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ORDER: GOD'S MAN'S AND NATURE'S

Laws of Nature, Moral Order, and the Intelligibility of the Cosmos

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A number of questions about the rise of modern science have preoccupied historians of science for some time now. At the most general level is the issue of why modern science begins in the seventeenth century and in Western Europe. More specifically, historians have been interested in identifying the distinctive features of Western society that make possible the emergence and persistence of modern science. Equally challenging has been the comparative question of why modern science seems to take off in Europe and nowhere else. Although the latter question has been controversial—why, critics might ask, should we define science in such a way that restricts its birth to the West—interesting studies have been conducted that compare the scientific cultures and institutions of China, Islamic societies, and the West. One partial answer to these questions has been the suggestion that the West had a unique conception of natural order that provided the necessary preconditions for the emergence of modern science. This chapter will explore this argument, drawing some brief comparisons between Western science and Chinese science and suggesting that an important difference lies in their respective conceptions of natural order. The idea of mathematical laws of nature, it will be argued, is unique to the early modern West and is underpinned by theological considerations that arise out of Western monotheism.

Jesuit Science and Chinese Astronomy

In 1687, the Jesuit astronomer Ferdinand Verbiest (1623–88) described for a European audience the inroads made by Western astronomy in seventeenth-century China:

> After Astronomy, marching like a venerable queen between the Mathematical Sciences and rising above all of them, had made her entry among the Chinese

> and had ever since been received by the Emperor with such an amiable face, all the Mathematical sciences also gradually entered the Imperial court as her most beautiful companions.…However, the aim of their fervent desire to please was not to keep the Emperor's eyes only upon themselves, but to direct them fully towards the Christian Religion, whose beauty they all professed to worship, in the same way as smaller stars worship the sun and the moon. (Golvers, 1993, 101)

Despite the rhetorical flourishes, Verbeist's celebratory account offers a reasonably accurate portrait of the status of Western astronomy in the imperial court during the late seventeenth century. In 1669, Verbiest had been appointed director of the Imperial Observatory in Beijing, a prestigious post that the Jesuits were to control for over a century. Verbiest also became one of the emperor's favorites, tutoring him in the sciences, and during his tenure European astronomy gained wide acceptance among the Chinese literati. [1]

These spectacular successes built on the foundations laid by previous generations of Jesuit scholars. Matteo Ricci (1552–1610) had initiated the Jesuits' contact with China in 1583,bringing with him Western maps of the world and various scientific instruments. On the basis of these, Ricci had achieved considerable renown as a mathematician and astronomer and by the early seventeenth century was installed in the Imperial Court in Peking. However, although Ricci had studied in Rome with the famous astronomer Christopher Clavius and indeed had translated parts of Clavius's works into Chinese, he was not primarily an astronomer and lacked the ability to compute the positions of the planets or determine the dates of eclipses. Realizing that Western science, and astronomy in particular, provided a means for extending Jesuit influence in China, Ricci wrote to Rome before his death in 1610 with a request that more astronomers be sent to China and that they bring with them the latest scientific works and instruments. His request was granted, and several able astronomers arrived in Peking to take over his work. Sabatino de Ursis (1575–1620) quickly made an impact by accurately predicting the date and time of the solar eclipse of December 15, 1610. Some years later, and less spectacularly, Johannes Terrentius (1576–1630), a sometime correspondent of both Galileo and Kepler, produced a new and comprehensive astronomical compendium that provided the foundations for calendar reform. Adam Schall von Bell (1592–1666) introduced the telescope to China in his *Yüan-ching shuo* (On the telescope, 1630) and was

[1] For this and the following three paragraphs I have drawn on Udias (2003), 37–60; Po-chia Hsia (1998), 186–93; Vogel (2006); and Pingyi Chu (1999).

appointed, in 1664, to the directorship of the Imperial Observatory—the position that Verbiest would subsequently assume.[2]

