Christianity and Mathematics: Kinds of Link, and the Rare Occurrences After 1750

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Abstract

The paper begins with a presentation of eight types of links between mathematics and (a) religion, with especial reference to Christianity. The links are potentially manifest in any period, and collectively the causal connections work in *both* directions. Then a review is given of the manifestations of these links between European mathematics and Christianity in the period from around 1750 to the early 20th century. A noteworthy feature is the *rarity* of their occurrence, and moreover during a time when the links between the natural sciences and Christianity were discussed intensively. Possible reasons for this contrast are sought in the final part.

> But what matters to me is not whether it's true or not but that I believe it to be true, or rather not that I *believe* it, but that *I* believe it. … I trust that I make myself obscure?
>
> Sir Thomas More on the theory of Apostolic succession, as in Robert Bolt, *A man for all seasons.*[1]

1. Introduction

While the links of Christianity to science have been well studied, those to mathematics have gained far less attention, presumably because of the lack of interest in mathematics among both historians and theologians.[2] Much has been missed, however, since several branches of mathematics and religions have inter-relating histories going back to antiquity; indeed, mathematics seems to have affected the *formation* of religions in the first place as well as received influence from them, a property evident only in astronomy among the other sciences. This paper is a foray into some features of links with Christianity.

In the first part of this paper I propose eight kinds of link between Christianity and mathematics, both cognitive and non-cognitive. They correspond to some of the ways in which a human being informed in mathematics and Christianity of his time might ponder upon the relationships between them. While basically different, they are not always mutually exclusive. Further, the distinctions between them may not always have been followed or even accepted; some conflations will be noted where appropriate. Applicable to any period, the examples given come from before 1750, when manifestations occurred with moderate regularity.

The second part of the paper records the occasions between the second half of the 18th century and the early 20th century when European mathematicians invoked a link in their work. However, a main feature is that these occasions were *very few in number*, and also rarely influential from one to another, even though far more mathematicians were at work than previously and (as far as I know) most of them professed some version of Christianity. This quietude also contrasts strikingly with the massive contemporary *increase* in concern in the natural sciences, especially in geology, mineralogy and the rise of Darwinism. The final part of the paper reviews this striking contrast, and also notes some

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[1] R. Bolt, *A Man For All Seasons,* London, 1960, 53.

[2] For two examples among many, beyond some general remarks on mechanics and modelling in astronomy, mathematics is virtually absent from the valuable surveys of issues given in J.H. Brooke, *Science and Religion. Some Historical Perspectives,* Cambridge, 1991; and I.G. Barbour, *Science and Religion. Historical and Contemporary Issues,* New York, 1997.

further mathematicians who never deployed such links in their work even though their belief was invoked in relationships between Christianity and other sciences and philosophy, and in a few cases even participated in theological disputes.

Some limitations to this foray need to be explained. Unfortunately, no attempt can be made to summarise the history of links between mathematics and Christianity prior to 1750, since the literature available is rather sparse and general, and lacking in detail (on the various kinds of link, for example).[3] Again, attention to the relationships of both mathematics and Christianity to logics are restricted to a few mentions and one major figure. Similarly, I confine to a few cases concern with the differences between the numerous versions of Christianity. I also do not consider other religions beyond a few mentions; but I follow some of my historical figures in admitting Deism, a position where the existence of some God is asserted but the Christian account is not necessarily affirmed. I postpone these desimplifications to another occasion, along with other questions such as the use made of mathematics, not always perspicuously, in *other* disciplines (including scientific ones) as a source for supporting Christian belief.

A general philosophical point also needs to be noted. When a scientific theory is (apparently) incompatible with experience or experimental findings, then some component(s) of it have to be modified, though the detection of the weakness(es) can be a very complicated process. But if mathematics is involved in that theory, its status is epistemologically more tricky. For example, in the early 1860s William Thomson (1824-1907) estimated the age of the Earth, a study which bore upon the relationship between geology and Christianity;[4] but his use of Fourier series involved no link to *mathematics*

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[3] It is not possible to give a representative selection of texts, for they usually occur as passages in works dealing with many other aspects or concerns (biography of a major figure, for example). D.E. Smith waffles about analogies between mathematics and Christianity (concerning notions such as infinity and continuity) in 'Religio Mathematici', *American Mathematical Monthly, 28* (1921) 339-349. A selection of relationships from various periods is provided in G.C. Henry, Jr., *Logos: Mathematics and Christian Theology,* Lewisburg, 1976. For short reviews of links, see W. Breidert, 'Theologie und Mathematik: ein Beitrag zur Geschichte ihrer Beziehung', in M. Toepell (ed.), *Mathematik im Wandel,* Hildesheim, 1999, 78-88; and G.B. Chase, 'How has Christian Theology Furthered Mathematics?', in J.M. van der Meer (ed.), *Facets of Faith and Science,* vol. 2, Lanham (Md.), 1996, 195-216. Chase and C. Jongsma edited a *Bibliography of Christianity and Mathematics: 1910-1983,* Sioux Center (Iowa), 1983, available on www.messiah.edu/ acdept/depthome/mathsci.acms/index.html. It lists publications on a wide range of themes, including philosophical, logical and educational issues, but rather few specifically on history; in particular, it confirms the lack of literature (as of 1983) on the period after 1750.

[4] See J. Burchfield, *Lord Kelvin and the Age of the Earth,* New York, 1975.

and Christianity, nor was the legitimacy of the theory endangered. Hence the defence and criticism of mathematical theories, both pure ones and especially when they are used in physical sciences, is a subtler matter than obtains for empirical sciences, so that possible roles for Christianity vary accordingly.

PART ONE: EIGHT KINDS OF LINK

Each link is given an abbreviating code, of the form ‘M***C’ or ‘C***M’. The capital letters denote ‘Mathematics’ and ‘Christianity’ respectively, the first one in each code being the source of the link involved and the second its recipient. The asterisks represent three lower case letters abbreviating the kind of link proposed; thus, for example, ‘CemuM’ names the link where Christianity influences mathematics by being its source of *emulation* concerning rigour and truth.

2. Mathematics influencing Christianity

MfrmC: involvement of mathematics in *the formation and/or development of Christianity*. Numerology was an important source already before Christianity and continued so throughout its formation and prosecution, drawing upon ancient reverence for positive integers and their properties. A widespread example is the prominent role given to three in orthodox Christianity; but various larger numbers were also involved (such as Peter catching 153 fish in John 21:11). Other manifestations include the number of gods asserted to exist in a polytheism.

The other main branch was geometry with trigonometry, where high status was given to basic shapes such as the circle, the square, and the regular pentagon, hexagon and octagon. Later designs include the so-called ‘fish bladder’, where two intersecting arcs of circles of the same diameter pass through each other’s centre and thereby enclose a pair of equilateral triangles. Many examples involve the influence of both mathematics and Christianity upon architecture. Texts and diagrams of this type exhibit both overt and covert or symbolic levels of meaning: the Bible is a rich case.

This link constitutes a very large topic, requiring separate treatment. Apart from new theories of the infinite (§13), very few innovations were made after 1750, although some good historical scholarship was achieved.[5]

MexgC: provision of *proofs of the existence of God*, or at least of attributes such as omnipresence and creating the universe, which God should possess. While called ‘mathematical’, they often hinged more upon logical reasoning than upon mathematics as

[5] Detailed discussion and further references are in preparation in I. Grattan-Guinness, ‘Manifestations of Mathematics in and around the Christianities: Some Examples and Issues’.

such.[6] For example, G.W. Leibniz (1646-1716) depended mainly on the ontology of pre-established harmony to show that God had created the best of all possible worlds; he also assumed that syllogistic logic was part of mathematics.[7] But this kind of link was falling out of favour even in Leibniz's time: for example and an important one, John Locke (1632-1704) had already asserted 'faith and reason, and their distinct provinces',[8] a separation which seems to have gained later favour, especially under the further stimulus of the Locke-awakened Immanual Kant (1724-1804).

3. Emulations

MemuC: *Mathematics emulated by Christianity* as a source for *certainty of theories.* Conversely,

CemuM: *Christianity emulated by Mathematics* as a source for *certainty of theories.*

The remark on interaction at the head of §1 can be expanded here. Christianity and mathematics developed together in antiquity, and both with close connections to astronomy; thus these two sciences exhibit more complicated relationships with religions than pertain with the other sciences, and over a far longer time. In particular, in these three domains of knowledge primitive man *began to systematise his scattered scraps of comprehension into theories*, and so bring some order and perhaps *certainty* into his understanding. Principles or assumptions were offered deploying invariant concepts: numbers, for example, or virtue.[9] Consequences were drawn from these principles; so (presumably) we also see the birth of logic, which often was and is entwined unclearly around mathematics. These developments may also have been interpreted as evidence that humans are (created) *capable* of such achievements.

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[6] For a modern review of the "proofs" see E.T. Whittaker, *Space and Spirit. Theories of the Universe and Arguments for the Existence of God,* London, 1946. See also note 62 on Whittaker.

[7] See J. Iwanicki, *Leibniz et les démonstrations mathématiques de l'existence du Dieu,* Strasbourg, 1933.

[8] J. Locke, *Essay Concerning Human Understanding,* London, 1689, Book 4, ch. 8. The histories of logic seem to be very inadequate in treating the bearing upon MexgC, but a few 18th-century examples are mentioned by R. Kennedy in his introduction to his (ed.), *Aristotelianism and Cartesian logic at Harvard,* Boston, 1995, 1-60.

[9] Good insights on the growth of arithmetic and geometry, but not religion, are found in C.R. Hallpike, *The Foundations of Primitive Thought,* Oxford, 1979, esp. chs. 6 and 7. Deploying anthropological principles nicely informed by developmental psychology, he also relies upon the work of Jean Piaget to an extent which I find hard to endorse.

