Early medieval science: the evidence of Bede

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The Venerable Bede used observable proofs and mathematical calculations in his early 8th-century treatise *De temporum ratione* to teach the astronomical principles that inform the calculation of the date of Easter. This suggests that the seeds of the modern scientific method might be found before the 12th century in the educational practices of the early medieval monasteries.

The contribution of the early medieval Church to the history of Western science is not widely recognized. The common perception is that little of scientific significance occurred between the fall of the Roman Empire around AD400 and the discovery of Arabic mathematics and the recovery of Aristotle's works in the 12th century. The persistence of this perception is encouraged by referring to the period as a 'scientific dark age'[1,2]. One 'survey' of early medieval astronomy simply presents the reader with four blank pages[3]. However, scholars have long recognized that elements of classical science and the rudiments of Ptolemaic astronomy were transmitted during the early Middle Ages[2,4,5]. Empiricism, the use of experiment and observable proof to demonstrate a hypothesis, distinguishes modern scientific method from the largely theoretical science of the Classical Age. The nature of the rise of empirical science is, therefore, an important question to historians of Western science. Whether the seeds of empiricism are to be found in monastic science before the 12th century is a question often overlooked by those who refer to the period as the 'dark ages'.

One of the earliest and most influential works of medieval science is *De temporum ratione* (*The Reckoning of Time*)[6,7], written around AD725 by the Venerable Bede (c. 673–735). Bede was a monk, teacher and writer of over 100 works on a variety of subjects including history, exegesis and philosophy. He lived most of his life at the monastery of Jarrow and Wearmouth in Northumbria. *The Reckoning of Time* is a manual of *computus*, the medieval study of time and astronomy. It explains the operation of the cosmos and the cycles of time, proposes a model for calculating the date of Easter within the framework of the Julian calendar, and ends with a narrative of world history according to Christian theology. Bede's work was read widely throughout the Middle Ages[8] and its calendrical model soon came to be regarded as authoritative. With a few adjustments, it remains the calendar that we use today.

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Recent reception of Bede's writings on *computus* has focused on his contribution to the development of science. Lindberg recognizes Bede's 'popularization and preservation' of classical science[4], and Stevens regards Bede's contribution to the calendar as his greatest scientific achievement[9]. More recent studies have argued that Bede played a role in the re-formation of science between late antiquity and the 12th century. For McCluskey, Bede 'added the natural learning of the continent to the older computistical tradition' and introduced 'into the curriculum of English monastic schools those concepts from which Ptolemy's astronomy had grown'[10]. In Wallis's assessment, *The Reckoning of Time* 'made *computus* into a science, with a coherent body of precept and a technical literature of its own'[11].

It is perhaps not so surprising to find that Bede transmitted elements of classical scientific knowledge; other Christian writers did that and are among Bede's many sources: Ambrose, Augustine, Isidore of Seville, Basil and Philippus Presbyter[12]. What is especially interesting to discover in Bede's work is evidence that he was able to revise and expand scientific knowledge and to use observational methods to demonstrate scientific ideas. However, this does not make Bede an 'isolated genius' as Whitfield claims[2]. Although his work is exceptional in many ways, it is also a product of the political exigencies of his society and of the culture of Christian literacy and education within which he lived and wrote.

The problem of Easter

Northumbrian politics during Bede's lifetime centred on the debate about how to calculate the date of Easter. Bede portrays the situation in his *Ecclesiastical History of the English People*. At the Northumbrian court in the middle of the 7th century, King Oswiu and Queen Eanflaed celebrated Easter at different times: the King, educated by Irish monks, observed Easter at the time calculated by the Celtic reckoning; the Queen was from Kent and celebrated the Roman Easter. Although this situation was tolerated, Bede wrote that the Easter question 'troubled the minds and hearts of many people who feared that, though they had received the name of Christian, they were running or had run in vain'[13].

