Chapter 1
New worlds and old worlds

Early modern accomplishments grew upon intellectual and institutional foundations established in the Middle Ages. Many of the questions early moderns strove to answer were posed in the Middle Ages, and many methods used for answering them were products of medieval investigators. Yet early modern scholars loved to disparage the medieval period and to claim that their work was wholly new, despite the fact they retained and relied upon at least as much as they discarded, or retailored it to fit the changing times. Specific changes between the Middle Ages and the early modern period, whether intellectual, technological, social, or political, did not occur simultaneously across Europe. Recognizably 'modern' developments in such areas as medicine, engineering, literature, art, economic and civic affairs were thoroughly established in Italy well before they appeared in more peripheral parts of Europe like England. Similarly, periods of development occurred at different times and speeds within different scientific disciplines. The period roughly 1500 to 1700 – call it what you will – was a rich tapestry of interwoven ideas and currents, a noisy marketplace of competing systems and concepts, a busy laboratory of experimentation in all areas of thought and practice. Text after text from the period testifies to the excitement their authors felt about their own times. One label, one book, one scholar, one generation will not comprehend it in its totality. To begin to understand it and its significance, we need to look closely at what actually took place then and why.

Understanding the Scientific Revolution requires understanding first its background in the Middle Ages and Renaissance. In particular, the 15th century witnessed significant changes in European society and a massive broadening of Europe's horizons, both literally and figuratively. Four key events or movements fundamentally reshaped the world for people living in the 16th and 17th centuries: the rise of humanism, the invention of movable-

type printing, the discovery of the New World, and the reforms of Christianity. While not strictly scientific developments, these changes reshaped the world for thinkers of the period.

The Renaissance and its medieval origins

The term ‘Italian Renaissance’ usually brings to mind masterpieces of art and architecture by well-known figures like Sandro Botticelli, Piero della Francesca, Leonardo da Vinci, Fra Angelico, and many others. But the Renaissance saw much more than a blossoming of fine arts. Literature, poetry, science, engineering, civic affairs, theology, medicine, and other fields prospered as well. The brilliance and importance of the 15th-century Italian Renaissance for history and for modern culture should not be underestimated. All the same, it should also be remembered that it was not the first significant flowering of European culture after the 5th-century collapse of Classical civilization that followed the fall of the Roman Empire. There had been at least two earlier ‘renaissances’ (a word which means ‘rebirth’).

The first, the Carolingian Renaissance, followed the late 8th-century military campaigns of Charlemagne that brought greater stability to Central Europe for much of the 9th century. Charlemagne’s court at Aachen (Aix-la-Chapelle) became a centre of learning and culture. The cathedral schools that would later provide the foundations for universities trace their origins to this period. Charlemagne’s crowning by Pope Leo III in 800 as ‘Emperor of the Romans’ encapsulates a basic theme of Carolingian reforms: the attempt to return to the glory of ancient Rome. Architecture, coinage, public works, and even writing styles were devised to reproduce the way imperial Romans had done things, or at least the way 9th-century people imagined the Romans had done things. This flowering was, however, short-lived.

The second ‘rebirth’ of Latin Europe was much broader and more permanent. Its momentum carried forward, although diminished in intensity, to the start of the Italian Renaissance. This second ‘rebirth’ was the

‘Renaissance of the Twelfth Century’, a great explosion of creativity in the sciences, technology, theology, music, art, education, architecture, law, and literature. The triggers for this efflorescence remain open to debate. Some scholars point to a warmer, more favourable climate for Europe beginning in the 11th century (called the ‘Medieval Warm Period’) coupled with improvements in agriculture that brought enough food and prosperity for Europe’s population to double and perhaps triple within a relatively short time. The rise of urban centres, more stable social and political systems, more abundant food, and thus more time for thought and scholarship, all contributed to initiating this Renaissance.

The intellectual appetite of a reawakened Europe found rich fare on which to feed in the Muslim world. As Christian Europe began to push back against the frontiers of Islam in Spain, Sicily, and the Levant, it encountered the wealth of Arabic learning. The Muslim world had become heir to ancient Greek knowledge, translated it into Arabic, and enriched it many times over with new discoveries and ideas. In astronomy, physics, medicine, optics, alchemy, mathematics, and engineering, the Dār al-Islām (‘Habitation of Islam’) towered over the Latin West. Europeans wasted no time in acknowledging this fact, nor in exerting themselves to acquire and assimilate Arabic learning. European scholars embarked upon a great ‘translation movement’ in the 12th century. Dozens of translators, often monastics, trekked to Arabic libraries, especially in Spain, and churned out Latin versions of hundreds of books. Significantly, the texts they chose to translate were almost entirely in the areas of science, mathematics, medicine, and philosophy.

The Latin Middle Ages had inherited from the Classical world only those texts the Romans possessed; by the end of the empire, only a handful of Roman scholars could read Greek, and therefore virtually the only texts the Romans had to pass on were Latin paraphrases, summaries, and popularizations of Greek learning. It was as if our successors got only newspaper accounts and popularizations of modern science and virtually no scientific journals or texts. Thus scholars of the Latin Middle Ages revered the names of the great authors of antiquity and had descriptions of their ideas, but possessed almost none of their writings.

The 12th-century translators changed all that. They translated works of original Arabic authorship and Arabic translations of ancient Greek works. The majority of ancient Greek texts thus came to Europeans in Arabic dress. From Arabic came the medicine of Galen, the geometry of Euclid, the astronomy of Ptolemy, and virtually the entire corpus of Aristotle we have today – not to mention the more advanced works of Arabic authors in all these fields and more. Around 1200, this explosion of knowledge crystallized into curricula for perhaps the most enduring legacy of the Middle Ages for science and scholarship: the university. Aristotle's writings on natural philosophy formed a core of the curriculum, and his logical works gave rise to Scholasticism, a rigorous and formalized methodology of logical inquiry and debate applicable to any subject, and upon which university studies were based.

The importance of the university as an institutional home for scholarship cannot be overemphasized. As the prominent scholar Edward Grant writes, the medieval university 'shaped the intellectual life of Western Europe'. While the highest degree in the university was in theology, one could not become a theologian without first mastering the logic, mathematics, and natural philosophy of the day, since those topics were employed routinely in the advanced Christian theology of the Middle Ages. Indeed, most great natural philosophers of the period were doctors of theology: St Albert the Great (now patron saint of natural scientists), Theodoric of Freiburg, Nicole Oresme, Henry of Langenstein. All these figures were educated in, taught in, and found a home in a university.

The vigorous cultural life of the 13th century was checked by the disasters of the 14th. Early in the century – possibly as a result of the end of the Medieval Warm Period – repeated crop failures and famine struck a now overpopulated Europe. At mid-century, the Black Plague swept across Europe with astonishing swiftness, killing its victims within a week of infection. We have no experience today of any loss of life or societal upheaval as rapid, unstoppable, or devastating as the reign of the Black Death. In four years, from 1347 to 1350, it killed roughly half of Europe's population. The first signs of a distinctive Italian Renaissance had begun to appear just before these troubled times – the poet Dante (1265–1321) was active before the plague, while the younger writers Boccaccio (1313–75) and

Petrarch (1304–74) lived through it.