The presence (or illusion?) of certainty in Christianity and mathematics is an important common feature. There is a striking similarity between Euclid's *Elements* (-4th century) divided into Books and propositions and providing authority by proof, and the Bible (settled +4th century) divided into chapters and verses and providing authority by decree. It is not known whether Euclid was an influence on the formation of the Bible, and the Books of the Pentateuch may have been written still earlier anyway)though the Greek translations (and organisation) by the Septuagint dates from the -3rd century). Maybe both works exhibit a style of presentation common to all authoritative texts; codes of law provide other examples. An interesting later case of MemuC, and also of MexgC, is the attempt of the physician and astrologer Jean-Baptiste Morin (1583-1656) to emulate the rigour of Euclid in his proofs of the existence of God.[10]

A related common feature is that of *idealisation.* In Christianity it arises, for example, in ethics. In mathematics it occurs in objects as humble as the straight line, which mankind cannot experience directly, not only because of the impossibility of us of drawing it exactly straight but also that in being one-dimensional it is invisible to us anyway. Extensions of such positions led to general 'Platonic' philosophies of mathematics, though usually without a religious import.

The *losses* of certainty in Christianity and in mathematics also shows some similarities; invoking theology to fill the vacuum caused by reduction or loss of faith has some parallel with the use of metamathematics to *study* the (lack of) rigour of mathematical theories. A well-known example is the criticism of the calculus made by Bishop Berkeley (1685-1753) in his book *The analyst* (1734), where he defended Christianity by rightly ridiculing the shaky foundations of the theory, whether limits as mishandled in Newton's fluxional version or the mysterious infinitesimals of Leibniz's alternative differential and integral calculus. Berkeley actually muddled the two theories together in his (secular) solution by compensating errors, which works anyway only for a small class of functions; but his criticisms led to serious efforts to improve the foundations. However, the links to Christianity were not strengthened.[11]

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[10] See J. Iwanicki, *Morin et les démonstrations mathématiques de l'existence du Dieu,* Paris, 1936.

[11] The general history has often been rehearsed, best in W. Breidert, 'Einleitung', in his (ed.), G. Berkeley, *Schriften über die Grundlagen der Mathematik und Physik,* Frankfurt am Main, 1985, 7-69; N. Guicciardini, *The Development of the Newtonian Calculus in Britain 1700-1800,* Cambridge, 1989, chs. 3-6 *passim* ; and H. Pycior, *Symbols, Impossible Numbers and Geometrical Entanglements,* Cambridge, 1997, epilogue. On Berkeley's solution see I. Grattan-Guinness, 'Berkeley's Criticism of the Calculus as a Study in the Theory of Limits', *Janus, 56* (1970), 215-227 (with a printing correction in *57* (1971), 80).

4. Christianity influencing mathematics

Emulation is much concerned with the *(in)validity of arguments* for or against a given position; it should be distinguished from claims of the *truth (or falsity) of propositions,* both of principles and of deduced consequences, which constitute another important similarity between Christianity and mathematics. In particular, until late in the 19th century axioms in mathematical theories were usually regarded as self-evident propositions; hence all the worry over the centuries about proving or replacing Euclid's parallel axiom. The pair following relate to truth claims, the second with cognitive import.

CtgtM: Christianity invoked as the ultimate *target* of (mathematical) knowledge without, however, being involved in its content. God may have made the integers, but the Bible plays no role in, say, finding properties of the primes. This kind takes an ontological form when mathematics is said to be used within (say) mechanics and physics to help disclose the 'Design of the Universe' and 'First Cause', or reveal 'God's Book', to quote three metaphors; there was also epistemological versions, which would regard a *theory* as dedicated to God, or expressing His truths. Such positions seems to have been commonly held by European mathematicians, though often not explicitly mentioned — in contrast to the routine though doubtless sincere declaration 'In the name of God ...' at the head of an Arabic text.

CfrmN: Christianity playing a role in the *formation and development* of a mathematical theory cognitively, unlike the kind just described. We shall note a case in §13 involving continuity and infinity.

An very important type of this kind is where the (Christian) God is invoked to *guarantee* the truth, rigour and/or generality of at least one part or principle of a mathematical theory. Mechanics seems to have been the branch of mathematics most often involved, especially in connection with cosmology and physics.[12] While not claiming to establish existence as in kind MexgC, this kind goes further than the emulation of CemuM; however, analogies may be deployed, as we shall see in §12.

This kind is converse to MfrmC (though I have not noticed a case where mathematics was invoked as a guarantee for Christianity). The two kinds can occur together when, for example, a mathematical theory uses numbers which have already been given status in Christian numerology under MfrmC. Isaac Newton (1642/43-1727) seems to provide an example. He adhered to Arianism, a faith heterodox without being apocryphal, holding a seven-point creed which included a Trinity composed of Christ between God and man rather than the Orthodox Father, Son and Holy Ghost. Numerology is surely in place

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[12] For a selection of medieval examples of this type, see the texts in E. Grant (ed.), *A Source Book in Medieval Science,* Cambridge, Mass., 1974, esp. pp. 554-568.

here: the status of three was noted in MfrmC, and seven also has a very long numerological history, with massive Greek advocacy.[13] These integers have both cognitive and non-cognitive effects on his work. It is surely no accident that his *Principia* (1687) and his *Optics* (1704) were written in three Books, the latter also in seven Parts (and both, especially the *Principia,* organised Euclid-style into numbered definitions and propositions). Further and more importantly, the mechanics of his *Principia* is based upon three laws of mechanics, which he must have known were insufficient for the theory developed.[14] Similarly, in the *Optics* he advocated a spectrum of seven colours in the rainbow and in his rings, relating the colours to the main intervals in the musical scale,[15] and seeing also a connection with 'Apollo with the Lyre of seven strings'.[16] Maybe seven was chosen not only to challenge the sextet of colours asserted by René Descartes; indeed, he confessed himself that the extra colour, indigo, was hard to see, and even that 'my owne eyes are not very criticall in distinguishing the colours'![17] Again, his theory of the motions of the Moon, which was not based upon his mechanics, used a mathematical expression of seven terms.[18] This sensitivity to numerology is entirely in line with his deep involvement with alchemy.

5. Social and institutional influences of Christianity

CprsM: Christianity affecting the *prosecution or presentation* of mathematics but not its content. There are many examples of positive influence here, such as the structuring of a theory in a book or paper in some way which does not affect its content. Apparent examples in Newton's books were just noted; a similar one appears in §8. Another type of case is providing opportunities to develop mathematics at all; it also has a negative version,

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[13] In a series of important but forgotten writings of the 1900s in the *Philologisch-Historische Klasse* of the *Abhandlungen der Königlichen Sächsischen Akademie der Wissenschaften zu Leipzig*, W.H. Roscher surveyed this literature in great detail: see, for example, 'Die Sieben- und Neunzahl im Kultus und Mythus', *24* (1904), no. 1, 126 pp..

[14] See the discussion of Newton manuscripts in R.S. Westfall, *Force in Newton's Physics,* New York, 1971, ch. 8.

[15] See P. Gouk, 'The Harmonic Roots of Newtonian Science', in J. Fauvel and others (eds.), *Let Newton Be!*, Oxford, 1988, 99-125.

[16] Quoted from a manuscript in J.E. McGuire and P.M. Rattansi, 'Newton and the Pipes of Pan', *Notes and Records of the Royal Society of London, 21* (1966), 108-143 (p. 115); part in I.B. Cohen and R.S. Westfall (eds.), *Newton,* New York, 1995, 96-108 (p. 102).

[17] Newton to Henry Oldenburg, 7 December 1675, in *Correspondence,* vol. 1, Cambridge, 1959, 376.

[18] See N. Kollerstrom, *Newton's Lunar Theory, his Contribution to the Quest for Longitude,* Santa Fe (New Mexico), 2000.

of preventing its prosecution. Other negative cases include European Christian resistance in the High Middle Ages to study the pagan Greeks, in any domain of knowledge; in Europe it was gradually overcome, but in Russia the opposition of the Orthodox Church to all sciences was very strong until Peter the Great founded his Academy of Sciences in Saint Petersburg in the 1720s, with the young Daniel Bernoulli (1700-1782) and Leonhard Euler (1707-1783) from Switzerland among the early members. An example from the 19th century is recorded in §14.

CtskM: Assignment of a *task* or a problem by a religion requiring mathematics for its fulfilment or solution.[19] A well-known Christian example was the construction of calendars, especially for determining Easter.[20] Indeed, the omission of zero from the year numbering when it was established in the +6th century exemplifies kind MfrmC, in that it seems to have been motivated by misidentifying zero with nothing. Concerning artefacts, perspective and design were encouraged in Western painting (where purely artistic stimuli were also significant), and mechanics by the construction of churches and especially cathedrals.[21] Among other types of case is the medieval concern with the possibility of angels flying with infinite speed (although contemporaries such as Nicole Oresme (1323?-1382) urged that science and religion be separated), and then efforts to Christianise the ancient doctrines of the 'music' (better, 'harmony') of the spheres,[22] which is based upon properties of ratios. An unusual later example is the attempt made by John Craige (d. 1731)

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[19] A curious example is the corroborated predictions of the Hebrew Bible described in M. Drosnin, *The Bible Code,* London, 1997. The absence of vowels in Hebrew must increase the chances of coincidences.

[20] L.B. Francoeur, *Théorie du calendrier et collection des lois des calendriers des années passées et futures,* Paris, 1842, gives a detailed catalogue of the main properties of the Jewish, Gregorian and modern calendars, and rules for their determination.

[21] Notable recent literature on these topics includes J.V. Field, *The Invention of Infinity. Mathematics and Art in the Renaissance,* Oxford, 1997; P. Radelet-De Grave and E. Benevuto (eds.), *Entre mécanique et architecture,* Basel, 1995; and J. Sakarovitch, *Epures d'architecture. Théorisation d'une pratique, pratique d'une théorie,* Basel, 1998. There are also various relevant articles in I. Grattan-Guinness (ed.), *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences,* 2 vols., London, 1994, esp. in pts. 1-2 and 13.

