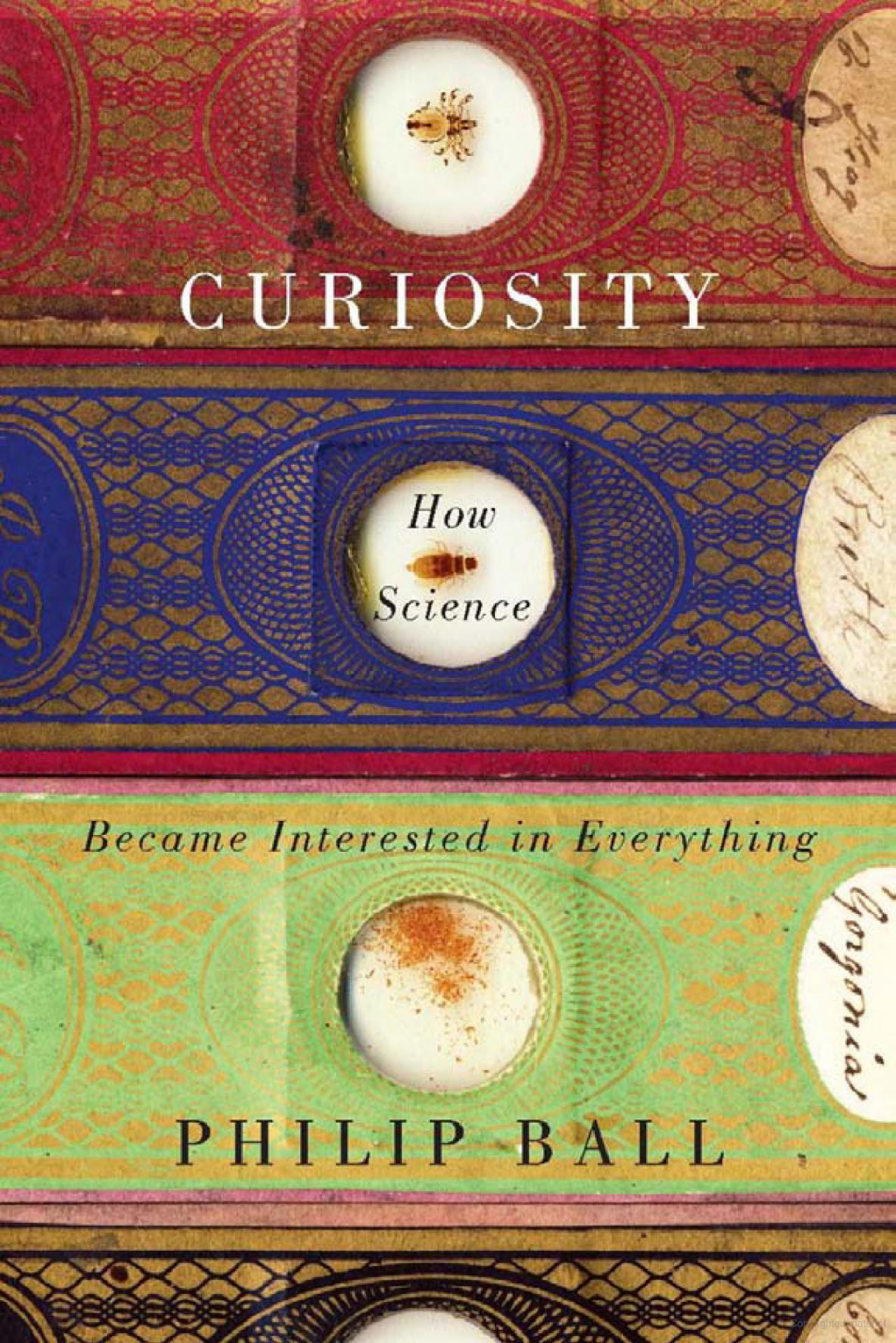
CURIOSITY
How
Science
Became Interested in Everything
PHILIP BALL

# Curiosity

## HOW SCIENCE BECAME INTERESTED IN EVERYTHING

Philip Ball

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Philip Ball worked for over twenty years as an editor for *Nature*, writes regularly in the scientific and popular media, and has authored many books on the interactions of the sciences, the arts, and the wider culture, including *Critical Mass, The Self-Made Tapestry: Pattern Formation in Nature, $H_2O$: A Biography of Water, Bright Earth, Universe of Stone,* and *The Music Instinct.*

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# Contents

# Preface

While I was talking about this book with the literary scholar Mary Baine Campbell, we considered the idea that curiosity could become pathological. Isn't there something problematic about responding to an analysis of, let's say, domestic accounting during the Thirty Years War or the detailed manoeuvres of a gastric enzyme not with glazed eyes but with a breathless 'But that's so interesting!'? Recalibration of one's curiosity threshold is a necessary preparation for most PhD students, but in the wider world mightn't there be something ill-disciplined, even improper, about a voracious curiosity that permits nothing to be too trivial or obscure?

It was a sobering thought, I suspect for the both of us, as we acknowledged what seemed to me a guilty complicity. Was there after all something in the old accusation that it is weak-willed to succumb to the wiles of curiosity? But the problem of our times – and also its great good fortune – is that temptation is everywhere. Not only is it now acceptable to be curious – and this book is largely about how that came to be the case – but it is easier than ever, because of the knee-trembling quantity of information we have at our fingertips. We no longer have to seek out this stuff in dusty vaults and ancient libraries; it sits waiting for us at our desk, humming gently, perhaps even in scanned, gorgeously browning facsimile. More, we carry it everywhere in our bags and pockets. Yes, of course this is all just so much data, amorphous and indeed meaningless unless we have some notion of how to select and organize and filter. And yes, of course it is in some ways a mere side effect of, or accompaniment to, new opportunities for turning our back on curiosity altogether and immersing ourselves in the empty immediacy of a virtual now, of chatter and gossip and a numbing profusion of 'choice'.

But is all this, too, really so new? It has always been a complaint levelled at curiosity that it is the enemy of productivity, an unwelcome distraction from our daily duties. Meanwhile, the Enlightenment's mockers of curiosity were, as we'll see, often not utilitarian Gradgrinds but gossipy, solipsistic wits and libertines. And a surfeit of information has always given cause for grumbling. Alexander Pope felt that the printing press, 'a scourge for the sins of the learned', would lead to 'a deluge of Authors [that] covered the land'.

The relationship between access to information and curiosity about it has, I think, yet to be well explored. But it is clear that the first 'professors of curiosity' who flourished in the century of Pope's birth had to work tremendously hard to get their knowledge, and curiosity was, before profit or fame or reputation, their most significant motivation. This situation has been rightly celebrated, but rarely has it been examined or explained. Mary is one of the scholars who have begun that exploration, and as such, is one of those to whom I owe an immense debt for this book. All the more so because she kindly agreed to read the manuscript and offered insightful and important views on it. For similar acts of generosity I offered sincere thanks to Brian Ford, Michael Hunter, Neil Kenny and Catherine Wilson.

It has been my great pleasure to have published several books under the editorship of Will Sulkin at Bodley Head, who I (and many others) shall miss greatly after his retirement in 2012. Will's enthusiasm, erudition and passion about writing and ideas has been a vital source of encouragement. I am consoled to know that I will still enjoy the thoughtful and diligent editorial support of Jörg Hensgen, and of his colleagues Kay Peddle and Hannah Ross. David Milner has done another splendid job of copy-editing the text. And my good fortune to have Clare Alexander as my agent is one of those things that I always find a little astonishing. As ever, the greatest consolation, support and inspiration comes from my family, within which these days I can delight in watching curiosity bloom in its purest form.

Philip Ball

January 2012

# 1 Old Questions

> To whatever object the eye first turns, the same is a wonder and full of wonder, if only we examine it for a little.
>
> Giovanni Dondi (*c.*1382)

> The important thing is not to stop questioning . . . Never lose a holy curiosity.
>
> Albert Einstein (1955)

'The Large Hadron Collider is a discovery machine. Its research program has the potential to change our view of the universe profoundly, continuing a tradition of human curiosity that's as old as mankind itself.' This is Robert Aymar, former director general of CERN, the European centre for particle physics in Geneva, explaining why the collider has been constructed.

The LHC is the world's most powerful particle accelerator. It uses electromagnetic fields to accelerate protons to 99.999999 per cent of the speed of light, so fast that they travel around the entire 27-km circumference of the tunnels in less than a ten-thousandth of a second. Then the protons are smashed into one another in collisions energetic enough to recreate the conditions in the first instants of the Big Bang from which the universe began. The hope is that this will spawn particles never before seen, which will help us to understand some deep questions about the nature of matter, such as why certain types of particle have mass.

At a cost of $6 billion and twenty-five years in the planning, the LHC is as big as Big Science gets. Why go to all this effort and expense?

Aymar appeals to the role of human curiosity. He implies that this is just the latest development in an unbroken history of curiosity about nature that stretches back to our own origins. It is, he says, an extension of what we have always done.

Perhaps it is therefore no surprise that, as the LHC's inaugural run in late 2008 approached, the media became fixated on ludicrous fears that the experiment would destroy the world, if not the universe. For tradition teaches us that curiosity – especially curiosity about the Creation – cannot be indulged with impunity. Even if this latest threat of apocalypse was more a public plaything than a genuine cause for dread, it showed that we have still not quite made our peace with curiosity.

But there's more to the LHC than a desire for knowledge. It seeks justification in practical spin-off benefits. 'We are constantly being told that we live in a competitive world in which innovation is the main driver towards growth and prosperity', says Aymar:

> History teaches us that big jumps in human innovation come about mainly as a basic result of pure curiosity. [Michael] Faraday's experiments on electricity, for example, were driven by curiosity but eventually brought us electric light. No amount of R&D on the candle could ever have done that.

The underlying assumption here is that voiced by Stephen Hawking in support of the LHC: 'modern society is based on advances in pure science that were not foreseen to lead to practical applications'. Leaving aside the fact that this presents a distorted view of the symbiosis (in fact it is an intimate merging) between science and technology, it is striking how the narrative that Aymar insists on here about curiosity, science and technology contrasts with the defence of curiosity offered by the French philosopher Michel Foucault:

> Curiosity is a vice that has been stigmatized in turn by Christianity, by philosophy, and even by a certain conception of science. Curiosity, futility. The word, however, pleases me. To me it suggests something altogether different: it evokes 'concern'; it evokes the care one takes for what exists and could exist; a readiness to find strange and singular what surrounds us; a certain readiness to break up our familiarities and to regard otherwise the same things; a fervor to grasp what is

> happening and what passes; a casualness in regard to the traditional hierarchies of the important and the essential.

Foucault seems to wish to be enchanted and beguiled by curiosity, to be awakened to wonder, to feel a hunger for experiences strange and new that will break down old ideas and distinctions. Here curiosity is a radical force. In science, on the other hand, curiosity is more often enlisted in the name of taming the world – it is a compulsion to *understand*. The curiosity (if that's what it is) motivating the Large Hadron Collider is likely to lead to *new* hierarchies in our conception of matter and space, while this and other 'curiosity-driven' research is advocated as a source of unforeseen practical bonuses. This is very much the sober view espoused by Francis Bacon in the early seventeenth century: curiosity as an engine of knowledge and power.