Humanism

The Italian Renaissance, fully underway a generation or two after the peak plague years, provided the first key background for the Scientific Revolution: the rise of *humanism*. Humanism proves difficult to define succinctly and rigorously. It is better to speak of *humanisms* – a collection of related intellectual, literary, sociopolitical, artistic, and scientific currents. Among the most widely shared beliefs of humanists was the conviction that they were living in a new era of modernity and novelty, and that this new era was to be measured with respect to the accomplishments of the ancients. They looked for a *renovatio artium et litterarum* (a renewal of arts and letters) to be brought about in part through the study and emulation of ancient Greeks and Romans. Accordingly, it was humanist historians of the Italian Renaissance – such as the Florentines Leonardo Bruni (1369–1444) and Flavio Biondo (1392–1463) – who devised the three-fold periodization of history with which we are all familiar (and from whose implications we still must struggle to free ourselves). According to this periodization, the antiquity of Greece and Rome constitutes the first era, while the third era is that of modernity, beginning of course with the Renaissance authors themselves. Falling between these two high points, according to the humanists, lies a ‘middle’ period of dullness and stagnation, which is thus called the ‘Middle’ Ages. Indeed, perhaps the most enduring invention of the Renaissance has been the concept of the Middle Ages, to the extent that we have no name for the period 500 to 1300 that is not suffused with the disdain Italian humanists felt towards it. Given the recent memory of famine and plague years as their immediate background, the restoration of prosperity in Italy around 1400 must surely have seemed the dawn of a ‘new age’.

Imitation is supposed to be the sincerest form of flattery, and humanists expressed their admiration of antiquity by imitating Roman styles. Attempts to return to antiquity had happened before, notably in the Carolingian Renaissance 600 years earlier. The grandeur of Rome casts a very long

shadow indeed in human memory. The humanist hunger to know more about that past era expressed itself in a quest for long-lost Classical texts. One early humanist, Poggio Bracciolini (1380–1459), taking advantage of recesses during the reform-minded Church Council of Konstanz (1414–18), where he was employed as apostolic secretary, ransacked nearby monastic libraries searching for survivals of Classical literature. He found Quintilian on rhetoric and previously unknown orations of Cicero, but – of greater importance for the history of science – he found also Lucretius' *On the Nature of Things*, a work that presented ancient notions of atomism, Manilius on astronomy, Vitruvius on architecture and engineering, Frontinus on aqueducts and hydraulics. These works had been copied and preserved through the centuries by medieval monks, and had lain – perhaps in just a single surviving copy – in their monastic libraries for generations.

The humanists' recovery of Roman learning was paired with a revival of the study of Greek. The background for the revival of Classical Greek, almost completely unstudied in the Latin West for a thousand years, was the arrival of Greek diplomats and churchmen on embassies to Italy around 1400. Their mission was to secure aid against the Turkish threat and a reunion of Eastern and Western Churches, divided by schism since 1054. One of the first, Manuel Chrysoloras (c. 1355–1415), arrived as a diplomat but stayed as a teacher of Greek; many prominent humanists were his students. Their appetites whetted for Greek texts, Italians travelled to Constantinople to hunt after manuscripts. Guarino da Verona (1374–1460) brought back crates of manuscripts that included Strabo's *Geography*, which he then translated. It is said that one crate of manuscripts was lost in transit, which made Guarino's hair turn grey overnight from grief. The Greek delegation to the Council of Florence in the 1430s included two notable Greek scholars. One was Basilios Bessarion (1403–72), later made a cardinal, who gave his collection of nearly a thousand Greek manuscripts to Venice. The other was a strange character named Georgios Gemistos, known as Pletho (c. 1355–c. 1453), who later advocated a return to ancient Greek polytheism. Pletho taught Greek in Florence, and brought the works of Plato and Platonists to the attention of the West. His teaching led the ruling Duke Cosimo I de' Medici to found a Platonic Academy in Florence. Its first leader, Marsilio Ficino (1433–99), translated the works of Plato and texts by several later Platonists, most of which had been unknown to Western European readers.

Thus the 15th century saw the recovery of huge numbers of ancient texts – many on scientific and technological topics – much as the 12th century had done. But humanists were distinguished not so much by a love of texts, as by a love of *pure and accurate* texts. They disdained the texts of Aristotle and Galen used in universities as corrupt – full of barbarisms, 'Arabisms', accretions, and errors. They rejected Scholasticism as sterile, barbarous, and inelegant. They considered the universities (particularly the northern ones, less so those in Italy) as relics of those stagnant 'Middle' Ages, and chided their scholars for writing a degraded Latin, devoid of elegance. Thus an important feature of humanism was its establishment of new scholarly communities outside the universities.

There is a modern misconception that humanists were somehow secularist, irreligious, or even anti-religious. It is true that some humanists criticized ecclesiastical abuses and disdained Scholastic theology, but in no way whatsoever did they reject Christianity or religion. Indeed, many advocated church reforms parallel with their desired reform of language – by a return to antiquity, to the Church of the first several centuries AD. Many humanists were in Holy Orders, employed in ecclesiastical administration, or supported by church benefices, and the Catholic hierarchy patronized humanism. Many Renaissance-era Popes were fervent humanists – particularly Nicholas V, Sixtus IV, and Pius II – as were their cardinals and courts, where humanists were encouraged. The modern error comes from a confusion with so-called *secular humanism*, an invention of the 20th century that has no counterpart in the early modern period.

Renaissance humanism's impact on the history of science and technology was both positive and negative. On the positive side, humanists made available hundreds of important new texts, and promoted a new level of textual criticism. The reintroduction of Plato, thanks especially to his adoption of Pythagorean mathematics, raised the status of mathematics and provided an alternative to the Aristotelianism favoured at universities. The desire to measure up to the ancients inspired engineering and building projects across Italy, with the ancient engineers Archimedes, Hero, Vitruvius, and Frontinus as models. On the downside, the adulation of antiquity could go too far by rejecting everything after the fall of Rome as barbarism. It is thus that Europe began to lose its respect for and knowledge of Arabic and

medieval achievements, which in the sciences, mathematics, and engineering were – let there be no doubt – substantial advancements over the ancient world.

The invention of printing

The invention of movable-type printing around 1450 well served the humanist interest in texts. This invention, or at least its successful deployment, is credited to Johannes Gutenberg (c. 1398–1468), originally a goldsmith in Mainz. The key to movable-type printing was the creation of cast metal type, each bearing a single raised letter. These type could be assembled into full pages of text, their surfaces smeared with an oil-based ink and pressed against paper, thus printing an entire page (or set of pages) at once. After printing numerous copies, the page of type could be taken apart and the letters readily rearranged into the next set of pages. Previously, books had to be copied by hand, resulting in slow production and high price. The late medieval growth of universities and increase in literacy created a demand for books that outstripped the supply, exerting pressure to produce books more quickly, thus leading to book-making enterprises outside the traditional monastic and university scriptoria. This increased production led to more copying errors – something humanists deplored. Printing allowed for faster and more reliable production, although the labour involved in paper-making, typesetting, and printing meant that books remained expensive. (Gutenberg's Bible, printed in 1455, cost 30 florins, more than a year's salary for a skilled workman.)

