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Historical Foundations for a Global Perspective on the Emergence of a Western European Regime for the Discovery, Development and Diffusion of Useful and Reliable Knowledge

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ABSTRACT

At a 'conjuncture' in pre-modern global history, labeled by previous generations of historians as the 'Scientific Revolution', the societies and states of western Europe established and promoted a regime of interconnected institutions for the accumulation of useful and reliable knowledge. This placed their economies on trajectories that led to divergent prospects for long-term technological change and material progress. Although the accumulation of such knowledge takes place over millennia of time, and in contexts that are global, critical interludes or conjunctures in a "dialogue of civilizations" have remained geographically localized, and indigenous in nature. Determining the locations, origins and forms of this particular conjuncture is often dismissed as an exercise in Eurocentric history. Modern scholarship has also preferred to emphasize the roles played by craftsmen in its progress and diffusion - ignoring metaphysical and religious foundations of knowledge about the natural world. My survey aims to restore traditional perceptions that the West passed through a transformation in its hegemonic beliefs about prospects for the comprehension and manipulation of that world in the sixteenth and seventeenth centuries. It will suggest that the Scientific Revolution's remote antecedents might be traced back to Europe's particular transition from polytheism to monotheism. Thirdly, it summarizes literature that analyses how centuries of tension between Christian theology and natural philosophy led, during the Renaissance, to a displacement of scholastic and beatified Aristotelian conceptions and obstacles to understandings of the natural world. Finally, the survey will elaborate on how new knowledge flowing into Europe from voyages overseas, and medieval advances in technology, together with scepticism arising from religious warfare, stimulated a widespread search for more useful and reliable forms of knowledge throughout the Catholic and Protestant West.

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Economic divergence and its connections to technology and the formation of natural knowledge

The inspiration for this survey is a meta-narrative in global history, which is concerned with the timing and reasons behind the emergence of contrasts in labour productivities and standards of living in eastern and western Eurasia. More than a decade ago, a wave of revisionist historiography emerged, which problematized explanations for a 'Great Divergence' in levels of human welfare, based upon Smithian models of long-term economic growth.1 This successful assault upon a triumphalist tradition of Eurocentric global economic history has prompted counter-attacks, which proceed on two fronts.

The first attempts to undermine data utilized by the 'California School', that suggests divergence in the East had not set in before the late eighteenth century. It includes an ongoing programme of statistical research, which is designed to produce acceptable estimates for standards of living enjoyed by typical peasant households living in the Qing empire and to measure differences in average levels of real wages, human health, literacy and numeracy among populations resident in large Eurasian towns over several centuries before 1800. Provisional results suggest that north-western Europe had probably drawn discernibly ahead well before the turn of the nineteenth century.[2]

The second counter-attack seeks to revive and update an explanation for divergence associated with views formulated decades ago by Max Weber and Joseph Needham[3]. Neither of these great scholars addressed divergence in quantifiable economic terms. Both, particularly Needham, focused on a famous conjuncture in global history, the 'Scientific Revolution', when the

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[1] The key texts are: David Landes, *The wealth and poverty of nations,* New York: W.W. Norton & Co, 1998 and Kenneth Pomeranz, *The great divergence: China, Europe and the making of the modern economy,* Princeton: Princeton University Press, 2000. An excellent survey covering a decade of academic debate is by Joseph M. Bryant, 'The west and the rest revisited: debating capitalist origins, European colonialism and the advent of modernity', Canadian Journal of Sociology, 31, 2006, pp. 403-44. Three very recent books are by Toby E. Huff, *Intellectual curiosity and the scientific revolution: a global perspective,* Cambridge: Cambridge University Press, 2011; R. Bin Wong and Jean-Laurent Rosenthal, *Before and beyond divergence: the politics of economic change in China and Europe,* Cambridge, MA.: Cambridge University Press, 2011 and Prasannan Parthasarathi, *Why Europe grew rich and Asia did not: global economic divergence, 1600-1850,* Cambridge: Cambridge University Press, 2011.

[2] Recent sources with up-to-date bibliographies for this programme are: Robert C. Allen et al (eds.) *Living standards in the past: new perspectives on well-being in Asia and Europe,* Oxford: Oxford University Press, 2005; Stephen Broadberry and Bishnupriya Gupta 'The early modern great divergence: wages, prices and economic development in Europe and Asia', *Economic History Review,* 59, 2006, pp. 2-31. See Asia in the Great Divergence, Special Issue of *Economic History Review* 64, 2011, pp. 1-184 and Robert C. Allen, 'Agricultural productivity and rural incomes in England and the Yangtze Delta, c. 1620 – c. 1820'*, Economic History Review,* 62, 2009, pp. 525-50.

[3] Max Weber, *General economic history,* New York: Collier Books, 1950; Max Weber, *The religion of China,* Glencoe: The Free Press, 1951; Max Weber, *The religion of India,* Glencoe: The Free Press, 1958; Joseph Needham, *The great titration,* Toronto: Allen and Unwin, 1969.

west reordered its cosmographical belief system and established a promotional regime, or cluster of institutions, for the discovery, development and diffusion of superior technologies for manufactures, services and agriculture, as well as warfare and imperialism.

How, when and why western Europe experienced this reordering is a question that could only be satisfactorily addressed by a programme of historical research based upon cogently specified reciprocal comparisons, heuristic concepts, and an aspiration to become global by transcending the myopias imposed by the frontiers and chronologies of continental, national or local histories. Implicitly, my essay shares this aspiration, but it is necessarily far more limited in its ambition. Its aim is to survey a bibliography in modern history dealing with European sciences, technologies, philosophies, cosmographies and religions, in order to construct a simplified narrative of how Western societies progressed through time towards a 'Scientific Revolution'. Since modern historians currently represent that Revolution in ways that range all the way from a conjuncture to a non-event, it seems timely to insert a selective and simplified summary of that literature into current discourses in global history. From that perspective, much of the modern debate on the 'Scientific Revolution' looks Eurocentric, provincial, and obsessed with local detail.[4] This essay from an 'outsider', is designed to convey histories of western sciences and technologies into the divergence debate. It may also help to reconfigure the economic significance of knowledge that was formed locally to the west of Eurasia, and then was adapted globally.[5]

Historians have become aware that representations of any supposedly unique European trajectories are all too often based upon foreshortened chronologies. They usually cover periods of time when the reordering of Western culture, and the reconstruction of Western institutions, could safely downplay histories of prior connections, when significant flows of knowledge occurred from eastern to western Eurasia - as explored in Arun Bala's 'dialogue of civilizations'.[6] Historians appreciate that all claims for any trajectory selected as peculiarly 'European' must ultimately be subjected to Marc Bloch's tests for reciprocal comparisons. Indeed that is why the programme of research from which this paper flows includes comparative studies of regimes for knowledge formation in China, India, West Asia and Japan, as well as Europe, in early modern times.[7]

Thus, this essay proposes to survey a discussion concerned with the scientific-cum-technological elements behind economic divergence, which may have emerged in the West as early

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[4] Jan Golinski, *Making natural knowledge: constructivism and the history of science,* Cambridge: Cambridge University Press, 1998 and Ian Hacking, *The social construction of what?* Cambridge, Mass.: Harvard University Press, 1999.

[5] This aspiration for global history is associated with the writings of Anthony G. Hopkins – vide Toyin Falola and Emily Brownell, eds., *Africa, empire and globalization*, Durham, NC.: Carolina Academic Press, 2011.

[6] Arun Bala, *The dialogue of civilizations in the birth of modern science ,* New York: Palgrave Macmillan, 2006.

[7] This programme: *Regimes for the production, development and diffusion of useful and reliable knowledge from the accession of the Ming to the industrial revolution* can be accessed at: http://www2.lse.ac.uk/economicHistory/Research/URKEW/aboutUrkew.aspx
On reciprocal comparisons read Roy Bin Wong, *China transformed and the limits of European experience,* Ithaca: Cornell University Press, 1997.

as 1500, became discernible before 1700, and were unmistakeably operational by 1800. The concept utilized here to structure a narrative of Europe's transition through a 'Scientific Revolution' also presupposes that technological innovations can be heuristically comprehended as connected, either in *ex post* or in *ex ante* senses, to their actual or potential epistemic bases.[8]

Any conflation of 'science' with technology is clearly a simplification, but it makes for an integrated and cogent narrative. Moreover, it conveniently circumvents inconclusive discussions concerned with the relative but immeasurable degrees of significance that might be accorded to artisanal skills, instruments, and transferable scientific knowledge, or the roles of theory, enlightened patronage, and state support. These, and numerous other tangible and intangible inputs, have been studied and implicitly weighted for their connections to increases in flows of innovations before the era of techno-science came fully on stream in the late decades of the nineteenth century.[9]

This essay selects and references recent research in separated but, after the cultural turn, potentially conjoined histories of science, technology, religion, philosophy, cosmography and skill formation. Its purpose is to reconfigure and update answers to the problem posed by Needham and Weber. They posited that a widening of a stock of disembodied and embodied knowledge became accessible to support a gradual acceleration in rates of innovation observed in the West after 1500, and possibly even earlier. They suggested that this might be plausibly connected to changes in hegemonic conceptions of the natural world, which culminated in a conjuncture for global history that has enjoyed an established status as an explicable 'Scientific Revolution' that emerged in western Europe.

The economically significant outcome of that revolution was that conceptions of the natural world, and prognostications for its manipulation based upon systematic investigations, became steadily more optimistic. Educated and wealthy elites across Europe were prompted to lend sustained support to the extension of embryo regimes of interconnected institutions, which might predictably generate and adapt knowledge, that embodied a potential to become instrumental for private profit, for the geopolitical power of states and, by way of unintended consequences, for the wealth, health and material welfare of Western populations. Today's successors of such regimes generate flows of modern science, which is grounded in observations, experiments and rigorous reasoning. Modern regimes employ a plethora of experts attached to a multiplicity of disciplines, who are supported and institutionalized in ways designed to be efficient for the comprehension

[8] Joel Mokyr, *The gifts of Athena: historical origins of the knowledge economy* Princeton; Princeton University Press, 2002; Ian Inkster, 'Potentially global: 'useful and reliable knowledge' and material progress in Europe, 1474-1914', *International History Review*, 28, 2: June 2006, pp. 237-472 and 'Pursuing big books: technological change in global history', *History of Technology,* 22, 2000, pp. 101-29.