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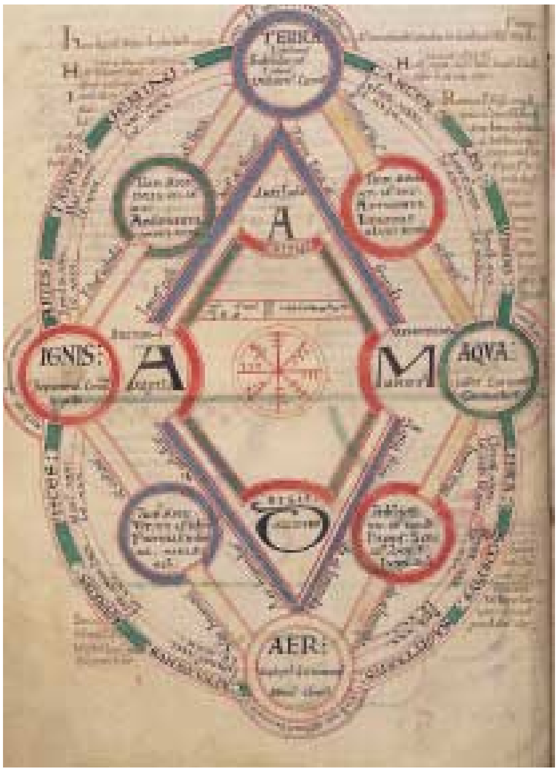

Figure 1 Byrhtferth's 'Diagram of the Physical and Physiological Fours', Oxford, St John's College manuscript, no. 17, folio 7 *verso*. This manuscript is a copy of Byrhtferth's *computus*, written in Thorney around AD 1110–1111. The diagram conveys the notion of an ordered universe, integrating the four seasons, the four elements, the four directions and the four 'ages of man' with the 12 signs of the zodiac and the months of the lunar and calendar years. Byrhtferth drew on Chapter 35 of *The Reckoning of Time* for this information[48]. The references to the four seasons are translated 'Autumn dry and cold, Winter cold and wet, Spring wet and hot, Summer hot and dry'. The schema presents this science within a Christian theological perspective; the letters A, D, A and M simultaneously spell the name of the 'first man' and stand for the four corners of the earth in Christian theology.

In fact, there were three systems for calculating the date of Easter in concurrent use in Britain during Bede's lifetime – the Celtic 84-year cycle, and two different 19-year cycles, the Victorian and Dionysian. The latter pair were similar but a conflict arose between them in 665. Wallis suggests this might have instigated the Synod of Whitby, which was held the previous year to debate the Easter question[14]. Wilfrid of Hexham, later Bishop of York, promoted the Dionysian Easter reckoning at Whitby. Thereafter, Bede devoted several works to presenting the mathematical data and theological arguments for the Dionysian system. These include three letters and *De temporibus* (*On Times*), written in 703. *The Reckoning of Time* is an expansion and revision of this work and also of *De natura rerum* (*On the Nature of Things*), completed soon after *On Times*[15]. Bede also presents a narrative argument for the Dionysian system in the *Ecclesiastical History* (3.25). It is noteworthy that *The Reckoning of Time* was written some 60 years after Whitby, and Wallis suggests that Bede still regarded the Victorian system as a threat that needed to be dispelled once and for all[16]. Bede was a prolific writer but, even so, the amount of ink he spilled on *computus* is testimony to the importance of the Easter question during his day.

Devising an authoritative date for Easter was an extremely complex astronomical, mathematical and theological exercise. Exodus 12.1–3 stipulates that Passover should be observed after the Spring equinox on the 14th day of Nisan, the first month of the Jewish calendar. It became Christian custom to celebrate Easter on a Sunday, in commemoration of the Resurrection of Christ, but the Council of Nicaea ruled that Easter could not coincide with Passover if the latter fell on a Sunday. Thus religious doctrine, custom and law had to be reconciled with a formula that accounted for the different lunar, solar and weekly cycles.