The transition to print was not immediate. Manuscripts continued to exist alongside books, although their use was increasingly limited to the restricted circulation of private, rare, or privileged materials. Printed typefaces mimicked manuscript writing; in Northern Europe this meant Gothic bookhands, but Italy, Venice in particular, soon became the centre of the printing industry. Italian printers, such as Teobaldo Mannucci, better known by his Latinized humanist name Aldus Manutius (1449–1515), adopted the cleaner, crisper shapes of letters developed by Italian humanists (which they thought imitated the way Romans wrote), thereby creating fonts that not only

displaced older ones, but also formed the basis for most fonts used today; hence our elegant slanted font is still known as ‘Italic’.

Printing presses sprang up rapidly across Europe. By 1500, there were about a thousand in operation, and between thirty and forty thousand titles had been printed, representing roughly ten million books. This flood of printed material only increased throughout the 16th and 17th centuries. Books became steadily less expensive (often with a loss of quality) and easier for less wealthy buyers to obtain. Printing allowed for faster communication through broadsides, newsletters, pamphlets, periodicals, and a slew of other paper ephemera. Although most of these ephemera perished soon after their production (like last week’s newspaper), such items were very common in the early modern period. The press thus created a new world of the printed word – and of literacy – like never before known.

One easily overlooked feature of printing was its ability to reproduce *images and diagrams*. Illustrations posed a problem for the manuscript tradition since the ability to render drawings accurately depended upon the copyist’s draftsmanship, and often upon his understanding of the text. Consequently, every copy meant degradation for anatomical renderings, botanical and zoological illustrations, maps, charts, and mathematical or technological diagrams. Some copyists simply omitted difficult graphics. Printing meant that an author could oversee the production of a master woodcut or engraving, which could then produce identical copies easily and reliably. Under such conditions, authors were more willing and able to include images in their texts, enabling the growth of scientific illustration for the first time.

Voyages of discovery

Since a picture is worth a thousand words, the ability to illustrate proved especially important given the strange new reports and objects that would soon flood Europe. This information came from new lands being contacted directly by Europeans. The first source was Asia and sub-Saharan Africa.

European contact with these places came about thanks to Portuguese attempts to open a sea route for trade with India in order to cut out the middlemen – predominantly Venetians and Arabs – who controlled the overland and Mediterranean routes. In the early 15th century, the Portuguese prince known as Henry the Navigator (1394–1460) began sending expeditions down the west African coast, establishing direct contact with traders in sub-Saharan Africa. Portuguese sailors pushed on further and further south, eventually rounding the Cape of Good Hope in 1488, and culminating in Vasco da Gama's successful trading voyage to India in 1497–98. The Portuguese established trading outposts all along the route, many of which remained Portuguese possessions until the middle of the 20th century, and eventually extended their regular voyages as far as China, transporting luxury goods like spices, precious stones, gold, and porcelain back to Europe. They also brought back stories of distant lands, strange creatures, and unknown peoples.

This broadening of European horizons did not begin abruptly in the Renaissance. The Middle Ages laid the foundations for Renaissance-era voyages. Indeed, the eastward voyages of the 15th century re-established contacts that had been made in the 13th but cut off in the 14th due to political upheavals in Asia. Medieval travellers, often members of the two new religious orders of the 13th century – Dominicans and Franciscans – embarked on distant religious and ambassadorial missions to an extent we are only now beginning to recognize. They established religious houses across Asia all the way to Peking, as well as in Persia and India, and sent back information to Europe that informed and inspired later mercantile voyages. These medieval travels resulted in a broader sense of the place of Europe within a much larger world to be explored.

While the Portuguese were opening sea routes eastward towards Asia, Christopher Columbus was staring off in the opposite direction. Convinced that the circumference of the earth was about one-third less than the fairly accurate estimates made in antiquity and still widely known in Europe, Columbus imagined that he could reach East Asia faster by sailing westwards. This mistaken impression was in part due to Ptolemy, the 2nd-century geographer and astronomer. Humanists had recently recovered his *Geography*, which included an anomalously small figure for the size of the earth and considerably overestimated the eastward extent of Asia. Financial

backers of Columbus were duly sceptical; they recognized that the westward route was the longer way around, and without intermediate places to take on fresh supplies, the crew would starve. (*No one* thought Columbus would 'sail off the edge of the earth', since the sphericity of the Earth had been fully established in Europe for over 1,500 years before Columbus. The notion that people before Columbus thought that the Earth was flat is a 19th-century invention. Medievals would have had a good laugh at the idea!) Hence, when in 1492 Columbus's ships struck land in the Caribbean, he thought he had reached Asia rather than discovered a new continent.

Whether or not Columbus later acknowledged his mistake, others quickly did, and hastened to travel to this New World. News of the new continent spread quickly, aided by the young printing press, and in 1507, a German cartographer gave the new lands a name – America – after the Italian explorer Amerigo Vespucci. Thanks to these maps and Vespucci's accounts of South America published with them, the name stuck. In 1508, King Ferdinando II of Spain created the position of chief navigator for the New World for Vespucci. This new position existed within the Casa de Contratación (House of Trade), a centralized bureau founded in 1503 not only for collecting taxes on goods brought back to Spain, but also for collecting and cataloguing information of all kinds from returning travellers, for training pilots and navigators, and for constantly updating master maps with new information gleaned from every returning ship's captain. The knowledge and practical know-how collected in Seville helped Spain establish the first empire in history upon which 'the sun never set'.

Other nations, not wishing to be left out of the territories and wealth Spain and Portugal were amassing, joined the fray, although trailing the Iberians by a century or more. Thus for a hundred years, virtually all the New World reports and samples that transformed European knowledge of plants, animals, and geography came into Europe through Spain and Portugal. It is hard to imagine the flood of data that poured into Europe from the New World. New plants, new animals, new minerals, new medicines, and reports of new peoples, languages, ideas, observations, and phenomena overwhelmed the Old World's ability to digest them. This was true 'information overload', and it demanded revisions to ideas about the natural world and new methods for organizing knowledge. Traditional systems of classifying plants and

animals were exploded by the discovery of new and bizarre creatures. Observations of human habitation virtually everywhere explorers could reach refuted the ancient notion that the world was divided into five climatic regions – two temperate ones and three rendered uninhabitable due to excessive heat or cold. Exploiting the enormous economic potential of the Americas and Asia required fresh scientific and technological skills. Geographical data and the recording of sea routes drove the creation of new mapping techniques, while getting safely and reliably between Europe and the new lands demanded improvements to navigation, shipbuilding, and armaments.