[9] Barry Allen, *Knowledge and civilization,* Boulder: West View Press, 2004; Graeme D. Snooks, *The dynamic society: exploring sources of global change,* London: Routledge, 1996 and Erick S. Reinert, 'Exploring the Genesis of Economic Innovations: The Religious Gestalt-Switch and the Duty to Invent as Preconditions for Economic Growth', *European Journal of Law and Economics,* 4: 1997, pp. 233-83. An early but still relevant take on the conflation of histories of science and technology was published in a special issue of *Technology and Culture,* 2: 1961, pp. 305-90.

and manipulation of the celestial, terrestrial and biological spheres of our natural world.[10] For global economic history the question is when, how and why did proto-regimes become significant?

Christian monotheism and natural philosophy

From the secular vantage points of our own times, a modern school of historians of religion have suggested that the emergence of monotheism not only helped to degrade the complexities, confusions and fantasies associated with ancient myths and folk tales about the natural world, but also, in the fullness of time, provided a logically acceptable and spiritually consoling impetus for a 'gestalt switch' in the perceptions of educated elites towards possibilities for its manipulation[11] This contestable view claims that the gradual diffusion of faith in a single God, who controlled the destiny of everyone and the motions of everything in his divinely created universe, embodied a greater potential for the development of a metaphysical cosmography for the comprehension of nature than the polytheistic, hermetic and animistic views that it gradually replaced.[12] Although cultural anthropologists and cognitive psychologists have published convincing rationalizations for other metaphysical views of nature, they have not suggested that such beliefs might have matured into effective metaphysical foundations for a transition to modern science.

Meanwhile, monotheism may not be represented as a necessary condition for that transition.[13] Long before its diffusion, 'pagan' intellectuals of eastern and western Eurasia had extended the cognitive capacities of mankind for accurate observation, reflexion and logical styles of argument. They came up with some inspired counterintuitive theories about the operations of the natural world, which were restored to prominence during the sixteenth and seventeenth centuries.[14] Nor, when the cases of Islamdom and Byzantium are brought into the frame, could interpretations of the natural world as manifestations of the designs of a single divine creator be regarded as a sufficient condition for western Christian Europe's transition to modern science.[15]

Nevertheless, historians of religion, well read in the history and philosophy of science, are currently developing a view that argues that in several respects, and to 'some' significant degree,

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[10] Richard R. Nelson, ed., *National innovation systems,* Oxford: Oxford University Press, 1993.

[11] Karen Armstrong, *The great transformation: the beginnings of our religious tradition,* New York: Alfred A. Knopf, 2006.

[12] Rodney Stark, *One true god: historical consequences of monotheism,* Princeton: Princeton University Press, 2001; Todd Tremlin, *Minds and Gods: the cognitive foundation of religion,* Oxford: Oxford University Press, 2006; Geoffrey E. R. Lloyd, *Cognitive variations: reflections on the unity and diversity of the human mind,* Oxford: Clarendon Press, 2007.

[13] Michael H. Barnes, *Stages of thought: the co-evolution of religious thought and science,* New York: Oxford University Press, 2000.

[14] H. Floris Cohen, *The scientific revolution: a historiographical inquiry,* Chicago: University of Chicago Press, 1994.

[15] Tomako Masuzawa, *The invention of the worlds religions:* or, how European universalism was preserved in the language of pluralism, Chicago: University of Chicago Press, 2005, and Stark, *One true God.*

the 'Scientific Revolution' may be historicized as a quasi-theological conjuncture in the intellectual history of western Europe.[16] Their analyses commence with the triumph of Christianity over classical traditions of thought, which had emerged in ancient Greece and continued under the Roman empire. These traditions ran into the buffers of scepticism, embracing rival schools as rigorous and skilled in the destruction of plausible theories about morals and nature as more famous Greek and Roman intellectuals became in demonstrating their logical coherence.[17] Over centuries that witnessed the geopolitical and natural disasters that attended the decline and fall of the western Roman empire, they also succumbed to intellectual subversion, associated with the rise and diffusion of monotheistic Christianity and Islam.

Yet, even before the spread of these Abrahamic religions, all schools of classical philosophy had already become vulnerable to three debilitating attacks. First, they offered nothing approximating to proofs for their theoretical and logical speculations. Secondly, their recommendations for actions and policies, based upon theories about the operations of political, social and natural worlds, never became highly regarded as economically useful or efficacious for ruling elites. Finally, neither Epicureanism, nor Platonism, nor Stoicism, nor Aristotelianism offered clear-cut designs for material welfare, effective prescriptions for bodily health, or, above all, any alleviation for mankind's eternal angst about life after death.[18]

When Christianity eventually became a hierarchically organized and powerful religion, which consolidated its hold over the minds and hearts of rulers and their subjects, it suppressed polytheism and atheism, and condemned most rival forms of hermetic thought as heresies. Its initial phase of development included fundamentalism, which inspired onslaughts on all philosophies that had elevated reason above revelation, and which conceived of no place for the divine in the operations of an eternal natural world.

Over the centuries between the fall of Rome and the times of Copernicus, a protracted debate evolved concerning classical modes of thought about the natural world. Before the Medieval Renaissance of the twelfth century, it was by no means clear that clerical intellectuals, in the service of an increasingly successful church, wished to engage seriously with classical perceptions of nature, or with methods for the comprehension of a natural world that the faithful inhabited for but a short while on their way to eternal salvation or damnation.[19] They preached that God had created man's habitat and everything in it operated according to his divine will and intentions. A long line of Christian fundamentalists, including Saints Ambrose and Bonaventure, were antipathetic to the more conciliatory views of Saint Augustine. Both the Roman and Eastern

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[16] James J. Bona, *The word of God and the language of man: interpreting nature in early modern science and medicine,* 1, Maddison: University of Winconsin Press, 1995.

[17] Geoffrey E. R. Lloyd, *Adversaries and authorities,* Cambridge: Cambridge University Press, 1996.

[18] Geoffrey E. R. Lloyd, *Methods and problems in Greek science,* Cambridge: Cambridge University Press, 1991.

[19] Marcia Colish, *Medieval foundations of the western intellectual tradition, 400-1400,* New Haven, Cn: Yale University Press, 1997; Edward Grant, *Science and religion from aristotle to copernicus 400 BC – AD 1550,* Baltimore: John Hopkins University Press, 2004; David C. Lindberg, ed., *Science in the middle ages,* Chicago: Chicago University Press, 2008.

churches held onto the belief that all speculations based upon modes of thought that elevated reason above revelation could become dangerous to their claims to possess the truth about human nature, the destiny of man, and an incomprehensible universe that was God's creation and humankind's temporary abode.[20]

Over time, however, it became more difficult for the Roman Catholic church to suppress or evade the eastern cum classical intellectual heritage of the West, or to deal with the encroachment of secular power.[21] Attempts to supplant classical beliefs were easier perhaps during the early middle ages, preceding the consolidation of monarchies, before the rise of Islam, and during the several centuries that it took to translate, transcribe and reproduce in printed form a body of accessible Latinized texts that constituted a core of the classical heritage for circulation among literate elites in the West.[22]

Eventually, the medieval Catholic church found it expedient to make concessions to established 'pagan' modes of rational argument, and to accept views of nature held by Western Europe's aristocracies and ruling elites. Once the church had become established as a powerful quasi-official organization, its clerical intellectuals cautiously embarked upon a protracted process of Christianizing elements of 'their' classical philosophical heritage. They formulated ways of conceiving the operations of nature in terms that could be reconciled with their own beliefs and interests in the propagation of revealed truths about the world, for which they held a monopoly of interpretation.[23]

Furthermore, although Christianity's initial transition from sect to religion was propelled by Roman power structures, thereafter the task of Christianizing the elites and populations of western Europe was arguably assisted by the division and collapse of the Roman empire. Centralized empires could promote conversions of pagan populations to monotheism, but imperial favour alternated with repression, and progress remained dependent upon the unpredictable decisions of emperors to extend support to one true faith and ideology. Political units smaller than empires, and operating in competitive geopolitical contexts, provided conditions conducive to varied, adaptable

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[20] Robert Bartlett, *The natural and the supernatural in the middle ages: the Wiles lectures given at the Queen's University of Belfast,* Cambridge: Cambridge University Press, 2008 and Robert M. Grant, *Miracle and natural law: in Greco-Roman early Christian thought,* Amsterdam: North Holland, 1952; Barnes, *Stages of thought*.

[21] David C. Lindberg and Ronald L. Numbers, eds., *God and nature: historical essays on the encounter between Christianity and science,* Berkeley: University of California Press, 1986.

[22] Scott L. Montgommery, *Science in translation: movements of knowledge through cultures and time,* Chicago: University of Chicago Press, 2000 and Adrian Johns, *The nature of the book: print and knowledge in the making,* Chicago: University of Chicago Press, 1998.