[22] These and related topics are well reviewed in E. Knobloch, 'Harmonie und Kosmos: Mathematik im Dienst eines teleologischen Weltverständnisses', *Sudhoffs Archiv, 78* (1994), 19-40. They are now under detailed examination by O. Abdounur (University of Sao Paolo, Brazil).

in 1699 to determine the decline in the level of belief due to its successive transmission among adherents.[23]

Similar cases can be found on other religions; an important one in Islam was calculating the *qibla* angle at a given location for a worshipper correctly to face Mecca.[24] Religion is a *necessary* source in this kind; for example, without Christianity there is no Easter to determine. They differ from cases in kind MfrmC where, say, the fish bladder property (§2) pertains in geometry independently of any religion. Maybe some religious position *stimulated* the interest discovery of such a theorem or property in the first place, though since most come from deep antiquity and/or secret(ive) contexts, historical evidence is very hard to find.

PART TWO: EVIDENCE AND CASES, 1750-1900S

We come now to written manifestations of these kinds between 1750 and the early 20th century; nuances appropriate to each context will be made. As mentioned in §1, the cases are very rare, and moreover few of them influenced later ones; but they include negative as well as positive influence (that is, reactions against a link as well as those in favour), come from both pure and applied mathematics, and involve both mathematical theories as such and individual mathematicians. They have been organised by a mixture of chronology and kinship of theme.

6. A turning point? Newton, Lagrange, and the stability of the planetary system

As is well known, one feature of the so-called 'Scientific Revolution' during the 17th century was the attempts to separate science and religion (as already with Oresme). Many scientists and theologians followed the dictum, including after 1750; thus much of the later silence can be explained. However, disputes over geology and mineralogy from the late 18th century onwards, and then the rise of Darwinism in the 19th century, show that the separation was impossible to maintain, neither concerning explanations of phenomena nor the susceptibility of theories to religious interpretation.[25] Further, some students of the physical sciences did not obey the dictum; let us consider one of the most eminent.

An important case of influence of Christianity upon Newton's conception of mechanics concerns the stability of the 'System of the World'. It did not seem to be provable from Newton's laws; the basic path of a planet P was determined by the central force from the Sun, but the perturbations off it caused by the forces coming from other

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[23] R. Nash, *John Craige's Mathematical Principles of Christian Theology*, Carbondale, Ill., 1991, with an English translation of the original Latin text.

[24] For a review of this topic, see D.A. King, 'Mathematics Applied to Aspects of Religious Ritual in Islam', in Grattan-Guinness (note 21), 80-84.

[25] For a good survey of these tensions, see Brooke (note 2), esp. ch. 3.

planets could be large enough either to send P elsewhere in the ecliptic or to give it a quite different inclination. The accidental nearby passage of a comet might produce similar effects.

For Newton these possibilities did not cause qualms: God would arrive to restore equilibrium should danger attend P, and hence God exists, CfrmM-style.[26] (This argument might be convertible into a proof of the existence of God of kind MexgC, though for Newton and many others that was already assured.) Indeed, it was thanks to the 'Divine Arm' that the planets moved the same way around the Sun, and in nearly circular orbits.

Similarly, as a good Christian 'sav[ing] divine revelation from the objections of freethinkers', Euler would have held the same view of stability;[27] he implied as much in his philosophical 'Letters to a German Princess' (1768) when seeing 'perfections of the highest degree' in the organisation of the planetary system.[28] However, he also provided the mathematical means to articulate an alternative, secular, position.

Perturbation theory was technically a very cumbersome affair, since inverse powers of distances in various directions and angular orientations have to be taken together (and vectorial mathematics had not yet been invented). In order to make feasible both this and some other problems in celestial mechanics, Euler realised during the 1740s that if the distances were expressed in polar co-ordinates, then the sum of their appropriate powers could be rendered as power series of the angles pertaining to P and the other planets, and thence via Cotes-type theorems as a trigonometric series in multiples of these angles (the form $\sum_r a_r \cos rx$).[29] In the mid 1770s Joseph-Louis Lagrange (1736-1813) adapted this approach by replacing the angles with new independent variables which allowed him cast into an anti-symmetric form the system of equations of motion, stated according to

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[26] See D. Kubrin, 'Newton and the Cyclical Cosmos: Providence and the Mechanical Philosophy', *Journal of the History of Ideas*, *28* (1967), 325-346; repr. in Cohen and Westfall (note 16), 281-296. I do not (need to) consider other aspects of Newton's religious position in this paper; a good survey, with further references, is provided in C.S. Snobelen, 'Isaac Newton, Heretic: the Strategies of a Nicodemite', *British Journal for the History of Science, 32* (1999), 381-419.

[27] I quote from the title of [L. Euler], *Rettung der göttlichen Offenbarung gegen die Einwürfe der Freygeister,* Berlin, 1747; repr. in *Opera omnia,* ser. 3, vol. 12, Zurich, 1960, 267-286.

[28] See especially Letters 60-61 of L. Euler, *Lettres à une Princesse d'Allemagne sur divers sujets de physique et de philosophie,* vol. 2, Saint Petersburg, 1768; repr. as *Opera omnia,* ser. 3, vol. 11, Zurich, 1960. Many other reprs., eds. and transs. are listed on pp. lxi-lxx.

[29] See C.A. Wilson, 'Perturbation and Solar Tables from Lacaille to Delambre', *Archive for History of Exact Sciences, 22* (1980), 53-188, 189-304. These series are not to be confused with Fourier series.

Newton's second law. Then, assuming also that the planets moved in the same direction around the Sun, he reduced the stability problem for P to a form which, in terms of matrix theory which this work was to help to create later, required proof that all the latent roots of a certain matrix associated with the coefficients of the expansion for P were real numbers, and that their attached latent roots took only real-valued components. He formulated this method for a collection of mass-points in general; P.S. Laplace (1749-1827) modified it more specifically for the planetary system.[30]

This analysis still left unresolved a related question: the *locations* of the orbits. A striking presage of the later paucity is evident in Newton: in the first edition of the *Principia* he declared that God had chosen the locations,[31] but he withdrew this *sole* explicit mention of God from the later editions, and the 'Bode-Titius Law' was an *empirical* proposal of the 1770s.

7. God and non-Newtonian mechanics in the 19th century

While Newton's laws soon became the principal means of working in celestial mechanics, they did not enjoy the same prestige within mechanics in general, especially on the Continent where most major developments occurred after 1750. An alternative theory stressing energy had gained ground, not least through the advocacy of *vis viva* in the 1690s by Leibniz; and from the 1740s a third line came through Jean d'Alembert (1717-1783), with a principle named after him which claimed to reduce dynamical situations to statical ones.[32]

In addition, at that time the principle of least action was expounded by Pierre Maupertuis (1698-1759) and Euler.[33] It asserted that in a mechanical situation the 'action' integral $\int_U m\,v\,ds$ of a system of masses m moving at velocity v along the path s over

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[30] For a summary with context, see esp. I. Grattan-Guinness, *Convolutions in French Mathematics, 1800-1840. From the Calculus and Mechanics to Mathematical Analysis and Mathematical Physics*, 3 vols., Basel and Berlin, 1990, 324-329. Matrices are used here for brevity; Lagrange and Laplace worked on the quadratic and bilinear forms associated with the matrix. On this and the later history of the problem, see T.W. Hawkins, 'Cauchy and the Spectral Theory of Matrices', *Historia Mathematica, 2* (1975), 1-29.

[31] See *Principia,* 1st ed. (1687), Book 3, prop. 8, cor. 5. For discussion, see I.B. Cohen, 'The review of the First Edition of the *Principia* …', in P.M. Harman and A.E. Shapiro (eds.), *The Investigation of Difficult Things,* Cambridge, 1992, 323-353.

[32] On these three traditions, see I. Grattan-Guinness, 'The Varieties of Mechanics by 1800', *Historia Mathematica, 17* (1990), 313-338.

[33] For a good discussion preceding a reprint of many of the main texts, see J.O. Fleckenstein, 'Vorwort des Herausgebers', in Euler *Opera omnia*, ser. 2, vol. 5, Zurich, 1957, vii-l.

some curve U was minimal relative to all possible curves.[34] To the discomfort of others, the principle gave mechanics approach a strongly teleological character, in that the path of least action seemed to be predetermined. Perhaps for that reason, Maupertuis asserted, as a 'metaphysical' principle, that God was the guarantee of the principle — a "proof" CfrmM-style of both its truth and its generality. Euler defended 'notre Ill. Président' of the Berlin Academy, although he relied more on mathematical concerns and on authorities such as Leibniz in advocating the principle. But in some of his later contributions to mechanics, such as the basic equations of elasticity theory and of hydrodynamics, he made no use of the principle; for he was finding *new* equations, a task for which teleological theories are usually ill suited.

The principal mathematician in the development of this kind of mechanics during the 18th century into the 'variational' or 'analytical' tradition was Lagrange.[35] However, as with the stability problem, he made no appeal to Christianity for the generality or truth of d'Alembert's or the least action principles, or of the principle of 'virtual velocities' which he adopted later.[36] This trait not only characterises Lagrange's mathematics but also locates part of his influence: he wished to secularise mechanics, and indeed mathematics in general. In his lifetime he was called an atheist, although I suspect that if Thomas Huxley's word 'agnostic' had been available at the time, it would have been more appropriate.[37]

The same judgement applies to Laplace; his famous attributed remark to Napoleon in the early 1800s about not needing the hypothesis of the existence of God in his astronomical theories conforms to agnosticism, although he may have phrased himself thus in order to accommodate the official atheism of his audience.[38] Both then and later he spoke of successful theories as 'exact', not true.[39]

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[34] See H. Pulte, *Das Prinzip der kleinsten Wirkung und die Kraftkonzeptionen der rationellen Mechanik*, Stuttgart, 1990.

[35] See C. Fraser, 'J.L. Lagrange's Early Contributions to the Principles and Methods of Mechanics', *Archive for History of Exact Sciences, 28* (1983), 197-241.

[36] The context, with further references, are explained in Grattan-Guinness (note 30), chs. 5-6.

[37] Note the little-known deathbed conversations of Lagrange reported in I. Grattan-Guinness, 'A Paris Curiosity, 1814: Delambre's Obituary of Lagrange, and its "Supplement"', in M. Folkerts and U. Lindgren (eds.), *Mathemata. Festschrift für Helmuth Gericke*, Munich, 1985, 493-510; also in C. Mangione (ed.), *Scienza e filosofia. Saggi in onore di Ludovico Geymonat*, Milan, 1985, 664-677.