Reforms of Christianity

While voyages around the world exposed Europeans to a diversity of religious perspectives, such perspectives were also diversifying at home. The year 1517 marks the beginning of a deep, often violent, and continuing rupture within Christianity. In that year, the Augustinian priest and theology professor Martin Luther (1483–1546) proposed his famous ‘Ninety-Five Theses’ in the university town of Wittenberg. These theses, or propositions, were written in the format of topics for Scholastic disputation, and centred on inappropriate and theologically indefensible contemporaneous local practices involving the sale of indulgences. While similar debates over practical and doctrinal issues were common fare in the disputative university culture of the Middle Ages, Luther’s protest passed beyond the usual confines of scholarly theological disputation and quickly became a broad-based political and social movement out of Luther’s control. Although initially quite mild, Luther’s claims became increasingly bold and confrontational, moving from relatively minor issues of local practices into serious doctrinal matters. These claims were quickly disseminated by the printing press, deepened by linkages to local nationalism, and abetted by Germanic rulers who saw separation from Rome as favourable to their political interests. A local protestation thus unexpectedly became Protestantism. Protestantism almost immediately splintered into sparring sects. Catholic-Lutheran controversies were soon joined by Lutheran-Calvinist ones, then by intra-Calvinist ones, and so on.

The so-called ‘Wars of Religion’ – often motivated more by political and dynastic manoeuvres than by doctrinal issues – convulsed Europe, particularly Germany, France, and England, for the next century and half.

Luther himself was no humanist, although some of his notions, such as an emphasis on a literal reading of the Bible as opposed to the allegorical readings favoured by Catholics, bear resemblances to humanist emphases on texts. But these resemblances are outweighed by his suspicion of Classical (‘pagan’) literature and ideas and his desire to expunge books from the Bible (such as the Letter of James) that disagreed with his personal notions. The much more learned Philipp Melanchthon (1497–1560), however, was quite a different story. Melanchthon’s very name testifies to his humanism, translated into Classical Greek from the original barbarous German Schwartzerd (‘black earth’). His great uncle, Johannes Reuchlin, who suggested this ‘self-classicization’, was the most prominent humanist in Germany. In the wake of the Lutheran rejection of university Scholasticism, Melanchthon (who as a humanist also disliked Scholasticism) renovated university curricula and pedagogy in German universities – in particular, Luther’s own University of Wittenberg – as they converted from Catholic to Lutheran. The new curricula he devised earned him the title *Praeceptor Germaniae* (‘Teacher of Germany’). His approach was not to banish Aristotle, but rather – in true humanist fashion – to banish medieval ‘accretions’ to Aristotle and to use better editions of the Greek philosopher. New Protestant universities found themselves in the enviable position of having to start afresh, that is, with a reduced burden of established methods, and were thus able to incorporate new subjects and approaches that had not found a place in older institutions.

Within Catholicism, reform movements were also underway. In the 15th century, church councils addressed some issues, although not very successfully. More dramatic was the Council of Trent (1545–63), an Ecumenical Council convened to respond to Protestantism by addressing corruption, clarifying doctrines, standardizing practices, and centralizing disciplinary oversight. The Council of Trent, the most important post-medieval church council until Vatican II (1962–5), launched the Catholic Reform, or ‘Counter-Reformation’. Its measures included improved education for priests, a reform many humanists had been advocating, but also increased oversight of orthodoxy including in published works. Tridentine

reforms were taken up most avidly by a newly organized society of priests, the Society of Jesus, or Jesuits. Organized by St Ignatius Loyola and given papal authorization in 1540, the Jesuits devoted themselves especially to education and scholarship, and made significant contributions specifically to science, mathematics, and technology.

The broader impact of the Jesuits, besides preaching for a return of Protestants to Catholicism, lay in the hundreds of schools and colleges they established within the first years of their existence. Jesuit pedagogy rested upon an innovative style of teaching and curriculum, one that preserved the importance of Aristotelian methods, but paired that with new emphasis on mathematics (by 1700, more than half of all the professorships of mathematics in Europe were held by Jesuits) and the sciences. Jesuit schools were often the first to teach some of the new scientific ideas of the Scientific Revolution, and educated many of the thinkers responsible for them. Jesuits spread out across the globe along the newly opened trade routes, establishing a high-profile presence (and schools, of course) in China, India, and the Americas, and the first global correspondence network. This network channelled everything from biological specimens and astronomical observations to cultural artefacts and extensive reports of native knowledge and customs back to Rome. The Jesuit attitude in studies of science and mathematics expresses their motto ‘to find God in all things’. While Jesuits emphasized this incentive, it was not unique to them – it undergirded virtually the entire Scientific Revolution.

The new world of the 1500s

Europeans of the 16th century inhabited a new and rapidly changing world. As in our own fast-paced days, many saw this situation as a source of anxiety, while others saw a world of opportunities and possibilities. The horizons of Europe had been expanded in every sense. Europeans had rediscovered their own past, encountered a wider physical and human world, and created new approaches and fresh interpretations of older ideas. Indeed, the best image for their world would be that of a tumultuous and richly

stocked market place. A cacophony of voices promoted a diversity of ideas, goods, and possibilities. Throngs jostled elbows to test, purchase, reject, praise, criticize, or just touch the varied merchandise. Almost everything was up for grabs. Whether we conclude the ‘Scientific Revolution’ to be something entirely new, or a revival of the intellectual ferment of the late Middle Ages after the interruption of the baleful 14th century, there can be no doubt that the learned inhabitants of the 16th and 17th centuries saw their time as one of change and novelty. These were exciting times; times of new worlds indeed.

Chapter 2
The connected world

When early modern thinkers looked out on the world, they saw a *cosmos* in the true Greek sense of that word, that is, a well-ordered and arranged whole. They saw the various components of the physical universe tightly interwoven with one another, and joined intimately to human beings and to God. Their world was woven together in a complex web of connections and interdependencies, its every corner filled with purpose and rich with meaning. Thus, for them, studying the world meant not only uncovering and cataloguing facts about its contents, but also revealing its hidden design and silent messages. This perspective contrasts with that of modern scientists, whose increasing specialization reduces their focus to narrow topics of study and objects in isolation, whose methods emphasize dissecting rather than synthesizing approaches, and whose chosen outlooks actively discourage questions of meaning and purpose. Modern approaches have succeeded in revealing vast amounts of knowledge about the physical world, but have also produced a disjointed, fragmented world that can leave human beings feeling alienated and orphaned from the universe. Virtually all early modern natural philosophers operated with a wider, more all-embracing vision of the world, and their motives, questions, and practices flowed from that vision. We have to understand their worldview if we are to understand their motivations and methods in investigating that world.

The concept of a tightly connected and purposeful world derives from many sources, but above all from the two inescapable giants of antiquity, Plato and Aristotle, and from Christian theology. From Platonic sources, particularly the thinkers called Late Platonists or Neoplatonists – philosophers actively developing Plato's ideas in Hellenized Egypt during the first centuries of the Christian Era – comes the idea of a *scala naturae*, or ladder of nature. According to this conception, everything in the world has a special place in a continuous hierarchy. At the very top is the One – the

utterly transcendent, eternal God, from whom everything else derives existence. The One emanates creative power that brings everything else into existence. The further this power radiates from its Source, the lower and more unlike the One are the things it creates. At the bottom lies inert, lifeless matter. The rungs in between, in ascending order, are filled with vegetable and animal life, then human beings, and then spiritual beings such as *daimons* and lesser gods. The goal of some Neoplatonists was to climb the ladder as it were, to became more spiritual and less material, to free the human soul – our most noble part – from the blindness caused by its descent into matter, and to rise through the levels of spiritual beings in journey towards the One. This late antique conception both influenced and was influenced by Christian doctrines, and could be readily adapted to orthodox Christian beliefs by replacing the pagan *daimons* and lesser gods with orders of angels, and the One with the Christian God, as was suggested by the 5th-century Christian Neoplatonist pseudo-Dionysius the Areopagite. Thanks to such Christianization, the idea of the *scala naturae* remained well known throughout the Latin Middle Ages, even if the ancient Platonic texts upon which it was based were lost for centuries.

