THE COSMOS AND HUMANITY

LAWS OF NATURE, MORAL ORDER, AND THE INTELLIGIBILITY OF THE COSMOS

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INTRODUCTION: WESTERN ASTRONOMY IN SEVENTEENTH-CENTURY CHINA

In 1687, the Jesuit astronomer Ferdinand Verbiest 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 frevent 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.[1]

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 which the Jesuits were to control for over a century. [2 Observatory] Verbiest also became one of the Emperor's favourites, tutoring him in the sciences,

[1] Noel Golvers, *The 'Astronomia Europaea' of Ferdinand Verbeist, S.J.* [1687] (Nettetal: Steyler, 1993), p. 101.

and during his tenure European astronomy gained wide acceptance amongst the Chinese literati.[2]

These spectacular successes built upon 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 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. Realising 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. Sabbatino de Ursus (1575-1620) quickly made an impact by accurately predicting the date and time of the solar eclipse of 15 December, 1610. Some years later, and less spectacularly, Johannes Terrentius (1576-1630), a sometime correspondent with Galileo, produced a new and comprehensive astronomical compendium which provided the foundations for calander reform. Adam Schall von Bell (1592-1666) introduced the telescope to China in his *Yüan-ching shuo* (On the telescope, 1630), and was appointed, in 1664, to the directorship of the Imperial Observatory—the position which Verbiest would subsequently assume.[3]

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[2] For this and the following three paragraphs I have drawn upon Agustin Udias, *Searching the Heavens and the Earth: The History of Jesuit Observatories* (Dordrecht: Springer, 2003), pp. 37-60; R. Po-chia Hsia, *The World of Catholic Renewal: 1540-1770* (Cambridge, 1998), pp. 186-93; Klaus A, Vogel, 'European Expansion and Self Definition', in Katherine Park and Lorraine Daston (eds.), *The Cambridge History of Science vol 3: Early Modern Science* (Cambridge, 2006), pp. 818-839; Pingyi Chu, 'Trust, Instruments, and Cross-Cultural Scientific Exchanges: Chinese Debate over the Shape of the Earth, 1600-1800', *Science in Context* 12 (1999), 385-411.

[3] The telescope was first mentioned in Chinese writings in 1615, and it was Terrentius's telescope that found its way into the possesson of the Emperor. Joseph Needham, *Science and Civilization in China: Volume 3*, (Cambridge, 1986) p. 445.

The efforts of these individuals enhanced the status of Western astronomy in China, they also encountered opposition. The elevation of Schall, for example, had resulted in the marginalization of the 'Muslim' faction within the Observatory, and this engendered considerable hostility.[4] The leader of this group, Yang Kuang-hsien [Guangxian] (1597-1669) accused Schall and his Jesuit colleagues of spreading false religion, teaching errroneous science and, most seriously, of treason. In fact, the accusations of scientific incompentence were linked to 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 16 January 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 rehabilitate Western astronomy, pointing out errors in the existing callendar and challenging his rivals to various tests. In specific test of rival astronomical systems, Verbiest challenged Yang Guangxian, to predict the length of the shadow of a vertical rod on a particular day at a particular time. Verbiest did this sucessfully 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 Verbeist was installed as Director of the Astronomical Bureau.[5] Following his death on 11 March 1688, Verbiest was buried near the graves of Ricci and Schall—on the present campus of the Beijing Administrative College.[6] [3]

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[4] On the 'Muslim' and 'Chinese' schools of astronomy see Udias, *Searching the Heavens*, pp. 38, 44.

[5] Udias, *Searching the Heavens*, pp. 46f. There is some irony here in the fact that the astronomy which the Jesuits brought was essentially Ptolemaic, although had the advantave of the possession of updated versions of the Rudolphine tables.

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

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 paper.

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 *tien* (*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 connexions have found expression in the notions of *Tien* (Heaven) and *tien 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 auspicous dates similarly suggests an important connection between the order and motions of the heavenly bodies and human affairs. Harmony in 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.

The second concern is to do with the relative fortunes of Chinese science and Western science, and the eventual victory of the latter. One question that has preoccupied historians of science for some time now is why modern science begins in the West in the seventeenth century. What are the distinctive features of Western society that make possible the emergence *and* persistence of modern science? And futhermore, why the West, and not somewhere else—for example, China? This was the 'grand question' of the eminent historian of science, and specialist in Chinese science and technology, Joseph Needham (1900-95) [4 Joseph Needham]. In various way this same question has also been explored by scholars as diverse as Max Weber, Toby Huff, Remi Brague and, most recently, Stephen Gaukroger.[7]

[7] Max Weber, *The Protestant Ethic and the Spirit of Capitalism*[1905](Penguin Classics, 2002); Toby Huff, *The Rise of Early Modern Science: China, Islam and the West,* 2nd edn, (Cambridge, 2003) Stephen Gaukroger, *The Emergence of a Scientific Culture: Science and*

One approach to this important historical question has been to embark upon 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 – AD9) was considerably advanced: astronomers had developed sophisticated star maps and astronomical instruments; they utilized an equatorial-polar reference system (not used in the West until the late sixteenth century by Tycho Brahe); they entertained the idea of celestial objects floating in an infinite void.[8] 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 saw a fertile engagement with Islamic astronomy, and the arrival of Persian and Arabian astronomers at the Imperial Court. (It was during this era that the Muslim school of astronomy was founded in Peking.) 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.[9] 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.'[10] 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?