[38] I have not found an authoritative source for Laplace's remark, but the story is quite credible; some short undated manuscripts rather sceptically appraising Christianity are conserved in his *dossier personnel* in the *Académie des Sciences*. On the context see R.

Striking national differences attend these developments of mechanics, mostly in connection with kind CfrmM (especially guarantee). In Britain, Newton's influence had given celestial mechanics a religious flavour absent from Continental versions; there Newtonian mechanics was less warmly received, with central forces accepted but the inverse square law treated circumspectly.[40] By contrast, the preference of Newtonian mechanics in Britain gave small place to least action, and thus to the invocation of God. However, as we shall see in §9 and §10, British applied mathematicians were to contribute much of the modest interest in roles for Christianity in the 19th century.

8. Cauchy against the secularisation of mathematics

By the 1780s France was by far the leading mathematical country, with Lagrange (who moved to Paris from Berlin in 1787) and Laplace among the senior figures. One of the main cultural features of its science is the virtual absence of religious talk, *especially* in spectacular problems such as the stability of the planetary system. The earlier efforts of the French Enlightenment to reduce the status of Christianity are well-known;[41] Voltaire's satire of Leibniz in *Candide* (1758) wonderfully encapsulates changes in attitude. The French Revolution of 1789 heightened the status of France still further, especially with the many new and existing institutions for higher education maintained in science and engineering. The Church was sidelined until Napoléon's opportunistic reversion to Catholicism in 1806; but the secular presentation and development of mathematics was not

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Hahn, 'Laplace and the Deterministic Universe', in D.C. Lindberg and R.L. Numbers (eds.), *God and Nature,* Berkeley and Los Angeles, 1986, 256-276.

[39] See C.C. Gillispie, *Pierre Simon Laplace. A Life in Exact Science,* 1998, Princeton, esp. chs. 24-26.

[40] See N. Guicciardini, *Reading the Principia: the Debate on Newton's Mathematical Methods for Natural Philosophy from 1687 to 1736,* Cambridge, 1999.

[41] A significant factor may lie in Freemasonry, which enjoyed world-wide influence at that time (for example, in the founding of the USA). Partly because of its obsession with secrecy and much loss of documentation, its historical place is poorly understood; for an important pioneering attempt using archives of various secret societies, see M. Jacob, *Living the Enlightenment,* Oxford, 1991. The links between mathematics and faith are clear in the study of perspective theory by Brother Brook Taylor (1685-1731), and later the descriptive geometry of Brother Gaspard Monge (1746-1818), where stone-cutting was one of his favourite applications. Otherwise, however, the effect of Masonhood upon the work of a scientist may be hard to specify; for example, I have not noticed any particular consequences for Brother Laplace (1749-1827).

affected, not even after the Bourbon Restoration of 1816, when King and Church were at centre stage.[42]

However, then there flowered an extraordinary counter-exception. A.-L. Cauchy (1789-1857) was born in the year of the French Revolution; but he became one of its most passionate opponents, affirming Catholicism to a fanatical degree and adhering ardently to the Bourbons from their restoration. Their reign from 1816 to 1830 corresponds exactly to a phenomenal amount of brilliant mathematics from him.[43] His most substantial achievements during that period included a reformulation of mathematical analysis and the calculus based upon limits, which came eventually to dominate over all other approaches; the invention of the calculus of complex variables and their integrals; and the basic theory of linear stress-strain elasticity theory, with applications to optics. He produced work which fills about 12 of the 27 quarto volumes of his (almost complete) collected works, and most of the best items. They include five textbooks, several pamphlets, and such a production of papers that in 1826 he even started his own journal, *Exercices de mathématiques,* and managed to produce 32 pages per month until near the end of the decade. Then the Revolution of July 1830 threw out the Bourbons; so he followed them into exile for eight years, serving as mathematical tutor to their pretender to the throne.

Cauchy the mathematician, Cauchy the royalist and Cauchy the Catholic were united to an extraordinary degree: truths in heaven and truth in applied mathematics (a mixture of kinds CtgtM and MemuC); and order in society and order in mathematics, to which alter he consciously brought new standards of rigour, even pioneering the systematic numbering of formulae in papers and books. He presented his version of the real-variable calculus in his *Résumé* of the course given at the *Ecole Polytechnique* in the important Christian number of 40 lectures, 20 each on the differential and on the integral calculus; in practice, he gave at least 50 lectures each year.[44] One of his theories concerned continuity,

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[42] For a detailed account of much French mathematics between 1800 and the 1840s see Grattan-Guinness (note 30).

[43] See B. Belhoste, *Augustin-Louis Cauchy. A Biography,* New York, 1991, esp. chs. 8-11.

[44] A.L. Cauchy, *Résumé des leçons données à l'Ecole Polytechnique sur le calcul infinitésimal,* Paris, 1823. Furthermore, each lecture was printed right to the bottom line of the fourth page of the signature (see Grattan-Guinness (note 30), 747-749), and moreover as a presentation of a theory based upon limits; this feature is lost in the reprint in the *Oeuvres complètes,* ser. 2, vol. 4, Paris, 1899. The actual numbers of lectures given by Cauchy, recorded in the archives of the *Ecole Polytechnique,* are given in my book just cited.

where his stress on an unbreakable sequence of values or states followed a Jesuit formulation as presented by predecessors such as Ruggiero Boscovich, S.J. (1711-1787).[45]

Cauchy's activities during exile included a strange lecture course in Turin on physics, which included passages on man and God.[46] After his return to Paris in 1838 he participated in organisations concerned with Catholic education, and refused to take oaths to the ruling authority.[47] His treatment of mathematical analysis was presented in textbooks from the 1840s by F.N.M. Moigno (1804-1884); but this Abbot avoided Christian overtones even when describing continuity or infinitesimals.[48] However, after Cauchy's death he also published the lecture course on physics.[49]

While Cauchy's Catholicism seems to have impinged cognitively on only a few aspects of his scientific work (CfrmM), it inspired his desire to raise the level of rigour in mathematics (CemuM), and also to see applications to the physical world as asserting truths about it rather than merely proposing hypotheses (CtgtM). Another effect of Catholicism *on* him was negative: he chastised his colleagues in the *Académie des Sciences* for studying natural history and biology, for their objects of study were God's work alone![50]

9. Whewell and the status of mechanics

Unlike Cauchy, applied mathematicians in the 19th century not only usually avoided appealing to Christianity but also more often spoke of hypotheses in their theorising. Especially from the 1840s, the certainties of Christianity became more out of reach, with alternatives to established Catholicism and Protestantism flourishing.

In this context William Whewell (1794-1866) is an intriguing British figure. As mathematician, scientist (his word), and orthodox Christian, with a lifelong career at Trinity

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[45] See U. Baldini, 'Boscovich e la tradizione gesuitica in filosofia naturale: continuità e cambiamento', in P. Bursill-Hall (ed.), *R.J. Boscovich. His Life and Scientific Work*, Rome, 1993, 81-132. While Boscovich doubtless subscribed to the CtgtM link, he does not seem to have used Christianity cognitively in his scientific writings. The same holds also for the mathematical and logical work of the Catholic priest Bernhard Bolzano (1781-1848).

[46] A.-L. Cauchy, *Sept leçons de physique générale …,* Paris, 1868, repr. 1885; also in Cauchy, *Oeuvres complètes,* ser. 2, vol. 15, Paris, 1974, 412-447.

[47] See the revealing hagiography in C.-A. Valson, *La vie et les travaux du Baron Cauchy,* vol. 1, Paris, 1868, repr. Paris, 1970, chs. 13-16.

[48] F.N.M. Moigno, *Leçons de calcul différentiel et de calcul intégral,* vol. 1, Paris, 1840; see esp. his introduction and lectures 1 and 6.

[49] Cauchy (note 46).

[50] See Belhoste (note 43), esp. chs. 8-11; and Valson (note 47), vol. 1, chs. 12-16. Cauchy also expressed his Christian fervour in poetry, some of which is transcribed in Valson, ch. 11.

(*sic*) College Cambridge, he affirmed and indeed extended the principles of natural theology, a doctrine of medieval origin where Christianity absorbed aspects of Platonism and Aristotelianism to reveal (the existence of) God through the study of nature. He pursued this position as an alternative to the growingly popular secular utilitarianism of his day. Especially concerning mathematics, his aim was not only epistemological but also pedagogic: the 'liberal education' (his phrase) provided by Cambridge University, in particular the Mathematical Tripos, was for the benefit of its students.

As a philosopher Whewell admitted roles for both empiricism and ratiocination, and studied the relationship between contingent and necessary truths. Mathematics was a prime ground for his exegesis, especially mechanics, and he adopted kind CemuM in seeking to demonstrate the truth of mathematical theories in emulation of Christian truths. Mathematics then launched a ladder of certainty up through the physical sciences (especially astronomy) to the natural sciences, and even further to consider man's place in nature and 'come to believe in God and the Governour of the moral word' through the use of 'Reason or Revelation'.[51]

In applying celestial mechanics to natural theology, Whewell hoped to convince, MexgC style, that the intricacy of the mechanism of the heavens exhibited the existence of a designing God. Curiously, while duly stressing the teleological aspects of natural theology he preferred to use Newton's laws rather than the more congenial principle of least action (§7); presumably Trinity College associations took prime place!