These Platonic texts were among those rediscovered by humanists in the Renaissance and translated by Marsilio Ficino. Ficino also acquired, translated, and published a set of texts attached to the name Hermes Trismegestus, meaning Hermes 'the Thrice-Great', a supposed ancient Egyptian sage contemporary with Moses. What Ficino obtained was a small selection out of a huge mass of diverse *Hermetica* (writings attributed to Hermes) dating from about the 3rd century BC to the 7th AD. Although initially believed to be much older, Ficino's *Hermetica* probably dates from the 2nd and 3rd centuries AD. Its importance lies in its Neoplatonic character that emphasizes the power of human beings, their place in the connected world of the *scala*, and their ability to ascend it. Many Renaissance readers found what they thought to be foreshadowings of Christianity in the *Hermetica*, and thus Hermes Trismegistus took on the status of a pagan prophet, and accordingly he can be found depicted among the prophets in the cathedral of Siena.

The *scala* envisions of a world in which every creature has a place, and each creature is linked to those immediately above and below it, such that

there is a gradual and continuous rise from the lowest level to the highest, without gaps, along what has been called ‘the Great Chain of Being’. A related concept – present in the *Timaeus*, Plato’s account of the origin of the universe, and the only work of Plato known to the Latin Middle Ages – is that of the *macrocosm* and *microcosm*. These two Greek words mean, respectively, the ‘large ordered world’ and the ‘little ordered world’. The macrocosm is the body of the universe, that is, the astronomical world of stars and planets, while the microcosm is the body of the human being. The essential idea is that these two worlds are constructed on analogous principles, and so bear a close relationship to each other. A late contribution to the *Hermetica*, an 8th-century Arabic work called the *Emerald Tablet*, concisely summarizes this view in a terse motto well known in early modern Europe: ‘as above, so below’. For Plato, the linkage of man’s microcosm with the planetary macrocosm had a practical moral meaning – we should look to the orderly, rational workings of the heavens as a guide for governing ourselves in an orderly, rational way. For early modern Europeans, the microcosm–macrocosm linkage had, above all, a medical meaning – it undergirded medical astrology. The various planets have particular effects upon particular human organs, whereby they can influence the bodily functions (see Chapter 5).

A second major contributor to the view of an interconnected and purposeful world comes from Aristotelian ideas about how to gain knowledge. According to Aristotle, proper knowledge of a thing is ‘causal knowledge’. That term requires explanation. Aristotle argued that knowing a thing requires identifying its four ‘causes’, or reasons for existing. The first of these, the *efficient cause*, describes what or who made the thing. The *material cause* describes what the thing is made of. The *formal cause* tells what physical characteristics make the thing what it is, in other words, an inventory of its qualities. The most important cause for Aristotelians, and the most difficult one for moderns to get their minds around, is the *final cause*. The final cause tells what the thing is for, that is, what its goal in existing is, and for Aristotle, everything has a goal or purpose. These ‘causes’ can be illustrated using a statue of Achilles. The statue’s efficient cause is the sculptor, its material cause is marble, its formal cause is the beautiful body of Achilles, and its final cause is to celebrate the memory of Achilles. There can be more than one of each of the causes (for example, the statue might also

have the final cause of being decorative, or perhaps, in some Attic house, to act as a coat rack).

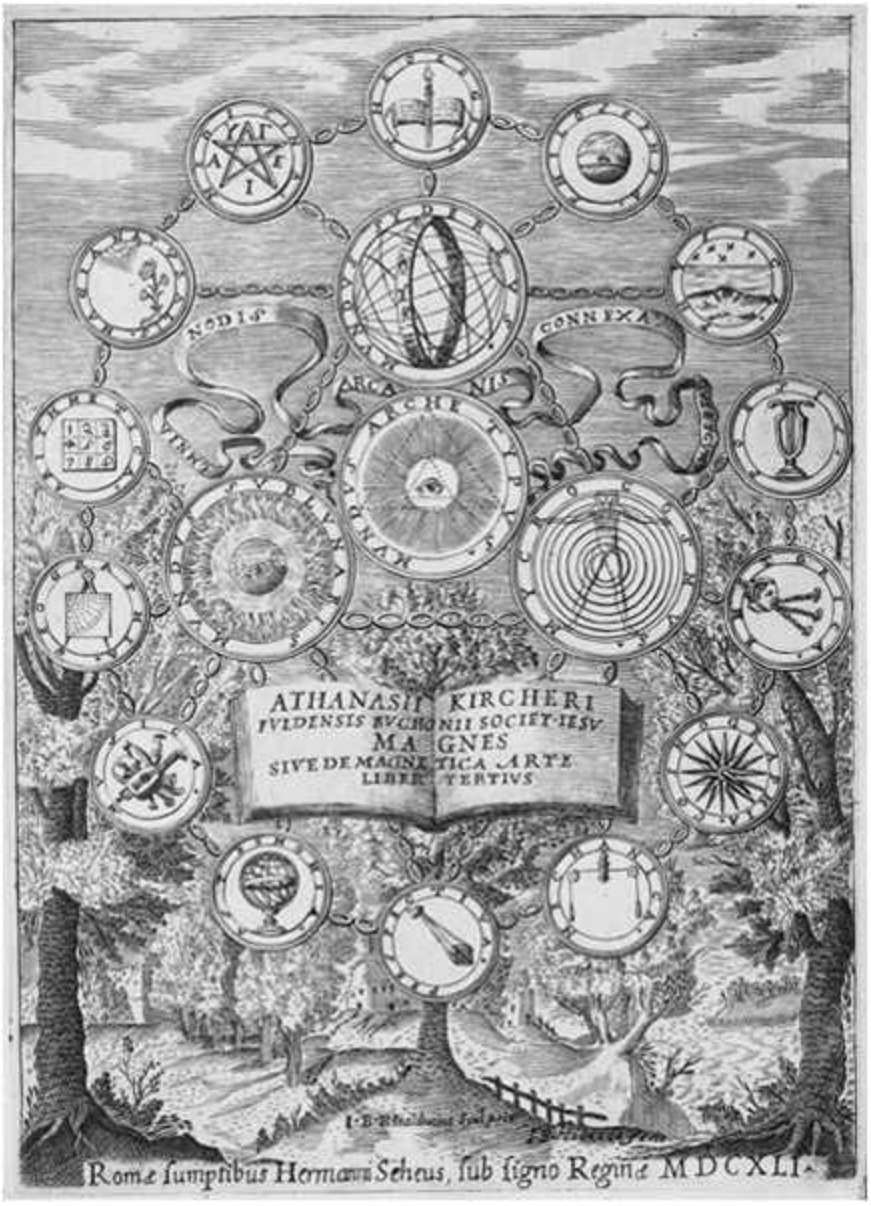
The crucial point is that Aristotelian forms of knowledge, particularly in regard to the efficient and final causes, acted to define objects *in the context of their relationship to other objects*. Coming to know a thing meant being able to position it within a network of relationships with other things, particularly the things that bring it into being and that make use of it. In the Christian context of Europe, the final cause harmonized well with the idea of divine design and providence. Final causes in nature were part of God's plan for creation, implanted and encoded within created things by the First Efficient Cause.