Several systems had been devised to coordinate the solar year and Roman months with a doctrinal Easter based on a lunar year[17]. Competing systems for calculating the date of Easter and the movement of the Church towards unified practice across Europe provided the impetus and demand for an authoritative argument for one system over the others. Wallis argues that *The Reckoning of Time* 'guaranteed the ultimate success of Dionysius' system' because of Bede's thorough learning, the organization of his sources and the usefulness of his text as a tool for teaching[18]. The survival of 240 manuscript copies of *The Reckoning of Time*, in whole or in part, indicates the popularity and influence of Bede's text during the medieval period[19].

The Reckoning of Time also treats material not directly related to Easter calculation, such as the operation of the tides and the pre-Christian months of the Anglo-Saxons. In the Preface to his work, Bede writes that *The Reckoning of Time* was borne of his students' desire for more detailed knowledge of *computus*.

> Some time ago I wrote two short books in a summary style which were, I judged, necessary for my students; these concerned the nature of things, and the reckoning of time. When I undertook to present and explain them to some of my brethren, they said that they were much more concise than they would have wished, especially the book on time, which was, it seems, rather more in demand because of the calculation of Easter. So they persuaded me to discuss certain matters concerning the nature, course, and end of time at greater length. I yielded to their enthusiasm, and after surveying the writings of the venerable Fathers, I wrote a longer book on time.[20]

The Preface indicates that the Easter question drove demand for revised and more detailed instruction in the mathematics and theory upon which the Dionysian Easter reckoning was founded. However, the complexity of the learning required to calculate the date of Easter might also have inspired in Bede's contemporaries a curiosity about the natural world that went beyond what was necessary for Easter reckoning.

The Christian context of Bede's scholarship and method

Medieval Christian theology was founded on the belief that God created an ordered universe. An oft-cited Scriptural authority for this was Wisdom 11.21: 'Thou hast ordered all things in measure, and number, and weight'. Bede expresses this notion in Chapter 1 of his treatise *On the Nature of Things*[7,21], and Byrhtferth of

Ramsey's so-called 'Diagram of the Physical and Physiological Fours' represents this idea in graphic form (Figure 1). In general, therefore, medieval Christian thought assumes that rational explanations for natural phenomena exist, if only they can be understood.

An important reason why early medieval Christian culture was open to classical science and empirical methods is that St Augustine of Hippo (354–430) authorized their use for Christian writers. Augustine laid down the methods that guided education and literary understanding during medieval times in his seminal work *De doctrina christiana* (usually translated *On Christian Doctrine*)[22]. *Doctrina christiana* means 'Christian teaching' and refers to lifelong education in the path of Christ through the discipline of learning to understand the true meaning of Scripture[23]. *On Christian Doctrine* is primarily a manual for interpreting Scripture and was the basis on which an extensive literature of commentary was written to interpret the narratives and many mysteries and contradictions in the Bible. Those commentators considered canonical by the Church are called the Fathers of the Church.

In Book 3 of *On Christian Doctrine* (28.39), Augustine warns that it is dangerous to rely on reason alone to clarify ambiguities in the Bible and recommended that problems of interpretation should be resolved by referring to other biblical passages where the meaning was clear. This encouraged a tradition of learning through consultation and comparison of sources, referring for ultimate authority to Scripture, as interpreted by the Fathers of the Church. Bede uses this method of analysis in *The Reckoning of Time*, as he tells the reader in the Preface (quoted above), but scholars have identified many non-patristic sources used by Bede as well[24]. This was also authorized by Augustine, who was careful not to exclude certain non-Christian works from the sources of knowledge available to Christians.