[23] Judith Herrin, *The formation of Christendom,* Princeton, N.J.: Princeton University Press, 1989; Barnes, *Stages of thought* and Colish, *Medieval Foundations.*

and flexible departures from inherent tendencies towards fundamentalist and canonical interpretations of nature.[24]

The pluralism that prevailed as a persistent discourse among rival schools of Christian theologians was, moreover, sustained by the post-seventh century conflict with Islam. Islam became a serious monotheistic contender for religious and political hegemony on Europe's southern and eastern frontiers.[25] Meanwhile, the development of its advanced economies also suggested that the forces of nature could be manipulated technologically to improve the health, security and material welfare of the faithful, and thus promoted the case for their systematic study.[26]

Over the centuries, as it evolved into a supra-national organization with a privileged and quasi-autonomous position within European states, the hierarchy of the Roman church recognized that faith underpinned by the gospels, and supplemented by a limited range of canonical references, could not remain powerful enough to maintain a position of intellectual hegemony. This became true both for its conflicts with Islam, and for struggles against internal heresies. Moreover, despite the autonomy allowed under constitutions for the separation of Church and State in 1122, the former found it hard to resist the encroachments of increasingly powerful political authorities.[27]

By the twelfth century, the medieval church had reacted to threats to its power by strengthening its intellectual foundations, in order to resist Muslim infidels, heretics, and secular authorities. Thus, under strictly regulated rules and conditions, the papacy allowed, and even encouraged, the introduction of faculties and curricula for the study of natural philosophy, based upon recovered texts by Aristotle, Plato, Ptolemy, Galen, Hippocrates and many other 'classical

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[24] Julia M. H. Smith, *Europe after Rome: a new cultural history 500-1000,* Oxford: Oxford University Press, 2005.

[25] Michael A. Gillespie, *The theological origins of the rise of early modernity,* Chicago: University of Chicago Press, 2008; Toby E. Huff, *The rise of early modern science: Islam, China and the West,* Cambridge: Cambridge University Press, 1993 and David C. Lindberg, ed., *The beginnings of western science: the European scientific tradition in philosophical, religious and institutional context 600 BC to AD 1450,* Chicago: University of Chicago Press, 2007; David Levine, *At the dawn of modernity: biology, culture and material life in Europe after the year 1000* (Berkeley: University of California Press, 2001)

[26] Marshall Clagett, *The science of mechanics in the middle ages,* Maddison, Wsn.: University of Wisconsin Press, 1959; Stephan R. Epstein and Maarten R. Prak, eds., *Guilds, innovation and the European economy 1400-1800,* Cambridge: Cambridge University Press, 2008; Bert S. Hall and Delno C. West, eds., *On pre-modern technology and science: a volume of studies in honor of Lynn White, Jr.,* Malibu, Ca.: Undena Publications, 1976; Frances Gies and Joseph Gies, *Cathedral, forge and waterwheel: technology and invention in the Middle Ages,* New York: Harper Collins, 1994; Jean Gimpel, *The medieval machine,* London: Victor Gollancz, 1977.

[27] Benjamin Nelson, 'Sciences and Civilizations: East and West' in Raymond J. Seeger and Robert S. Cohen, eds., *Philosophical foundations of science: proceedings of Section L, 1969, American Association for the Advancement of Science,* Dordrecht: Reidel, 1974, pp. 445-93

authorities'.[28] Natural philosophy emerged along with the establishment of cathedral schools and monasteries, before developing into compulsory preparatory courses in institutions for higher education (prototype universities), which spread across the cities of medieval Europe.[29]

Faculties of natural philosophy appeared between the twelfth and fifteenth centuries to provide advanced preparatory courses for the education of clerics, lawyers, doctors, officials, and philosophers. By way of written commentaries, they carried forward to new levels of sophistication the methods and insights derived from a gradually restored heritage of classical thought. That heritage had been primarily concerned with human nature, but had always included some rudimentary observations upon, theories of, and recommendations for rational and potentially heuristic modes of enquiry into the demarcated celestial, terrestrial and biological spheres of the natural world.[30]

For some three to four centuries preceding the Reformation and the times of Copernicus, 'pagan' texts (emanating from Byzantium and, in elaborated form, from Islamdom) flowed in a succession of waves into Western Europe.[31] They were translated, absorbed, accommodated and utilized in different ways and degrees by a multiplicity of competing institutionalized authorities, both secular and clerical. Resistance and bouts of suppression marked the propagation of views based upon the circulation of pagan and Islamic ideas that contradicted core tenets of Christianity. These were that God created and controlled everything in the world and could, through divine interventions (miracles) suspend the operations of familiar natural forces as comprehended by common sense, and which classical philosophers had 'rationally' explained.[32] Tensions between revelation and reason thus remained an omnipresent source of conflict among and within Europe's courts and aristocracies, and between and within faculties of theology and natural philosophy at universities and academies in the West, where communities of urban-based intellectuals became charged with emotion in their search for truth.[33]

Nevertheless, Europe's 'secularised' Roman Catholic establishments and their obedient theologians found no insuperable difficulties in accommodating selected, expurgated and reconfigured classical philosophies with Christian beliefs, as set out in canonical texts written by

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[28] Stephen, Gaukroger, *The emergence of scientific culture: science and the shaping of modernity 1210-1685,* Oxford: Oxford University Press, 2006 and Colish, *Medieval Foundations.*

[29] Hilde de Ridder-Symoens and Walter Rüegg eds., *A history of the university in Europe,* Cambridge: Cambridge University Press, 1996; John Gascoigne, *Science, politics and universities in Europe, 1600-1800,* Aldershot: Ashgate, 1998.

[30] Edward Grant, *A history of natural philosophy: from the ancient world to the nineteenth century,* Cambridge: Cambridge University Press, 2007.

[31] John Freely, *Aladdin's Lamp: how Greek science came to Europe through the Islamic world* (New York: Knopf Doubleday, 2009; George Saliba, *Islamic science and the making of the European Renaissance,* Cambridge, Mass.: MIT, 2007.

[32] Barnes, *Stages of Thought* and Gillespie, *Theological origins of modernity*.

[33] Randall Collins, *The sociology of philosophies: a global theory of intellectual change,* Cambridge, Mass.: Belknap Press of Harvard University Press, 1998.

evangelists, founding fathers, and saints. They even found analogous notions of God behind the design and operations of the universe in analyses attributed with ecumenical ingenuity to Plato, Aristotle and Seneca. They welcomed observations and investigations into nature, which could be read allegorically as signs of God's presence in the world, and which could be interpreted metaphorically as lessons for personal and political morality.[34]

Although scholastic theologians resolutely insisted upon the sovereignty of revelation over reason, they encouraged the application of syllogistic logic and mathematical techniques, derived from oriental and Greek mathematics and classical concepts of proof, to major, complex, and counter-intuitive elements of revealed Christian beliefs. 'Liberal' theologians anticipated that, with help from methods and theories deployed by natural philosophers trained in such logical modes of argument, they too might construct rational proofs for the existence of God, the virgin birth, the resurrection, transubstantiation, the trinity, the immortal soul, miracles, and other articles of faith.[35]

As true believers, natural philosophers accepted the subordinate status of their discipline as a handmaiden to theology. For centuries before, during and after the 'Scientific Revolution', most prudently refrained from entering into disputes concerned with any of Christianity's foundational beliefs. They concentrated upon translations into Latin of books written in Greek, Arabic and Syriac. They also focused on the restoration, analysis, elaboration and critique of classical authors, who had attempted to render nature's celestial, terrestrial and biological phenomena more intelligible for mankind's sojourn on earth. They operated within authoritarian regimes for the extension of knowledge about the natural world, were confined by personal faith based upon revelation, and took the risk of persecution for heresy by secular and ecclesiastical hierarchies with vested interests in a sacred canon. In this context, the record of natural philosophy in constructing a Christian cosmography with potential for development is not nearly so unimpressive as the vehement criticism that 'scholasticism' attracted during periods of Renaissance, Reformation and Enlightenment, and which generations of liberal social scientists and historians have found congenial to repeat.[36]

The historical record shows that scholastic philosophers read, taught and deferred to prestigious classical authors, particularly Aristotle, but also Plato, Ptolemy, Galen, and Hippocrates. More courageously, they referred for support and guidance to Averroes (Ibn Rushd), Avicenna (Ibn Sina), and other Muslim commentators and critics of Greek and Greek-inspired writings.[37] They also deployed classical modes of logical reasoning to persuade ecclesiastical and secular elites in the

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[34] Lindberg and Numbers, eds., *Gods and Nature* and David Lindberg and Ronald Numbers, eds., *When science and Christianity meet,* Chicago: Chicago University Press, 2003.

[35] Richard G. Olson, *Science and religion, 1450-1900: from Copernicus to Darwin,* Westport, Conn.: Greenwood Press, 2004; Gillespie, *Theological origins of modernity.*

[36] Ernest Gellner, *Reason and culture: the historic role of rationality and rationalism ,* Oxford: Blackwell, 1992 but vide James Hannam, *Gods philosophers: how the medieval world laid the foundations of modern science,* London: Icon Books, 2009.

