world of the gods. Take the *Iliad* or the *Odyssey*: the angry voice of Zeus (Jupiter) is heard in a thunderstorm; volcanic eruptions and earthquakes are caused by Hephaestus (Vulcan) hammering on his anvil; if rain should fall while the Sun is shining, Iris hurries to place a rainbow in the heavens. In the pantheons of other civilisations it was much the same if with different names. But such explanations still left open the possibility of penetrating more deeply into specific phenomena. The Babylonians, for instance, produced strikingly accurate predictions of the positions of the Moon, stars and planets by systematically tracking their movements through the night sky. The Polynesians, by sophisticated observation of subtle changes in cloud formations and bird flight, were able to navigate their canoes accurately over hundreds of miles of ocean.

Among the civilisations that developed such specialised nature-knowledge, two took a further decisive step. They were the Greeks in the sixth century BC and the Chinese at about the same time. Both ceased appealing to explanations of the Zeus/Iris type, and came up with a very different picture of the natural world. They did not abandon their belief in gods and the spirit world, but they no longer attributed the myriad of natural events to divine action. Instead, they posed certain principles of natural order and established certain explanatory schemata that enabled them to understand and chart the whole of the natural world from a few fundamental points of view.

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There are of course many ways of doing this, and just as one can choose between eating with a knife and fork or with chopsticks, or writing with letters or characters, so one can choose between different ways of approaching natural phenomena and breaking them down into manageable portions. Accordingly, how the Greeks chose to approach and order the natural world turned out to be very different from how the Chinese did essentially the same thing. The Chinese approach relied primarily on observation and focused on practical use. In the second century, Zhang Heng attempted to detect regularity in the occurrence of earthquakes in order to find a way of predicting them. His observation-based research was conducted against the background of a coherent world-view that had taken shape gradually and had allocated to each phenomenon its specific place. The Greek approach, by contrast, was not 'bottom-up' like the Chinese, but 'top-down' – i.e. generalisation preceded the collection of data, and the observed facts were fitted into an intellectual construction. The empirical element was minimal; the thinking was abstract and theoretical. And whereas in China, after the unification of the empire under one emperor in 221 BC, a synthesis emerged in which one approach and one world-view largely prevailed, in Greek thought a permanent division developed. In Athens abstraction and theorising took the form of philosophy; in Alexandria of mathematics. For instance, Athenian philosophers explained in broad outline the structure of the cosmos from the Earth up to the outer sphere of the stars, whereas in the Greek colony of Alexandria mathematicians used models to calculate the planets' trajectories through the heavens.

The existence of that dichotomy between the Athenian and Alexandrian approaches is a key element in this book. Without an insight into its whys and wherefores, it is hardly possible to explain the much later emergence of modern science. Taking that as our starting point, we shall first consider the Athenian mode of nature-knowledge and then the Alexandrian, before charting how they differed and how deeply rooted their differences were.

IN ATHENS

Philosophy is all things to all people. It provides solace, worldly wisdom, mental discipline, ideas on good statesmanship and advice on how to deal responsibly with our fellow human beings. Each of the four schools of philosophy that were founded in Athens more than two thousand years ago had answers to such questions. Furthermore, they each had a fully worked-out conception of the natural world and claimed to have an understanding of nothing less than its very essence. Whether you visited the Academy which Plato founded, the Lyceum of his pupil Aristotle, the Stoa's colonnade or the garden of Epicurus, you would always find someone to explain to you the ultimate source of natural phenomena. Of course, the views of each of these schools differed but there was nevertheless one thing that they all had in common: they each had their own explanation for the same problem, the problem of change.

How can change be a problem? After all, things are changing around us all the time. The branch of a tree blows off and falls to the ground, water evaporates in the Sun's heat, a volcano spews out lava, a child becomes an adult and eventually withers away. Surely the search for nature-knowledge should focus on detecting regularity within this ceaseless change? Had not a very early Greek thinker, Heraclitus, expressed this in his celebrated *panta rhei* (everything is in flux . . . nothing endures but change)?

But change was turned into a problem by that most contrary of the early philosophers known as the 'pre-Socratics', Parmenides. In fifty-odd lines of didactic verse, he declared that change is a delusion. There is only Being and Non-Being and no intermediate or transitional form can be conceived of without inner contradiction. For if that into which something changes did not originally exist, where could it possibly have come from? Or it was there from the beginning, in which case there is no change at all since everything has remained as it always was:

How might what is then perish? How might it come into being?
 For if it came into being it is not, nor is it if it is ever going to be.
 Thus generation is quenched and perishing unheard of.

Cambridge University Press

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In short, it is unthinkable that between Being and Non-Being there exists a category of Becoming. If we believe that we observe change all the time in our daily lives, then our observation is at fault and we must conclude that our senses fail to provide us with reliable information about the real world. What is at one and the same time impressive and off-putting about early Greek thought is that cold-blooded readiness to draw such a conclusion. And as so often happens in the history of ideas, inspired nerve brings its rewards. There are scholars who believe that those fifty-two rather obscure lines of verse by Parmenides have determined the direction of the Greek philosophical tradition ever since.

Sensory perception, so peremptorily cast aside by Parmenides, was soon rehabilitated, although it was not by pretending that nothing had happened. The *paradox* of Parmenides, that in spite of appearances Becoming is impossible, is creatively converted into the *problem* of Parmenides: how can we recognise the validity of the paradox and at the same time render it harmless through equally rigorous reasoning? Can we rescue 'Becoming' from its logical difficulties and make it comprehensible after all?

The fundamental principles adopted by the four philosophical schools that were established in Athens in the period after the pre-Socratics all had an answer to the problem of Parmenides.

Plato goes along with him the furthest. He makes a distinction between the imperfect world that we observe with our senses and a perfect world of Ideal Forms of which the objects of sense are merely a poor reflection. There are pine trees and oaks and palm trees to which all kinds of things may happen, but what really matters is the unchanging Idea of the Tree, the ideal tree from which all those pines, oaks and palms take their specific form. Knowledge of nature, of human beings and of human society is always concerned with their ideal forms. Plato's prime concern was the constitution of the state, which should embody as closely as possible the Idea of Justice. But in one of his dialogues, the *Timaeus*, he provides an insight into his view of the natural world. He recounts a creation myth in which nature