Why has curiosity come to stand for these rather different agendas? Can we reconcile them? Is either borne out by history? Those are some of the questions I seek to examine in this book.

The turning point in Western attitudes to curiosity occurred in the seventeenth century, which began with an essentially medieval outlook and ended looking like the first draft of the modern age. This change can be seen in dramatic fashion simply by charting the use of the word 'curiosity' (and its cognates) in the European literature of the period, as historian Neil Kenny has done. The frequency of usage varies little from the mid-sixteenth century until 1650, when it takes off suddenly, peaking in 1700 but remaining high thereafter.

The transformations in thought, particularly in the natural sciences, that characterize the span of nigh on a hundred years between the


The number of uses of 'curious', 'curiosity' and cognate words in books of the 1500s to the 1700s rises dramatically in the mid-seventeenth century. Note that this graph does not allow for variations in the total number of books published each year.

death of Elizabeth I (1603) and the coronation of Queen Anne (1702) have often been called the Scientific Revolution. Its stories are familiar: Galileo validating Copernicus's sun-centred universe; Isaac Newton explaining the motions of the celestial bodies with his theory of gravity and outlining the basic laws of all mechanical motion; the Anglo-Irish scientist Robert Boyle tolling the death knell of alchemy; the endlessly inventive Robert Hooke exploring the microscopic world and the Dutch cloth merchant Antony van Leeuwenhoek discovering microbes wriggling therein. The conventional narrative identifies the *scientific method* itself as the key innovation of the age: a logical system for investigating and interpreting all of nature.

This cosy tale tends to imply that natural philosophers simply got better at asking and answering questions, forsaking tautological or mystical reasoning in favour of explanations that invoked cause-and-effect mechanisms, amenable to measurement and testing. There is some truth in that, but it will not get us very far in understanding what these proto-scientists thought and why. Least of all does it justify the conventional narrative in which science merely expands to crowd out superstition. The now well-known interest of Newton and Boyle in alchemy is merely one manifestation of the true origins of the new philosophy in a mode of thought that arose largely outside the formal university system. To the new philosophers, the natural world was replete with secrets that they must hunt down diligently with an experimental approach that was closely allied to the tradition of natural magic. This 'hunt' was to be engaged by international, sometimes occult fraternities of virtuoso-scientists, themselves a construct of utopian visions of which Francis Bacon's *New Atlantis* (1624), the foundational text of the Royal Society of London, was the most influential.

Underpinning all this was a profound change in the nature of the questions one might ask. Nothing was too mean or trivial to be neglected, for as Boyle said, it was all God's work and therefore worthy of attention. A glance at Boyle's own notebooks reveals the dizzying consequence. His lists of 'things to be remembered' suggest that he would, if he could, have made an exhaustive inventory of all that existed or occurred under the sun: 'Remember', he wrote,

the use of a Coach
the eyes of Puppys newly whelpt
the Feathers, Claws and Beaks of birds yet in the shell
the Gunpowder whole and ground
Insects and other Creatures that lye as it were dead in the Winter
Moses's Serpent and the Transmuted water
that Beauty do's not make the Parts, but result from them as do also Health, Harmony, Symmetry
that Internal Forms may be but lasting Dispositions to be wrought upon by External Objects
the seal'd weather glass &c. and the consequences of such thing
Monsters, and the longings and frights of teeming women
the unskilfull Restitution in Springs made by hammering &c.
to breake a Glass buble in a Barometre.

Popular accounts of the Scientific Revolution rarely stop to think how odd this is. While there was a long, if controversial, history of asking questions about nature and human activity, such enquiries had tended to limit themselves to what was obviously useful, or important, or universal: why plants grow, why winds blow, why we get sick, how the stars and planets progress across the sky. But suddenly, the slightest blemish seen on the surface of a distant planet might spark earnest and learned debate, or the question why fleas can jump so high, or why concentric coloured rings could be seen in mineral flakes under the microscope. The early meetings of the Royal Society embraced a phantasmagoria of phenomena and inventions – some evidently valuable, such as watches for helping chart longitude, others sounding like superstitious or fantastical rumour, such as monstrous births and weird lights in the sky.

And this glimpse of Boyle's restless mind hints at the problem of such eclecticism: how does one make sense of it all? If you can ask anything, then there is no end to the questions. How do you organize all the observations? How do you decide which phenomena are important and which are frivolous? Is anything truly frivolous? But then the task of science is hopeless, because you must always suspect that the next question will challenge your current theory.

Because my survey of the roles of curiosity in science is located almost wholly in the seventeenth century, it might seem unlikely that it will have much to say about the particle physics of the twenty-first.

On the contrary, I contend that we can only truly understand what today's scientists – what people like Aymar – say and believe about curiosity if we examine this critical period in which it first came to be explicitly claimed for the purposes of science. It was in the seventeenth century that science first emerged as a modernizing force and altered both our conception of the world and our ability to manipulate it. Pronouncements like those used to justify the LHC are very much predicated on a narrative that roots itself in the conventional, triumphal picture of this 'Scientific Revolution'.

Historians of science tend now to look askance at the bald assertion of a Scientific Revolution. Or rather, they typically adopt the view eloquently expressed by Steven Shapin in his 1996 book on the subject, which begins 'There was no such thing as the Scientific Revolution, and this is a book about it.' Which is to say, perhaps, that the traditional accounts give us the right facts but connect them together in a warped manner. I agree with Shapin that something changed profoundly in natural philosophy in the seventeenth century, but that it prejudices an examination of this transformation to imagine that we know what we are talking about even in using the words 'scientific' and 'revolution'. I argue that one better way to understand this critical period is to look at changes in the meanings and the values it attached to the notion of curiosity. In homage to one of the most perceptive historians of this era, I suggest that there is no such thing as what Robert Aymar calls a 'tradition of human curiosity that's as old as mankind itself' – and this is a book about it.

### *This singular passion*

For the seventeenth-century English philosopher Thomas Hobbes, curiosity was one of the defining characteristics of humankind (and as such, a good thing):

> Desire, to know why, and how [is called] CURIOSITY; such as in no living creature but *Man*; so that Man is distinguished, not onely by his Reason; but also by this singular Passion from the other *Animals*.

It was curiosity, said Hobbes, that motivates 'the continuall and indefatigable generation of knowledge'. It was 'a more than ordinary

curiosity' about a particular optical phenomenon that made Isaac Newton determined to discover 'from whence it might proceed' – to search for the principles behind it. Unlike carnal passion, said Hobbes, curiosity was not expended with 'short vehemence' but was inexhaustible – as his one-time mentor Francis Bacon said, 'of knowledge there is no satiety'.

But curiosity does not mean and has never meant just a single thing. Even if we accept the modern definition of 'eagerness to know or learn something',* there are many ways to be curious. One can flit in gadfly manner from one question to another, acquiring little bits of knowledge without ever allowing them to cohere and mature into a real understanding of the world's mechanisms. One can store up snippets of information like a miser, never putting them to good use. One can pose questions idly or flippantly, with no plan for coherent enquiry into nature. One can be curious about matters that really are none of one's business, such as the sexual habits of one's neighbours. But one can also seek knowledge with serious and considered intent – and may then do so either in the manner of Isaiah Berlin's fox who would know many little things, or as the hedgehog who knows a single thing profoundly. One can be curious obsessively, or passionately, or soberly, or with clinical detachment.

But this is only to scratch the surface of what the word could connote in earlier times. 'Curiosity', says Neil Kenny, 'was understood in so many ways that it had no ineliminable core that always characterized it.' People could be curious, but so could objects: it was an attribute as well as a state of mind. If we call something curious as Alice did ('curiouser and curiouser'), we generally mean to allude to some quality of strangeness in it. This sense is implied in the cult of cabinets of curiosities (explored in Chapter 3), where the 'curios' may be objects that are unusual and intricate but which offer little purchase for the enquiring mind that wants to understand and explain the world. To call an object curious could mean that it was rare, exotic, elegant, beautiful, collectable, valuable, small, hidden, useless, expensive – but conversely, in certain contexts, common, useful or cheap. At any rate, the curious object was one towards which curiosity might properly be directed: to call it 'curious'

* When I shall use the word, it is generally in this provisional sense unless the meaning is explicitly refined or modified by the context.

was not simply to label it as singular, odd or worthy, but to say 'Look at this – and look closely.'

Small wonder, then, that it is often impossible to say whether a particular writer is for or against curiosity. At least three of the key figures in this story – Francis Bacon, René Descartes and Galileo – use 'curiosity' to mean different things at different times. Yet when writers, philosophers and moralists of all ages have pronounced on curiosity, they have typically had only one or some of these many meanings in mind, and their judgements both good and bad can therefore hardly be said to speak to the full range of what it means to be curious. Lorraine Daston and Katharine Park, two of the foremost 'historians of curiosity' (a small but perceptive bunch), say of the curiosity praised by Hobbes and that condemned by medieval theologians that, while they share some kinship, they are 'not of the same emotional species'.

'Curious' derives ultimately from the Latin *cura*, meaning care, and until at least the seventeenth century a 'curious' person could simply refer to one who undertook investigations with diligence and caution.* When Robert Hooke said of the blue fly under his microscope that 'the hinder part of its body is cover'd with a most curious blue shining armour', he meant that it appeared to be carefully crafted. From *cura* also comes the curator, the person who looks after obligations or objects with care, whose modern incarnation as a collator and administrator of collections in a museum or gallery stems directly from the tradition of collecting that spawned the cabinets of curiosities.

### *Incurious ancients*

Francis Bacon described Pliny's encyclopaedic work *Natural History* as 'fraught with much fabulous matter, a great part not only untried, but notoriously untrue, to the great derogation of the credit of natural history with the grave and sober kind of wits'. While he might equally have been describing almost any of the encyclopaedias of the natural world produced between the age of Imperial Rome and the Renaissance, he has a point. Pliny, a Roman administrator of the first century AD, had a credulous, sprawling, magpie-like infatuation with the most peculiar and unlikely of stories. Cut open a hairy phalangium spider

* It is telling, however, that for the Romans, *curiosi* were spies or secret informers.

and take out the two little grubs in its belly, put them in a pouch made from the leather of a red deer, tie this to the arm of a woman before sunrise, and she will then be incapable of conceiving a child. Rubbing mouse dung on a bald head will replenish its hair. A wayfaring man with a rod made of myrtle will never tire. The bodies of drowned men always float face upwards, but those of women downwards, 'as if Nature had provided to save their honesty and cover their shame'. And so on. To Pliny we owe the notion that elephants 'cannot abide a mouse' and that ostriches 'hide' by burying their heads when frightened. (Less well known and perhaps more contentious is his assertion that the cornered male beaver will bite off its own testicles.)