While the efforts of these individuals enhanced the status of Western astronomy in China, they also engendered considerable resentment. The elevation of Schall, for example, had resulted in the marginalization of the “Muslim” faction within the Observatory, and this exacerbated underlying tensions.[3] The involvement of Islamic astronomers in the operations of the Observatory dated from the Mongol Yuan Dynasty (1279–1368), when Persian and Arabian astronomers had helped establish the Observatory and make it a state-of-the-art institution. During the Ming Dynasty (1368–1644) that followed, the initial vigour of the astronomical sciences had gradually waned, and by the time of the arrival of the Jesuits in China astronomy was ripe for a reformation. Not surprisingly, however, the successes of the Jesuits were resented by the incumbent astronomers. The leader of the Muslim group, Yang Kuang-hsien [Guangxian] (1597–1669), accused Schall and his Jesuit colleagues of spreading false religion, teaching erroneous science, and, most seriously, treason. In fact, the accusations of scientific incompetence were linked to a more serious political charge. An important element of Yang’s case was the claim that Schall had chosen an inauspicious date for the burial of the empress’s daughter—the selection of propitious dates for important events being the responsibility of Imperial astronomers—and that this had ultimately resulted in the deaths of the empress and Emperor Shunzhi. A protracted trial began in September 1665, involving tests of rival astronomical systems. Although Schall and Verbiest accurately predicted the solar eclipse of January 16, 1665 (their Chinese rivals were more than half an hour astray), Schall was sentenced to death, his Chinese assistants were executed, and other Jesuits were imprisoned or exiled. On the day scheduled for the execution, however, Peking was visited with a great earthquake, which persuaded the judges to reverse their ruling.

In the years that followed, Verbiest worked persistently to reestablish the reputation of Western astronomy, highlighting errors in the existing calendar and seeking to best his rivals in various astronomical competitions. In a specific test of competing astronomical systems, Verbiest challenged Yang Guangxian to predict the length of

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[2] The telescope was first mentioned in Chinese writings in 1615, and it was Terrentius’s telescope that found its way into the possession of the emperor. See Needham (1986), 445.

[3] On the Muslim and Chinese schools of astronomy see Udias (2003), 38 and 44.

the shadow of a vertical rod on a particular day at a particular time. Verbiest did this successfully on several occasions before the emperor, while Yang was unable to do so. It was following his successes with these astronomical trials that Verbiest was appointed director of the Imperial Observatory. Eventually, the superiority of Western astronomy was secured, Yang was humiliated and exiled, and Verbiest was installed as director of the Astronomical Bureau (Udias, 2003, 46).[4] Following his death on March 11, 1688, Verbiest was buried near the graves of Ricci and Schall—on the present campus of the Beijing Administrative College.[5]

In addition to providing some local background for our discussions about the significance of the invention of the telescope and of cosmology, this brief history raises a number of related issues, two of which I want to pursue in further detail in the rest of this chapter. One issue concerns what we might call the ideological use of astronomy as a means of propagating Western values in general and Christianity in particular. Another issue concerns the notion of *Tian* (heaven) and the extent to which it maps onto Western theological conceptions and ideas about natural order. But the two matters that I wish to pursue in more detail are these. First is the possible relation of the physical sciences, such as astronomy, to human affairs. This is the general question of the relation of celestial order in the heavens to terrestrial order in human societies. In Chinese thought these connections have found expression in the notions of *Tian* (Heaven) and *tian ming* (the mandate of heaven). The apparent alliance between human affairs and cosmic order is evident in the account just provided. The injustice that had led to Schall's condemnation was manifested in the physical disturbances that led to the earthquake. The importance of using the calendar to select auspicious dates similarly suggests an important connection between the order and motions of the heavenly bodies and human affairs. Harmony in the social realm is reflected by harmony in the cosmos. In the West, these connections have been understood in terms of the relations between human laws and divine laws.

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[4] There is some irony here in the fact that the astronomy that the Jesuits brought was essentially Ptolemaic, although they had the advantage of the possession of the Rudolphine tables—updated planetary tables based on the observations of Tycho Brahe and the theoretical heliocentric astronomy of Johannes Kepler.

[5] See http://www.bac.gov.cn/webnew/swdx/2en/about/listdetail.aspx?NodeID=25&ID=667.