> All branches of heathen learning have not only false and superstitious fancies and heavy burdens of unnecessary toil … [but] they contain also liberal instruction which is better adapted to the use of truth … Now these are, so to speak, their gold and silver [which] the Christian, when he separates himself in spirit from the miserable fellowship of these men, ought to take away from them, and to devote to their proper use in preaching the gospel.[25]

Bede, therefore, was authorized to draw on pagan works such as the Elder Pliny's *Natural History* and Vegetius' *Epitoma rei militaris*[24], and to discuss pagan science in his *computus* writings. He even devoted Chapter 15 to explaining the significance of the pre-Christian, pre-literate month names of the Anglo-Saxons[26]; Figure 2 demonstrates one way in which this knowledge was transmitted in later times. Bede does not regard enthusiasm for knowledge of the natural world and the study of classical science as a threat to Christianity, as long as they are directed to the purpose of teaching Scripture. That Bede regarded *The Reckoning of Time* as being integral to the teaching of Scripture is demonstrated by the last section of his work (Chapters 66–71), a chronicle of world history from a Christian perspective.

Figure 2 British Library manuscript, Cotton Tiberius E iv, folio 38 *verso.* The month of August from the Calendar that precedes a full copy of Bede's *De Temporum Ratione*, written c. 1205. The manuscript also includes Bede's *On Times* and his computistical letter to Wicthede. The Hebrew, Greek, Anglo-Saxon and Egyptian month names appear in the semi-

In addition to encouraging the dissemination of classical science through Christian literature, Augustine also promoted the use of empirical methods by granting permission to Christian teachers to use the art of Roman rhetoric. Cicero defined three parts or purposes of rhetoric: to delight, to persuade and to prove. Augustine adapted Cicero's 'gold and silver' for Christian purposes in Book 4 of *On Christian Doctrine*. Significantly, he adapted the third part of rhetoric, to prove, to the purpose of teaching. 'If the hearers need teaching, the matter treated of must be made fully known by means of narrative. On the other hand, to clear up points that are doubtful requires reasoning and the exhibition of proofs'[27].

In Augustine's treatise, teaching begins with narrative and uses reason and the exhibition of proofs to resolve doubts in the doctrinal message. Thus 'to teach' has become the third part of rhetoric and proofs are to be deployed for the purpose of indoctrination[28]. Bede is adept in *The Reckoning of Time* at exhibiting explicit proofs to demonstrate astronomical facts to his audience. One of his most eloquent proofs explains why the full moon appears to be farther away than the sun from the earth at midwinter (Chapter 26). The reason for this illusion is that the full moon is high in the sky towards the north and the sun is low in the sky to the south at midwinter. Bede describes an experiment with two lamps hanging at different heights from the ceiling of a church. If the church is dark, the nearest and lower lamp will appear to be higher than the more distant and higher one[29]. The aesthetic beauty of this proof must have delighted Bede's audience, showing that he was also adept at the first part of rhetoric.

Bede devises other practical experiments to explain astronomical phenomena. For example, he demonstrates the need for leap years by indicating that, if you observe where the sun rises at the Spring equinox, it will rise slightly lower each year thereafter, but that if you insert an extra day in the fourth year, the sun will rise again where it did four years before[30]. Such proofs reveal Bede's view that *computus* was not an abstract theory but a science of natural phenomena that could be observed and taught empirically. The expectation that astronomical science can be demonstrated by observation is significant, even though Ptolemaic astronomy was not fully understood during the early medieval period. Although the primary objective of early medieval monastic education was knowledge of the Scriptures, Augustine's teaching methods could potentially be applied to other forms of knowledge. Bede's effective use of them in *The Reckoning of Time* shows the potential of the Augustinian method to teach astronomy empirically.

Bede's contribution to scientific knowledge

One of the most interesting ways in which Bede demonstrates the observational potential of early medieval science is in his discussion of tidal operation in Chapter 29. Bede thoroughly appraised and reprised his classical and computistical sources on the tides and added his own observations and calculations. Classical understanding of the tides was limited by the fact that tidal movements in the eastern Mediterranean are very slight. The link between the moon and the tides was long known but many of Bede's sources expressed the notion that the tides are caused by an increase and decrease in the volume of water in the oceans, and that the tides occur at the same time all over the earth. For example, Philippus Presbyter wrote in his *Commentary on the Book of Job* that there was a geyser under the sea that produced the tides. Two of Bede's Irish sources, Pseudo-Augustine and Pseudo-Isidore, also said that there was a change in the amount of water in the oceans, but they attributed the cause to the moon. Isidore of Seville said the ocean was an animal that breathes water[31]. Bede shows his readiness to question and correct his sources in the following passage.