This is now part of the immense charm of *Natural History*, every page offering wonders so bizarre and whimsical that their invention would vex the imagination. This tradition was still thriving in the semi-fantastical bestiaries and accounts of faraway marvels during the late Renaissance, such as *La minera del mondo* (*Riches of the World*) by the Italian Giovanni Maria Bonardo, which attests that 'On the top of Mount Palombra there is a wonderful fountain and those that drink of its waters will never feel pain of any sort for as long as they live and will also preserve their youthful appearance for ever.' It was no coincidence that one of the most popular English translations of Pliny's books, by the scholar Philemon Holland, was published in 1601 during the Elizabethan infatuation with curiosities of nature. Holland's version was probably read by Shakespeare, who seems to allude to some of its strange claims in *Othello* (1604). John Donne, a connoisseur of occult philosophies, refers to the elephant and the mouse in *Progress of the Soul* (1601).

But Pliny intended that his miscellany of marvels should be seen as a serious guide to all that was known to humankind. '[I] take it upon me', he wrote, 'to speak of everything, and to gather as it were a complete body of arts and sciences (which the Greeks call *enkyklapaideios*) that are either altogether unknown or become doubtful, through the overmuch curiosity of fine wits.' Other men may have written some of these things before, Pliny admitted, but they had done so obscurely or at tedious length. His was an unashamedly populist project: to present all knowledge in a convenient, easily digestible form. To gather the material, he claimed to have read 2,000 books by a hundred different writers, and from them to have extracted '20,000 things, all worthy of regard and consideration'.

From the existence of such compendia, one might be inclined to infer an ancient tradition of curiosity. But it was not exactly that; in some ways it was quite the opposite. Pliny's compatriots were notoriously indifferent to anything resembling a scientific study of the world. They were content to take instruction from the ancient Greeks, who, the Romans believed, had already discovered everything (even if much of it was now lost). 'There was nothing left untried or unattempted by [the ancients],' wrote Pliny, 'nothing kept secret, nothing which they wished to be of no benefit to posterity.' The medieval encyclopaedias that are so obviously indebted to Pliny – the bestiaries, lapidaries, herbaria – never sought to explain or understand what they reported. They were a strange mixture of sensationalist display and down-to-earth guidebook. And since in the Middle Ages truth was often expressed and perceived in symbolic rather than literal terms, these collections might also supply a palette of moral metaphors. It was for this very reason that a need for descriptive accuracy was not strongly felt.

For the Greeks, curiosity was not even a clearly articulated concept. To the extent that it was acknowledged at all, it stands in contrast to its mercurial sibling, wonder. Aristotle believed that all humans naturally desire knowledge, but he felt that curiosity (*periergia*) had little role to play in philosophy. It was a kind of aimless, witless tendency to pry into things that didn't concern us. Wonder (*thauma*) was far more significant, the true root of enquiry: 'It is owing to their wonder', he wrote, 'that men both now begin and at first began to philosophize.'* Daston and Park argue that until the seventeenth century, wonder was esteemed while curiosity was reviled.

It was after all the ultimate cause of the ills of the world, unleashed from the jar by the meddlesome Pandora. 'It was not her cunning or wiliness that prompted her to open the jar', says the classicist Willem Jacob Verdenius in his commentary on Hesiod's version of the myth, 'but her curiosity.' In his *Moralia*, Plutarch considers curiosity the vice of those given to snooping and prying into the affairs of others: the kind of busybody known in Greek as a *polypragmon*.† It is true that

* The aphorism that philosophy, science or knowledge 'begins and ends in wonder' has been attributed to many others since, including Samuel Coleridge and Alfred North Whitehead.

† Both *periergia* and *polypragmosyne* were usually translated into Latin as *curiositas*.

Plutarch recommends that the *polypragmon* might cure himself by directing his attentions instead to questions about nature – why does the moon wax and wane? Why are fruits of different shapes? – and insists that 'these truly are the secrets of nature, neither is she offended and displeased with those who can find them out'. But the overwhelming sense in the classical world is that the curious person is a meddler and a nuisance or hazard to society.

### *Against curiosity*

In early Christianity it was worse than that. Now curiosity was not merely frowned upon but condemned as a sin. 'We want no curious disputation after possessing Christ Jesus,' wrote the second-century Christian apologist Tertullian, 'no inquisition after enjoying the Gospel.' The Bible told us all we needed – and should expect – to know.

In Christian Scripture, the dangers of curiosity were apparent from the outset. It might seem surprising, given the medieval hierarchy of nature in which humankind is unambiguously at the apex, that Adam and Eve were the last living beings to be created in Genesis – they were made only after God had filled the seas with fish and the skies with birds. But the Roman writer Lactantius in the third century AD had an explanation for this: being last on the scene, Adam would not see how it had all been done. (His descendants are evidently now striving to evade that divine precaution by running the tape of Creation once more.)

That some knowledge was forbidden to humankind is of course central to the Christian Creation myth: this is the basis of the Fall. 'When you eat of it your eyes will be opened and you will be like God', the serpent tells Eve of the fruit on the tree of knowledge. The transgressive aspect of curiosity is an insistent theme in Christian theology. Time and again the student of the Bible is warned to respect the limits of enquiry and to be wary of too much learning. 'The secret things belong to the Lord our God', proclaims Deuteronomy. Solomon (if it was he who wrote Ecclesiastes) cautions that:

> with much wisdom comes much sorrow;
> the more knowledge, the more grief.

And then again, he says:

> Do not pry into things too hard for you
> Or examine what is beyond your reach . . .
> What the Lord keeps secret is no concern of yours;
> Do not busy yourself with matters that are beyond you.

Or, as the King James version has it:

> Be not curious in unnecessary matters:
> For more things are shewed unto thee than men understand.

St Paul was considered to have echoed this sentiment in the admonition 'Seek not to know high things.' The fact that he did not actually write this at all speaks volumes in itself, suggesting that the mistranslation fitted with prevailing prejudice. In the fourth-century Vulgate Bible, the phrase is rendered as *noli altum sapere, sed time*, for which a fair translation is 'do not become proud, but stand in awe'. It was a rebuke against false claims to moral wisdom; but *sapere*, to be wise, became interpreted as something closer to *scire*, secular knowledge – the root of 'science'. 'Seek not to know high things' is then the result, as it appears in a late fifteenth-century translation of the Bible into Italian, by which time Paul's words had become irretrievably associated with a condemnation of curiosity. 'Do not take pride in the arts or sciences,' wrote Thomas à Kempis in the fifteenth century, 'rather, fear what has been told to you.' The British monk Pelagius disputed the idea that St Paul intended to discourage learning – but who would listen to Pelagius, a notorious heretic? The sixteenth-century scholar Erasmus of Rotterdam, as ever speaking calm and erudite wisdom into a world that did not care for it, argued that 'the words do not condemn learning, but attempt to free us from pride in our worldly excesses'. But distrust of curiosity and of the desire for worldly knowledge ran too deep in medieval Christian thought for these objections to be heeded.

No one, after all, was likely to question the greatest authority among the early Christian Fathers, St Augustine of Hippo, who proclaimed in his *Confessions* that curiosity is a 'disease', one of the vices or lusts at the root of all sin. 'It is in divine language called the

lust of the eyes', he wrote. 'From the same motive, men proceed to investigate the workings of nature, which is beyond our ken – things which it does no good to know and which men only want to know for the sake of knowing.' He claimed that curiosity is apt to pervert, to foster an interest in 'mangled corpses, magical effects and marvellous spectacles'. And it leaves us prey to pride:

> Nor dost [God] draw near, but to the contrite in heart, nor art found by the proud, no, not though by curious skill they could number the stars and the sand,* and measure the starry heavens, and track the courses of the planets.

Thus the astronomer, viewing an eclipse, is wont to assert grandly that he understands it, rather than to submit in awe to this demonstration of divine power.

This aversion to curiosity as an impulse to know more than is good for you did not originate in the Christian world – Socrates is attributed as saying 'We should not concern ourselves with things above' – but Christianity established a robust moral basis for it. Augustine's injunctions were repeated by the twelfth-century Cistercian theologian St Bernard of Clairvaux, for whom curiosity was 'the beginning of all sin':

> Seek not what is too high for you, peer not into what is too mighty . . . Stay in your own place lest you fall if you walk in great and wonderful things above you.

According to St Bernard, Lucifer 'fell from truth by curiosity when he turned his attention to something he coveted unlawfully and had the presumption to believe he could gain'. As a result, he says:

> The Seraphim set a limit to impudent and imprudent curiosity. No longer may you, Satan, investigate the mysteries of heaven or uncover the secrets of the Church on earth.

* In *The Sand Reckoner*, Archimedes set out to estimate how many grains of sand it would take to fill the universe. This apparently pointless exercise in fact requires Archimedes to estimate the size of the universe and to develop a new notation for recording very large numbers.

Not all curiosity was on so grand a scale; it could also be petty seeking after trivia and things not worth knowing – a 'passion for knowing unnecessary things' as William of Auvergne, Bishop of Paris, put it in the thirteenth century. This is how Thomas Aquinas – who was no enemy of the desire for knowledge – expressed his aversion to curiosity, casting it in the classical mould as being associated with a certain mental and moral inertia and idleness. But this was scarcely less deplorable. The central problem with curiosity was that it was thought to be motivated by excessive pride. The accumulation of pointless learning ran the risk not that one would become another Lucifer but that one would primp and preen rather than bow one's head before the Lord. 'O curiosity! O vanity!', cried the late twelfth-century theologian Alexander Neckam. 'O vain curiosity! O curious vanity!'

The imperative of pious humility was what commended wonder to Augustine at the same time as it indicted curiosity. There was nothing frivolous or hedonistic about wonder. It instilled awe, reminding us of our powerlessness and insignificance before the glory of God. That is why wonder in the face of nature's splendour was seen as the educated response, and a willingness to believe in marvels and prodigies was not only praiseworthy but virtually a religious duty. Curiosity, like scepticism, was a sign that you lacked devotion and faith.

### *Thinking for yourself*

All this can too easily feed the stereotype of an austere, anti-intellectual Middle Ages ruled by proscriptive priests. That is only part of the story. The increasing availability of Latin translations (via the Arabic) of the works of the ancient Greeks, particularly Aristotle, from the twelfth century brought with it a genuine interest in nature – not as a Platonic allegory but as an entity worthy of study for its own sake. Aristotle was no experimentalist, but nonetheless he took an interest in the particulars of the world, the distinctions between species of animal, plant and mineral, and he was a careful observer. The rise of Aristotelianism in the thirteenth century was accompanied by a greater realism in the visual and plastic arts: plants and animals are less stylized and more recognizable as particular species.

Yet Aristotle's advocacy of compilations ('histories') of natural

things and phenomena did not imply, neither did it engender, a perceived need to explain and understand them except as particulars that illustrated general rules. It was these generalities that were the quarry of the philosopher. Anyone could see that nature was full of variety, but these 'accidents' were of no account in themselves. The aim was not to explain all of natural history, but to rub away its bumps and blemishes until only the broad outlines remained.