The second and more general concern is that identified at the beginning of this chapter, regarding the relative fortunes of Chinese science and Western science, and the eventual victory of the latter. The question of why the West and not China was the “grand question” of the eminent historian of science and specialist in Chinese science and technology Joseph Needham (1900–95).[6] In various ways this same question has also been explored by scholars as diverse as Max Weber (2002), Toby Huff (2003), Remi Brague (2002), and, most recently, Stephen Gaukroger (2006).[7]

One approach to this important historical question has been to embark on a comparative exercise and examine other scientific cultures—in particular Chinese and Islamic civilizations—in order to explore how different sets of cultural values might have had an impact on the development of science in different cultural contexts. It is significant, for example, that Chinese astronomy in the Han Dynasty (206 BC–AD 9) was considerably advanced: astronomers had developed sophisticated star maps and astronomical instruments; they utilized an equatorial-polar reference system; they entertained the idea of celestial objects floating in an infinite void (Needham, 1986, 438). In these respects, Chinese astronomy was considerably superior to the Western astronomy of the same period. Further advances were made during the Yuan Dynasty (1279–1368), which, as we have already noted, saw a fertile engagement with Islamic astronomy and the arrival of Persian and Arabian astronomers at the Imperial Court. These earlier periods also bear witness to Chinese ingenuity and technological accomplishment. The Chinese invented printing and paper, the wheelbarrow, the umbrella, gunpowder, the compass, stirrups, and suspension bridges.[8] As Voltaire observed in the eighteenth century, “4,000 years ago, when we could not read, the Chinese knew all the indispensably useful things of which we know today” (Voltaire, 1972, 115). With this background in mind, then, our more general question becomes, How did Western science in the seventeenth century come to overtake Chinese science and technology, given the rather more promising start of the latter?

[6] On the framing of this question, see Yung Sik Kim (2004).

[7] See also Harrison (1998).

[8] For a complete list see Simon Winchester’s (2008) biography of Joseph Needham, 267–78.

Not surprisingly, there are a number of theories about how cultural differences of various kinds have played out in the development of science, and some have suggested that this is not even a question that we can sensibly ask. However, one influential line of thought refers us back to the first question that I raised, concerning different understandings of the relation between heavenly order in the physical realm and social order in the human realm. In the West, thinking about these relations gave rise to the idea of "laws of nature," and it has been argued, plausibly in my view, that *part* of what made modern science possible in the West was a new conception of the "laws of nature" that originally took as its point of departure the idea of divinely ordained moral laws. Thus, I turn now to the issue of "laws of nature."

Moral Laws and Laws of Nature

The medieval West had a conception of natural laws, but they were typically understood to be universal *moral* laws, which human beings became cognizant of on account of their rationality. Thomas Aquinas (1225–74) explained that on analogy with a ruler who promulgates laws in his kingdom, God enacts eternal law. Natural law (*Lex naturalis*) is simply the imprinting of that eternal law on human minds, which leads to participation of human agents in this eternal law (Aquinas, 1964–76, 1a2ae, 91, 2). Specific human laws (*Lex humana)* and the law of nations (*Ius gentium*) are derived from this natural law. All of this was premised on the commonsense idea that only rational agents with a will can obey laws.

By way of contrast, the regularities observed in nature were understood not in terms of universal laws, but rather as arising out of the inherent natures of individual things (in keeping with Aristotle's understanding of motion and change and his conception of material, formal, efficient, and final causes). This Aristotelian position could be given a theological gloss as, for example, when Aquinas speaks of "the order *that God has implanted* in nature" (Aquinas, 1934, 3, 100). [9] This order was not invariant or deterministic, for the natural powers of things could sometimes miscarry. Hence, the course of nature was accordingly understood as that which happened usually or "for the most part" (Aquinas, 1934, 3, 99).

In the later Middle Ages, developments in both theology and natural philosophy led to modifications of this understanding of nature. Already in the thirteenth century, reactions against certain Aristotelian doctrines had led to speculations about how it was possible for God, on account of his omnipotence, to overrule the internal

[9] See also Aquinas (1932), q. 3, a. 8, ad 2.

tendencies of things that, according to Aristotle, were essential to their natures (Piché, 1999). An increasing emphasis on the part of certain theologians on the omnipotence of God and on the primacy of his will promoted discussions of ways in which God might directly intervene in nature. In the early modern period these tendencies culminated in the idea that God directly imposed his will on nature in the form of natural laws. This view was reinforced by a new matter theory—the corpuscular hypothesis, or what we would call atomic theory—according to which nature was made up of minute and inert (i.e., causally impotent) particles. At the same time, the idea that the world was like a machine was rapidly overtaking the older idea that the world was like an organism as the predominant model for understanding the operations of nature. In this new understanding of the natural world, "laws of nature" were for the first time conceptualized as regularities that God had imposed directly on the natural world. Henceforth, scientific explanations of natural events will be couched not in terms of the inherent causal properties of things, but in terms of universal laws that have been externally imposed on an essentially passive matter.[10]