Writers of the early modern period expressed their understanding of a connected world in many different ways. The English natural philosopher Robert Boyle (1627–91), renowned for his work in chemistry (chemistry students still have to learn Boyle's Law that the volume of a gas is inversely proportional to the pressure exerted upon it), wrote that the world is like 'a well contriv'd Romance'. Here, Boyle alludes to the massive French novels of his day (of which he was very fond). These romances often run to more than two thousand pages in length, and feature a memory-taxing myriad of characters whose complex storylines constantly converge and diverge in surprising ways, full of revelations about who is secretly in love with whom and who is really whose long-lost brother, child, or what-not. For Boyle, the Creator is the ultimate romance writer, and scientific investigators are the readers trying to figure out all the relationships and crisscrossing storylines in the world He wrote.

The Jesuit polymath Athanasius Kircher (1601/2–80), who maintained a museum of wonders in Rome and was a centre of Jesuit correspondence about natural philosophy, portrayed the connected world in an elegant Baroque frontispiece to his encyclopaedic work on magnetism (Figure 1).

The image shows a series of circular seals, each bearing the name of one branch of knowledge: physics, poetry, astronomy, medicine, music, optics, geography, and so on, with theology at the top. A single chain connects the seals together, expressing the inherent unity of all branches of knowledge. For early moderns, there were no strict barriers that kept sciences,

humanities, and theology insulated from one another – they formed interlocking ways of exploring and understanding the world. In Kircher's image, these branches of knowledge stand chained to three larger seals representing the three chief parts of the natural world: the siderial world (everything farther away than the Moon), the sublunar world (the Earth and its atmosphere), and the microcosm (human beings). These three parts of the world are likewise chained together indicating the inescapable interdependence that exists between them. At the centre of the entire image, in direct contact with each one of the three worlds equally, stands the *mundus archetypus* – the archetypal world, that is, the mind of God that not only created everything, but also contains within itself the models or archetypes of everything possible in the universe. Kircher completes his image with the Latin motto: 'Everything rests placidly, connected by hidden knots.'



1. Engraved title page to Athanasius Kircher, *Magnes sive de magnetica arte* (Rome, 1641) expressing the interconnectedness of the branches of knowledge and of God, humanity, and nature

This sense of connectedness both between disciplines and between various facets of the universe characterizes *natural philosophy* – the discipline practised by early modern students of the natural world. Natural philosophy is closely related to what we familiarly call *science* today, but is

broader in scope and intent. The natural philosopher of the Middle Ages or of the Scientific Revolution studied the natural world – as modern scientists do – but did so within a wider vision that included theology and metaphysics. The three components of God, man, and nature were never insulated from one another. Natural philosophical outlooks gradually gave way to more specialized and narrow 'scientific' ones only during the 19th century (the age in which the word 'scientist' was first coined). The work and motivations of early modern natural philosophers cannot be properly understood or appreciated without keeping the distinct character of natural philosophy in mind. Their questions and goals were not necessarily our questions and goals, even when the very same natural objects were being studied. Hence, the history of science cannot be written by pulling scientific 'firsts' out of their historical context, but only by seeing with eyes and minds of our historical characters.

Natural 'magic'

The 'cosmic' perspective was widely shared in the 16th and 17th centuries, and it undergirded a variety of practices and projects, even if different thinkers considered the interconnections in the world to be of varying degrees of importance to their work. The facet of natural philosophy most closely tied to this vision of the world was *magia naturalis*. It is misleading to translate this Latin term directly into English as 'natural magic'. The word 'magic' naturally makes modern readers think of costumed men pulling rabbits out of hats, or of wizened black-robed characters in pointy hats mumbling over cauldrons, or, rather more benignly, of Harry Potter and Hogwarts. The *magia naturalis* of the early modern period was, however, something very different; it forms an important part of the history of science.

Magia is perhaps best translated for moderns as 'mastery'. The goal of the practitioner of *magia*, called a *magus*, is to learn and to control the connections embedded in the world in order to manipulate them for practical ends. Look again at Kircher's frontispiece. In the upper left-hand corner,

magia naturalis is listed among the branches of knowledge, between arithmetic and medicine. Kircher symbolizes it with the turning of a sunflower to follow the Sun across the sky throughout the day. (Several plants display this behaviour, known as *heliotropism*.) Why does the sunflower always turn towards the Sun while most plants do not? Clearly, there must be some special link between Sun and sunflower. The ability of the sunflower to follow the Sun provided a prime example of the hidden connections and forces in the world that the magus endeavoured to identify and control.

Medieval Aristotelians divided properties of a thing into two groups. The first were *manifest qualities* – qualities that anybody endowed with sense organs could detect. Hot, cold, wet, and dry were the primary qualities. Other qualities included things like smooth, rough, yellow, white, bitter, salty, sonorous, fragrant, and so forth – all things that activated the senses. After all, Aristotelianism was fundamentally a common-sense way of engaging with the world. Aristotelians used these manifest qualities to explain the action of one thing upon another: cooling drinks lower a fever because cold counteracts hot, for example. But some objects acted in weird ways that manifest qualities could not explain. These objects were held to have *hidden qualities* (*qualitates occultae*, often misleadingly translated as 'occult qualities') that we cannot detect with our senses. These qualities often acted in highly specific ways, suggesting a special, invisible connection between specific things and the objects they acted upon. Medieval natural philosophers compiled lists of such phenomena. One classic example is the magnet. We can sense nothing about the lodestone (a naturally magnetic mineral) that could possibly explain its mysterious ability to attract iron specifically. The same is true of the apparent attraction between the Sun and the sunflower, the turning of a compass needle towards the pole star, the sleep-inducing effect of opium, the Moon's effect on the tides, and many other things. *Magia naturalis* was the endeavour to seek out these hidden qualities of things and their effects, and to make use of them.