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, to do with 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

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the Shaping of Modernity (Oxford, 2007); Remi Brague, *Eccentric Culture: A Theory of Western Civilization* (Chicago, 2001).

[8] Needham, *Science and Civilization in China: Volume 3*, pp. 438f.

[9] For a complete list see Simon Winchester's biography of Joseph Needham, *The Man Who Loved China* (HarperCollins, 2008), pp. 267-78.

[10] Voltarie, 'Christianity', *Philosophical Dictionary*, tr. Theodore Besterman, (Penguin Classics, 1972), p. 115.

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' which originally took as its point of departure the idea of divinely-ordained moral laws. So 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 explained, for example, that on analogy with a ruler who promulgates laws in his kingdom, God enacts eternal law. Natural law (*Lex nauralis*) is simply the imprinting of that eternal law on human minds, which leads to participation of human agents in this eternal law.[11] 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.'[12] This order was not invariant or deterministic, for the natural powers of things could sometimes miscarry. So the course of Nature was accordingly understood as that which happened usually or 'for the most part'.[13]

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 over-rule the internal

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[11] Thomas Aquinas, *Summa theologiae* 1a2ae. 91, 2.
[12] Thomas Aquinas, *Summa contra gentiles* 3b, 100, tr. English Dominican Fathers, 5 vols., (London: Burns, Oates & Washbourne, 1934), vol. 4, p. 58; *Quaestiones disputatae de potentia dei,* Bk. 1, q. 3, a. 8, rp. 2, English translation, *On the Power of God*, tr. English Dominican Fathers (London: Burns, Oates & Washbourne, 1932), p. 143.
[13] Aquinas, *Summa contra gentiles* 3b, 99 (vol. 4, p. 57, my emphasis).

tendencies of things which according to Aristotle were essential to their natures.[14] 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 conceptualised 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.

The French philosopher René Descartes played a major role in inaugurating this new idea. In the *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.[15] 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' which 'did not necessarily spring from the nature of matter, but depended on the will of the divine author of things.'[16] [5a Boyle and quote] The Newtonian Samuel Clarke wrote in the same vein that 'the *Course of Nature*, cannot possibly be any thing else, but the *Arbitrary Will and pleasure of God* exerting itself and acting upon Matter continually.'[17] [5b Clarke quote]

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 which had been transposed from the moral realm to the physical. The necessity and

[14] David Piché, *La Condamnation parisienne de 1277* (Paris: Vrin, 1999).
[15] Descartes, *Principles of Philosophy*, *CSM* vol. 1, pp. 240, 286.
[16] Robert Boyle, *The Christian Virtuoso*, in *Works* 5:521.
[17] Samuel Clarke, *Works* II, 698.

universality of laws of nature was 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. [Slide 6 Melanchthon and quote] '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.'[18] 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.[19]

These connexions appear again in the moral philosophy of Immanuel Kant. 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 connexion was expressed in the celebrated juxtaposition set out in the *Critique of Practical Reason* (1788) [Slide 7 Kant's Tombstone and quote]: '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.'[20] 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

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[18] Melanchthon, *De legibus* (1535), *Corpus Reformatorum* XI, 912, qu. in Methuen, '*Lex Naturae* and *Ordo Naturae*', p. 121. See also Barker and Goldstein, 'Theological Foundations of Kepler's Astronomy', p. 95. In certain respects, the idea that the cosmic order portends moral order is an ancient one. Plato suggested that the lover of wisdom who becomes familiar with the divine order in the cosmos 'will himself become orderly and divine'. *Republic* VI, 500d, *Collected Dialogues*, p. 736. Ptolemy wrote similarly 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's Almagest*, tr. G. J. Toomer (Princeton: Princeton University Press, 1998), p. 37.Cf. John Dee's Mathematical Preface.

[19] Barker and Goldstein, 'Theological Foundations', pp. 25f.; Methuen, *Kepler's Tübingen*, pp. 209f.; Barker, 'Kepler's Epistemology', p. 360. See also Kepler, *Harmony of the World*, tr. and introduced by E. J. Aiton, A. M. Duncan, and J. V. Field (Philadelphia, 1997), p. 146, and *Apologia Pro Tychone contra Ursum*, tr. in N. Jardine, *The Birth of History and Philosophy of Science* (Cambridge, 1988), p. 144.