By the thirteenth century, Aristotle's thinking and methods had come to dominate natural philosophy as part of the intellectual movement known as scholasticism, which held sway in the cathedral schools and in the universities that began to flourish in Paris, Montpellier, Oxford, Bologna and other great cities of Europe. There has been a tendency until recent decades to contrast both the 'Scientific Revolution' and Renaissance humanism with a preceding era of alleged stagnation and dogmatism in which timid, hidebound scholastics spent their time amassing tedious arguments pro and con by scouring the works of the ancient authorities. This image, which mirrors the exaggeration of scholars from the sixteenth and seventeenth centuries who were keen to emphasize the novelty of their own ideas, does scant justice to the variety and often the vibrancy of medieval thought. An era that produced philosopher-theologians as dextrous and diligent as the great Dominicans Thomas Aquinas in Oxford and Albertus Magnus at Cologne, or Roger Bacon, Robert Grosseteste, William of Ockham, John Duns Scotus and Jean Buridan, scarcely deserves to be dismissed as an intellectual wasteland.

And yet . . . it remains true that much of what passed for learning in the Middle Ages amounted to rearranging old knowledge (much of it spurious) rather than adding to it anew. New ideas were often greeted with scepticism, for why should anyone trust them when they had not been through the rigorous filter of the ages? Originality of thought was a sign of unhealthy pride, and the pedantic, twisting paths of logic evident in some medieval works can hardly be mistaken for curiosity. The natural philosopher was expected to conform to the tenets of Aristotelianism – an orthodoxy that, after Aquinas had 'Christianized' it, became almost as unassailable as the Scriptures. Natural phenomena were 'explained' by making them fit with some permutation of Aristotelian first principles, an a priori approach known as deductive reasoning. This deployment of indisputable reason and

logic was deemed to be the only way to achieve knowledge of the world as sound as the principles of geometry. It not only prescribed a particular method but also defined the scope of permissible (or at least, worthwhile) questions.

The very methods of scholastic Aristotelianism helped to make it impervious to serious challenge. The university academics would consider all questions about the world in isolation, listing arguments for and against a particular explanation of a phenomenon before offering their own interpretation. There was no attempt to find connections between different phenomena, so that contradictions and inconsistencies in Aristotle's teleological epistemology were barely noticed, let alone resolved. This atomization of knowledge meant that the overarching framework was never itself exposed to doubt. And if experience itself conflicted with Aristotle, so much the worse for experience: deviations from 'the norm' were by definition of little consequence.

Even some of the most innovative thinkers found it expedient to detach learning from curiosity, which they regarded *pace* Aristotle as an aimless wish to pry into trivial matters, distinct from true devotion to learning (*studiositas*). 'No wrongful curiosity can attend intellectual knowledge', Aquinas insisted, while Albertus Magnus wrote that:

> Curiosity is the investigation of matters which have nothing to do with the thing being investigated or which have no significance for us; prudence, on the other hand, relates only to those investigations that pertain to the thing or to us.

It was curiosity, Albertus said, that led to an inappropriate fixation on details and particulars rather than the true objective of identifying Aristotelian generalities. When he wrote about plants and animals he tended to describe what is 'typical', and only at the end to list specific features. It is, he admitted condescendingly, 'pleasureable for the student to know the nature of things and useful to the life and preservation of the cities' – but that is hardly the concern of the philosopher. When he lists particular species of plant in his *De vegetabilibus*, he makes it clear that he is merely 'satisfying the curiosity of students rather than philosophy, for there can be no philosophy of particulars'.

By this means, scholastic learning could be maintained on a higher intellectual plane than the knowledge of the untutored folk. Craftspeople,

labourers and farmers generally knew far more than philosophers about plants, animals and minerals, but that didn't count, because they knew only the secondary, superficial details. The philosopher did not need to explain why the world is as we find it, but rather, to extract from it (and most importantly, from what the ancients had said about it) universal truths which they would pass on to students.

### *Rebel angels*

A few individuals defied these constraints on what one should know and ask. Inevitably, they suffered accusations of heresy, blasphemy and witchcraft as a consequence. Even becoming a pope (Sylvester II) did not save the formidable tenth-century scholar Gerbert of Aurillac, an authority on astronomy and mathematics, from rumours of having studied magic under the Arabs and of having made a Faustian pact with the Devil. The pugilistic Norman scholar William of Conches poured scorn on those who denounced his penchant for asking awkward questions: 'Ignorant themselves of the forces of nature and wanting to have company in their ignorance, they don't want people to look into anything; they want us to believe like peasants and not to ask the reason behind things.' Like his spiritual heirs in the seventeenth century, he defended the impulse to enquire about nature on the grounds that it was our Christian duty to understand all we can about the world God has made. He believed that the Lord had fashioned it with reason, making of it a system that operated by intelligible laws. To those who argued that it was not only hubristic to seek the laws but heretical to imply that God himself was confined by them, William answered:

> One will say that it conflicts with divine power to say that man is made thus. To this I respond: on the contrary, it magnifies it, since we attribute it to Him to have given things such a nature, and thanks to this nature, to have created thus the human body . . . Certainly God can do everything, but what is important is that he did such and such a thing. Certainly God could make a calf out of the trunk of a tree, as country bumpkins might say, but did he ever do so?

One of the most curious men of the Middle Ages is now unjustly remembered primarily as a mere translator of ancient books. Adelard

of Bath travelled far from south-west England in search of knowledge, studying in Tours, Laon and Chartres in France and passing into Sicily around 1116 before journeying into the lands of the Saracens to devote himself to the study of Arabic wisdom. Here he visited Antioch and Tarsus, and among the works of the Greeks that he found there in Arabic translation and translated into Latin was the pre-eminent ancient treatise on geometry, Euclid's *Elements*. He is also considered the likely translator of the *Mappae clavicula* (*The Little Key*), a treatise on the preparation of pigments and other (al)chemical materials that derives from Greek sources and which is now one of the best windows on the chemical technology of the classical world. Several other translations have been attributed to Adelard in error, but it seems clear that he played a major part in bringing Arabic knowledge of geometry, astronomy and mathematics to the West. 'It is worth while to visit learned men of different nations', he wrote,

> and to remember whatever you find is most excellent in each case. For what the schools of Gaul do not know, those beyond the Alps reveal; what you do not learn among the Latins, well-informed Greece will teach you.

If the details of Adelard's life are sketchy, the image of the man that leaps out from the pages of his own original works is nonetheless extraordinarily vivid: calm, wry, sceptical and deeply intrigued by the natural world, he could be a medieval Erasmus. He railed against the conservative tendency of his contemporaries to dismiss any original thinking because it lacked the imprimatur of ancient authorities. This was the reason why so many works from this period were written under the pseudonyms of revered Greeks and Arabs: 'Thus when I have a new idea, if I wish to publish it, I attribute it to someone else and declare: "It is so-and-so who said it, not I."'

But Adelard did publish some works under his own name, the most notable of them being an elegy to the study of philosophy, *De eodem et diverso* (*On the Same and Different*), and an ode to the delight and value of asking questions about the world, *Quaestiones naturales*. (Neither work is precisely dated, but both were written in the early twelfth century.) The former contains one of those uncanny premonitions about future science and technology that seem a speciality of

the curious medieval mind. Anticipating the telescope and the microscope, Adelard wrote:

> The senses are reliable neither in respect to the greatest nor the smallest objects. Who has ever comprehended the space of the sky with the sense of sight? . . . Who has ever distinguished minute atoms with the eye?

And *Quaestiones naturales* presents a discourse on a delightful miscellany of issues in natural history, in the form of an imagined dialogue between the narrator and his inquisitive yet somewhat naïve nephew after the author has returned from the Arab lands.* The nephew serves as a foil with which Adelard can prick the stubbornness of the scholastics for whom ancient authority trumps reason. When the nephew asks about animals, he replies, 'It is difficult for me to discuss animals with you. For I learned from my Arabian masters under the leading of reason; you, however, captivated by the appearance of authority, follow your halter.' But the nephew is also haltered by dumb wonder, which obstructs rational thought:

> I know that the darkness that holds you, shrouds and leads into error all who are unsure about the order of things. For the soul, imbued with wonder [*admiratione*] and unfamiliarity, when it considers from afar, with horror, the effects of things without [considering their] causes, has never shaken off its confusion. Look more closely, consider the circumstances, propose causes, and you will not wonder at the effects.

The list of 'natural questions' examined here reveals both an awakening curiosity at the dawn of the Gothic age and the difficulty of harnessing it in the absence of any programme for a systematic enquiry into nature. Here are some of them:

—when one tree is grafted upon another, why is all the fruit that of the grafted portion?
—why do some animals ruminate?

* This format of a dialogue involving *quaestiones* was a commonly used vehicle for exploring issues that ventured beyond Aristotle, and prefigures the same device used by Galileo to challenge Aristotle's earth-centred cosmology in his incendiary *Dialogue Concerning the Two Chief World Systems* (1632) (see Chapter 7).

—why do some animals lack a stomach?
—why do some animals drink but do not urinate?
—why is the sea salty?
—why do men grow bald in front?
—why don't humans have horns?
—why do some animals see better at night?
—why can we see objects in the light while standing in the dark, but not vice versa?
—why are the fingers of unequal length?
—why don't babies walk as soon as they are born?
—why do we fear dead bodies?

There was no theoretical basis for answering such questions, unless one was content with the blithe tautologies of the ancients. But for Adelard, there was no harm in asking.

### *Experiments and secrets*

Adelard's frank curiosity and the populist inclusiveness of Pliny's encyclopaedic tradition contrast with a quite different practice of recording and conveying knowledge in the Middle Ages. It came to be seen as something to be hoarded, or at best shared only among a privileged few. It became *secret* knowledge, and in consequence acquired an air of mystery and danger, even of heresy. One of the most popular encyclopaedias of the High Middle Ages was the *Secreta secretorum* (*Secrets of Secrets*), falsely attributed to Aristotle but in fact an Arabic work probably dating from the tenth century and based on older sources. Translated into Latin in the twelfth century, it was an eclectic mix of politics and ethics, alchemy, astrology and medicine. According to the thirteenth-century Franciscan friar Roger Bacon in Oxford, whoever reads and understands the *Secreta* will find 'the greatest natural secrets to which man or human invention can attain in this life'.

Bacon was himself rumoured to know such secrets; some said he was a wizard who dabbled in diabolical activities. Today Bacon has a reputation as a pioneering experimentalist; his readiness to find out about the world through experiment has even earned him the rather meaningless epithet 'the first scientist'. There seems no doubt that

Bacon did use technical materials and equipment in his studies – he was especially interested in optics and the nature of light, and probably conducted alchemical studies too. But most of his 'experiments' were done in his mind: they were descriptions, in the Aristotelian deductive mode, of what *would* happen in such and such a circumstance, rather than empirical investigations of what actually *did* happen.

Bacon perceived concrete reasons for keeping some knowledge secret. He experimented with gunpowder, and is sometimes attributed with introducing it to the West. He advocated the use of what we would now call scientific principles for the development of war engines and other military technologies in defence of Christendom. He appealed to Pope Clement IV to support science for that reason, arguing (rather speciously) that 'by the paths of knowledge Aristotle was able to hand over the world to Alexander'. Knowledge was power for this Bacon too.