One of the best-known examples of early modern formulations of laws of nature are Johannes Kepler's (1571–1630) laws of planetary motion. Kepler's third law, for example, states that the square of the orbital period of a planet (the time it takes to orbit the sun) is proportional to the cube of its semimajor axis (its mean distance from the sun). Kepler is quite explicit about the fact that his proposal that the planets are governed by mathematical laws is informed by, and indeed grounded in, specific theological convictions. He acknowledges also that his novel formulation of mathematical rules for describing the actual motions of the planets will attract the ire of traditional natural philosophers. "I shall have the physicists against me in these chapters," he confesses, "because I have deduced the natural properties of the planets from immaterial things and mathematical figures." The "natural properties" of things, as we have already noted, had been usually understood in terms of their intrinsic qualities, rather than mathematically imposed laws. Kepler's response to his imagined critics is to point out that "God the Creator, since he is a mind, and does what he wants, is not prohibited, in attributing powers and appointing circles, from having regard to things that are either immaterial or based on imagination" (Kepler, 1999, 123). Kepler also suggested that the reason Aristotelian science had

[10] On the emergence of the idea of laws of nature see Henry (2004), Harrison (2008a), Milton (1998), and Steinle (1995).

overlooked the possibility of a divine imposition of mathematical order was because of Aristotle's conviction that the world was eternal, and that the Aristotelian God did not create or impose order on the world. By way of contrast, Kepler pointed out, "our faith holds that the World, which had no previous existence, was created by God in weight, measure, and number, that is in accordance with ideas coeternal with Him" (Kepler, 1997, 115 and 146).[11]

It is possible to interpret Kepler's conception of a world based on mathematical ideas, which are "coeternal with God," as an endorsement of a kind of Christian Platonism. The Greek philosopher had famously held that the temporal and imperfect material world that we detect with the senses is based on an eternal and perfect world of ideas, accessible only by reason. But the notion of laws of nature was equally compatible with the decidedly non-Platonic idea that the universal mathematical truths were not eternally true, but true only by virtue of God's willing them. This was the view of the French philosopher René Descartes (1596–1650), who contended that all logical and mathematical truths derived from the will of God. In 1630, for example, Descartes wrote to his friend Marin Mersenne, arguing that "the mathematical truths, which you call eternal, were established by God and totally depend on him just like all the other creatures" (Cottingham et al., 1985–91, 3, 23).[12] The early modern idea of laws of nature is therefore not a revival of an ancient Platonic conception of nature, but a radically new idea about how God directly exercises his will in the natural realm.

Descartes played a major role in inaugurating this new idea and in linking it to the divine will. In his *Principles of Philosophy* (1644), he identifies three "laws of nature," which he describes as constant and immutable. They derive these characteristics, he insists, from their divine author, who likewise is said to be constant and immutable (Cottingham et al., 1984–85, 1, 240, and 286). English natural philosophers were to follow suit. Robert Boyle, the "father of chemistry" and discoverer of the eponymous gas law, wrote about "laws of motion" that "did not necessarily spring from the nature of matter, but depended on the will of the divine author of things" (Boyle, 1966, 5, 521). The Newtonian Samuel Clarke wrote in the same vein that "the *Course of*

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[11] The reference to "weight, measure, and number" comes from the Book of Wisdom 11:12, a favourite passage of Augustine. See *The Trinity* XI.iv; *The Literal Meaning of Genesis* IV, 3, 7–12; *Confessions* V.iv.7; *Answer to an Enemy of the Law and the Prophets* I, 6, 8; *Free Will* III, 12, 35.

[12] See also Descartes, *Objections and replies*, in Cottingham et al. (1984–85), 2, 29.

Nature, cannot possibly be any thing else, but the *Arbitrary Will and pleasure of God* exerting itself and acting upon Matter continually" (Clarke, 1738, 2, 698).