> So let him who is capable, see if what Philip says is true or no: *There are those who claim and affirm that an enormous outpouring of the ocean takes place in all the streams of every region and land at one and the same time.* But we who live at various places along the coastline of the British Sea know that where the tide begins to run in one place, it will start to ebb at another at the same time. Hence it appears to some that the wave, while retreating from one place, is coming back somewhere else; then leaving behind the territory where it was, it swiftly seeks again the region where it first began. Therefore at a given time a greater *malina* deserts these shores in order to be able all the more to flood other [shores] when it arrives there.[32]

Here, Bede makes the original observation that the tides do not occur everywhere at the same time. He was the first to express the idea of 'rule of port'[33]. Bede's ability to correct the science of one of the Fathers of the Church with knowledge that he had acquired locally from those 'who live at various places along the coastline of the British Sea' is a practical realization of the potential for empirical science contained in the Augustinian method.

Bede was also able to use mathematics to refine the science of his sources. Philippus said that each tide occurs about 45 minutes later than it did the day before. However, he did not connect the tides with the moon. (Bede's Irish sources, Pseudo-Augustine and Pseudo-Isidore, were silent about daily tidal retardation.) Pliny's measurement of daily tidal retardation is 47.5 minutes in his *Natural History*, which is closer than Philippus to the correct figure of 50 minutes. Bede repeated Pliny's measure of daily tidal retardation in his earlier work, *On the Nature of Things* (Chapter 39), but revised the figure in *The Reckoning of Time* to 48 minutes.

Bede presents his teaching on the tides in Chapter 29 according to Augustine's method. He begins by explaining 'the great fellowship that exists between the ocean and the course of the Moon'. He cites his sources and adds some poetic phrases to delight his readers: 'The sweet streams of the rivers [i.e. the tide] abundantly mingles together and covers over with salty waves.' Having established the relationship between moon and tides, Bede cites a fact that he explained in Chapter 17, that the moon rises and sets each day 48 minutes later than it did the day before. Then he states the claim that, 'likewise, both ocean tides, be they by day or by night, morning or evening, never cease to come and go each day at a time which is later by almost the same interval' (that is, 48 minutes).

In the next section, the presentation of the mathematical proofs for this claim is less poetic. Bede describes several calculations to show the link between the moon's course and the tides during periods of a month, 15 days and a year. He concludes that, in one year, the moon circles the earth precisely half the number of times that the tides rise and ebb during the same period. In this chapter, Bede has followed Augustine's teaching method from narrative to the exhibition of proofs in order to add to the knowledge of tidal operation. As Wallis says, 'For the first time, he connected lunar retardation to the daily period of tidal retardation, and he corrected the figures for the latter.'[34]

It is uncertain how Bede carried out the research that informs his calculations and observations of the tides. Stevens suggests that, between writing *On the Nature of Things* and *The Reckoning of Time* some 20 years later, Bede carried out a programme of research into tidal movements, drawing on the assistance of friends in other parts of Britain[35]. It is true that Bede indicates that he has discussed the tides with others: 'those who live north of me on the same coastline usually receive and give back each tide sooner than I do, and those to the south much later.'[36] However, aside from the calculations presented in *The Reckoning of Time* and some references to the tides in the *Ecclesiastical History*, Stevens produces no other evidence of calculations or correspondence that might suggest a systematic programme of research. Wallis is sceptical of Stevens' argument but does not speculate upon an alternative method of research. She agrees with Stevens, however, that the monks of Lindisfarne (farther north along the coast from Bede's monastery at Jarrow) must have had a good knowledge of tide times in order to cross the causeway between Holy Island and the

mainland[37]. However, the Anglo-Saxons were a seafaring and coast-dwelling people before they migrated to Britain from northern Germany in the 5th and 6th centuries. It is likely, therefore, that Bede's society possessed a good understanding of the tides, which was passed down through oral tradition long before Bede committed it to writing.