Whewell's use of kind CemuM shows that for him Christianity was pre-eminent: while science could inspire questions, the answers lay only in Christian revealed truth; thus kind CtgtM was also in play. Perhaps this was the reason for his surprising silence over the

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[51] A typical phrase from Whewell's Bridgwater Treatise on *Astronomy and General Physics, Considered With Reference to Natural Theology,* London, 1833, 252. Among many publications by him on mechanics, see especially *The Mechanical Euclid,* Cambridge, 1837; and 'On the Nature of the Truth of Laws of Motion', *Transactions of the Cambridge Philosophical Society, 5* (1835), 149-172, repr. in R.E. Butts (ed.), *William Whewell's Theory of Scientific Method,* Pittsburgh, 1968, 79-100, where some other relevant texts are included. From his massive *History* and *Philosophy* of the inductive sciences he distilled the passages most pertinent to natural theology in his *Indications of the Creator*, London, 1846. On Whewell see H. Becher, 'William Whewell and Cambridge Mathematics', *Historical Studies in the Physical Sciences, 11* (1980), 3-48; and M. Fisch and S. Schaffer (eds.), *William Whewell*, Oxford, 1991, especially the articles by Becher, Fisch, J.H. Brooke, P. Williams and D.B. Wilson.

During the century natural theology became an umbrella position; the internal differences lay more in the natural than the physical sciences (see P. Corsi, *Science and Religion. Baden Powell and the Anglican Debate, 1800-1860,* Cambridge, 1988, ch.15).

role of mathematics in Christian architectural design (§2): his *Architectural Notes on German Churches* (1835) is notable both for his detailed knowledge of architecture and *lack* of concern with the religious significance of geometrical designs, of which he must have been aware.

Whewell granted two levels of utility for mathematics: training the (student's) mind 'liberal' style; and more elevated tasks such as studying God's 'Forces' and 'Laws of force' involved in the motions of the heavenly bodies, as 'discovered by Newton'. The quotations come from Whewell's colleague Thomas Worsley, Master of Downing College, when considering in 1865 the Christian element in Cambridge education; while not citing Whewell, his position was very similar.[52]

One of the very few students of mechanics who *explicitly* advocated similar links was the American Benjamin Peirce (1809-1880), a major figure in a country which was then still of little importance in mathematics. In affirming his belief, he saw mathematical theories as products of the Divine Mind (CtgtM); but even he rarely put his view in print. One example occurs in a 500-page textbook of 1855 on mechanics: a very short passage on the theme that the occurrence of perpetual motion in nature 'would have proved destructive to human belief, in the spiritual origin of force and the necessity of a First Cause superior to matter, and would have subjected the grand plans of Divine benevolence to the will and caprice of man'.[53] Even here only the rhetoric of CtgtM was involved, and maybe in a general Deist sense; nowhere did he invoke any cognitive relations.

Peirce's most explicit religious assertions occurred in a posthumous work on 'ideality in the physical sciences', where the first word connoted 'ideal-ism' as evident in certain knowledge. However, even though it was 'pre-eminently the foundation of the mathematics', he concentrated almost entirely upon cosmology and cosmogony with some geology; even types of mechanical equilibrium were not discussed.[54]

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[52] T. Worsley, *Christian Drift of Cambridge Work,* London and Cambridge, 1865, 75: he also hinted at the stability problem on p. 136. In ch. 2 he treated mathematics, and in chs. 3 and 4 the 'cosmical symbol'.

[53] B. Peirce, *Physical and Celestial Mathematics,* Boston, 1855, 31. The book was based upon the Lowell Lectures given at Harvard University in 1879. The American enthusiasm at that time for Protestantism in the sciences is excellently conveyed in H. Schweber, 'Law and the Natural Sciences in Nineteenth-Century American Universities', *Science in Context, 12* (1999), 101-121.

[54] B. Peirce, *Ideality in the Physical Sciences* (ed. J.M. Peirce), Boston, 1881; quotation from p. 165. He was more guarded here on the authority of the Bible than in his earlier writings; for discussion see S. R. Peterson, 'Benjamin Peirce: Mathematician and Philosopher', *Journal of the History of Ideas*, *16* (1955), 89-112 (with some inaccurate page citations).

10. Aethers and mathematical physics

One general connection from earlier times did endure throughout the late 18th and 19th centuries, though forged more closely with physics than with mathematics. In electricity and magnetism (and, after 1820, in their interactions), theories were still often based upon assuming the existence of the aether; and for some figures this ubiquity pantheistically showed God at work.[55] Cauchy affirmed this position at the end of his physics lectures of 1833 (§8). In Scotland Thomson also assumed the existence of the aether, but seemed not to give it any religious connotation. But an allusion occurred in an essay of 1852 'On a universal tendency in Nature to the dissipation of mechanical energy', when he asserted that 'it is most certain that Creative Power alone can either call into existence or annihilate mechanical energy';[56] however, he left more developed considerations only in draft.[57] With P.G. Tait (1831-1901) he published a *Treatise on Natural Philosophy* (editions of 1873 and 1879), very comprehensive in its range and especially concerned with energy; but no links to Christianity of any kind was mentioned.

Similarly, G.G. Stokes (1819-1903), friend of Thomson and Whewell, kept secular his many contributions to mathematical physics, even in aether theory. However, he was much concerned with the status of Christianity; largely following Evangelical principles, he claimed authority for the Bible. In the early 1890s he delivered two series of Gifford lectures on natural theology, but *no* kind of link to mathematics was analysed: he touched on Trinitarianism twice (MfrmC) but slid quickly away.[58] His main argument for the existence of God was that of design, such as that of the eye (an example sometimes put

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[55] On this general theme, see G. Cantor and M.J.S. Hodge (eds.), *Conceptions of Ether. Studies in the History of Ether Theories 1740-1900,* Cambridge, 1981, especially the articles by J.Z. Buchwald, D.M. Siegel and M.N. Wise. The important case of A.M. Ampère is convincingly argued by K. Caneva in 'Ampère, the Etherians, and the Oersted Connexion', *British Journal for the History of Science, 13* (1980), 121-138; Cauchy also followed it in optics, as had Ampère's lodger A.J. Fresnel (see Grattan-Guinness (note 30), ch. 13 and pp. 1036-1040).

[56] Lord Kelvin, *Mathematical and Physical Papers,* vol. 1, Cambridge, 1882, 511.

[57] See C. Smith and N. Wise, *Energy and Empire. A Biography of Lord Kelvin,* Cambridge, 1989, 329-332.

[58] G.G. Stokes, *Natural Theology,* 2 vols., London and Edinburgh, 1891-1893; vol. 1, 164 ('threefold aspect of the Divine body'), vol. 2, 225 (the Trinity). Stokes records several times his Evangelist disquiet over Lord Gifford's stipulation that revelation not be considered by the lecturer; but this cannot have determined his silence over mathematics. For discussion, see D.B. Wilson, 'A Physicist's Alternative to Materialism: the Religious Thought of George Gabriel Stokes', *Victorian Studies, 6* (1971-72), 69-86.

forward nowadays as evidence of *bad* design!). His appeal to the infinite was unusual: he opposed the doctrine of eternal punishment (normally affirmed by Evangelists) but defended conditional immortality.

Whewell, Thomson and Stokes were graduates from Cambridge University, where the status of the Mathematics Tripos was strange from our point of view: a major course in an Established institution, with mechanics and some mathematical physics given major roles, nevertheless links to Christianity were rarely mentioned. But an exception occurred when James Challis (1803-1882), the Plumian Professor of Astronomy and Experimental Philosophy, meditated at the end of his career upon 'Cambridge mathematical studies, and their relation to modern physical sciences' (1875). His stimulus was the anonymous book on the *Unseen Universe* (1875) published by Tait and Balfour Stewart (1828-1887), in which they tried to reconcile sciences (especially the physical ones) with Christianity.[59] Challis did not object to their enterprise as such, but he faulted their failure to regard notions such as atom and inertia as absolutes; for him they 'must be conceived to have been originally imposed, and to be maintained, together with constancy of form and magnitude by the will and power of the *Creator of the Universe* ' — the kind CfrmM of link that Thomson had kept mostly in draft. He agreed with his opponents about the existence of the aether, for example that its pressure was the source of force; but he complained about their construal of forces, and also atoms, in terms of continuity (the principal notion in their argument), again preferring 'the immediate will' of the Creator.[60]

The link of science via aethers continued until the early 20th century, partly connected to efforts to reconcile science and Christianity through spiritualism.[61] However, E.T. Whittaker (1873-1956) omitted all manifestations from his *History of the Theories of Aether and Electricity* (editions of 1911 and 1951) — a very striking silence in itself, for he was not only a fine mathematician but also a fervent Christian who wrote at length on religious issues, without however invoking mathematics in any particular way.[62]

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[59] See P.M. Heimann, 'The *Unseen Universe* : Physics and the Philosophy of Nature in Victorian Britain', *British Journal for the History of Science, 6* (1972), 73-79; and C. Smith, *The Science of Energy,* London, 1998, 247-260 (Thomson and Maxwell noted also).

[60] J. Challis, *Cambridge Mathematical Studies, and Their Relation to Modern Physical Sciences,* Cambridge, 1875, 76, 82. On his mathematical work, of moderate significance, see H.F.K.L. Burkhardt, 'Entwicklungen nach oscillirenden Functionen und Integration der Differentialgleichungen der mathematischen Physik', *Jahresbericht der Deutschen Mathematiker-Vereinigung, 10* (1908), pt. 2, 1056-1107.

[61] See F.M. Turner, *Between Science and Religion,* 1974, New Haven.

[62] See Whittaker (note 7) on kind MexgC (proving existence); and *The Beginning and the End of the World* (London, 1942), largely CfrmM (especially guarantee) since science could not account for creation. Sadly, there is no major study of any aspect of his work.