But could secret knowledge really be science? For Aristotle, *scientia* was the demonstration of the causes of things. Yet 'secrets' were typically phenomena of a sort that could not be demonstrated to follow from Aristotelian first principles. They were not knowable in the way Aristotle's science was; their causes were hidden, *occult*. Magnetism was the archetypal example: wonderful and undeniable, but at the same time mysterious and inexplicable. Such things were prodigies, one-offs, unpredictable and opaque to the light of reason. That was why in antiquity they had not been deemed an important part of knowledge – not because their empirical validity was in any doubt, but because the phenomena seemed self-contained and hermetic. They were a matter of experience pure and simple – but experience as such was widely distrusted both by Platonists, who considered it superficial, and by Aristotelians, who considered it contingent and untidy. Whether or not Roger Bacon deserves much credit as a hands-on experimentalist, he proposed to alter the rules of the game significantly in suggesting that empiricism was a valid form of knowledge – that there are things worth knowing that cannot be deduced from scratch.

All the same, these two sources of knowledge tended to be held at arm's length: there was a *via rationis* and a *via experimentalis*, the former being generally regarded as superior. The thirteenth-century French physician Bernard de Gordon summed up the prevailing

scholastic prejudice with a patronizing remark: 'Because the young greatly enjoy *experimenta*, let me give some here.' Finding things out, rather than working them out, was not beyond the pale, but it was indulged like a harmless hobby.

The medieval view of curiosity as a lust and a sin was by no means eclipsed by the early seventeenth century, and we will see that it was a charge against which Francis Bacon had to defend his new experimental philosophy. In his popular emblem book *Iconologia* (1593) showing classical personifications of the human qualities, the Italian author Cesare Ripa depicted curiosity as a wild, dishevelled woman, driving home the message in the caption: 'Curiosity is the unbridled desire of those who seek to know more than they should.' The Antwerp-born Jesuit priest Martín del Rio, an enthusiast of witch-hunts, wrote in his condemnation of the magic arts *Disquisitionum magicarum* (1599–1600) that the *mala curiositas*, the plague of curiosity, is an affliction among those who try 'to get to know that which they should not know'. By that time, however, moralists like del Rio had plenty of targets – for curiosity had become a European obsession.


'Curiosity' as depicted in Cesare Ripa's *Iconologia* (1593).

# 2 The Academies of Secrets

> It must certainly be allowed, that nature has kept us at a great distance from all her secrets, and has afforded us only the knowledge of a few superficial qualities of objects; while she conceals from us those powers and principles, on which the influence of these objects entirely depends.
>
> David Hume, *An Enquiry Concerning Human Understanding* (1748)

> Where secrecy or mystery begins, vice or roguery is not far off.
>
> Samuel Johnson

Leonardo da Vinci was good at acquiring projects but not at completing them. He was especially enchanted by the character of water, particularly as manifested in the forms and furies of its flow, a subject that appealed equally to his artistic, scientific and engineering sensibilities. He studied these things in great detail, and intended to write a book called *The Nature of Water*, but it is not clear if he ever did so. All we have to go on is a sketchy treatise known as the Codex Leicester, which bears the title 'On the Nature, Weight and Movement of Water'. Here Leonardo provides an outline of his grand scheme, and it becomes evident soon enough why it was probably never anything more than a dream.

The work was to comprise fifteen separate 'books', as follows:

| | |
|---|---|
| Book 1 | Of the nature of water |
| Book 2 | Of the sea |
| Book 3 | Of subterranean rivers |
| Book 4 | Of rivers |

| | |
|---|---|
| Book 5 | Of the nature of the depths |
| Book 6 | Of the obstacles |
| Book 7 | Of gravels |
| Book 8 | Of the surface of water |
| Book 9 | Of the things that move on it |
| Book 10 | Of the repairing of rivers |
| Book 11 | Of conduits |
| Book 12 | Of canals |
| Book 13 | Of machines turned by water |
| Book 14 | Of raising water |
| Book 15 | Of the things which are consumed by water |

These are not all natural or obvious categories of enquiry, but rather, a ragbag of issues that occurred to Leonardo as hydraulic engineer and as natural philosopher. The list could go on indefinitely: what about the freezing of water, or boiling? Waterfalls? Rain and snow and mountain mist?

But it soon becomes clear in the Codex Leicester that the hapless Leonardo was already overwhelmed by such questions. He seeks a taxonomy of vortices and waves. He veers off into speculations about the biblical Deluge. He lists sixty-four descriptive terms for water in motion, from 'rotating' and 'repercussing' to 'submerging' and 'surging'. He attempts to delineate what distinguishes a sea from a lake, a river from a torrent, a well from a pool. And just look at the list of questions he accumulates about the nature of flow through rivers:

Of the different rates of speed of currents from the surface of the water to the bottom.
Of the different cross slants between the surface and the bottom.
Of the different currents on the surface of the waters.
Of the different currents on the bed of the rivers.
Of the different depths of the rivers.
Of the different shapes of the hills covered by the waters.
Of the different shapes of the hills uncovered by the waters.
Where the water is swift at the bottom and not above.
Where the water is slow at the bottom and swift above.
Where it is slow below and above and swift in the middle.

Where the water in the rivers stretches itself out and where it contracts.
Where it bends and where it straightens itself.
Where it penetrates evenly in the expanses of rivers and where unevenly.
Where it is low in the middle and high at the sides.
Where it is high in the middle and low at the sides.
Where the current goes straight in the middle of the stream.
Where the current winds, throwing itself on different sides.
Of the different slants in the descents of the water.

These are all matters that demand meticulous observation, and often recourse to controlled and methodical experiment. Leonardo did investigate flow down artificial channels and past barriers, sketching the forms of the ripples and eddies with marvellous grace. These records look superficially like modern experimental science: the investigator creates a particular set of circumstances and watches how they constrain the play of nature, carefully noting the outcomes in a lab book. And indeed, not only do some of the flow patterns correspond to those now recognized in the science of fluid mechanics, but Leonardo even introduced some of the experimental techniques still in use today, such as the addition of 'tracers' like floating seeds or dyes to make the flow forms more evident.

But it is a mistake (often made) to turn Leonardo into a modern scientist. For one thing, his experimental programme is incontinent: an outpouring of questions, apparently listed simply in the order in which they popped into his head. This is merely a ledger of phenomena, uncontained by any fundamental hypothesis about how nature behaves. It is well-nigh impossible to imagine emerging from this programme a unified picture of how fluid flow occurs, like the one that scientists possess today.* Rather, if Leonardo had been at liberty

* The flow of liquids can be expressed mathematically by the so-called Navier-Stokes equation, devised in the late nineteenth century, which is essentially an expression of Isaac Newton's second law of motion applied to the liquid everywhere at once. As such, it is a 'theory' of sorts, but of limited utility, since the equations cannot be solved to map out the motions of the fluid except in some very particular circumstances. The problem, then, is not in *understanding* what is happening, but in *predicting* it. While Leonardo considered mechanics the 'paradise of mathematics', the art historian Ernst Gombrich is right to point out that 'a quick glance into the most elementary text-book of fluid mechanics will convince you that this branch is the hell of mathematics'.

Leonardo's sketches of water flow show astonishing attention to detail.

to investigate each of his questions, he would have gathered together a roster of particulars, none of them obviously deducible from the others: a body of facts, not an explicatory framework.

This is not because Leonardo had an ill-disciplined mind – at least, it was not simply because of that. Leonardo could not draw up a coherent research agenda because there was no philosophical tradition of doing so. Worse, the prevailing (scholastic) tradition was to take precisely the route that Leonardo chose, to divide and subdivide, making ever finer distinctions between the categories of things and questions. What distinguishes Leonardo was not the method he used to approach the nature of water flow, but the fact that he considered these things worth studying in the first place: not that he was obsessive in drawing up his lists, but in the object of his obsession.

Leonardo was also set apart from the scholastics by having Neoplatonic sympathies. Thinking about the behaviour of the seas and skies and the circulation of water between them, he was constantly aware of the relationship that Renaissance champions of this ancient tradition perceived between the macrocosm and the microcosm: it was more than metaphor when he called rivers the 'blood of the earth'. This belief in an inner unity of the diverse forms and effects of nature encouraged his use of analogy: light becomes akin to rippling water, and water to hair and smoke.

Leonardo's Neoplatonism explains why he was not in the end quite the faithful recorder of nature that he is commonly made out to be. His flow forms are idealized, exaggerated so that they resemble more closely the patterns of wavy and braided hair – connections all but invisible to ignorant eyes, yet which reveal to the adept the deep structure of the world. To art historian Martin Kemp, these sketches are 'an intricate synthesis of observations and theoretical constructions, with neither separate from the other'. Leonardo's fascination with hidden forms is not exactly that of the scientist as we would recognize it, but that of the philosopher who believes that nature is inherently creative and that the artist only mimics her inventiveness. Painting, said Leonardo, is 'a subtle *inventione* which with philosophy and subtle speculation considers the nature of all forms'. Particular phenomena – specific kinds of flow, for example – were to be understood not as explicit realizations of some underlying mathematical process so much as capricious variations on it.

Leonardo believed that the artist can hope to make a convincing depiction of nature only by penetrating beneath the caprice – his aim was not to render as skilfully and accurately as possible what he thinks he sees, but to grasp and illustrate the forces at play. As Kemp says, 'Each painting is, in a sense, a proof of Leonardo's understanding.' Recognizing that few artists will have the patience (or perhaps the aptitude) for such dedicated observation, Leonardo concedes that 'At this point . . . the opponent says that he does not want so much *scienza*, that practice is enough for him in order to draw the things in nature.' But that would leave one skating over the surface of the world, bewitched by arbitrary invention and ephemera: 'The answer to this is that there is nothing that deceives us more easily than our confidence in our judgement, divorced from reasoning.'

### *Hermetically sealed*

Abjuring both the arid logic of the scholastics and a slavishly literal empiricism devoid of interpretation, Leonardo thus seems to unite a belief in experiment with the quest for underlying causes that characterizes science today. On the one hand, 'those who fall in love with practice without science are like a sailor who enters a ship without helm or compass, and who never can be certain whither he is going'; on the other hand, 'although nature begins with the cause and ends with the experience, we must follow the opposite course, namely, begin with the experience, and by means of it investigate the cause'. His experimental programme, if we may call it that, even included the need for replication:

> Before you base a law on this case test it two or three times and see whether the tests produce the same effects . . . This experiment should be made many times so that no accident may occur to hinder or falsify this proof, for the experiment may be false whether it deceived the investigator or no.

He seems 'modern' also in his conviction that nature is law-bound and thus predictable and reliable: 'Nature does not break her law; nature is constrained by the logical necessity of her law which is inherent in her.' Furthermore, today's physicists would applaud his notion that these natural laws are as simple as they could be:

> O marvellous necessity, thou with supreme reason constrainest all effects to be the direct result of their causes, and by a supreme and irrevocable law every natural action obeys thee by the shortest possible process . . . Necessity is the mistress and guide of nature.