[37] Alistair C. Crombie, *Science, art and nature in medieval and modern thought,* London: Hambledon Press, 1996; Bona, *The Word of God and the Language of Man* and Olson, *Science and Religion* and Colish, *Medieval foundations.*

West that, God had created and designed a natural world to operate on intelligible principles, which were open to investigation and explanation. That said, they all agreed that God could intervene at will in the operations of the natural world, in unpredictable and arbitrary ways that ran counter to common sense.[38]

As the status of natural philosophy rose at royal courts, among noble households and became an established part of the curriculum taught by all faculties of Europe's corporate and quasi-autonomous institutions for higher education, its agendas widened to include observations and investigations into a range of natural phenomena. Among these were the age, size, shape and limits of planet earth, the sun, the moon and the stars, tides, climates, earthquakes, minerals, chemical substances, soils, plants, animals, and human bodies.[39] One strand of natural philosophy even questioned the subordination of reason to revelation, although most natural philosophers prudently pursued their endeavours for higher intellectual and political status by advocating rational methods for the study of medicine, law and even theology. A minority elaborated upon premature, and for theologians outrageous, arguments for the recognition of two separable kinds of knowledge, each with its own mode of reasoning: the metaphysical and the physical (or the sacred and the secular).[40]

Although theology had embraced dialectical methods and logical arguments, and co-existed in a state of uneasy tension with natural philosophy, clerical intellectuals became disappointed that classical methods could not substantiate revealed truths. They also remained hostile to the claims of rival natural philosophers that 'rational' procedures for the acquisition of knowledge provided a superior mode of access to understanding the mind and designs of God for his universe. Despite the ingenuity on display in the writings of Thomas Aquinas and his Dominican followers, reason and revelation could not be reconciled.[41]

For their part, most natural philosophers concentrated upon philological analyses of the classics, the theories and semantic abstractions connected with meta-cognition, and investigations into logical and mathematical ways of knowing. A minority, including Roger Bacon, Bradwardine, Grossteste, Albertus, Oresme, and Buridan, produced texts that have become posthumously famous among historians of science for their critiques of Aristotelianism. They anticipated meta-theories and speculations about the universe that appeared during the 'Scientific Revolution'. These

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[38] Vide seminal books by Edward Grant: Grant, *Planets, stars and orbs: the Medieval cosmos, 1200-1687,* Cambridge: Cambridge University Press, 1994 and *The nature of natural philosophy in the late Middle Ages (Studies in philosophy and history of philosophy, V. 52)* Washington, DC., Catholic University of America Press, c.2010 and Hannam, *God's philosophers.*

[39] Vincent Bulloush (ed.), *Universities, Medicine and Science in the Medieval West,* Aldershot: Ashgate, 2004 and Roy Porter, 'The Scientific Revolution. A spoke in the wheel' in Roy Porter and Mikuláš Teich, eds., *Revolution in history,* Cambridge: Cambridge University Press, 1986; Peter Harrison, ed., *The Cambridge companion to science and religion,* Cambridge: Cambridge University Press, 2010.

[40] Similar arguments had emerged for the economic sphere. Vide: Joel Kaye, *Economy and nature in the fourteenth century: money, market exchange and the emergence of scientific thought,* Cambridge: Cambridge University Press, 1998. And in Islam – Bala, *Dialogue of civilizations.*

[41] Gillespie, *Theological origins of modernity* and Bartlett, *The natural and the supernatural.*

included laws of motion, atomic theories of matter associated with Epicurus, Democritus and Lucretius, and early premonitions that controlled experiments might become superior to reason and common sense as ways of settling disputes about the operations of the natural world. Some even considered an embryo heliocentric view of the universe.[42]

These advances consisted basically in restoring classical modes of reasoning to positions of political and theological acceptability. They defined, exposed and refined knowledge about celestial, terrestrial, biological and chemical objects. Medieval Christian contributions to a deeper intelligibility about the natural world, embodying Islamic discoveries, included astronomy, the anatomies of human bodies and optics. They treated the natural world as something that could be investigated and explained in terms that could be separated from revealed and sanctified truths about the origins, operations and limits of the universe as a spiritual, moral and political habitat for man's life on earth.[43] Deeply indebted to a famous line of Islamic philosophers and scientists, Christian scholastics cleared the way for what continues to be represented as a profound 'gestalt switch' in Western approaches to conceptualizing, comprehending, investigating and manipulating everything and anything in the natural world.[44]

While Christendom's natural philosophers conceded to the omnipotence of God the creator, eventually they virtually convinced the secularized and politicized hierarchy of the Roman Church that God's universe was broadly designed on principles that could be exposed by utilizing the methods for rational investigation, which were outlined in the expurgated texts of classical authors, particularly Ptolemy, Galen, and, above all others, Aristotle. However, these principles did not question the sanctity surrounding doctrines of the trinity, the birth and resurrection of Christ, the eucharist, and a plethora of intuitively implausible miracles.[45]

The agendas of Christendom's natural philosophers had, moreover, been functional for diminishing the appeal of a rival set of 'false claims', based upon hermetical modes of thought. These were derived from ancient sages, astrological signifiers, occult portents, magic, demonic and other supernatural forces. All were castigated as offensive to God, and were condemned as both heretical and 'irrational' by his church.[46]

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[42] Olson, *Science and religion;* Alistair C. Crombie, *Robert Grosseteste and the origins of experimental science,1100-1700,* Oxford: Clarendon Press, 1953 and Lindberg, ed., *Science in the middle ages.*

[43] Lindberg and Numbers, eds., *God and nature* and Gaukroger, *Emergence of scientific culture.*

[44] David F. Noble, *The religion of technology: the divinity of man and the spirit of invention,* New York: A.A. Knopf, 1997.

[45] Rossi, *Philosophy, technology and arts* and Paulo Rossi, *The birth of modern science,* Oxford: Blackwell, 2001.

[46] William Eamon, *Science and the secrets of nature: books of secrets in medieval and early modern culture,* Princeton: Princeton University Press, 1994; Carl Sargan, *The demon-haunted world: science as a candle in the dark,* New York: Norton, 1996; Robert S. Westman and James E. McGuire, eds., *Hermeticism and the scientific revolution: papers read at a Clark Library seminar,* Los Angeles: University of California, 1977 and Bartlett, *The natural and the supernatural in the middle ages.*

In short, Europe's 'Scientific Revolution' took off on the basis of a prior critique of a traditional and established set of religious, 'pagan' and hermetical conceptions, theories and methods for investigations of the natural world. Claims to truth about the operations of nature, as held by educated Europeans, suggest that displacement had already been taken forward and upward to a plateau of possibilities by the late middle ages. This occurred through the restoration of classical texts, borrowing from Islamic knowledge, and the introduction of logical modes of reasoning into curricula for all forms of higher education, including the study of theology. These ideas were conveyed, *mutatis mutandis*, in simplified and memorable forms into the consciousness of aristocratic, plutocratic and professional elites. Scholastic forms of Aristotelian, Platonic and other ancient modes of thought, infused with and clarified by Muslim commentaries and innovations, had over the centuries undermined appeals to authority about the operations of nature as revealed in the bible, the scriptures and the writings and lives of saintly theologians.[47]

The Scientific Revolution in the West as a conjuncture for a global history of knowledge formation

Irreversible and fundamental changes in flows of useful and reliable knowledge in line with developments anticipated during the middle ages, came on stream during the Renaissance, and accelerated between the times of Copernicus (1473-1543) and Newton (1642-1727).[48] Despite a generation of postmodern scholarship written to undermine its status, an older alternative historiographical tradition has continued to maintain that the lives of these two scientists mark a conjuncture when the intellectual, philosophical and cosmographical foundations behind the extension and reconstruction of Western regimes for the discovery, development and diffusion of such knowledge became radically transformed in scope and scale.[49]

That tradition does not, however, command a consensus among competing tribes of historians. The Scientific Revolution has been portrayed as reductively cognitive in character, rejected as a discontinuity with the past, and depicted as repressively Western in origin. Moreover, the link to subsequent and divergent developments in technology and power between Orient and Occident arouses ideological ire. Indeed, the entire notion of a Scientific Revolution is regarded either as a Eurocentric and anachronistic concept for the writing of global history, or dismissed as tangentially connected to the technological and economic rise of the West, which, according to Pomeranz, only became discernible about a century after the publication of Newton's *Principia*

[47] Colish, *Medieval foundations* and Harrison, ed., *Cambridge companion to science and religion* .

[48] Colish, *Medieval foundations*; Theodore K. Rabb, *The last days of the Renaissance and the march to modernity,* New York: Basic Books, 2006 and David C. Linberg and Robert S. Westman, eds, *Reappraisals of the scientific revolution,* Cambridge: Cambridge University Press, 1990 and Margaret J. Osler, ed., *Rethinking the scientific revolution,* Cambridge: Cambridge University Press, 2000.

[49] Peter Dear, *The iIntelligibility of nature: how science makes sense of the world,* Chicago: University of Chicago Press, 2006, Gellner, *Plough, sword and book* and Hannam, *God's philosophers.*

Mathematica in 1687.[50] Sceptics about the conjuncture might be advised that the reordering of conceptions of the natural world held by Western elites seems to have been clear enough to educated and enlightened contemporaries of the day.

Nevertheless, and if global historians wish to retain the Scientific Revolution as a major chapter locatable within meta-narratives concerned with long term economic material progress, they will have no problem in conceding that the representation of this period in European history as central for an analysis of divergence does not imply that it came without Eastern, as well as Western, antecedents. They will agree that it cannot be represented as any immediate triumph for rational over religious and hermetic modes of thought. They will recognise that its tempo was neither revolutionary in pace, nor linear in trend. They will not suggest that it became pervasive across the whole of Europe, or connected, directly and without lags, to an ongoing process of technological change in the West.[51]

To circumvent other irrelevant criticisms, global historians may certainly concur with the view that variations in any society's cognitive capacities to undertake potentially useful investigations into the natural world are socially, politically and economically, as well as intellectually, constructed. They do appreciate that the 'Scientific Revolution' does not refer to a 'victory' of a progressive Europe over an unenlightened Asia, or the triumph of moderns over ancients, which was followed by rapid and extensive uplift in scientific and technological understandings. Above all, they will certainly reject any explicit or implicit claim for the neural superiority of Western minds.[52]

However, what does seem evident, from a library of books testifying to a tide of theoretical discourse and a wave of experiments that appeared between the lives of Copernicus and Newton,

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[50] Lissa L. Roberts, 'Situating science in global history', *Itinerario* 33, 2009, pp. 1-47; Steven Shapin, *The scientific revolution,* Chicago: University of Chicago Press, 1996; Pomeranz, *Great Divergence.*

[51] The contentious area of debate concerned with connections (or conduits) to technologies have been discussed by economic historians for more than four decades and the historiography is fully referenced in Joel Mokyr's *The gifts of Athena* and his text book *The lever of riches: technological creativity and economic progress,* Oxford: Oxford University Press, 1990. The connections were traced decades ago by Marie Boas Hall and Alfred R Hall, *The scientific renaissance, 1450-1630,* New York, Harper Brothers, 1962 and have been fully elaborated by scholars of Renaissance Italy. Vide: Judith V. Field and Frank A. S. L. James, *Renaissance and revolution: humanists, scholars, craftsmen and natural philosophers in early modern Europe,* Cambridge: Cambridge University Press, 1993 and Pamela O. Long, *Openness, secrecy, authorship: technical arts and the culture of knowledge from antiquity to the Renaissance,* Baltimore: John Hopkins University Press, 2001; Brian W. Ogilvie, *The science of describing: natural history in Renaissance Europe,* Chicago: University of Chicago Press, 2006.