11. The place of probabilities and statistics

The influence of the Enlightenment upon mathematics was most evident in probability theory, especially in dominating France. But the developments after 1750 did *not* buttress Christian belief; on the contrary, discussion of the probability of miracles decreased greatly after 1750.[63] An important application was to determine the reliability of belief (as formed by judges in tribunals, for example) using reason alone. A major probabilist of that time was the Marquis de Condorcet (1743-1798); he doubted the merits of the interpretation of probability as a measure of belief, and sought for it a more empirical basis.[64]

Probability theory continued to develop in the 19th century, though rather fitfully and with more opposition to its utility in the social sciences than had obtained during the Enlightenment period. Further, although a frequent argument for the truths of Christianity was the high likelihood of a Designer, redolent of kind CtgtM but not MexgC, probability *theory* does *not* seem to have been invoked to elaborate or quantify the reasoning. The Irish writer James Wills (1790-1868) even sought in 1860 the ‘antecedent probability’ of Christianity, and found it to be ‘the highest existing probability, the only solution of the known sum of things’; in particular it was ‘very high’ that the Creator must have had a distinct purpose or final end in view’, with the ‘human race’ as the ‘main object’.[65] However, he proffered no mathematical arguments, Bayesian or otherwise.[66] Similarly, while evolution theory contained elements of statistical *thinking* (for example, in the notion of variation), no mathematical *theory* seems to have been involved in discussing its conflict or reconciliation with Christianity.[67]

A noteworthy link between probability theory and Christianity was of kind CtskM. In a converse to Craige on the decline of belief (§5), in 1872 Francis Galton (1822-1911)

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[63] See L. Daston, *Classical Probability in the Enlightenment,* Princeton, 1988, 306-342.

[64] See Daston *ibidem,* 211-219; and K.M. Baker, *Condorcet: from Natural Philosophy to Social Mathematics,* Chicago, 1975, esp. chs. 3-4. Condorcet discussed ‘la persistance de l’âme’ only in an undated manuscript published in *Arithmétique politique. Textes rares ou inédits (1767-1789)* (ed. B. Bru and P. Crépel), Paris, 1994, 316-326.

[65] J. Wills, *An Estimate of the Antecedent Probability of the Christian Religion, and of its Main Doctrines, in Six Sermons ...; Being the Donnellan Lectures for 1858*, Dublin, 1860; quotations from pp. 163 and 39.

[66] The general histories of 19th-century probability theory of which I am aware do not discuss links with religions at all; but this may reflect a lack of concern by the historians themselves.

[67] Among the available literature, I am guided for Britain by J.R. Moore, *The Post-Darwinian Controversies,* Cambridge, 1979, esp. ch. 9.

attempted to detect the efficacy of concerted prayer by comparing data from target and control groups of appropriate persons from 'the praying and non-praying classes'.[68]

Various of Galton's reflections upon statistics and its data were noted by a distinguished probabilist, John Venn (1832-1923), in his *The Logic of Chance,* which appeared in editions between 1866 and 1888. But Venn did not include the prayer experiment; indeed, the most explicit connection made between Christianity and probability theory was to *reject* CtgtM-style the 'old Theological objection' that admission of chance denied the Creator overall control. Again, Christian texts were not cited in the chapters on testimony and on the 'Credibility of extraordinary stories'.[69] Yet he was a fervent believer; soon after the publication of the first edition of this book he gave the Hulsean lectures on divinity at Cambridge, choosing as his topic 'some characteristics of belief'. Again probability theory played only a passing role, and his main concerns lay in the complications of the historical evidence and the vagaries of emotion.[70]

Venn's other main research interest lay in logic, to which we now turn. England again is very prominent.

12. Boole and the ecumenism of the algebra of logic

The secular status of probability theory is evident also in the contributions made to it by George Boole (1815-1864); and his case is especially striking because he *did* invoke his religious stance when developing logic. He formed an algebra to symbolise logical reasoning, in which he conceived of a universe of discourse 1 and split it into complementary parts x and $(1 - x)$. Part of his inspiration seems to have been his youthful awareness of Jewish Monism, and in his mature development of the theory he linked it to ecumenism, that is, a single unifying Christian doctrine affirmed over and above the x s and $(1 - x)$s of the numerous disputing brands. He held this position from exactly the time, the late 1830s and the 1840s, when the Dissenting faiths were rising very rapidly in prominence in Britain. It lay in tune with Unitarian truth, construed as an invariant relative to all means of human examination, which gained considerable popularity at this time. It furnished further links via logic to truth; for example, he invoked his universe again in writing 'A=1',

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[68] F. Galton, 'Statistical Inquiries into the Efficacy of Prayer', *Fortnightly Review, n.s. 12* (1872), 125-135; repr. in *Inquiries into Human Faculty and its Development,* 1st ed., London, 1883, 277-294.

[69] J. Venn, *The Logic of Chance,* London, 1st ed.1866, 2nd ed. 1876, 3rd ed. 1888 (repr. New York, 1962), 236-238 on objection (note also p. 260 on the Creator and the distribution of stars) and chs. 16 and 17.

[70] J. Venn, *Some Characteristics of Belief Scientific and Religous,* London and Cambridge, 1880; note (only) the appendix on Pascal's interest in probability theory and the impossibility of proving the existence of God by reason alone (pp. 115-126).

which asserted that the proposition A is true for all time.[71] Thus he exemplified kind MemuC in the analogy between ecumenism and his logical universe; and if the Jewish influence was formative, he also exhibits kind CtgtM (guarantee).

In his later years Boole became very enthusiastic for the presentation of logic by the French theologian A.J.A. Gratry (1805-1872), who stressed claims such as God as the source of truth (kind CfrmM), and topics such as nullity versus unity, universal laws of thought, and the exercise of the human mind.[72] In the late 1850s he and his wife became profound admirers of Frederick Denison Maurice (1805-1872), who in 1853 had been dismissed from his post as professor of Divinity at King's College London for advocating ecumenist instead of party-line Trinitarian Christianity; Boole had Maurice's portrait placed by his death-bed.

However, as usual with our figures Boole rarely mentioned religion in his writings; in particular, he did not analyse the mind itself as a product of God's creation, and his logic was concerned only with the products of thought, not with the processes of their formation. But in his *The Laws of Thought* (1854) he analysed passages from the writings of Samuel Clarke and Baruch Spinoza which surely did *not* just happen to deal with properties of the one and only God. Again, in his final paragraph he saw the 'juster conceptions of the unity, the vital connexion, and the subordination to a moral purpose, of the different parts of Truth, among those who […] profess an intellectual allegiance to the Father of Lights',[73] this phrase a code term for his kind of Dissenter to refer to the unifying Godhead.

This aspect of Boole's logic was not durable; his widow seems to have been its only follower.[74] Among the others, Venn did *not* adopt it in his strong advocacy of Boole's logic.[75] Indeed, in the strong revival of logic in Britain during the 19th century he seems to be the only significant figure using cognitive relations with Christianity. The founding work of the revival was the *Elements of Logic* by the Reverend Richard Whately (1787-1863)

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[71] On this theory of truth relative to mathematics, see J. Richards, *Mathematical Visions: the Pursuit of Geometry in Victorian England*, San Diego, 1988, esp. ch. 1. Earlier British concerns with truth in the context of algebra(s) are noted in Pycior (note 11), 11.

[72] See I. Grattan-Guinness, 'Psychology in the Foundations of Logic and Mathematics: the Cases of Boole, Cantor and Brouwer', *History and Philosophy of Logic, 3* (1982), 33-53; also in (no ed.), *Psicoanalisi e storia della scienza*, Florence, 1983, 93-121.

[73] G. Boole, *An Investigation of the Laws of Thought*, Cambridge and London, 1854; repr. New York, 1958, ch. 13 and p. 424.

[74] See L.M. Laita, 'Boolean Algebra and its Extra-Logical Sources: the Testimony of Mary Everest Boole', *History and Philosophy of Logic, 1* (1980), 37-60. On manifestations of Christianity in Boole's (unpublished) poetry, see the examples and discussion in D. MacHale, *George Boole – his Life and Work*, Dublin, 1985, ch. 12.

[75] J. Venn, *Symbolic Logic,* London, 1st ed. 1881, 2nd ed. 1894 (repr. New York, 1970).

when it first appeared in book form, in 1826; it was in its fourth revised edition in 1832 (the year after he was appointed Archbishop of Dublin) and reached its ninth in 1848. But he drew upon Christianity only for a few Biblical passages for logical analysis; he never invoked God as the creator of the human mind itself and of its powers of reasoning, with which logic was then often taken to be closely linked.[76]

13. Cantor, the transfinites and the Creator

Boole invoked Christianity in a theory of a very foundational character. The same appeal was made by Georg Cantor (1845-1918), the principal creator of set theory, including a (for him, the) theory of the actual infinite. His 'Mengenlehre', as he came finally to name it, grew out of mathematical considerations; in fact, it was partly inspired by Cauchy (and, following him in Germany, Karl Weierstrass) using the theory of limits to increase the level of rigour in mathematical analysis (§8).

At first, in the early 1870s Cantor had called his transfinite numbers ∞, $\infty+1$, … 'infinite symbols' as he had no basis for these mathematical objects, especially concerning '…'. But in the early 1880s he found a grounding for his symbols to make them ordinal *numbers* 'ω, $\omega+1$, …', in a theory in which he also developed their arithmetic; and he became aware, and indeed deeply informed about, predecessors who had affirmed the actual infinite, often in a Christian context. Especially drawn to Giordano Bruno and (like Boole) to Spinoza, his metaphysical framework included a central Christian component;[77] for he saw his theory of the infinites as explicating and clarifying Christian doctrines of infinitude (kind MfrmC). The audience for this aspect of his theory increased after 1879, when Pope Leo XIII issued an encyclical requiring Catholics to pay much more attention to the development of science, and various philosophers and theologians of that persuasion corresponded with him.[78]

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[76] R. Whately, *Elements of Logic,* 1st ed., London, 1826; repr. with introduction by P. Dessì, Bologna, 1988. The book was based upon an article published in the *Encyclopaedia Metropolitana* in 1823, which did *not* gain much attention. On his work, see S. Neil, 'The Right Hon. and Most Rev. Richard Whately', *The British Controversialist and Literary Magazine, (3)17* (1862), 1-21; J. Van Evra, 'Richard Whately and the Rise of Modern Logic', *History and Philosophy of Logic, 5* (1984), 1-18; and Corsi (note 51), esp. chs. 7 and 14.

[77] See M.-L. Heuser-Kessler, 'Georg Cantors transfinite Zahlen und Giordano Brunos Unendlichkeitsidee', *Selbstorganisation, 2* (1991), 221-244; and F. Bandmann, *Die Unendlichkeit des Seins. Cantors transfinite Mengenlehre und ihre metaphysischen Wurzeln*, Frankfurt am Main, 1992, pt. 1.