Equally will they celebrate his suggestion that these necessary laws are mathematical:

> There is no certainty where one can neither apply any of the mathematical sciences nor any of those which are connected to the mathematical sciences . . . Whoever condemns the supreme certainty of mathematics feeds on confusion, and can never silence the contradictions of the sophistical sciences, which lead to an eternal quackery.

But again, Leonardo doesn't always mean what we might like to imagine. Take his reliance on 'experiment'. In the Renaissance this word was often more or less synonymous with 'experience': not the kind of carefully planned, often highly constrained and artificial procedure used by scientists to explore a particular phenomenon in isolation from others and to test a hypothesis about how it happens, but rather, a simple, raw observation of nature. From the seventeenth century, the scientific experiment came increasingly to be an abstraction from and a manipulation of what happens 'naturally', precisely because the natural situation typically involves so many complicating factors and influences that interpretation becomes difficult. This widening gap between nature and the laboratory was to prove controversial.

And Leonardo does not propose to use experiment as we do today, for testing hypotheses. Rather, it supplies a means to identify what it is that reason must explain. 'First', he declares, 'I shall test by experiment before I proceed further, because my intention is to consult experience first and then with reasoning show why such experience is bound to operate in such a way.' This could easily provide a prescription for the tautologies and Just So stories that hamper the natural philosophy of antiquity: although the theory must accord with what we experience, it can nonetheless be formulated with armchair logic and reasoning.

What is more, Leonardo's belief in mathematical order and simplicity in nature did not necessarily impute simplicity to experience. In the Renaissance, 'laws' of nature did not have the binding character that they are awarded today. In the Aristotelian view formulated by Thomas Aquinas, a law describes what is normally the case. But nature, like an artisan, could make mistakes and aberrations: monsters, freaks, wondrous phenomena might occur, not just – as many believed – because they were divine portents, but also because nature had wrought in error or whimsy. Leonardo's position here is somewhat ambiguous. As we've seen, he felt that nature enjoys latitude for invention and variety, although he does not quite specify whether this is simply because the laws permit it, or because they can be relaxed, or because there are many more laws than we imagine: 'Nature is full of infinite causes that have never occurred in experience', he wrote.

Most of all, the Neoplatonism that informed Leonardo's faith in an orderly cosmos is, despite its immense and under-acknowledged

influence on the development of early science, quite different from the motivation for this notion today. In *Timaeus* Plato asserted that the universe was made by the Creator through a process of geometrical division according to laws of simple proportion, rather like cutting and folding a strip of paper. As a result, mathematical proportion and harmony is woven into the very fabric of the world. Several of the founding fathers of the Christian Church, including Augustine and Boethius, were sympathetic to this idea, which flourished during the eleventh and twelfth centuries before Platonism was eclipsed by a reliance on Aristotle. The Neoplatonism of the Renaissance mixed this geometrical cosmology with the mystical tradition known as Hermeticism, which originated in Hellenistic Greece and promoted the study of natural magic and alchemy. The Florentine philosopher Marsilio Ficino was one of the principal architects of this synthesis. At the request of the city's prince Cosimo de' Medici he founded the Platonic Academy in a villa at Careggi in the hills outside the city, and in 1462 Ficino translated for Cosimo the newly discovered works of Hellenistic Gnosticism known as the Corpus Hermeticum, as well as a new version of *Timaeus* and the writings of Plato's disciple Plotinus, the founder of classical Neoplatonism.

There's no harm in attaching to Ficino the cliché exhausted on Leonardo – that he was a Renaissance man – if we turn it on its head in meaning precisely that he was a product of his times. While it was not the case that every educated person of that age had multivalent talents – Erasmus never painted altarpieces, Raphael never played the lute – nonetheless the notion that a 'complete man' was competent in several of the roles we regard as distinct today ensured that the philosopher would have little difficulty in becoming a physician or poet if that was how his inclination went. Ficino was not only one of the foremost scholars of the Italian Renaissance, but a priest, a doctor and a musician, entertaining Bishop Campano with Orphic hymns on the lyre just as Leonardo's performances later enthralled the Duke of Milan. Despite his short stature and slight stammer, Ficino made an impression of grace and refinement on all who met him, aided no doubt by his angelic wavy golden locks, his relaxed temperament and reputed ability to procure the finest wines.

Because Leonardo was in Florence as an apprentice in the workshop of Verrocchio while Ficino was active in the city, it is tempting to

imagine that he may have acquired his Neoplatonism from, as it were, the horse's mouth. But although Ficino had close links with Florentine artists, being a friend of the Pollaiuolo brothers and apparently responsible for overseeing Botticelli's work on the *Primavera*, there is no evidence that he knew of Verrocchio's promising student. All the same, when Leonardo read the *Timaeus*, it was probably Ficino's version.

### *Hidden nature*

The Neoplatonists' assertion of cosmic order – a mystical belief that had no real empirical basis – permeated early modern science, and has remained lodged in the scientific enterprise ever since. Most scientists continue to believe that the universe is fundamentally orderly and rule-bound, and moreover that these rules will be comprehensible, simple to state (if not to understand) and most probably beautiful to those with an aesthetic sensibility that can register it. There is today no logical reason to expect this to be the case at all, except for the fact that such an expectation of regularity underlying variety has worked rather well so far.

But the legacy of Neoplatonism at the start of modern science has another aspect, which conditioned the emerging culture of curiosity. For Plato, the world could not be taken at face value: superficial appearances are a mirage, a flawed and contingent screen behind which the eternal perfection of reality is concealed. The truth is then hidden from us – it is literally *occult*. To Neoplatonists, raw experience is replete with signs that only the adepts can interpret. Some of those who endorsed this philosophy followed the lead of the Corpus Hermeticum in thinking that the hidden structure was an alchemical one: the macrocosm and the microcosm were united through chemical analogies that entailed processes of transformation and rebirth. Others more closely observed the *Timaeus* in considering mathematics and geometry, not chemistry, to be the unifying scheme. But all Neoplatonists regarded nature as a repository of *secrets*, and considered that the aim of natural philosophy was to decode them. The answers would not be found in old books; nature had to be coaxed directly – by experiment – into revealing herself. In the late Renaissance, this viewpoint shaped the study of the natural world.

'Hidden nature' was explicitly gendered as a coy young woman who

must be tricked into displaying what is normally concealed and private. The leering misogyny of that age, which turned nature into a maiden who must be unveiled either by cunning artifice or by brutal insistence, has been widely deplored by feminist historians, and is hardly exonerated by a defence which maintains that the language of coercion did not necessarily imply rape. It is as futile to deny the titillating role of this metaphor for the almost universally male audience who employed it, as it is to pretend that the fleshy females adorning the canvases of the High Renaissance were objects of purely intellectual appreciation. One can sometimes almost hear the panting excitement of the natural philosophers as they contemplate the removal of nature's garments and the penetration of her 'secrets'. This clandestine or sublimated sexuality is not pleasant to observe; neither is it incidental.

But the allure of secrets was not solely carnal. Access to secrets implies privilege, simultaneously a demonstration of power and a means to acquire more. The alchemist who possessed knowledge of the transmutation of metals would be rich and welcomed in any court; likewise the physician who knew the secrets of medicine. By uncovering the secrets of flowing water, Leonardo could claim an ability to control rivers and floods, to the advantage of princes and kings. This was more than theory: he and Niccolò Machiavelli collaborated on a project to divert the river Arno so that Florence's enemy Pisa would be deprived of water. Francis Bacon's dictum that knowledge is power has grown stale from exposure, but we must recognize that it rests on a tradition in which nature is a web of secrets.

This talk of secrets was more than rhetorical. The plain fact is that nature is, for the most part, hard to understand. Science exists at all because the way nature works is not obvious to everyone at a glance. It demands dedicated, patient and thoughtful study, and in one sense the discourse of secrecy merely reflects that. We still use this image today, in books or television programmes that promise to disclose the 'secrets' of plants or cells or the cosmos: all things that are hidden from everyday view. Yet there is an important distinction between the view that nature is hard to understand and that nature retains secrets, for the latter implies intentional withholding. Nature was either coy (which was exciting) or jealous (which was frustrating, and justified the use of force), and either way she (I will use but not condone the conventional gendering) would be revealed only with cunning. This

promotes a very different view of the scientist from the one that prevails today, when he or she who discovers some particularly recondite aspect of nature is hailed simply as clever or ingenious. To be a scientist in the late sixteenth century demanded a degree of wiliness.

### *Secret society*

In 1585 an Augustinian monk named Tommaso Garzoni published a book called *The Universal Piazza of All the Professions of the World*, among which he identified a recent category: the 'professors of secrets', who seek obscure and occult things. These secrets, he said, are things

> whose reasons are not so clear that they might be known by everyone, but by their very nature are manifested only to a very few; nevertheless they contain certain seeds of discovery, which facilitate finding out the way towards discovering whatever the intellect may desire to know.

While some of these secrets were 'good', and their pursuit an honourable trade, Garzoni clearly had a rather low opinion of these professors, who all too often sought 'ridiculous and vain secrets' that offered no benefits to humankind. And there are some, he said, who 'attend to this profession of secrets so zealously that they yearn for it more than for the necessities of life itself'. The stereotype on which Garzoni drew is the obsessive alchemist who lets his life go to ruin in foolish and futile pursuit of the philosopher's stone. Brueghel's caricature of this pathetic creature in his chaotic laboratory is the most famous of many sardonic depictions of the fool's quest. Like alchemists, the professors of secrets were a product of the Hermetic tradition, where grimy empiricism mixed with natural magic to offer what in the public gaze was apt to become a somewhat disreputable attempt to understand nature.

Among the people who Garzoni listed as 'professors of secrets' in Italy was Alessio Piedmontese, whose 1555 book *Secreti* can be described without too much anachronism as an international bestseller. It went through no fewer than seventeen editions in the first four years of circulation, and was still being published at the end of the seventeenth century, 104 editions later.

But no one knew who this 'Alexis from Piedmont' was. In the book's preface he claimed to be a devout man who had amassed his knowledge of 'secrets' outside of any academic tradition, by wandering the world gathering information from ordinary folk. His identity remains disputed. Of course, secrets are hardly that when they are published in a bestselling book, and Alessio's title is surely in part a marketing ploy. But since he pays lip service to the Hermetic convention of considering some knowledge too powerful to be appropriate for public disclosure, he is obliged to offer a moral justification for his decision to 'reveal' these precious secrets to the world. He explains that he had once withheld a remedy from a physician-surgeon, for fear that the man would use it 'for his own profit and honour'. As a result the physician's patient died, forcing Alessio to recognize that such valuable information should be disclosed to everyone.