Bede's inclusion in *The Reckoning of Time* of tidal knowledge that had not previously been recorded in classical literature demonstrates the openness of early medieval Christian culture to the appropriation of pagan knowledge that could expand understanding of the natural world. Bede's inclusion of this knowledge and the fact that he consulted the widest variety of sources available to him, literary and non-literary, patristic and pagan, in order to revise what he had written in his earlier writings indicates the work of a curious, critical and open mind. Bede shows that the search for truth in early medieval Christian culture could be advanced by theory demonstrated empirically, and need not relate directly to Christian doctrine. Although Bede regarded *computus* as an integral part of Christian teaching, he was able to apply Augustine's method to a subject of natural science beyond the focus of his major aim, teaching the Dionysian Easter reckoning.

The limitations to Bede's science

It is worth remembering that computistical calculations had to be made without the facility of Arabic numerals or the notion of zero, which did not appear in Western Europe until the 12th century. Roman numerals are unsuited to written calculation because integers within each rank of units, tens, hundreds and so on are represented by one or more symbols; for example, iv (4) and viii (8). This makes decimal calculation practically impossible. In Chapter 1, Bede provides a list of Greek numerals, which assign a different symbol for each integer from 1 to 9, from 10 to 90 and from 100 to 900. It is likely, however, that computists used finger reckoning rather than Greek numerals for their calculations. Wallis presents some evidence that Bede's calculations in *The Reckoning of Time* are descriptions of finger reckoning[38]. Bede explains finger reckoning in Chapter 1. Certain fingers on each hand were designated to units, tens, hundreds and thousands, and Wallis indicates how complex addition, subtraction, multiplication and division could be performed. Perhaps the greatest disadvantage of finger reckoning was that its calculations could not be represented directly in writing. Bede expresses frustration in Chapter 55 when describing how to calculate the cycles of the epacts: 'many aspects of this discipline … are better conveyed by the utterance of a living voice than by the labour of an inscribing pen.'[39] The considerable number of calculations described in *The Reckoning of Time* are testimony to Bede's perseverance and dedication to his subject. The limitations of existing numbering systems and the importance of *computus* to the regulation of the calendar in the medieval Church must have provided Bede's readers in subsequent centuries with a powerful incentive to seek a new numbering system.

There is evidence that early medieval Christians were interested in mathematics and desired a more effective numbering system long before the 12th century. Aside from the many numerological interpretations of Scripture inspired by the example of Augustine, there was prolific copying and imitation of the so-called *argumenta* or mathematical problems in Dionysius' *computus*[40]. In the view of C.W. Jones, the *argumenta* 'stimulated western thought' and show 'how much the new Germanized Latin world needed and wanted a fresh stream of thought'[41]. In the 11th century, Byrhtferth of Ramsey wrote a *computus* manual in both Latin and English that drew on *The Reckoning of Time* as a major source[42]. Byrhtferth's *Enchiridion* includes the first treatise on the meaning of numbers[43]. Although these writings had little direct impact on the growth of scientific knowledge, they reveal a genuine interest in numbers that probably inspired the discovery of Arabic mathematics in the 12th century.