[52] Roberts, 'Situating Science in Global History'; David N. Livingstone, *Putting science in its place: geographies of scientific knowledge,* Chicago, Ill.: University of Chicago Press, 2003 but see Paul Kurtz and Tim Madigan, eds., *Challenges to the enlightenment: in defence of reason and science,* Buffalo, N.Y.: Prometheus Books, 1994; Raymond Tallis, *Aping mankind: Neuromania, Darwinitis and the misrepresentation of humanity,* Durham: Acumen Publishing, 2011. For postmodern and other objections to any form of engagement with comparative styles of global history, see Patrick K. O'Brien, 'Historiographical traditions and moral imperatives for the restoration of global history' in *Journal of Global History* 1, 1996, pp. 3-41; Lloyd, *Cognitive variations.*

is something approximating to a pronounced leap forward in the perceptions, conceptions and confidence of Europe's educated minorities. People making decisions of significance for the development of western economies came to believe that the natural world had become more intelligible and manipulable for improvements to human health and material welfare than their ancestors had imagined, and that it could well become even more so in future.

Thus, historians engaged with the divergence debate may sensibly retain the 'Scientific Revolution' as a venerable and heuristic label for an interlude in European history when trajectories for the discovery, development and diffusion of useful and reliable knowledge became more steeply inclined, more productive, and potentially universal in their applications. These trajectories have been plotted as lists of recognized contributions to the accumulation of many systemic bodies of knowledge. Several matured into specialized disciplines, based upon methods and paradigms for investigation, which were particular to demarcated problems, phenomena, things, and human bodies. These disciplines have been traced by historians of modern sciences, author by author, book by book, and subject by subject.[53] Their scholarship leaves historians of knowledge formation on a global scale with a firm impression that, between circa 1543 and circa 1727, frontiers for speculation, theorizing and observations about the natural world were significantly extended within long established spheres, and moved outward into new areas for investigation.

Historians have also elaborated on ranges of evidence that show how many more educated and skilled Europeans became involved, networked and attached to republics of letters, associations, societies and other institutions for the advancement of such knowledge.[54] They have also traced and quantified pronounced discontinuities in flows of printed and illustrated books, encyclopaedias, manuals and treatises of a proto-scientific nature published over these years.[55]

Scholars have noted an increase in the volume of seminal contributions towards the comprehension of natural forces, particularly in the celestial sphere, but also in terrestrial and biological spheres. These contributions emerged from a line of famous European names active in research in astronomy, physics, mathematics, chemistry and medicine during this period. Nearly all of them were committed Christians, but presented their observations, theories and discoveries as innovative. Of their time, they nevertheless anticipated a different future for mankind. They operated, to paraphrase the words of their most famous promoter, Francis Bacon, as participants in a loosely connected programme for the production of a rich store house of knowledge for the glory of God and the relief of man's estate.[56] Whatever historians of modern sciences in retrospect might

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[53] Geoffrey E. R. Lloyd, *Disciplines in the making: cross-cultural perspectives on elites, learning and innovation,* Oxford: Oxford University Press, 2009 and Mokyr, *Gifts of Athena.*

[54] Silvio A. Bedini, *Patrons, artisans and instruments of science, 1600-1750,* Aldershot: Ashgate, 1999; Paulo Rossi, *Philosophy, technology and the arts in the early modern era,* New York: Harper and Row, 1970.

[55] Everett Mendelsohn, ed., *The social production of scientific knowledge,* Dordrecht, Holland: D. Reidel Pub. Co., 1977; Daniel Headrick, *When information comes of age: technologies of knowledge in the age of reason, 1700-1850,* Oxford: Oxford University Press, 2000.

[56] Antonio Perez-Ramos, *Francis Bacon's idea of science and the makers knowledge tradition,* Oxford: Clarendon Press, 1988 and Robert K. Faulkner, *Francis Bacon and the project of progress,* Lanham, Md.: Rowman & Littlefield, c.1993.

expose *post hoc* about their claims for 'innovatory' ideas, that is how most proto-scientists of the day saw themselves. It was, moreover, how they were perceived by their opponents, who had interests vested in the preservation of established conceptions about the physical universe. Above all it was also how they obtained support and funding from a wider community of 'enlightened' patrons and among Europe's aristocratic, business and political elites, many of whom had been educated in classical natural philosophy.[57]

Historians (including global historians) will be less concerned than their colleagues in the history of science with detecting truly innovative and potentially sustainable ideas, which could, in retrospect, be validated as steps towards the consolidation of mathematically rigorous and physically plausible theories. Most of us lack the credentials to understand the wider implications of laws of motion and gravity, or the role of different styles of mathematics as tools for the discovery of new knowledge. Latterly, however, historians have appreciated the potential realised from the experiments of alchemists, who were involved in separating, distilling, liquefying and compounding organic and inorganic chemical substances. They have also observed that improvements to bodily health and therapies derived from anatomical dissections of early modern times took centuries to mature. They have recognised that the taxonomies formulated for the classification of ever extending varieties of plants, animals, soils, rocks and other physical matter would only eventually provide an ontological basis for theories of biological, botanical and geological evolution. [58]

Historians of global economic development might wish to retain the 'older' view of the 'Scientific Revolution', as an explicable but fortuitous reordering of western Europe's cosmography because in time, that reordering had profound ramifications for the construction of regimes for the formation, development and diffusion of useful and reliable knowledge, first in the Occident and later on in the Orient. Its initial effect was basically to resituate and reconfigure trajectories upon which systemic bodies of knowledge could be accumulated on more politically secure, better endowed, socially elevated, spiritually acceptable, and economically productive foundations.[59] Furthermore and although the knowledge embodied in technology was represented by previous generations of historians of science as 'potentially' significant, rather than immediately seismic in character and outcome, an impressive flow of technological innovations came on stream during the sixteenth and seventeenth centuries. [60] Long ago, Max Weber posed a meta-question (tackled in

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[57] John G. Burke, ed., *The uses of science in the age of Newton,* Berkeley: University of California Press, 1983 and Gascoigne, *Science, politics and universities.*

[58] David Wootton, *Bad medicine: doctors doing harm since Hippocrates,* Oxford: Oxford University Press, 2006 and Alistair Crombie, *Styles of scientific thinking in the European tradition,* Vols. 2 and 3, London: Duckworth, 1994 and Gerald Holton, *Thematic origins of scientific thought: Kepler to Einstien,* Cambridge, Mass.: Harvard University Press, 1980.

[59] Peter Dear, *Revolutionizing the sciences: European knowledge and its ambitions, 1500-1700,* Basingstoke: Palgrave, 2001 and James R. Jacob, *The scientific revolution: aspirations and achievements, 1500-1700,* Atlantic Islands: Humanities Press, 1998.

[60] Edgar Zilsel, 'The Genesis of the Concept of Scientific Progress', *Journal of the history of ideas,* 1945, pp. 325-99 predates Butterfield's classic text: Herbert Butterfield, *The origins of modern science, 1300-1800,* London: G. Bell & Sons Ltd, 1949; Rupert A. Hall, *Science and society: historical essays on the relations of science, technology and medicine,* Aldershot: Variorum, 1994.

depth for China by Joseph Needham) of why a conjuncture, which marked the onset of an accelerated trend towards the comprehension of the natural world, occurred when it did in western, rather than in eastern, Eurasia. As Pomeranz himself has always recognised that question remains central for the unresolved concerns of global economic history with the origins and role of technological innovation for divergence. [61]

Reasons for the accelerated displacement of Medieval Europe's classical, largely Aristotelian and beatified conceptions of the natural world and its replacement by a more effective cosmography has been explicated in detail with reference to a library of influential texts, which appeared in the sixteenth and seventeenth centuries within the established realms of natural philosophy, alchemy, and theology.[62] Along with restored neo-Platonic and related hermetic traditions of writing, as well as the revival of a rhetoric of humanism flow of printed words contributed battalions of publications to what Jonathan Swift evocatively referred to as the 'battle of the books'. That literature has been well surveyed, and has been evaluated positively as part of recent and heuristic extensions to traditional boundaries for a cultural history of the rise of European science.[63]

Prior to Newton's death in 1727, the reordering in the education and cultures of Western elites included a confinement of God's role in the operations of the natural world, and a derogation of understandings of that world contained in canonical texts of the Roman, Orthodox and Reformed Christian churches. Above all it had been reconfigured by a conceptual, empirical and logical demolition of beatified classical knowledge about the universe, and its observable

[61] Kenneth Pomeranz, 'Ten years after: responses and reconsiderations', *Historically Speaking,* Sept, 2011, pp. 20-25 and 'Without coal, colonies and calculus: Europe, China and the industrial revolution' in Ned Lebow, et al, eds., *Unmaking the west: what if scenarios that rewrite world history,* Ann Arbor, Mi.: University of Michigan Press, 2006. For a postmodern view that regards the scientific revolution as a "myth about the inevitable rise to global domination of the west" read the introduction to Katharine Park and Lorraine Daston, eds., *Early modern science,* Cambridge: Cambridge University Press, 2006 and the critiques of such views in Noretta Koertge, ed., *A house built on sand: exposing postmodern myths about science,* Oxford: Oxford University Press, 2000.

[62] Gaukroger, *Emergence of a scientific culture*; Tom Sorrell, ed., *The rise of modern philosophy: the tension between the new and traditional philosophies from Machiavelli to Leibniz,* New York: Oxford University Press, 1993 and Richard S. Westfall, *Science and religion in seventeenth century England,* Hamden, Conn.: Archon Books, 1970.