What are these secrets? The reader hoping to find esoteric insights into the nature of the world was likely to be disappointed. On the other hand, Garzoni's disparaging remarks about the lack of practical value in secrets are here confounded, for *Secreti* was filled with useful recipes for everyday life: medicines, perfumes, soaps, lotions, cosmetics, cooking recipes and some more specialized craft procedures such as prescriptions for making metals or pigments. In the distance between the grandiose promise of the title and the mundane character of the contents, *Secreti* reveals the true span and significance of the tradition it represents. The first thing to notice is that, as a technical craft manual, the book is not connected to the academic disciplines studied at the universities. Even medicine, which was a scholarly subject, tended to be taught in terms of the vague and ineffectual theoretical principles expounded by ancient writers such as Hippocrates and Galen, while in practice the doctors relied on the practical skills of unlettered surgeons and the kinds of herbal and mineral concoctions that differed from folk medicines only in that they cost more. 'Secrets' were craft-based, largely devoid of theory, and scorned by the university professors as rudely empirical rather than the fruits of reason and logic. And yet, while books like Alessio's were nothing more than glorified versions of the popular recipe anthologies of the sixteenth century known as *Kunstbuchlein* ('booklets of the arts'), they gained prestige by asserting an association with the natural-magic tradition.

Alessio claims that one of his recipes, a cure for pleurisy, was given

to him in Bologna by a gentleman called Girolamo Ruscelli. This Ruscelli was also on Garzoni's list, and what makes Alessio's story intriguing is that some historians now believe that Alessio was none other than Ruscelli himself. The basis for that claim seems at first rather secure, for Ruscelli made it himself in the introduction to his posthumous *Secreti nuovi* in 1567. Yet we should be wary of taking Ruscelli at his word – given his profession, he clearly stood to gain by being associated with such a popular title.

Ruscelli was one of the pre-eminent professors of secrets in the mid-sixteenth century. Born in Tuscany and educated at the University of Padua, he became a courtier to the Marquis of Vasto in the Abruzzo region of southern Italy, serving as a poet and ambassador. After the marquis's death, Ruscelli moved to Venice, where he became a proof-reader and writer for the publisher Vincenzo Valgrisi. His duties were those of a glorified hack: as a so-called *poligrafo*, Ruscelli would write anything the publisher demanded, from plays to travel books, all somewhat lowbrow and aimed at a general market. So it is quite possible that Ruscelli could have been involved in assembling a populist collection of 'secrets' for which the suitably mysterious author Alessio was concocted.

But Ruscelli may have played a more significant part in the establishment of a professoriat of secrets. He claims that he founded an 'experimental academy' called the Accademia Segreta (Academy of Secrets) in the kingdom of Naples. This was not only an institution for collecting secrets but also a secret society in itself: the twenty-four members took an oath to reveal the existence of the academy to no one unless approved by the others. Ruscelli declines to reveal the academy's patron, a prince of the city in which the members met every month, although one candidate is Ferrante Sanseverino, Prince of Salerno.

The aim of the society, according to Ruscelli, was 'to make the most diligent inquiries and, as it were, a true anatomy of the things and operations of Nature itself'. Although this knowledge was to be assembled in secret, the ultimate purpose was altruistic and egalitarian. 'In addition to our own pleasure and utility', says Ruscelli, 'we devoted ourselves equally to the benefit of the world in general and in particular, by reducing to certainty and true knowledge so many useful and important secrets of all kinds for all sorts of people, be they rich or

poor, learned or ignorant, male or female, young or old' – a mission anticipating Francis Bacon's statement that science should strive towards 'the relief of Man's estate'. Ruscelli says that once the academy has collected all it seeks, the veil of secrecy would be withdrawn: 'it would be manifested and publicized to everyone as a thing most honoured, most virtuous, and most worthy to elicit the noblest rivalry from every true Lord and Prince in his state, and from every beautiful and sublime mind'. He takes care here to remind wealthy patrons what is in it for them.

The academicians of secrets in Naples did not just collect recipes, but tested them carefully before adding them to their list, so that only those that worked would eventually be published. Here, then, was apparently a systematic realization of Leonardo's method of trial and replication, distinct from the credulity of the much-maligned 'empiric' of the early Renaissance who would believe everything he was told. The Accademia Segreta allegedly based their programme on, if not exactly scepticism, then at least discernment. Crucially, their experiments were not tests of theories – on the whole the professors of secrets were wary of theorizing. Rather, they were tests of whether the claims espoused for particular procedures and concoctions were valid. To assist with this process of experimental sifting, the academy hired artisans including apothecaries, metalworkers, perfumers and gardeners.

It sounds all remarkably close to the practices of the scientific academies that flourished a hundred years later. Except for one thing: it is not clear that the Accademia Segreta ever existed beyond the imagination of Girolamo Ruscelli. There is no evidence of the society apart from his testimony, and it seems hard to credit that so substantial an enterprise could have really been kept otherwise entirely hidden. The ambiguities surrounding Alessio Piedmontese raise suspicion that Ruscelli is an unreliable witness, and his refusal to disclose any specific details of the academy's other members, patron or location only add to it.

All the same, his claim is not totally implausible. There may have been good political motives for maintaining strict secrecy. In Naples at this time, the Spanish rulers suspected private societies of fomenting social unrest and religious subversion. In 1543 the Spanish viceroy Don Pedro of Toledo closed down the humanist Accademia

Pontaniana on suspicion of heresy, and dismissed its leader Scipione Capece from the University of Naples. In retaliation, Ferrante Sanseverino brought Capece to Salerno and made him a professor of law, an act of defiance that supports Sanseverino's candidacy as patron of Ruscelli's academy. Four years later a public uprising in Naples provoked Don Pedro to close down all the philosophical and literary academies in the kingdom, and it is conceivable that this dangerous climate may have prompted Ruscelli to move to Venice around 1547, there to publish in the pseudonymous *Secreti* all that his academy of secrets had discovered so far.

Despite these obstacles, Naples remained a centre for the study of nature in the late Renaissance. The humanist scholar Bernardino Telesio spent much of his time there at the home of Alfonso Carafa, Duke of Nocera, and his son and heir Ferrante. In his home town of Cosenza in Calabria to the south, Telesio became the head of the Accademia Cosentina, a centre for the kind of natural philosophy that the schools spurned.

Telesio criticized the classical authorities Aristotle and Galen for their reliance on reason over the evidence of our senses, a position adopted in his great work *De rerum natura iuxta propria principia* (*On the Nature of Things According to their Own Principles*) (1586), which rejected the Aristotelian description of the material world in terms of matter and form. Telesio argued that our senses do not exist to support our sensitive human soul but are mere mechanical portals that mediate experience, conveyed by impulses in air and light. Understanding, in Telesio's view, stems not from analytical reasoning but from the senses.

In this cosmos there is no necessary role for the Aristotelian teleological agency that Thomas Aquinas equated with God's will. Things behave as they do of their own accord, motivated by an active force that ultimately derives from the opposing tendencies of hot and cold. Telesio never questioned that the world was made and shaped by God – he had spent time as a Benedictine monk, after all, and was even offered (but declined) the archbishopric of Cosenza by Pope Pius IV. But his God fashioned nature so that it might run without further intervention, governed by natural laws. These views would surely have got Telesio into trouble had he not cultivated good relations with the highest authorities of the Church.

In all of this, it is easy to appreciate Francis Bacon's assessment that Telesio was 'the first of the moderns'. But when we delve into the essence of what he believed, we find plenty that would make modern scientists uncomfortable with that association. For Telesio's vision borders on mystical pantheism: he believes that a corporeal spirit pervades all of nature and that to know nature we must unite with it. By learning what will help humanity survive and what will threaten it, the enquiry into nature becomes a moral quest.

Telesio's determination to ascribe rational, mechanistic causes to natural phenomena was the hallmark of the natural-magic tradition. The Italian physician and mathematician Girolamo Cardano, a native of Pavia, displayed the same impulse to account for things in terms of a balance in the opposed forces of sympathy and antipathy. This often left Cardano focused more on the mechanical explanation than on the veracity of the phenomenon in the first place, which was why he could end up seeking to rationalize such superstitions as the idea that eggs laid after the new moon in August would not rot or that if one spat on one's hand after hitting someone, it lessened the victim's pain. Such apparent capitulations to fantasy, along with Cardano's enthusiasm for astrology,* led historian Lynn Thorndike to be rather impatient with him: his 'voluminous works', Thorndike said, 'are very repetitious [and] ramble on and on without evidencing any inclination to stop'. But Thorndike's complaint that 'they contain much that would seem of no possible interest to anybody except apparently the author himself' is an indication that Cardano had the characteristically exhaustive curiosity of the natural magician. He sought specific explanations for parochial effects, rather than the generic reasons of Aristotelianism: maize grows without rain in the high Andes, he said, because the sun is weaker there and dries only the surface of the soil, while Ireland is snake-free because the 'bitumen' (peat) in the soil kills them with its bad smell.

Yet even Thorndike cannot deny Cardano's occasional acumen, especially in the field of mathematics. In his treatise on algebra *Ars magna* (*The Great Art*) (1545), he provides algebraic solutions for cubic and quartic equations (which contain variables raised to the powers

* Cardano's ill-advised publication of the horoscope of Jesus exposed him to charges of heresy in 1570.

3 and 4), and presents the first known reference to imaginary numbers (those containing the square root of –1). His *Liber de ludo aleae* (*Book on Games of Chance*) presents one of the first accounts of probability in relation to the rolling of dice – a topic that Cardano had ample cause to study, since his unconventional interests and theories excluded him from the universities and often forced him into gambling to pay his bills. He also came close to understanding the true nature of combustion two centuries before Antoine Lavoisier's oxygen theory, saying that a flame is merely burning air.

For Cardano, curiosity was spurred by wonder and an appreciation of the marvellous – which, he said, is more abundantly exhibited in nature than in art. In his *De rerum varietate* (*On the Variety of Things*) (1557) he provides a veritable taxonomy of wonders: 'wonders of the earth', 'wonders of water', and so forth. He argued that while some things are truly wonderful (and perhaps therefore beyond rational explanation), others are 'worthy of wonder, but not great wonder', and some simply not marvellous at all. In the first of these classes he places the 'blue clouds' said to be sighted in the Strait of Magellan off the tip of South America, and in the second, the foot jugglers of Mexico – indications that the discovery of the New World was expanding the categories of things that may exist and happen (see Chapter 6).

### *The magic man*

In the 1560s Naples acquired its own Academy of Secrets: the Accademia dei Secreti, whose founder was Giambattista Della Porta, another of the 'professors of secrets' on the disapproving Garzoni's roster. It is possible that this group represented a revival of Ruscelli's programme after the political climate had become more settled, for Della Porta may have been a part of Ruscelli's Accademia Segreta too.

If it seems disturbing to place Telesio at the roots of modern science, locating Della Porta at that juncture will appear a whole lot worse. His 1558 book *Natural Magick* provided the definitive exposition on the view of nature as an occult storehouse of secrets. How could the author of a magical book be a predecessor of the scientist?

To understand that, we need to forget pretty much all we think we know about magic. The scorn that today's scientists reserve for

the word is fully justified insofar as it relates to the modern, debased meaning, and is nicely illustrated in this recent exchange between Richard Dawkins and David Attenborough as Dawkins talks about his forthcoming children's book:

> *Dawkins*: It is called *The Magic Of Reality* and one of the problems I'm facing is the distinction between the use of the word magic, as in a magic trick, and the magic of the universe, life on Earth, which one uses in a poetic way.
> *Attenborough*: No, I think there's a distinction between magic and wonder. Magic, in my view, should be restricted to things that are actually not so. Rabbits don't really live in hats. It's magic.