The idea that there are laws of nature—a fundamental assumption of much Western science— thus rested initially on the notion of divinely imposed ordinances, a notion that had been transposed from the moral realm to the physical. The necessity and universality of laws of nature were attributed to the immutability of their divine source, God. Over the next few centuries, some thinkers reversed the order of reasoning that had given rise to the idea of laws of nature, arguing from the existence of physical laws to the existence of moral laws. Already in the sixteenth century, the Protestant reformer Philipp Melanchthon (1497–1560) stressed the affinity between the order and lawfulness apparent in the heavens and the political and moral order of the human realm. "Like the order of the motions of the heavens," he wrote, "so too the whole of this political order, the bond of marriage, empires, the distinction of states, contracts, judgements, punishments, indeed all most true statutes originate from God" (Melanchthon, 1535, XI, 912).[13] Melanchthon's ideas provided a major theological incentive for the study of astronomy and had an important influence on the development of Johannes Kepler's conceptions of a divinely imposed celestial order (Barker and Goldstein, 2001, 25; Methuen, 1998, 209; Barker, 1997, 360).[14]

Indeed, in certain respects, the idea that the cosmic order portends moral order has its roots in antiquity. Plato had suggested that the lover of wisdom who becomes familiar with the divine order in the cosmos "will himself become orderly and divine" (Plato, *Republic* VI 500d). Hence, one reason for studying the regularities of nature was to effect personal transformation. This is in keeping with a classical conception of philosophy—including natural philosophy or what we would now call "science"—which held the basic philosophical task to be that of moral or spiritual formation (Hadot, 2002). It is not particularly surprising, then, to find the most influential astronomer of antiquity making a similar claim. Claudius Ptolemy (90–168) insisted that study of the mathematical regularities of the heavens "makes its followers lovers of this divine beauty, accustoming them and reforming their natures, as it were to a spiritual state"(Ptolemy, 1998, 37).

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[13] See also Barker and Goldstein (2001), 95.

[14] See also Kepler (1997), 146; Kepler (1988), 144.

These connections between moral and cosmic order appear again in the moral philosophy of Immanuel Kant (1724–1804), albeit in a rather attenuated fashion. As is well known, Kant sought to find a rational basis for a universal *moral* law that was analogous to the universal *physical* law of gravitation that Newton had discovered in the heavens. This connection was expressed in the celebrated juxtaposition set out in the *Critique of Practical Reason* (1788): "Two things fill the mind with ever new and increasing admiration and awe, the more often and steadily we reflect upon them: the starry heavens above me and the moral law within me" (Guyer, 1992, 1). Neither should we forget that while Kant is best known for his philosophical achievements, he also made major contributions to speculative cosmological theory, and that while his scientific ideas had their limitations, the nebular hypothesis that he outlined was in a sense the first statement of modern evolutionary cosmology.[15] However, by the time of Kant, the connection between moral and cosmic order was based on a loose analogy. Kant was attempting to effect a kind of Newtonian reformation in the realm of moral philosophy, but he did not suggest that the former is directly relevant to the latter.

In light of this discussion about the emergence of the idea of laws of nature, one answer to the question about the rise of science in the West—the question articulated by Joseph Needham and, more recently, Toby Huff, Remi Brague, and Stephen Gaukroger—has to do with these theological ideas that gave rise to the distinctive notion of "laws of nature." As it turns out, this is not too far from the answer that Needham himself gave. He wrote:

> The available ideas of a supreme being, though certainly present from the earliest times, failed to retain enough personalized creativity to allow [for] the development of the conception of precisely formulated abstract laws ordained from the beginning by a celestial lawgiver for non-human Nature, and capable, because of his rationality, of being deciphered or re-formulated by other lesser rational beings. (Needham, 1951, 230)

In sum, "the conception of a divine celestial law-giver never developed in China." As a consequence, they lacked a conception of laws of nature and did not develop an understanding of the natural world that was similar in structure to Western science.

Needham's account is plausible as far as it goes. However, I want to suggest that part of what was distinctive about the intellectual background of the West was not just the idea of "laws of nature" or even, more generally, the presupposition of the rationality of the cosmos and its transparency to the human intellect. While the notion of laws of nature is exclusive to the early modern West, these more general

[15] See the essays in Butts (1986).

assumptions may be found, in various guises, in Pythagoreanism, Platonism, Stoic thought, and to some extent in the Chinese conception of *tian*. In addition to this assumption of the underlying rationality of the universe, there are two crucial constraining principles, one to do with the role of divine choice, the other to do with the perceived limitations of the human mind.