[63] William R. Newman and Anthony Grafton, eds., *Secrets of nature: astrology and alchemy in early modern Europe,* Cambridge, Mass.: MIT Press, 2001 and Judith V. Field and Frank A. J. L. James, eds., *Renaissance and revolution*; Margaret J. Osler, 'Mixing metaphors: science and religion or natural philosophy and theology in early modern Europe', *History of Science*, 35, 1997, pp. 91-113 and Richard F. Jones, *Ancients and moderns: a study of the background of the "Battle of the books".* St. Louis: Washington University Press, 1936.

properties and operations. This demolition job was anticipated by medieval critiques of classical knowledge, which was after all over 2000 years old by the time of the Florentine Renaissance.[64]

The undermining of religious authority and its connections to perceptions and comprehensions of the natural world by the Reformation continues to arouse ire and debate. Protestantism effectively destroyed the control of the Roman Catholic hierarchy over theological beliefs and moral codes for a large segment of the European intelligentsia, including by extension its 'repressive tolerance' towards views about the natural world. It would be difficult to prove that translating the bible and other canonical religious texts into secular texts widened and deepened understandings of nature.[65] Five centuries after the outbreak of the Reformation, it has, however, become apparent that most of the Protestant churches and sects that emerged out of the turmoil unleashed by Martin Luther displayed no greater tolerance than the Roman hierarchy towards the claims of rational compared to revealed truths or faith.[66] Historians who continue to evoke Protestant origins for modern science may be declining into a minority. Agreed, they can plausibly claim that the Reformation fortunately left Europe without a single hierarchical authority capable of enforcing views of nature across the length and breadth of the continent.[67] Yet was it not the barbaric and highly destructive wars of religion that pushed many Europeans, Catholics and Protestants alike, towards states of anxiety and a widespread stance of scepticism towards the claims to truth and authority from all religious hierarchies?[68] Even before the fragmentation of Christendom religion had anyway lost a great deal of power to prescribe on philosophical as well as moral matters to secular rulers, whose interests lay in harnessing useful knowledge to serve political, geopolitical and economic ends, rather than in moral or spiritual purposes.[69]

Many historians continue to contest and obfuscate the very notion of conjunctures in comprehensions of the natural world. Typically, such historians are based in national archives,

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[64] Bono, *The word of God* and Grant, *History of natural philosophy*; Lindberg and Westman, eds., *Reappraisals of the scientific revolution.*

[65] Vide 'The unintended reformation: a forum', *Historically Speaking,* 13, 2012, pp. 1-21; Ulinka Rublack, *Reformation Europe,* Cambridge: Cambridge University Press, 2005; Mordechai Feingold, *Jesuit science and the republic of letters,* Cambridge, Mass.: MIT, 2002 but read Peter Harrison, *The Bible, Protestantism and the rise of natural science,* Cambridge: Cambridge University Press, 1998.

[66] Lindberg and Numbers, eds., *God and nature*; Olson, *Science and religion*; Mario Bagioli, ed., *The science studies (reader),* New York: Routledge, 1999; John W. O'Malley, ed., *The Jesuits: cultures, sciences and the arts, 1540-1773,* Toronto: University of Toronto Press,1999.

[67] I. Bernard Cohen, K. E. Duffin, Stuart Strickland, eds., *Puritanism and the rise of modern science: the Merton thesis,* New Brunswick, N.J.: Rutgers University Press, 1990. Peter Harrison recently linked the advance of science to biblical based doctrines about the fall of man: Peter Harrison, *The fall of man and the foundations of science,* Cambridge: Cambridge University Press, 2007 but see his edition of the *Cambridge companion to science and religion.*

[68] Richard H. Popkin, *The history of scepticism from Savonarola to Bayle,* New York: Oxford University Press, 2003; Gillespie, *Theological origins of modernity.*

[69] Mordechai Feingold, ed., *The new science and Jesuit science: seventeenth century perspectives,* Dordrecht: Kluwer Academic Publishers, 2003 and Gaukroger, *The collapse of mechanism and the rise of sensibility*

constrained by short-term chronologies, and suspicious of any notion of major discontinuities in modes of conceptualising, comprehending and investigating nature. They are particularly sceptical about notions of a 'revolution' that proceeded over a span of two centuries, remained for a long time concentrated in the minds of elites, and took far longer to trickle down into folk wisdom.[70] Such scepticism is not persuasive, because commitment to the novel ideas of intellectuals, which could undermine religion and contradict classical authorities, could only have occurred gradually. Furthermore, in pre-modern times, educated elites, with an interest in the status quo, continued to be the principal agents involved in patronizing the personnel and institutions behind the accumulation and diffusion of knowledge. Divergences in technological development, material progress and geopolitical power only became unmistakeable after the death of Newton.[71]

Other objections warn that significant areas of modern scientific endeavours, such as chemistry, geology, botany, medicine and engineering, remained on systemic bases that were only marginally improved by innovatory contributions contained in the reconfigured conceptions of nature and the proto-scientific knowledge that appeared during the sixteenth and seventeenth centuries. However, these views have been exposed as exaggerated by recent research into a plethora of manuscripts, manuals, printed books and contemporary records of discourses in alchemy, astrology, natural history, medicine and the mechanical arts.[72]

Again there is no need to enter specialized debates. Let us instead consider in general terms what a majority of educated Europeans may plausibly have read, considered and believed about the intelligibility of nature. By the second half of the seventeenth century their views had been informed by European voyages and imperial expansion overseas, the intellectual vibrations of the Renaissance, the turmoil of the Reformation, and the horrendous catastrophes of religious warfare between the times of Luther and the Peace of Westphalia in 1648.

First and foremost, educated Europeans believed in a God who had created and designed his universe on rational principles, which he could revoke at any time, but rarely did. Those principles were, moreover, accessible to rational investigations, to explication, to potential manipulation for geopolitical power, and ultimately for the welfare of populations existing in poor states of health and low levels of literacy on the margins of subsistence. For millennia before the 'Scientific Revolution', people had lived in a world surrounded by an enormous variety of organic and

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[70] Shapin, *The scientific revolution* and Gerald Holton, *Science and anti-science,* Cambridge, Mass.: Havard, 1990.

[71] Malcom Oster, ed., *Science in Europe 1500-1800,* Basingstoke: Palgrave in association with the Open University, 2002 and Michael Adas, *Machines as the measure of man: science, technology and ideologies of western dominance,* Ithaca: Cornell University Press, 1989.

[72] Helaine Selin, ed., *Encyclopaedia of the history of science, technology and medicine in non-western cultures,* Dordrecht: Kluwer Academic Press, 1997; Gaukroger, *Emergence of a scientific culture*; William R. Newman, *Atoms and alchemy: chymistry and the experimental origins of the scientific revolution*, Chicago: University of Chicago Press, 2006; Pamela H. Smith and Benjamin Schmidt, *Making knowledge in early modern Europe: practices, objects, and texts, 1400-1800,* Chicago, Ill., University of Chicago Press, 2007 and Jan Golinski, *Science as public culture: chemistry and enlightenment in Britain 1760-1820,* Cambridge: Cambridge University Press, 1992.

inorganic matter which they could see, touch, smell, understand with their senses, reflect upon with their minds, and systematize and store in many ways as useful knowledge.[73] Following Aristotle, other classical texts, and elaborations upon them by Islamic and scholastic philosophers, educated Europeans had for several centuries classified and comprehended an ever extending proportion of such matter, bit by bit, in terms of its perceptible attributes, substances, forms, colours, and, above all, by way of the teleological purposes or functions of all natural things contained within specific environments.[74] Change proceeded in stages, which, for a reordering of cultures and comprehensions based upon common sense, could hardly take the form of short sharp discontinuities. First came a Renaissance, which, in retrospect, has been represented as a period of preparation for a 'Scientific Revolution'.[75] Then, over the course of the seventeenth century, Aristotelianism, as an intuitively plausible, conceptually satisfying and widespread way of understanding forces and phenomena in nature, came under sustained and ultimately successful attack.

Then followed precursors and developers of a Cartesian cosmography, which historians of philosophy and science call 'mechanism'. This culminated in the acceptance of a Newtonian synthesis over the course of the eighteenth century.[76] 'Mechanism' and related natural philosophies developed on the assumption that the best way of including all the manifold organic and inorganic things observed in the world in one universal and acceptable theory would involve the refutation of Aristotelian and other classical views as erroneous, superficial and useless. After a prolonged rhetorical and philological assault, natural philosophers became free to construct and refine a metaphysical basis for the study of the natural world. Within this reconfigured cosmography, it was perceived to be more rational, and potentially more useful, to conceive of everything in nature as composed of particles at rest or in motion, which could be described and predicted in mathematical terms.

Cartesians of several persuasions proclaimed that this new atomic theory of the universe, which had respected antecedents in Greek and Islamic thought, constituted the best of all possible representations of God's creation and design. It would, they anticipated, stimulate all manner of

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[73] Levine, *At the dawn of modernity*.

[74] Anthony Grafton, *Defenders of the text: traditions of scholarship in the age of science,* Cambridge, Mass.: Harvard University Press, 1993.

[75] Rabb, *The last days of the Renaissance*; Charles B. Schmidt, *The Aristotelian tradition and Renaissance universities,* London: Ashgate, 1984 and Sara J. Schechner, *Comets, popular culture and the birth of modern cosmology,* Princeton: Princeton University Press, 1997. My comprehension of new cosmographies that preceded and developed even before the times of Copernicus and Newton has been greatly enriched by H. Floris Cohen's magnus opus *How modern science came into the world: four civilizations, one 17th-century breakthrough,* Amsterdam: Amsterdam University Press, 2010.