We have perhaps already some intimation (we will acquire more later) that Attenborough's view of wonder is problematic when seen through the lens of history. The same is true in spades for his take on magic, although as an eminent natural historian he can be trusted for his knowledge of rabbits. That magic has come to connote 'things that are not actually so' is a story in itself, for in the mid-sixteenth century it was the closest thing that existed to experimental science. To its principal advocates, natural magic was the most promising avenue for eliminating the supernatural agency of demons or of God from the natural world. These supporters had constantly to refute charges of heresy by insisting that natural magic was in no way incompatible with the idea of God as omnipotent creator and prime mover. Like the modern scientist, the natural magician believed that natural phenomena are governed by invisible forces. And as historian William Eamon explains, natural magic was 'the science that attempted to give rational, naturalistic explanations' of those forces. Far from utilizing supernatural means, natural magicians knew how to harness the forces and tendencies inherent in nature. As the great early sixteenth-century proponent of the art, Cornelius Agrippa, explained:

> Magicians are like careful explorers of nature only directing what nature has formerly prepared, uniting actives to passives and often succeeding in anticipating results so that these things are popularly held to be miracles when they are really no more than anticipations of natural operations . . . therefore those who believe the operations of magic to

> be above or against nature are mistaken because they are only derived from nature and in harmony with it.

The natural magicians, says Eamon, believed that 'nature teemed with hidden forces and powers that could be imitated, improved upon, and exploited for human gain'. For this reason, there was no more potent challenge to the old concept of forbidden knowledge – and therefore no greater validation of curiosity as a virtue – than that offered by natural magic.

Della Porta became regarded as 'the most diligent scrutinizer of the secrets of nature' in his time, and before Galileo he was the dominant figure of Italian science. It was said at the end of the sixteenth century that, alongside the famous Roman baths at Pozzuoli, Della Porta was the greatest tourist attraction in the kingdom of Naples. This is all the more remarkable when we find that his reputation today rests as much on his skill as a playwright; he wrote at least thirty-three plays, some of which no longer survive.

He was born into a wealthy and influential family of Naples (hailing originally from Salerno), and he allegedly composed his *Natural Magick* at the age of fifteen. Since we do not know exactly when he was born (between 1535 and 1540), it is hard to know the truth of that claim,* but Della Porta was surely a prodigy: the book was printed in 1558, a year after Alessio's *Secreti*, when its author could not have been more than twenty-three years old. *Natural Magick* had a much stronger link with that intellectual tradition than Alessio's compendium of recipes, but in other ways it was not so different. After an introductory chapter explaining the causes of natural and artificial phenomena both 'manifest' and occult, according to such principles as the sympathy and antipathy of forms and substances and how they are influenced by the celestial bodies, it proceeds to list a collection of tricks, experiments and chemical procedures: how to write secret messages, how to make cosmetics and love potions, what the special powers of gems and stones are, and how to conduct a range of optical tricks with mirrors, magic lamps and the camera obscura that paints images with light. The book was expanded in later editions, incorporating all kinds

* This is partly Della Porta's doing: he was apt to lie about his age, as well as to distort other facts, to the advantage of his reputation.

of useful agricultural lore such as how to crossbreed plants and animals and how to preserve fruits. The prosaic nature of much of the book's content no doubt helps to explain its popularity: this was 'magic' that anyone could use.

*Natural Magick* shows us precisely where curiosity was located in the mid-sixteenth century. The attraction of the natural-magic tradition for those of an inquisitive disposition is obvious: it is relatively undogmatic, open to experience, and can embrace just about any topic you like, from cryptography to apple-growing. Nothing is off-limits: as Della Porta put it, 'Magic is nothing else but the knowledge of the whole course of Nature.' You need not be a learned professor to participate in this exploration of nature, nor need you become mired in the rhetorical swamps of classical disputation. Natural magic is largely free from the proscriptions of religion, as well as from the imperatives of Aristotle, which try to tell nature what it can and cannot do. The testimony of antiquity counts for nothing if it is not borne out by your own direct experience. None of this amounts to true science, but it paves the way for it.

On the other hand, there are hazards. The most immediate is that you are liable to be accused of sorcery and necromancy. This frequently happened to Della Porta, who complains in the 1589 edition that a French jurist, Jean Bodin, had denounced him as a 'great Neapolitan sorcerer' and declared *Natural Magick* fit for burning because it included an unguent made by witches (Della Porta insists that he took the recipe instead from the writings of theologians). Often the mere inclusion of experiments, rather than the allusions to magic per se, was enough to arouse suspicion. Della Porta was hounded by the Inquisition, who investigated him in the 1570s after closing down his Accademia dei Secreti. It seems likely that he was forced to recant some of his views after being imprisoned, and he felt compelled to join the Jesuits and spend a day each week working on religious duties to allay suggestions of impiety. Even so, he struggled to gain Church approval to publish his books, on one occasion being threatened with excommunication if he did so without the permission of the Roman High Tribunal.

It is odd that conventional histories of science, so eager to leap from Copernicus to Galileo, ignore all of this: to be a martyr to science, it seems, you have to have been 'right' – or perhaps one must even say,

to fit within a particular narrative. In some ways, Della Porta's natural magic was more threatening to the Church than Copernicus's heliocentric astronomical theory, since it sought to erode the superstitions on which ecclesiastical authority depended. The efficacy of holy relics and faith healing demanded an unquestioning acceptance of miracles that a naturalistic explanation undermined. And religious condemnation of demons, along with Church rites to quell their interfering ways, were rendered superfluous if the likes of Della Porta were going to leave these wicked spirits no role to play. As Eamon puts it:

> Just as the Church was intensifying its campaign against popular superstitions, Della Porta was developing a theory that would undermine its entire conception of superstition . . . the Church needed demons as much as it needed Aristotle . . . Witchcraft legitimized established authority and the instruments by which it exercised its power.

Perhaps a reluctance to afford natural magic its proper place in the beginnings of science stems from another of its dangers, glaringly evident in retrospect: it is credulous. If occult forces act in nature, how can you tell what they can and cannot do? If the compass needle can be oriented toward the north from anywhere in the world by some hidden power, is it so hard to believe that a 'marvellous water' can restore impaired vision (as Della Porta swears happened to him) or that certain gems can confer protection against disease, or that Ptolemy had a magical mirror (perhaps a lens) that could see ships 600 miles away? Della Porta was no more gullible than any of his contemporaries, including many of the acknowledged heroes of early science. Some of the ambitious claims and recipes in *Natural Magick* teeter on the brink of plausibility, such as drugs that will make a man think he is a bird or a fish, or the effect of diet on dreams, or a method for preventing dogs from barking. Other fantastical phenomena that the book describes, such as spontaneous generation, were universally accepted.

More importantly, Della Porta stands out not so much for what he believed but for why he believed it. He was convinced that even the most marvellous of events must have naturalistic explanations, being caused by the forces of nature rather than by God or demons. Jean Bodin's damaging diatribe was provoked by Della Porta's rational explanation for the salve that enabled witches to fly: Della Porta argued

that they only *think* they do, because of the effects of a hallucinogenic drug rubbed on their bodies. It was this implied criticism of the witch-hunts that led the Inquisition to command Della Porta to account for himself in Rome.

Della Porta's book established experiment as the modus operandi of natural magic. He says that he personally tested claims found in older writings that seemed hard to credit, and ruled out ones that did not pass muster. Never mind that Albertus Magnus suggests that iron be hardened by tempering it in radish juice or 'water of earthworms' – it doesn't work, Della Porta attested. (In fact, with characteristic exaggeration apt to undermine his empirical credentials, he says it makes the metal as soft as lead.) The 1589 edition of *Natural Magick* reports that the long-standing idea that the attractive force of a magnet is nullified by rubbing it with garlic does not pass this empirical test either (nor, for that matter, does the alleged enhancement in attractive power caused by goat's blood). This experimental disproof of garlic's 'anti-magnetic' property is sometimes attributed instead to the English natural philosopher William Gilbert in his 1600 work *De magnete* (*Of Magnets*), perhaps because Gilbert has been deemed a more respectable precursor to science. Della Porta himself grumbled that Gilbert 'took the whole seventh book of my *Natural Magick* and split it into many books, making some changes . . . the material which he adds on his own account is false, perverse and melancholy'. He does not help his case, however, by making Gilbert's claim that Earth is in motion one of these 'mad ideas'. But we should be wary of making into 'moderns' and 'medievalists' those at the turn of the century who were and were not Copernicans.

Della Porta is particularly insightful on the subject of optics. In the 1584 edition of *Natural Magick* he explains that:

> Concave Lenticulars [lenses] will make one see most clearly things that are afar off. But Convexes, things near at hand. So you may use them as your sight requires. With a Concave Lenticular you shall see small things afar off very clearly. With a Convex Lenticular, things nearer to be bigger, but more obscurely. If you know how to fit them together, you will see both things afar off, and things near hand, both greater and clearly. I have much helped some of my friends, who saw things

> afar off weakly, and what was near, confusedly, that they might see all things clearly.

Although he is writing here not, as it might appear, of the telescope or the microscope, but of spectacles and other correctives to faulty vision, it is clear enough where the ideas are heading. If Telesio was right that our senses are mechanical, perhaps they can be supplemented and augmented by mechanical aids.

Della Porta's natural magic offered one of the main alternatives to Aristotelian natural philosophy during the late sixteenth and early seventeenth centuries. While it remained rooted in the Neoplatonism and Hermeticism championed by Ficino, exhibiting a (not altogether uncritical) enthusiasm for alchemy, astrology and the new 'chemical medicine', it took on different complexions in different hands. Perhaps the most well-known support er of the magical world view during this period is also one of the wildest and least influential. The Neapolitan friar Giordano Bruno had an arrogant and argumentative nature that was bound to get him into serious trouble eventually, although if he had not happened to promote Copernican cosmology it is doubtful whether he would command any greater fame today than the many other intellectual vagabonds who wandered Europe during the Counter-Reformation. It seems a vain hope that Bruno should ever cease to be the 'martyr to science' that modern times have made of him; maybe we must resign ourselves to the words spoken by Brecht's Galileo: 'Unhappy the land where heroes are needed.'

The fact is that Bruno's Copernicanism is not mentioned in the charges levelled against him by the Inquisition in 1576, nor the denunciation of 1592 that led to his imprisonment and lengthy trial. Of the heretical accusations that condemned him to be burnt at the stake in 1600, only two are still recorded, which relate to obscure theological matters. He held many opinions of which the Church disapproved deeply, on such delicate matters as the Incarnation and the Trinity, not to mention having a long history of associating with disreputable types. Bruno's death stains the Church's record of tolerance for free thought, but says little about its attitude to science. There is nothing in Bruno's espousal of a world soul, or his long discourses on demons and other spiritual beings, or his unconventional system of the elements, that makes him so very unusual for