How did one go about finding these connections, these 'hidden knots', in nature? One way was to observe the world closely. Everyone can agree that careful observation is a crucial starting point for scientific investigation; the pursuit of *magia naturalis* promoted such observation. A method of equal

importance lay in mining the records of earlier observers of nature – accounts and observations, ranging from the commonplace to the bizarre, recorded in various texts from contemporaneous times back to the ancient world. Much *magia* was therefore based on a careful reading of texts in humanist fashion, building up complex networks by compiling claims from earlier writers. Given the immense variety of nature, the task of the aspiring *magus* is mind-bogglingly immense – no less than cataloguing the properties of everything. Could there be a shortcut? Some natural philosophers believed that nature contained clues to guide the magus, perhaps as hints implanted there by a merciful God who wants us to understand His creation and benefit from it. The *doctrine of signatures* claims that some natural objects are 'signed' with indications of their hidden qualities. Often, this means that two connected objects look somehow similar, or have some analogous characteristics; for example, the sunflower not only follows the Sun, its blossom actually *resembles* the Sun in colour and shape. Various parts of plants resemble various parts of the human body; a walnut nestled in its shell looks remarkably like a brain inside the skull. Is this a sign that walnuts would provide good medicines for the brain? The practitioner of *magia* would have to try these things out to be sure, but observation coupled with the idea of signatures provided a useful point of departure for investigating, explaining, and using the natural world.

The doctrine of signatures represents but one facet of a broader mode of analogical thinking ubiquitous in the early modern period. While moderns would tend to see such similarities as mere coincidence or accident, or as 'poetic' rather than physical, many early moderns saw things quite differently – they *expected* analogical links between different parts of the world, and the discovery of an analogy or symmetry in nature signified for them a real connection between things. Rather than being the product of human imagination, every analogy between two objects in the natural world marked out another line in the blueprint of creation, a visible sign of a hidden connection divinely implanted in the universe. Thus, arguments from analogy carried special strength and evidentiary power beyond what we are accustomed to give them today. The sureness of this linkage was founded upon an unshakable faith in a cosmos that was not random or fortuitous, but rather one that was suffused with meaning and purpose, guided in various ways by divine wisdom and providence for the benefit of human beings. This

certainty, and the attendant use of analogical reasoning, was not the exclusive property of those interested in *magia naturalis*, but of virtually *every* serious thinker of the period.

Using direct observation, analogy, textual authorities, and signatures, early modern thinkers compiled huge aggregates of things they considered to be linked. For example, what else might relate to the Sun–sunflower connection? The Sun is the source of warmth and life in the macrocosm, its counterpart in the microcosm must be the heart. (Have yet another look at Kircher's frontispiece – there is a tiny Sun in the place of the heart in the human figure representing the microcosm.) The Sun is the most noble of the heavenly bodies, brilliant and yellow, and thus it bears a similitude to gold in the mineral realm, and further afield to all yellow or golden things. In the animal realm, the Sun causes the rooster to crow, indicating a special link between the two. The lion, with its tawny colour, royal status, and head that resembles the Sun (its mane frames its head like solar rays), also seems linked to the Sun. Likewise, the bravery of the lion corresponds in turn with the heart. Sun, sunflower, heart, gold, yellow, rooster, and lion all bear links of commonality and thus real but hidden connections. For the advocates of *magia naturalis*, these analogical links translate into operative links that can be put to use. The most down-to-earth application would involve using gold or sunflowers to make a medicine for the heart – but things could get much more dramatic, as we shall see.

Opinions varied as to what actually linked objects bound up in these webs of correspondence, but they were usually considered to function by means of 'sympathy', which literally means 'suffering together or receiving action together'. Think of two well-tuned lutes on opposite sides of a room, pluck a string on one of them, and the corresponding string on the other will immediately start to vibrate and hum on its own, echoing the note plucked on the first lute. Today, we still call this phenomenon *sympathetic* vibration. For early modern thinkers, this phenomenon exemplified the operation of unseen links acting at a distance between things that were 'in tune' with one another. Some argued that a medium was necessary to transmit the action between spatially separated objects; Aristotle had argued that one thing could not act on another thing a distance away without an intervening medium to carry the effects. In the case of lute strings, for example, we know that the intervening

air carries the vibrations between the two instruments. For other sympathetic actions, this medium might be the so-called *spiritus mundi*, or spirit of the world – a universal, all-penetrating incorporeal or quasi-corporeal substance, capable of keeping even distant objects in virtual contact with one another by transmitting influences from one to the other. This ‘spirit’ was not some sentient supernatural entity; rather, it is the macrocosmic equivalent of the microcosmic animal spirits, the subtle substance in our bodies that transmits the command ‘move!’ through the nerves to our feet when our intellect realizes that a two-ton truck is speeding towards us. The spirit of the world likewise carries ‘signals’ from the Sun to the sunflower or from the Moon to the waters of the sea. Once again, the microcosm and the macrocosm are reflections of one another; both contain spirits that transmit signals. Incidentally, this analogous nature should also mean that the macrocosm itself has a soul of some sort – a point Plato asserts in the *Timaeus* and is especially difficult for moderns to understand – the next chapter returns to this point.

Practical ‘mastery’ from the kitchen to the study

The theory of natural magic in regard to a connected world is impressive, even elegant and beautiful, yet the key feature of *magia naturalis* is practical application. The practical parts of early modern *magia* range from the banal to the sublime, the former often having little to do with any theoretical foundations. The book *Magia naturalis* of Giambattista della Porta (1535–1615) provides a good example. Della Porta is renowned for establishing in Naples the earliest scientific society – the Academy of Secrets – and for being a member of the Accademia dei Lincei, the early 17th-century scientific society that counted Galileo as a member. The first chapter of Della Porta’s book recapitulates the principles of an interconnected world, noting how magic ‘is the survey of the whole course of nature’ and ‘the practical part of natural philosophy’. He advises his reader to ‘be prodigal in seeking things out; and while he is busy and careful in seeking, he must be patient also … neither must he spare any pains: for the secrets of nature are not revealed to lazy and idle persons’. The practical secrets of nature that the rest

of della Porta's book reveals do include observations about magnetism and optics, but the majority of the book is a miscellany of recipes for everything from making artificial gems and fireworks, to animal and plant breeding, to household hints about making perfumes, roasting meat, and preserving fruit, none of which draws upon any theoretical conception of the world. Della Porta's book fits instead with a tradition of 'books of secrets' that became increasingly popular throughout the 16th and 17th centuries, some of which were reprinted even into the 19th. Many such books begin with an exposition of grand and lofty notions about the cosmos, but consist principally of recipes for household management or cottage industries, and contain little or nothing about the nature of the world.

At the sublime end of the scale stands Marsilio Ficino (1433–99), whose practical application of the connectedness of the world was expressed in ways of living and in rituals. Ficino often complained of his melancholy temperament; perhaps he suffered from what we now label as depression. The established medicine of the day held that a preponderance of black bile – one of the four 'humours' of the body that must remain in balance to provide health – produces depression. Indeed, the Greek term for black bile – *melaina chole*[notdef]– is the origin for our word *melancholy*. (In the same way, personalities that are still called sanguine, choleric, and phlegmatic arise from the preponderance of one of the other three bodily humours: blood, yellow bile, or phlegm, respectively; see Chapter 5.) Ficino explored the connection between the scholarly life and melancholy, and proposed lifestyle changes for his fellow intellectuals to help them address the problem. He formulated a diet and medicinal supplements to prevent the formation of excess black bile in the body, and his 'On Obtaining Life from the Heavens' proposes using celestial influences to counteract this occupational hazard of scholars.