[76] Gaukroger's two volumes are seminal for cultural interpretations of the scientific revolution - Gaukroger, *Emergence of a scientific culture* and Stephan Gaukroger, *The collapse of mechanism and the rise of sensibility: science and the shaping of modernity,1680-1760,* Oxford: Oxford University Press, 2012; Margaret C. Jacob, *Scientific culture and the making of the industrial west,* Oxford: Oxford University Press, 1997 and Margaret C. Jacob, *The scientific revolution: a brief history with documents,* Bedford: St. Martin's, 2010.

enquiries into organic and inorganic matter.[77] They wrote polemically, in order to move the dominant natural philosophy of Christendom forward from what they asserted to be limited, opaque and unsystematic classical and scriptural observations. They parodied scholastic classifications, trivial disputes and ontologically unreal depictions of diverse natural phenomena in terms of their purposes.

To replace hegemonic, but teleological, Aristotelianism, a famous line of natural philosophers (Beeckman, Mersenne, Gassendi, Hobbes, Huygens, Rohault, and pre-eminently Descartes) constructed a metaphysical theory of the universe. This was based on axioms that corpuscules, particles or atoms could be construed to represent the composition, structure and motions of all natural phenomena. They anticipated that this foundational, non-observable premise about the natural world, together with the systematic deployment of a priori but logically compelling mathematical models, could lead, case by case, and problem by problem, to a wider, deeper and more useful foundation for the formation of knowledge about all natural forces, including the operations of human bodies. God, they believed, and most prudentially posited, had created a universe composed of particles, which clustered moved and interacted according to his rational designs, operating like the mechanisms of a clock. Slowly but surely, this meta-theory, with its evocative metaphors, together with the cognitive imperialism of mathematics, overcame and displaced both religious and beatified classical cosmographies for rendering nature intelligible. Cartesianism became the means for widening and deepening the metaphysical basis for conducting investigations into the operations of the natural world.[78]

In their explanations for changes in the scale, scope and modes of conducting research into that world that occurred in the sixteenth and seventeenth centuries, historians have accorded different weights and emphases to the circumvention of ecclesiastical authority (coupled to a reigning Aristotelian cosmography based upon common sense, syllogistic logic, and the taxonomical and intuitive appeal of teleological thought) by an alternative metaphysical theory of the universe.[79] In any event, the new image, metaphor or cosmography of a mechanistic universe, constructed by a divine clockmaker or geometer, which could be modelled mathematically, became intelligible, plausible, and acceptable among western Europeans. Indeed, it matured over time into folk wisdom, and eventually became a secular religion for the West. Gradually it served to promote more extensive, and ultimately more instrumental investigations and controlled experiments into nature than anything derivable from the metaphysical perceptions it had displaced.[80]

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[77] Margaret J. Osler, *Divine will and mechanical philosophy: Gassendi and Descartes on contingency and necessity in the created world,* Cambridge: Cambridge University Press, 1994.

[78] Cohen, *How modern science came into the world;* Dear, *Revolutionizing the sciences*; Osler, *Divine will and mechanical philosophy*; Bono, *The word of God*; Gillespie, *Theological foundations of modernity.*

[79] Jesuit philosophers and proto scientists formed the last bastion for the defence of an Aristotelian natural philosophy. Vide: O'Malley, ed., *The Jesuits* and Feingold, *Jesuit Science and the Republic of Letters.*

[80] David Gooding et al, eds., *The uses of experiment: studies of experiment in the natural sciences* Cambridge: Cambridge University Press, 1989; Cohen, *How modern science came into the world* and Dear, *Intelligibility of nature.*

Europe's new cosmography retained, and indeed in some ways strengthened, a belief in the divine origins of the universe, which satisfied the spiritual needs of its Christian elites. With God in place as the ultimate cause, the new cosmography, initially in a Cartesian form, and, by the eighteenth century, as a Newtonian synthesis of mathematical axioms under validation by controlled experimental methods, became acceptable as the foundation for the construction of more directly related, systemic paradigms and procedures for research. Within these parameters, Western physics, chemistry, physiology, medicine, botany, biology, geology, mechanics and other sciences developed, proliferated and operated over the centuries that followed the 'Scientific Revolution'.

Fortuitously but fortunately, mechanistic vocabularies and metaphors also appealed to engineers and artisans.[81] Following the advocacy of Francis Bacon, and the lead taken by famous Renaissance architects, engineers and humanist projectors, as well as the acclaimed examples of Galileo, Hooke, Boyle, Beekmans, Huygens and Newton, more and more 'scientists' turned to practical considerations. They reflected upon, consolidated and unified their styles of constructing knowledge included under the prestigious label of natural philosophy with the mundane practices of mechanics, craftsmen, artisans, doctors, alchemists and other practitioners, who were directly engaged with the manipulation of natural forces for practical, political and commercial purposes.[82] Many famous scientists of the period visited arsenals, foundries, and workshops, and engaged with artisans. Some appreciated how indebted they were to these 'humble' craftsmen for the development of a range of instruments, devices and experimental apparatus that made innovations possible, and in effect validated their hypotheses.[83] In these and other ways, praxis, mathematical models, mechanistic philosophies and clock-like metaphors all operated as powerful stimuli for the accumulation of useful and reliable knowledge. This occurred in contrast to Aristotle's separation of *episteme* and *techne*, his organic conceptions of nature, and his teleological methods for its investigation, which had run into diminishing returns.

The greatest weight should be accorded to the contributions made by mathematical astronomers to an understanding of a quasi-spiritual celestial sphere of the universe, through which they and their patrons hoped to pass through en route to heaven. With indispensible assistance from the development of telescopes and micrometers, they exposed Aristotle's errors about voids above and below mountains on the moon. A famous line of astronomers (Copernicus, Kepler, Brahe, Galileo and Newton) observed that the heavens contained an infinite number of stars and satellites, comets and planets. They formulated mathematical proofs that planets (including man's

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[81] Robert Friedel, *A culture of improvement: technology and the western millennium,* Cambridge, Mass:, MIT Press, 2007; Hall, *Essays on the relations of science, technology and medicine*; David S. Landes, *Revolution in time: clocks and the making of the modern world,,* Cambridge: Harvard University Press, 1983.

[82] Pamela H. Smith and Gerald Findler (eds.) *Merchants and Caravels. Commerce, Science and Art in Early Modern Europe* (New York: Doubleday, 2002); Rossi, *Birth of modern science*; Domenico B. Meli, *Thinking with objects: mechanics in the seventeenth century,* Baltimore, M.D.: The John Hopkins University Press, 2006.

[83] Albert Van Helden and Thomas L. Hankins, eds., 'Instruments', special issue of *Osiris*, 9, Chicago: Chicago University Press, 1994; Roberts, *Mindful hand*; Bedini, *Patrons, artisans and instruments of science.*

own planet earth) were propelled along routes that circled the sun. They posited that planets moved in predictable response to Newton's mysterious physical force, gravity, which operated in terms of divine laws of motion, in both the celestial and terrestrial spheres of the universe. It could be represented by a parsimonious, accessible and ultimately convincing mathematical formula.[84] Earth's route in space and time, and its position in relation to other planets and the stars, could be mapped and predicted with increasing precision. This turned out to be useful, not simply for the refutation of pervasive astrological fantasies, but also for marking the seasons, for meteorology, constructing calendars, and navigating the oceans.[85] As ecclesiastical hierarchies, Protestant as well as Catholic, recognised, the new astronomy represented wonderful and vivid threats to canonical interpretations of the universe.[86] However, astronomers circumvented the dangers associated with heresy by presenting their models and theories as congruent with God's creation and design. By the mid-seventeenth century, their discoveries had become famous as an inspirational (or fearsome) portent for science, along with the irresistible rise in the prestige of mathematical forms of natural philosophy, associated with Kepler, Galileo and Newton. [87]

The discourse and controversies at the core of the Scientific Revolution culminated in a consensual view that had been long debated among generations of natural philosophers concerned with procedures for the validation of claims to truth about the attributes and operations of natural phenomena. For example, many claims based on accepted truths, which were left undefined as sacred by ecclesiastical hierarchies, were nevertheless published in the bible and in other in canonical texts of the Christian religion. These could now be reconfigured as allegorical, or prudentially set aside.88 At the same time ancient and previously venerated classical authorities could be undermined as outdated, weakened by ever increasing flows of systematic observations, and defeated by logical arguments, especially those elaborated in rigorous mathematical forms by Kepler, Galileo and Newton. As time went on, they could be denied by demonstrations based upon transparent experiments, which moved anatomy towards physiology, alchemy into controlled experiments in chemistry, medicine towards biomedicine, the mathematics of motion towards mechanics, and the latent potential of atmospheric pressure towards steam power.89

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[84] Schechner, *Comets, popular cultures and the birth of modern cosmology.*

[85] Thomas S. Kuhn, *The Copernican revolution: planetary astronomy in the development of western thought,* Cambridge, Mass.: Harvard, 1957 and Curtis Wilson, *Astronomy from Kepler to Newton,* Aldershot: Variorum, 1989.

[86] William A. Wallace, *Galileo, the Jesuits and the medieval Aristotle,* Brookfield: Variorum, 1991.

[87] Lindberg and Numbers, eds., *When science and Christianity meet,* and Alan Cromer, *Uncommon sense: the heretical nature of science,* Oxford: Oxford University Press, 1993); Richard Olson, *Science deified and science defiled: the historical significance of science in western culture*, Vol. 2, Berkeley: University of California Press, 1990.

[88] Bono, *The word of God*; Gillespie, *Theological foundations of modernity.*

[89] Gaukroger, *The collapse of mechanism*; Russo, *Forgotten revolution*; Olson, *Science deified and science defiled* and Margaret C. Jacob, *The cultural meaning of the scientific revolution,* New York: Knoft, 1988 and Donald S. L. Cardwell, 'Science and Technology in the Eighteenth Century', *History of Science,* 1, 1962, pp. 30-43.