Human Knowledge and Nature's Laws

As we have seen, central to the idea of laws of nature is the notion of a divine legislator. Equally important, however, is the idea that the divine legislator is not constrained in the choices he might make when instantiating a particular cosmic order. This means that whatever we might intuit about the order of the cosmos, such rational intuitions will of themselves be insufficient and will invariably need to be supplemented by empirical investigation.[16] Réne Descartes (who is often wrongly imagined to be an "armchair scientist") put it this way: "Since there are countless different configurations which God might have instituted here, experience alone must teach us which configurations he actually selected in preference to the rest" (Cottingham et al., 1985–91, 1, 256). In the preface to the second edition of Newton's *Principia* (written by Roger Cotes) we find a similar sentiment: "the business of true philosophy is to derive the natures of things from causes truly existent, and to inquire after those laws on which the Great Creator actually chose, to found this most beautiful Frame of the World, not those by which he might have done the same, had he so pleased" (Cotes, 1999, 393).[17] Hence, while we can be assured that there *is* a rational pattern to nature, on account of the choices available to the divine legislator we still need to engage in careful empirical investigation in order to find out what that specific pattern is.

Consider how such a constraint might work in practice. A belief in the rationality and mathematical intelligibility of nature is completely consistent with, and indeed might well promote, the long-held assumption that planetary orbits will be perfect circles. It is the assumption of a Creator who exercises a degree of arbitrary choice in his designs, within a range of options, that enables speculation about the possibility of elliptical orbits. The idea of divine choice, as well as the conviction that it makes a

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[16] This is the so-called voluntarism and science thesis. See Klaaren (1977), Heimann (1978), and Osler (1994). For some reservations about this thesis see Harrison (2002).

[17] Paradoxically, this statement appears in the context of an attack on Descartes' philosophy.

difference in how we approach the study of nature, is explicit in the positions of Descartes, Boyle, Newton, and indeed many early modern natural philosophers.

The second constraining principle is a belief that the human mind and the human senses are somewhat limited in what they can know. According to a standard Western reading of human origins, the first human beings as created by God once enjoyed a perfect intuition of the structure of the world and its operations, but they lost this as a consequence of human sin. In this, the Christian idea of the fall, the first man was imagined to have had a complete knowledge of nature, on account of both his rational capacities and perfect sense organs (Harrison, 2007). As Martin Luther put it in his commentary on Psalm 127: “Here it appeareth that at the beginning there was planted in man by God himself, a knowledge of husbandry, of physicke, and of other artes & sciences; Afterward men of excellent wit by experience & great diligence did encrease those gifts which they had by nature. And this is but the strength of humane wisedome created in man at the beginning in Paradise” (Luther, 1577, 129). The idea of a virtually omniscient Adam was a commonplace during the sixteenth and seventeenth centuries, and the scientific enterprise was often understood as aiming to restore, at least in part, the scientific knowledge that Adam had possessed before his fall from grace. Francis Bacon (1561–1626) thus declared, “For man by the fall fell at the same time from his state of innocency and from his dominion over creation. Both of these losses however can even in this life be in some part repaired; the former by religion and faith, the latter by arts and sciences” (Bacon, *Novum Organum* II, § 52). A key motivation for the pursuit of science during this period, then, was the conviction that by engaging in scientific activity, the human race would gradually repossess a natural knowledge once lost and by virtue of these gains reestablish dominion and control over the natural world.

As part of this intriguing set of beliefs, a number of Western thinkers, up until the eighteenth century, thought that Adam had enjoyed the advantage of a kind of “telescopic vision” and that his knowledge of astronomy had been the equal of the best that modern astronomy could offer. Luther, again, contended that before his fall, Adam “could have seen objects a hundred miles off better than we can see them at half a mile, and so in proportion with all the other senses” (Luther, 1848, 57). Joseph Glanvill, an early member of Royal Society, agreed that Adam had not needed “Galileo’s tube”—the telescope—to have had knowledge of the heavenly bodies (Glanvill, 1661, 1 and 5). In this understanding of things, scientific instruments such as the telescope were prosthetic devices that enabled the human race to recapture a

knowledge of the world that they had once possessed through their natural sensory endowments alone (Glanvill, 1661, 1 and 5).