[78] See J.W. Dauben, *Georg Cantor,* Cambridge, Mass. and London, 1979; repr. Princeton, 1990, esp. ch. 7.

Cantor refuted the common belief that the actual infinite was God's work, not man's. But he was also aware of a third kind of infinitude, the 'absolute infinite' of the supposedly greatest cardinal number G, and found that two paradoxes followed — both G=G but also G>G, and G>2^G but also G≤2^G. (The corresponding version of the first paradox also awaits the supposedly greatest ordinal number.) Cantor invoked Christianity (kind CfrmM) to avoid *this* kind of infinity: it 'appears to me in a certain sense as an appropriate symbol of the Absolute',[79] and if mankind played with it, so much the worse for them. By the late 1890s he had decided that Man should stick to 'ready' ('*fertig*') sets, for which it 'is possible that […] *all its members as being together* without contradiction, thus to think of the set itself as a *composed thing for itself*'.[80]

As with Boole, these aspects of Cantor's theory were not durable. However, they arose again in 1904 when Bertrand Russell (1872-1970) argued against the need for an axiom of infinity in set theory, on the grounds that infinite sets could be produced by deploying mathematical induction. He was replying the claim made by the American mathematician and Christian Cassius J. Keyser (1862-1947) that alleged proofs of the existence of such sets begged the question. Keyser had good mathematical points to make; but he saw the actual infinite as beyond human capacities and belonging to God's realm (kind CfrmM). His exchange with Russell occurred in *The Hibbert Journal,* a 'quarterly review of religion, theology and philosophy' (and deserving to be *far* better known by historians of science and of religion).[81] By 1906 Russell admitted that an axiom was needed after all, though as a fervent atheist he had changed his mind because of mathematical reasons similar to Keyser's handled without the theological overlay.[82]

Later in the decade Keyser described in the *Journal* many features of Cantor's theory in a (rambling) 'message of modern mathematics to theology', akin to MfrmC in

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79 G. Cantor, 'Über unendliche, lineare Punktmannichfaltigkeiten', pt. 5 (1883), in *Gesammelte Abhandlungen mathematischen und philosophischen Inhalts* (ed. E. Zermelo), Berlin, 1932; repr. Hildesheim 1966, 165-209 (p. 205).

80 For commentary see W. Purkert and H.-J. Ilgauds, *Georg Cantor,* Basel, 1987, 150-159, with letters on pp. 224-231 (quotation on p. 226).

81 C.J. Keyser, 'The Axiom of Infinity: a New Supposition of Thought', *The Hibbert Journal, 2* (1903-04), 532-553 and 'The Axiom of Infinity', *3* (1904-05), 380-383; in between, B. Russell, 'The Axiom of Infinity', *2* (1903-04), 809-812. The journal also contains, for example, regular articles by Oliver Lodge on science and spiritualism; for context, see D.B. Wilson, 'The Thought of Late Victorian Physics: Oliver Lodge's Ethereal Body', *Victorian Studies, 6* (1971-72), 29-48.

82 See I. Grattan-Guinness, *Dear Russell — Dear Jourdain. A Commentary on Russell's Logic, Based on his Correspondence with Philip Jourdain,* London and New York, 1977, 24-25.

informing Christianity and matching Cantor in ambition though not in exposition.[83] More importantly, shortly earlier he had arranged for Benjamin Peirce's son, the polymath Charles S. Peirce (1839-1914), to contribute to the *Journal* in 1908 a variant on kind MexgC in the form of 'A neglected argument for the reality of God'; it was based on the assumption that 'musement' upon God could persuade the muser of his reality by means expressible within Peirce's triadic (but not necessarily Christian) metaphysics.[84]

A superior version of Keyser's type of interest was made in 1914 by another mathematician and believer, the Russian Pavel Florensky (1882-1937). He included in a dozen letters on theology and belief not only set theory but also mathematical logic and a little probability theory, in contexts such as infinity, paradoxes and identity. The Revolution three years stifled his enterprise, and 20 years later decided upon his murder.[85]

PART THREE: REVIEW

14. The variety of links, the paucity of cases

In the first part of this paper a taxonomy of links between mathematics and Christianity was proposed, with influence passing in each direction. The purpose was to bring via the attendant distinctions some clarity to a complicated web of connections which has received little analysis.

In the second part of this paper cases were described in mathematics where some kind of role was assigned to Christianity between the mid 18th and early 20th centuries. Most belong to the kinds CfrmM (formation), CemuM (emulation) or CtgtM (exemplar or guarantee of certainty), and some come from CtskM (task) and CprsM (presentation). Theories with a large foundational component were involved relatively often (Cauchy,

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[83] C.J. Keyser, 'The Message of Modern Mathematics to Theology', *The Hibbert Journal, 7* (1908-09), 370-390, 623-638.

[84] C.S. Peirce, 'A Neglected Argument for the Reality of God', *The Hibbert Journal, 7* (1908-09), 90-112: repr. in *Collected Papers,* vol. 3, Cambridge, Mass., 1935, paras. 6.452-491; and in *The Essential Peirce,* vol. 2, Indianapolis, 1998, 434-450. Much later Kurt Gödel (1906-1978) proved in 1970 a theorem in modal logic showing the existence of an object possessing all 'positive' properties, but he was reluctant to interpret it theologically as a case of MexgC (*Collected Works*, vol. 3, Oxford, 1995, 388-404, 429-437).

[85] P. A. Florensky, *Stolb' i utverzhdernie istini,* Moscow, 1914; English trans. by B. Jakim as *The Pillar and Ground of Truth,* Princeton, 1997, esp. ch. 6 (paradoxes) and apps. 14, 18 and 19 (identity), 15 (set theory), 17 (irrational numbers) and 23 (probability theory). Interestingly, he skipped by numerology (pp. 45, 302-204). On his influence on a fellow Christian and set theorist, see S.S. Demidoff and C.E. Ford, 'N.N. Luzin and the Affair of the "National Fascist Center"', in J.W. Dauben, M. Folkerts, E. Knobloch and H. Wussing (eds.), *The History of Mathematics: States of the Art,* Boston, 1996, 137-148.

Boole, Cantor). The affirmations were made either covertly or by allusion (Boole) or marginally (Cauchy, Peirce, Challis), in forms that many contemporaries may well have thought privately; Thomson rarely put his position into print.

The other main lessons in this second part was the *rarity* of such concerns, and also their isolation from each other; and none led to a durable influence on successors. Hence the survey was unavoidably discontinuous. Although many mathematicians for this period were (presumably) believers in some version of Christianity, very rarely did they mention links or uses, even non-cognitive ones, in their publications. The point is not that they failed to *declare* their Christian belief, but that it was *immaterial* to their mathematical purposes, even in physical applications, although the newer branches such as mathematical physics are not more detached from Christian interpretation than are the older ones.

A striking English example is Baden Powell (1796-1860), Professor of Geometry at Oxford University, who wrote extensively on Cauchy's version of the wave theory of light (§10) but did not even highlight its aetherial aspects never mind its pantheism. His silence is striking because throughout his career he was involved with Christian controversies, defending Anglican orthodoxy against Unitarianism and upholding the distinction between science and religion by allowing Christianity to control the interpretation of scientific theories. He also sought to improve science education at Oxford, but on the ground of training the mind and emphasising rigour, especially in the alleged certainty of mathematical theories; however, though a former student of Whately he did not advocate the study of logic as such.[86]

A similar and more prominent figure is James Clerk Maxwell (1831-1879); his passionate belief guided his stress on the limitations of science, and maybe also his advocacy of non-mechanical theories of phenomena and analogies between the physics of things and the mathematics of thought-objects.[87] Nevertheless, he omitted Christianity almost entirely from his scientific writings: even his popular book on mechanics and physics, *Matter and Motion* (1877), is secular in expression, though a posthumous edition prepared by J.J. Larmor was published in 1920 by the Society for Promoting Christian Knowledge!

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[86] For an excellent study of Powell and his time, see Corsi (note 51), esp. chs. 4, 5, 9 and 10.

[87] See Maxwell's letters to his wife in L. Campbell and W. Garnett, *The Life of James Clerk Maxwell,* London, 1882, 338-340; interestingly, his biographers rarely even mention his religious position. For discussion of the background, including the place of Scottish reformed theology, see T.F. Torrance, *Transformation and Convergence in the Frame of Knowledge,* Belfast, 1984, ch. 6. Like Cauchy and Boole (notes 50 and 74 respectively), Maxwell wrote poetry though only occasionally with Christian sentiments, to judge by the selection given in Campbell and Garnett (see esp. pp. 594-601, 607-609).

Conversely, Charles Babbage (1791-1871) had explicitly affirmed his Christian belief and considered possible links between science and religion; but he eschewed mathematical arguments to argue for his stance, and indeed offered a clever non-religious interpretation of miracles. While sympathetic to Deism, he did not associate Christianity with his own mathematical work, although most of it treated new algebras in the 1810s and 1820s, a time and in a country where truth was a serious concern in mathematics (the context later for Boole also in §12).[88] The same lack of discussion is evident among mathematicians in this century who considered Christianity/Deism and science.[89]

Keyser was a very rare (though waffly) case of *explicit* affirmation of faith. A much more important example, especially from the 1890s onwards, is the Frenchman Pierre Duhem (1851-1916). He wrote about being both scientist and Catholic, and partly under the influence of neo-Thomism, which gained currency in France after the Papal decree of 1879 mentioned in §13 in connection with Cantor. A principal venue was the *Revue des questions scientifiques,* similar in role to the English *Hibbert journal* (and also rather forgotten).[90] Again, he argued his position more on general philosophical grounds rather than from especial concern for mathematics.

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[88] See principally C. Babbage, *The Ninth Bridgewater Treatise: a Fragment*, 2nd ed., London, 1838, chs. 9-11; and *Passages from the Life of a Philosopher,* London, 1864, ch. 30 (kinds MexgC, CtgtM and CfrmM) and ch. 29 and appendix (miracles). These books appear respectively as vols. 9 and 11 of *The Works of Charles Babbage,* 11 vols. (ed. M. Campbell-Kelly), London, 1989; vol. 1 includes his mathematical papers. On Babbage's views on the mind, see W.J. Ashworth, 'Memory, Efficiency, and Symbolic Analysis. Charles Babbage, John Herschel, and the Industrial Mind', *Isis, 87* (1996), 629-653.