Recent research continues to broaden the parameters of the 'Scientific Revolution' by looking into the writings of a plethora of figures, who were actively engaged in unscientific and even disreputable branches of early modern knowledge. Connections between alchemy and chemistry, and primitive anatomy and medical science, are being revised. So are more positive claims for astrology, hopeful pharmacology, and improbable cures for specified diseases. Modern research has brought to our attention an impressive list of innovators and innovations, which now appear in comprehensive histories tracing paths towards chemistry, astronomy, physiology, and biochemical medicine.[90] Doctors conducted anatomical dissections that questioned the almighty Galen's classical authority about the organs of the human body.[91] Apart from Boyle, many forgotten names continued to observe, to count, to experiment with minerals, salts, acids, sulphurs, mercury, alum and other substances, which they melted, cooled, compounded, distilled, fermented and generally transmuted into metals, dyes, medicines and other products of potential value and utility.[92] Many represented this potentially useful knowledge and praxis in all kinds of mysterious, magical and mystical ways, in order to sell themselves and their products to credulous patrons and consumers in early modern Europe.[93] Others among these neglected scholars aspired to fashion their practices, experiments and know-how in the vocabularies of Cartesian and Newtonian theories and natural philosophies, and to wrap them in mantles of systematic quantification.[94]

Latterly, historians have recognised that these arcane traditions, steeped in curiosity as well as fantasy and fraud, were engaged with methods for acquiring natural knowledge that anticipated the transparent and prototype controlled experiments of modern science. They have revealed how alchemists, herbalists, numerologists, and even astrologers, added to and diffused flows of useful data that served wider and deeper possibilities for the long run development of systemic knowledge in astronomy, botany, chemical science, biochemical medicine, engineering and eventually biology.[95] The re-examinations by historians of such flows of potentially useful knowledge, coupled with the spread of semi-efficient and transparent methods for the controlled

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[90] Bruce T. Moran, *Distilling knowledge: alchemy, chemistry and the scientific revolution,* Cambridge, Mass,: Harvard University Press, 2005; William R Newman, *Promethean ambitions: alchemy and the quest for perfect nature,* Chicago: University of Chicago Press, 2004; Lindberg and Westman, *Reappraisals of the scientific revolution* and Golinski, *Science as public culture.*

[91] Harold J. Cook, *The decline of the old medical regime,* Ithaca: Cornell University Press, 1986 and Wooton, *Bad medicine.*

[92] Newman, *Atoms, alchemy and chemistry* and William R. Newman, *Starkey*, *Boyle, and the fate of Helmontian chemistry,* Chicago, Ill.: University of Chicago Press, 2002.

[93] Geoffrey E. R. Lloyd, *Demystifying mentalities,* Cambridge: Cambridge University Press, 1990 and Pamela H. Smith, *The business of alchemy: science and culture in the Holy Roman Empire,* Princeton, N.J.: Princeton University Press, 1994.

[94] Alfred W. Crosby, *The measure of reality, quantification and western society,* Cambridge: Cambridge University Press, 1997.

[95] Stephen A. McKnight, *Science, pseudo-science and utopianism in early modern thought,* Columbia: University of Missouri Press, 1992; Newman and Grafton, *Secrets of nature*; Kuhn made this point decades ago : Thomas S. Kuhn, 'Mathematical vs. experimental traditions in the development of physical science', *Journal of Interdisciplinary History,* 7, 1976, pp. 1-31.

investigations of the natural world, have exposed tributaries of the Scientific Revolution that an older historiography, concentrated upon histories of celestial and terrestrial physics, had neglected to include as an integral part of this important conjuncture in global history.[96]

Thus the 'Scientific Revolution' is emerging as something less than a short, sharp discontinuity in the accumulation of scientific knowledge, and more as a profound conjuncture locatable for its time in the history of western Europe. It occured when methods for the discovery, development, testing, diffusion and presentation of such knowledge were being gradually but systematically transformed. The once celebrated conjuncture is also being plausibly restored as a period when the dispositions of Europe's ruling classes, the cultures of aristocratic, plutocratic and even ecclesiastical elites became more hospitable, even promotional, toward the reconstruction of cosmographies and institutions for the production of useful and reliable knowledge. In the fullness of time these 'regimes' spawned disciplines (physics, chemistry, engineering, geology, biology, botany, pharmacology, agronomy) producing systemic knowledge for new forms of energy (steam, and eventually electrical power). Above all these sciences operated to accumulate and test bodies of useful and reliable knowledge required to promote and assist in the conception, construction and development of improved technologies for agriculture, industry, commerce, transportation, health, human welfare and, alas, for an endemic resort to warfare and imperialism by western states.

That said, although core features of the 'Scientific Revolution' are no longer located in any comprehensive range of dramatic and innovative breakthroughs, some were more dramatic than others. Ideas of planetary motion had profound and relatively rapid cultural outcomes.[97] Another great leap forward included the rediscovery of an ultimately highly significant source of energy, atmospheric pressure. This flowed from a long sequence of controlled experiments, following the translation of Heron's classical treatise into Latin in 1571, and the demolition of Aristotle's rejection of the vacuum.[98]

Conclusion

This essay agrees that the 'Scientific Revolution' did not emanate from any sudden transformation in Europe's cosmography. Deeper intellectual origins have been properly located in Indian, Chinese, Arab, and Persian thought. Moreover, its medieval antecedents can be traced back to a variant of monotheism associated with both the Catholic and Protestant religions of western

[96] Larry R. Stewart, *The rise of public science: rhetoric technology and natural philosophy in Newtonian Britain,* Cambridge: Cambridge University Press, 1992 and Bruce T. Moran, ed., *Patronage and institutions: science, technology and medicine at the European court, 1500-1750,* Woodbridge: Boydell, 1991.
[97] John D. North, *The Norton history of astronomy and cosmology,* London: Norton, 1994 and Howard Margolis, *It started with Copernicus: how turning the world inside out led to the scientific revolution,* New York: McGraw-Hill, 2002.
[98] Ian Inkster, ed., Special Issue of *History of technology,* 25, 2004, on the steam engine.

Europe, and can be positioned in the study of natural philosophy and theology. The 'Scientific Revolution' was also linked to praxis and to fields for investigation that have long been grouped under such disreputable labels as alchemy, astrology and craft secrecy. Powers vested in traditional ecclesiastical institutions to resist more rational and instrumental investigations into natural phenomena had to be circumvented, circumscribed, and ultimately replaced by a regime with greater potential to promote transitions into modern forms of science. The ground for the displacement of a religious and classical cosmography by another, and potentially more productive, way of conceiving, comprehending and manipulating the natural world had thus been well prepared.[99]

Despite its famous sequence of innovations, its manifestations in the form of seminal books, documentation from republics of letters, papers delivered to associations of professional and learned men, cosmographical displacement, and institutional change, the 'Scientific Revolution' did not, however, occur simply as an outcome of an intellectual discourse confined to a quasi-autonomous realm of natural philosophy. Familiar and major historical forces peculiar to western Europe are also chapters in any narrative that seeks to explain the location, timing, trajectory and momentum of that conjuncture. For example, early attacks on the pretensions towards claims to truth emanating from religious sources and classical texts about phenomena located in worlds beyond Europe have been plausibly connected to new information, observations and artefacts that flowed back into European maritime cities following from the voyages of discovery and commerce, which were initiated by the Portuguese as early as 1415. Other contributory factors included humanist attacks on the sterility of scholasticism, and a Reformation that unleashed truly horrendous episodes of religious warfare.

On the assumption that over the long run histories of sciences and technologies can be heuristically integrated, the 'Scientific Revolution' could become the core chapter for meta-narratives dealing with technological and economic divergence. If that becomes orthodox historiography, the mega-question posed decades ago by three great scholars in modern global history (Max Weber, Marshal Hodgson and Joseph Needham) of why it occurred in western rather than eastern Eurasia, and during a time of intensified upheaval and violence, might begin to be answered. This is a problem that only a book length narrative, embodying reciprocal comparisons between western Europe, Byzantium, India, China, Japan, and, above all, Islamdom could seriously and comprehensively address.[100] For now this survey has attempted to use but a fraction of the

[99] Editors and authors of appraisals and reappraisals of the scientific revolution cited above might well agree with the view which takes contemporary perceptions as the starting point for conceptualizing and historicizing this period in European history. Vide Focus: 'Thoughts on the scientific revolution' in a special edition of the *European Review,* 15, 2007, pp. 439-512. Contemporary perceptions are, moreover, the starting point for classic texts in the history of science: I. Bernard Cohen, *Revolution in science,* Cambridge, Mass,: Harvard, 1985; Hall, *Revolution in* science and in Rabb's brilliant interpretation of the transitions of the 16th and 17th centuries – Rabb, *Last days of the Renaissance*.

[100] As Marshall Hodgson told us decades ago: *Rethinking world history: essays on Europe, Islam and world history* (ed. E. Burke III, Cambridge, 1993). See also A. Bala, *The dialogue of civilizations*. For recent texts that are explicitly comparative, see Huff, *Intellectual curiosity and the scientific revolution*; Bin Wong and

awesome bibliography of secondary literature from European history to construct a negotiable narrative that restores the 'Scientific Revolution' in the West to a place of significance and debate for history that aspires to be universal. Historians seeking global perspectives can plausibly regard the 'Scientific Revolution' as a conjuncture of profound significance for the welfare of mankind, despite its somewhat deplorable origins, and its numerous malign outcomes.[101]

Rosenthal, *Before and beyond divergence* and Hans Ulrich Vogel and Gunter Dux, eds., *Concepts of nature: a Chinese cross cultural perspective,* Leiden: Brill, 2010.

[101] Four recent essays by distinguished historians of western science: Findlen, Harris, Bagioli and Daston suggest that their academic community should revive big pictures of the scientific revolution. Vide *Configurations,* 6 : 1998, They might wish to go global?

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