[20] Paul Guyer, "Introduction: the starry heavens and the moral law" in P. Guyer, (ed.) *The Cambridge Companion to Kant*. Cambridge,1992), p. 1

nebular hypothesis that he outlined was in a sense the first statement of modern evolutionary cosmology.[21]

One answer to question about the rise of science in the West, then, is to do with these theological ideas that gave rise to the distinctive notion of 'laws of nature'. (Indeed this was the answer that Needham himself gave: 'The conception of a divine celestial law-giver never developed' in China: they lacked a conception of laws of nature.[22]) This is plausible as far as it goes. However, I want to suggest that 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 assumptions may be found, in various guises, in Pythagoreanism, Platonism, Stoic thought and to some extent in the Chinese conception of *tien*. In addition to this assumption of the underlying rationality of the universe, 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. Réne Descartes (who is often wrongly imagined to be an 'armchair scientist'), put it this way [8 Descartes and quote]: 'Since there are countless different configurations which God might have instituted here, experience alone must teach us which configurations he actually selected in

[21] See the essays in Robert E. Butts (ed.), *Kant's Philosophy of Physical Science* (Dordrecht: Reidel, 1986).

[22] '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 decipered or re-formulated by other lesser rational beings…' Joseph Needham, 'Human Laws and the Laws of Nature in China and the West', *Journal of the History of Ideas,* 12 (1951): 3-32, 194-230 (230).

preference to the rest.'[23] In the Preface to the second edition of Newton's *Principia* we find the same sentiment [9 Newton and quote]: '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.[24] So 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-hold 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, and the conviction that it makes a 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. This is the Christian idea of the Fall [9 Expulsion] Adam, the first man, was imagined to have had a complete knowledge of nature, on account of both his rational capacities and perfect sense organs. Interestingly, a number of Western thinkers, up the eighteenth century, believed 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. [10 Superman] Martin Luther, for example, contended that before his Fall, Adam 'could have seen objects a hundred miles off better than we can see them at

[23] Descartes, *Principles of Philosophy*, §100

[24] Roger Cotes, Preface to the second edition of the *Principia*, in *Isaac Newton: The Principia*, tr. I. Bernard Cohen and Anne Whitman (Berkeley: University of California Press, 1999), p. 393. Paradoxically, this statement appears in the context of an attack on Descartes' philosophy.

half a mile, and so in proportion with all the other senses.'[25] 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.'[26] In this understanding of things, scientific instruments such as the telescope were prosthetic devices which enabled the human race to recapture a knowledge of the world that they had once possessed through their natural sensory endowments alone.[27]

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 upon 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].'[28] 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: that God exercised his choice in the creation of a particular natural order; and that we need to be sceptical 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, that science can only aspire to success if is a disciplined, collective and cumulative activity, assisted by instruments and experiments.

THE RELIGIOUS LEGITIMACY OF WESTERN SCIENCE

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[25] Martin Luther, *Table Talk*, CXXVIII (p. 57); *Lectures on Genesis 1-5*, LW 1, 62; Cf. *Lectures on the Psalms*, LW 12, 117.
[26] Glanvill, *Vanity of Dogmatizing*, pp. 1, 5.
[27] *Ibid*., p. 67; 'Modern Improvements of Useful Knowledge', p. 23, in *Essays*. Cf. idem, *Plus Ultra*, pp. 52f.
[28] Robert Hooke, *Micrographia* (London, 1665), Preface.

The argument to this point has been that the idea of laws of nature is a distinctively Western idea that it promoted the emergence of modern science. And beyond this, that 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 primaeval 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 the human sin. The role of experimental science was to attempt to bridge this gap and partially restore this original correspondence. [Slide 11] 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.'[29] At its birth, modern science was thus envisaged by some as a set of remedial practices directed towards a re-establishment of the natural bond between the reason of the mind, and the rationality of the cosmos. Science was thus a restorative exercise

It should be acknowledged as this point that there is some tension between these Baconian justifications for experimental science, and the kinds of the justifications that we see in the writings of someone like Kepler. 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.

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 support. 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. This is evident by the controversy generated by the new experimental philosophy and by robust criticisms that were levelled against the fledgling Royal Society. A key criticism was this: what use is this new science? How

[29] Bacon, *Great Instauration*, *Works* IV, 7.

is this knowledge socially useful? [12 Hadron Collider] In some respects, this parallels the 9-billion dollar question, about whether the CERN's new Large Hadron Collider is worth the money] 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.

The Baconian programme 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.

CONCLUSION

There are two 'big questions' that I have raised in this paper—questions which historians can help provide answers for [slide] : First, what assumptions make science *possible*? Second what values make science *desirable*? My tentative answers have both involved reference to unique religious landscape of the early modern West.

On the first question, as we have seen, it was the theologically informed assumption that there were laws of nature, promulgated by God, and which were discoverable by human minds. The scientific programme, 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. Of course, in the years that have elapsed between seventeenth century and now, we have largely lost sight of these original theological justifications. The question that remains concerns 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.[30]

[30] See, e.g., Nancy Cartwright, 'No God, no laws'.

The second question, to do with 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 want to, but there are other things that we believe to be equally or more important.

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 consideration was whether or not experimental science was a suitable activity for scholar and a gentleman. Traditionally the priority had 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 master over nature.[31]

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. A society needs not only to be able to do science, it must wish to do so, and be prepared to sacrifice other priorities in order to do so.

[31] This also makes for an interesting comparison with the Confucian concept of 'the Gentleman' (*Chun-tzu*) for whom the cultivation of an inner natural virtue (*jen*) is the first priority.