Physicians considered black bile to have the manifest qualities of cold and dry. The planet Saturn shares these qualities, and thus the two bear a sympathetic connection. Therefore, anything in the web of correspondences with black bile and Saturn was to be avoided. The opposing qualities of the Sun (hot–dry) and Jupiter (hot–wet) counteract the cold–dry of black bile, and so by analogical extension anything in the web of correspondences with the Sun and Jupiter could help counteract scholarly melancholy. (Our word 'jovial' literally means 'relating to Jupiter', an indication preserved in our

language of how thoroughly entrenched and accepted this reasoning really was.) Thus, in order to make use of sympathetic links to the Sun, the Florentine humanist suggested wearing yellow and golden clothes, decorating one's chamber with heliotropic flowers, getting lots of sunlight, wearing gold and rubies, eating 'solar' foods and spices (like saffron and cinnamon), hearing and singing harmonious and stately music, burning myrrh and frankincense, and drinking wine in moderation. For some readers, however, he did tread a little too far when he also suggested – following the lead of the ancient Neoplationists Plotinus and Iamblichus, whose works he translated from Greek – making images that could attract and capture planetary powers, a rather questionable thing for an ordained Roman Catholic priest to be doing. Indeed, Ficino can be read as crossing the line at this point from *natural* magic into *spiritual* magic, although he might well have disputed that interpretation. The former used the hidden sympathies in nature, while the latter elicited the help of spiritual beings – the *daimons* and gods of pagan Greek philosophy, or the demons and angels of Christian theology. The former *magia* was unobjectionable, the latter (reasonably enough) drew the condemnation of theologians. Questions were raised about Ficino's orthodoxy, but apparently no actions were taken, since such rituals could be interpreted as entirely physical and medicinal, and thus entirely acceptable. Over a century later, for example, the Dominican friar Tommaso Campanella and Pope Urban VIII used a ritual of lights, colours, smells, and sounds, not unlike Ficino's prescriptions, to counteract any possible ill effects from the temporary loss of healthful solar influences during a solar eclipse that had been predicted to bring about the pontiff's death. The Pope survived. Yet while this *magia* was natural in intended operation, some onlookers did view such applications as suspect.

At the present time, applications of *magia naturalis* and the whole idea of an interconnected world of sympathies and analogies are sometimes dismissed as irrational or superstitious. But this harsh judgement is faulty. It results from a certain smug arrogance and a failure to exercise historical understanding. What our predecessors did was to observe various mysterious and apparently similar phenomena in nature and to extrapolate thence into a more universal statement – a law of nature – about connections and the transmission of influences in the world. This extrapolation led to one tenet that they held that we do not; namely, that similar or analogous objects

silently exert influence upon one another. Once that assumption is made, then the rest of the system builds upon it rationally. They were trying to understand the world; they were trying to make sense of things and to make use of the powers of nature. They moved inductively from observed or reported instances to a general principle and then deductively to its consequences and applications. We might choose to say, informed as we are by more recent studies, that the action between Sun and sunflower, or Moon and sea, or magnet and iron, can be better explained by something other than hidden knots of sympathy. But that does not permit us to say that their methods or conclusions were irrational, or that the beliefs and practices that came from them were ‘superstitious’. If that leap were allowed, then every scientific theory that comes ultimately to be rejected in the course of the development of our understanding of the world – no doubt including some things that we today believe to be true explanations of phenomena – would have to be judged irrational and superstitious as well, rather than simply *mistaken* notions that were arrived at rationally given the ideas, perspectives, and information available at the time.

Religious motivations for scientific investigation

Magia naturalis is only the strongest expression of widely held ideas of a connected world, of the macrocosm and microcosm, and of the power of similitude. The same kinds of connections and thinking were often implicit in the work of natural philosophers who never gave natural magic a second thought. Every thinker of the period, for example, was confident of the intimate connections among human beings, God, and the natural world, and consequently of the interconnections between theological and scientific truths. This feature brings up the complex topic of science and theology/religion. In order to understand early modern natural philosophy, it is necessary to break free of several common modern assumptions and prejudices. First, virtually everyone in Europe, certainly every scientific thinker mentioned in this book, was a believing and practising Christian. The notion that scientific study, modern or otherwise, requires an atheistic – or what is euphemistically called a ‘sceptical’ – viewpoint is a 20th-century

myth proposed by those who wish science itself to be a religion (usually with themselves as its priestly hierarchy). Second, for early moderns, the doctrines of Christianity were not opinions or personal choices. They had the status of natural or historical facts. Dissension obviously existed between different denominations over the more advanced points of theology or ritual practice, just as scientists today argue over finer points without calling into question the reality of gravity, the existence of atoms, or the validity of the scientific enterprise. Never was theology demoted to the status of 'personal belief'; it constituted, like science today, both a body of agreed-upon facts and a continuing search for truths about existence. As a result, theological tenets were considered part of the data set with which early modern natural philosophers worked. Thus theological ideas played a major part in scientific study and speculation – not as external 'influences', but rather as serious and integral parts of the world the natural philosopher was studying.

Many people today acquiesce in the widespread myth, devised in the late 19th century, of an epic battle between 'scientists' and 'religionists'. Despite the unfortunate fact that some members of both parties perpetuate the myth by their actions today, this 'conflict' model has been rejected by every modern historian of science; it does not portray the historical situation. During the 16th and 17th centuries and during the Middle Ages, there was not a camp of 'scientists' struggling to break free of the repression of 'religionists'; such separate camps simply did not exist as such. Popular tales of repression and conflict are at best oversimplified or exaggerated, and at worst folkloristic fabrications (see Chapter 3 on Galileo). Rather, the investigators of nature were themselves religious people, and many ecclesiastics were themselves investigators of nature. The connection between theological and scientific study rested in part upon the idea of the Two Books. Enunciated by St Augustine and other early Christian writers, the concept states that God reveals Himself to human beings in two different ways – by inspiring the sacred writers to pen the Book of Scripture, and by creating the world, the Book of Nature. The world around us, no less than the Bible, is a divine message intended to be read; the perceptive reader can learn much about the Creator by studying the creation. This idea, deeply ingrained in orthodox Christianity, means that the study of the world can itself be a religious act. Robert Boyle, for example, considered his scientific inquiries to be a type of religious devotion (and thus particularly appropriate to do on Sundays) that heightens the natural philosopher's knowledge and awareness

of God through the contemplation of His creation. He described the natural philosopher as a ‘priest of nature’ whose duty it was to expound and interpret the messages written in the Book of Nature, and to gather together and give voice to all creation’s silent praise of its Creator.

In sum, early moderns saw – in various ways – a cosmically interconnected world, where everything, human beings and God and all branches of knowledge, were inextricably linked parts of a whole. In some respects, the recent development of ecology and environmental sciences might be seen as restoring some lines of the unseen networks of interdependence early modern natural philosophers envisioned in their own world. However that may be, early modern thinkers, like their medieval forebears, looked out on a world of connections and a world full of purpose and meaning as well as of mystery, wonder, and promise.