More generally, new instruments and experiments, along with the idea that natural science should be a corporate and cumulative activity, were justified by appeals to the fallen, and hence weakened, condition of human bodies and minds. The conviction that knowledge could be improved was thus premised on a belief in the present mediocrity of human knowledge and of human knowledge-making capacities. As Robert Hooke, first curator of experiments at the Royal Society, expressed it in the preface of *Micrographia* (1665), "every man, both from a deriv'd corruption, innate and born with him, and from his breeding and converse with men, is very subject to slip into all sorts of errors.…These being the dangers in the process of humane Reason, the remedies of them all can only proceed from the real, the mechanical, the experimental Philosophy [i.e. the new science]" (Hooke, 1665, preface). Thus was new experimental science commended as a palliative for human sin and the natural ignorance that was the consequence of that sin.

There are, then, two crucial constraining principles that modify the more general assumption about the intelligibility of the universe: first, that God exercised his choice in the creation of a particular natural order; and second, that we need to be skeptical about the knowledge generated by fallen human minds. Together these assumptions promoted the idea that science is difficult business, that we need to focus on small problems, and that science can only aspire to success if it is a disciplined, collective, and cumulative activity, assisted by instruments and experiments.

Religious Justifications of Western Science

The argument to this point has been that the idea of laws of nature is a distinctively Western idea and that it was one factor that led to the emergence of modern science. Moreover, the assumption of a natural correspondence between the lawfulness of the cosmos and the rational structures of the human mind was qualified by a commitment to the myth of a primeval fall, and to the necessity of a critical approach to human knowledge. Once there had been a perfect reciprocal relation between the mind and the cosmos. However, this had been distorted by human sin. The role of experimental science was to attempt to bridge this gap and partially restore this original correspondence. Francis Bacon, who in essence set out the justifications for the new approach of experimental science of the seventeenth century, thus wrote that the goal of the new science was to see "whether that commerce between the

mind of man and the nature of things…might by any means be restored to its perfect and original condition, or if that may not be, yet reduced to a better condition than that in which it now is" (Bacon, 1857, 4, n. 7). At its birth, modern science was thus conceptualized as a set of remedial practices directed toward a reestablishment of the natural bond between the reason of the mind and the rationality of the cosmos. Science was a restorative exercise.

It should be acknowledged that there is some tension between these Baconian justifications for experimental science and the kind of justifications that we see in the writings of someone like Kepler. These tensions have at times been expressed in terms of a standard distinction between rationalism (which stresses the power and primacy of human reason) and empiricism (which emphasizes the importance of observation and experiment). These two traditions sit somewhat uneasily together in the work of someone like Newton, who, in spite of his spectacular successes, never really managed to resolve this essential tension between a commitment to the inherent rationality of the universe on the one hand and human incapacity to grasp the mind of God on the other. Nevertheless, modern science seems to have been forged in the creative tension between a kind of optimistic rationalism and a critical empiricism.

There is perhaps one more thing to be said about the Baconian ideas, and that is that they provided the new sciences with a vital source of religious legitimation. Whereas we now tend to think that the practice of science is something that is self-evidently a good thing, it was by no means as clear-cut in the seventeenth century, when modern science was first emerging. The situation with regard to new science becomes apparent when we consider the controversy generated by the new experimental philosophy and by robust criticisms that were leveled against the fledgling Royal Society. A key criticism was this: What use is this new science? How is this knowledge socially useful? It is important to understand that during the course of the seventeenth century, science had yielded few practical or technological benefits, and even if it had, there was still a question of whether the provision of material comforts was an appropriate occupation for serious thinkers.

One vocal critic of the Royal Society, Henry Stubbe (1631–76), thus complained that the new science was utterly incompetent to provide "that Moral discipline which instructs us in the nature of virtue and vice" (Stubbe, 1670a, 14). The derided philosophy of Aristotle, by way of contrast, was capable of promoting moral formation. For Stubbe, the new science consisted only in a crude "mechanical

education" and such undignified pursuits as "*planting of Orchards, making of Optick Glasses, magnetic and hortulane Curiosities*" (Stubbe, 1670b, 13). Others voiced similar concerns over what they regarded as the unsophisticated and unfulfilled utilitarianism of the mechanical and experimental sciences.[18]

What these criticisms suggest is that the new science needed not only discoveries and new applications but also new social attitudes that valued those discoveries and their practical applications. The Baconian program provided just the kind of justification that the new natural philosophy needed, by stressing that science provides the means by which human beings can regain the mastery of nature that they lost at the fall. The idea of science as a kind of redemptive process was vital for establishing its religious legitimacy in the seventeenth century and arguably gave modern science the religious and moral foundations that established its enduring importance as a central feature of Western society. The remarkable success of science in the West is often assumed simply to be the result of its being self-evidently the right way to pursue knowledge, and of the practical benefits that it confers. What the history suggests is that the success of modern science owes not merely to the brilliance and ingenuity of its first practitioners but also to the emergence of a set of values, underpinned by religious considerations, that ensured it a permanent and central place in the societies of the modern West.