[89] See especially A.N. Whitehead, *Religion in the Making,* New York, 1926; H. Weyl, *The Open World. Three Lectures on the Metaphysical Implications of Science,* New Haven, 1932; and N. Wiener, *God and Golem Inc. A Comment on Certain Points where Cybernetics Impinges on Religion*, Cambridge, Mass., 1964. The last two books are rather superficial; for example, as with much literature of this kind, even Whittaker's, they are contaminated by pop history. Some later physicists with mathematical expertise affirmed religious positions; for example, Arthur Eddington (1882-1944) and and James Jeans (1877-1946). On successors up to recent times see R. Ruyer, *La gnose de Princeton. Des savants à la recherche d'une religion,* Paris, 1974. Modern cases include 'theories-of-everything' science and anthropic principles, and often ambiguous remarks about God being a mathematician (of course he was: if he existed, he created mathematics anyway, or at least the capacity of mathematicians to produce it).

[90] See H. Paul, *The Edge of Contingency. French Catholic Reaction to Scientific Change from Darwin to Duhem,* Gainesville, 1979, ch. 5; S.L. Jaki, *Uneasy Genius: the Life and Work of Pierre Duhem,* Dordrecht, 1984; and R.N.D. Martin, *Pierre Duhem: Philosophy*

15. The prominence of the British Isles

Mention of Duhem breaks the British dominance of this survey. In general the links between mathematics and Christianity were considered far more in Britain than on the Continent, especially in France (despite Duhem). To recall from §3 the similarities between the Bible and Euclid's *Elements,* it is surely no coincidence that concern with Euclidean geometry was much greater in Britain during the 19th century than in any other country, even to the extent that from the 1870s a professional split developed among mathematics teachers: orthodox followers of the *Elements* wished to preserve the order of propositions and their proofs, but dissenters wanted to admit other orders and proofs of theorems.[91] Similarly (or so it seems), the British concern with relationships between Christianity and sciences in general, such as natural theology, were greater in Britain than on the Continent.[92]

Part of the British preoccupation seems to be due to Whewell, whose position (§9) was the most penetrating of all mathematicians'. Its concern with emulations was taken up by Thomas Birks (1810-1883); soon after becoming second Wrangler and second Smith's Prizeman in mathematics at Whewell's Trinity College, he wrote in 1833 on the 'analogy between mathematical and moral calculi', with morality mediated by Christianity. Kind MemuC is evident when he looked 'into the nature of moral certainty, we may not find, in the certainty of geometry, an attendant to guide us'; but analogy was restricted by the apparent fact that the axioms of geometry 'no one denies' whereas those who wish to deny moral principles 'most earnestly cannot always' do so. He also noted the presence of prejudice in moral discussion (allegedly) absent in geometry, but he could not identify an ultimate authority for mathematics corresponding to the 'Divine Will' guiding morals.[93] I know of no such comparison in the Continental literature.

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and History in the Work of a Believing Scientist, La Salle (Ill.), 1991. Duhem's relationship to neo-Thomism, somewhat disputed by his historians, will not be examined here. His affirmation of faith may have contributed to his failure to obtain a position in Paris, although he committed other professional sins such as taking seriously the history and philosophy of science, and also specialising in applied rather than in pure mathematics.

91 See M. H. Price, *Mathematics for the Multitude? A History of the Mathematical Association,* Leicester, 1994, esp. chs. 2-3. Those disputes are not to be confused with two far more important developments of the time: exposing the hidden axioms of Euclidean geometry, and popularising non-Euclidean geometries.

92 On this theme, see Brooke (note 2), esp. ch. 6.

93 T. Birks, *Oration on the Analogy of Mathematical and Moral Certainty,* Cambridge, 1834, delivered 16 December 1833; reprinted in his *The Treasures of Wisdom, or Thoughts*

Twenty years later, in his career as a vicar, Birks reprinted the text at the end of a more extended comparison of the 'revealed truth' with sciences, starting with mathematics and astronomy. The converse kind, CemuM, and also CtgtM, are evident: 'Wonderful Numberer, the Son of God' for arithmetic, while diagrams and formulae 'are parables to teach us the mysteries of the kingdom of heaven'.[94] Indeed, mathematics in general is 'bound to the throne of the almighty; and 'all its treasures of knowledge are hidden in Christ', not God.[95] In 1872 he was appointed to the chair of Moral Philosophy at Cambridge upon the death of Maurice (§12), who had held it since 1866 — an Evangelist to replace Unitarian Maurice.

As was noted in §9, Whewell was anxious to combat the rise of doubts over (orthodox) Christianity in Britain. A leading doubter was the mathematician and scholar Francis Newman (1805-1897), whose confession in 1850 of the phases of his loss of faith led to a wide discussion. However, his motivations began with his inability as an undergraduate at Oxford to accept the 39 articles as truths; later ones included the unconvincing layers of doctrine imposed over 'primitive Christianity', second-hand testimony such as Paul's, failed Christian prophecies, and the incompatibility with contemporary geology and biology. But he invoked no mathematical aspects or arguments, not even probabilistic ones.[96]

The greater British than Continental interest may mark a difference between predominately Protestant and Catholic countries. In this context it is worth noting that almost all major Irish scientists in our period were Protestants: it seems that their parents wanted them to advance to a profession maybe new in the history of the family, whereas Catholic youngsters were still usually counselled to see the seminary or nunnery as the prime aim for life (a negative influence, of kind CprsM).[97] Attitudes to Christianity in more 'mixed' countries such as the German states could be studied usefully from this point of view. An oft repeated remark by Leopold Kronecker (1823-1891), 'the dear God has made

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on the Connection between Natural Science and Revealed Truth, London, 1855, 190-225 (quotations from pp. 194 and 209).

[94] Birks *Treasures ibidem*, pp. 14, 20.

[95] *Ibidem*, pp. 12, 23.

[96] F.W. Newman, *Phases of Faith; or, Passages From the History of my Creed,* 1st ed. London, 1854, 3-9; later eds. to 9th (1874). Despite the considerable reaction, this event is not analysed at all in O. Chadwick, *The Secularization of the European Mind in the Nineteenth Century*, Cambridge, 1975, which otherwise provides good background material.

[97] I am not aware of any general study of this case, but several individual examples are evident in J. Nudds and others (eds.), *Science and Engineering in Ireland 1800-1930; Tradition and Reform,* Dublin, 1988.

the whole numbers, all else is man's work', seems to be only a clever quip made to a general audience, with its weight lying in the constructivistic philosophy of mathematics stated in its second clause more than the Christianity advocated CfrmM style in the first one:[98] his published writings did not exhibit the latter sentiments.

Kronecker was a converted Jew. As a non-case of CprsM, during the 19th century Jews began to appear in mathematics (and science in general) after centuries of exclusion by Christians; but Judaism seemed not to affect the development or practice of mathematics. A significant figure is J.J. Sylvester (1814-1897) because he *practised* his religion instead of converting to Christianity (and suffered an irregular career as a consequence);[99] but his theories were not accompanied by any religious overtones, even though one of his specialities was invariant theory!

16. Final considerations

Doubtless the cases reported in the second part of the paper do not exhaust the occasions when Christianity was invoked in mathematical publications in the period at hand (although the index volumes for mathematics and mechanics of the *Royal Society Catalogue of Scientific Papers* do not disclose any papers on our theme for the literature of the 19th century). But the full list must be *minute* relative to the total production. Maybe the private correspondence of mathematicians reveals more concern with Christianity (or Deism in general), though I have hardly ever noticed it in the numerous collections that I have used (for other purposes). After around 1750 mathematics seems to have become almost entirely secular, or at least religiously neutral, with Christian belief rarely in print though not out of mind — in striking contrast with the great growth of involvement of Christian and/or Deist belief in the natural sciences. This situation obtained in all countries, and in both research and teaching; presumably it developed by consensus, though perhaps encouraged by the great prominence of France between the 1780s and the 1830s, and the influence of the Enlightenment and the stance of major figures such as Lagrange and Laplace, and also Condorcet.

Astronomy and physics seem also to have followed a largely secular paths, presumably for analogous reasons; but the strong contrast with the 19th-century discussions in the natural sciences is hard to understand. If connections with Christianity are open again, why not revive the older ones to mathematics and the physical sciences? Was the Christian "defeat" over heliocentric astronomy in the 16th century decisive for *all* branches

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[98] Kronecker made this remark in 1886 in a lecture at the annual meeting of the *Gesellschaft Deutscher Naturforscher und Ärtze*; it became known in the obituary by H. Weber in *Mathematische Annalen, 43* (1893), 1-25 (p. 19).

[99] See K.H. Parshall, *James Joseph Sylvester. Life and Work in Letters,* Oxford, 1998; A.C. Crilly, biography of Arthur Cayley, near completion.

of mathematics and astronomy, and if so, why?[100] Most of terrestrial mechanics is unaffected by the issue of whether the Sun or the Earth is at rest; indeed, it is usually developed in a geocentric manner in that, for example, a coordinate system is “fixed” relative to the surface of the Earth. Across mathematics, theories continued to be created somehow, and seemed to talk about something or other; yet only the eccentrics recorded in the second part of this paper posited some theologically commodious source or inspiration to explain either feature.

The special complications involved in using mathematics in scientific theories (§1) may have helped to discourage invoking links; but the near silence is puzzling. Understandably, then, neither topic addressed in my title has been well considered in the history of mathematics; but each deserves further study, and maybe even integration into the vigorous general discussion of the history of links between science and religion.

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[100] This is the claim made by H.H. Odom in ‘The Estrangement of Celestial Mechanics and Religion’, *Journal of the History of Ideas, 27* (1966), 533-548; but he (unwittingly?) discusses only Newtonian mechanics, and the bulk of his details refer to before 1750.