Conclusion

In the course of this chapter I have considered two "big questions"—questions that I believe history can shed some light on. We have discussed the assumptions that make science *possible*, along with the values that make science *desirable*. The tentative answers offered in this chapter have both involved reference to the unique religious landscape of the early modern West and hence shed light on a third question, implicit in the first two: why the West?

On the first question, as we have seen, part of what makes science possible is the theologically informed assumption that there are laws of nature, promulgated by God and discoverable by human minds. The scientific program, however, requires more than just rational intuition, because of the range of possible rational orders in the cosmos and, equally importantly, because of limitations of the human mind. Science is thus made possible by the idea of an intelligible order of nature, along with a critical skepticism that demands that we constantly interrogate our methods and

[18] On the Royal Society and its critics see Harrison (2008b).

revise our findings. While science assumes that some ultimate rational truth about the cosmos lies out there, at the same time it also generally accepts that our versions of that truth at any one time will be partial, fragmentary, and provisional. These features of the modern scientific landscape are vestiges of its religious origins. Of course, in the years that have elapsed between the seventeenth century and now, we have largely lost sight of its original theological justifications. Nonetheless, intriguing questions remain about the extent to which we are warranted in still assuming that there are, for example, laws of nature, given that relatively few scientists still subscribe to the theological ideas that provided the foundation for these assumptions. Some have argued, more or less on these grounds, that we ought to abandon the classical notion of laws of nature (Cartwright, 2005).

The second question, regarding the value of science, is also often overlooked because the virtues of science seem so obvious. One way of getting some perspective on this question is to think about the old joke of the definition of the gentleman: a gentleman is someone who can play the bagpipes but chooses not to. *Mutatis mutandis*, in the case of the history of science, not becoming a scientifically advanced culture may not be a matter of lacking the relevant capacities. It may also be a matter of choosing different cultural priorities—that is, of endorsing the position: yes, we can do science if we want to, but there are other things that we believe to be equally or more important. Western historians have sometimes proceeded on the assumption that Western science serves as a measure of its superiority, but such a view rests on a number of uncritical assumptions about cultural values and priorities.

In thinking about this question, the definition of “the gentleman” actually turns out to be a historically relevant consideration. In seventeenth-century England, one important concern was whether or not experimental science was a suitable activity for a scholar and a gentleman. As we have seen, educational priority had traditionally been placed on the moral sciences, rather than the natural sciences. The former were regarded as the most useful both for individual edification and for society as whole. The eventual success of science was achieved by appealing to the kinds of religious values identified by Francis Bacon, who emphasized the importance of mastery of the world, rather than self-mastery, and who pointed to the redemptive value of exercising that mastery over nature.[19]

[19] This also makes for an interesting comparison with the Confucian concept of “the Gentleman” (*Chun-tzu*), forwhom the cultivation of an inner natural virtue (*jen*) is the first priority.

These distinctive features of Baconian science, along with the factors that ensured its longevity, also point to key cultural and religious differences between China and early modern Western Europe, and to why, comparatively speaking, scientific activity gained such an impetus in the West. Confucianism and Taoism, in different ways, acknowledge the order of nature. But, oversimplifying the matter somewhat, in the case of the former, priority is placed on social order and moral cultivation; in the case of the latter, the emphasis is on living in conformity to the natural state of affairs. Neither approach promotes a skeptical attitude to our commonsense intuitions about the world, and neither provides a justification for the pursuit of mastery over nature.

To conclude, then, scientific success is not merely a matter of having the necessary presuppositions about the rationality of the cosmos, or knowledge of the requisite methods to uncover that rationality, or sufficiently brilliant minds capable of implementing those methods. The long-term success of science requires also a set of social values that promotes the goals of the sciences. Not only does a society need to be able to do science, it must wish to do so, and be prepared to sacrifice other priorities in order to do so. The seventeenth century was the period that witnessed the first articulation of a set of values that gave priority to the natural sciences. Interestingly, it was also at this time that the quest for cosmic order first became disengaged from the quest for moral order.

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