Bede's teaching was not always transmitted with the same effectiveness. Aelfric was cautious when he translated *The Reckoning of Time* into English around the end of the 10th century[44]. Aelfric probably intended his translation for novices still acquiring the rudiments of Christian teaching because he was very selective in what he chose to translate from Bede's work. He summarized Bede's factual material and left out most of the argument and calculations. In a section translated from Bede's *On the Nature of Things*, Aelfric indicates his reasons for curtailing Bede's discussion of the planets: 'These seven are called the seven planets, and I know that it will seem to the unlearned to have nothing to do with faith if we discuss these stars and their courses in detail.'[45] In a neat piece of propaganda, Aelfric assumes that his students will possess only the most worthy Christian intentions. However concerned Aelfric might have been, as Henel remarks[46], about the danger of encouraging superstition, the fact that he translated *The Reckoning of Time* at all indicates that there was an audience interested in study of the natural world for its own sake. Despite this, Aelfric's omission of Bede's proofs and calculations reveals a very different approach to the study of the natural world from Bede's.

Conclusion

In his chapter on the 'dark ages', Whitfield says that 'Science, like all other study, meant learning rather than discovery … Astronomy was what Ptolemy had reasoned it to be; natural history was what Pliny had observed'[47]. This might be a reasonable generalization but it does not account for the fact that Bede corrected and expanded Pliny's observations on the tides, and devised empirical proofs to demonstrate the basics of astronomy to his students. Augustine's *On Christian Doctrine* informed the way in which Bede structured the discourse of *The Reckoning of Time* to provide his students with effective instruction in *computus* and observable proofs to demonstrate certain astronomical phenomena. It also provided the method and authority for the way in which Bede drew on both classical science and local knowledge of the natural world.

Contention over the dating of Easter instigated Bede's *computus* writings but there are indications that his society was curious about the workings of the natural world, valued observable proofs in teaching and was eager to find a more effective numerical system. The many students of *The Reckoning of Time* in medieval monasteries had an opportunity not only to learn *computus* but also to discover certain natural phenomena through both learning and observation.

Acknowledgement

I express my gratitude to Angela Williams of St John's College Library, Oxford, for her generous help to obtain Figure 1.

Notes and references

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2 Whitfield, P. (1999) *Landmarks of Western Science: From Pre-history to the Atomic Age*, pp. 67–70, British Library

3 McCluskey, S.C. (1998) *Astronomies and Cultures in Early Medieval Europe*, p. ix, note 3, Cambridge University Press

4 Lindberg, D.C. (1992) *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 BC to AD 1450*, p. 159, University of Chicago Press

5 The idea that medieval people believed in a flat earth is a fallacy. See Jones, C.W. (1934) The flat earth. *Thought* 9, 296–307; Burton Russell, J. (1991) *Inventing the Flat Earth: Columbus and Modern Historians*, Praeger

6 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, Liverpool University Press

7 Jones, C.W., ed. (1943) *Bedae Opera de Temporibus*, Medieval Academy of America

8 For scholarship on the widespread use of Bede's work, see Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. lxxxvi, note 231; Liverpool University Press

9 Stevens, W.M. (1995) Bede's scientific achievement. *Cycles of Time and Scientific Learning in Medieval Europe*, II, pp. 42–44, Varorium

10 McCluskey, S.C. (1998) *Astronomies and Cultures in Early Medieval Europe*, pp. 94–95, Cambridge University Press

11 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. xvii, Liverpool University Press. Wallis evaluates Brigitte Englisch's argument that empiricism in Bede's writings provides evidence for a break with the classical scientific tradition that prepared the ground for the development of speculative science in later centuries. See Englisch, B. (1996) Realitätsorientierte Wissenschaft oder praxisferne Traditionswissen? Inhalte und Probleme mittelalterlicher Wissenschaftsvorstellungen am Beispiel von *De temporum ratione* des Beda Venerabilis. In *Dilettanen und Wissenschaft. Zur Geschichte und Aktualität eines wechselvollen Verhältnisses* (Strauss, E., ed.), pp. 11–34, Rodopi

12 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. lxxii–lxxxv, Liverpool University Press; McCluskey, S.C. (1998) *Astronomies and Cultures in Early Medieval Europe*, p. 94, Cambridge University Press

13 Colgrave, B. and Mynors, R.A.B. (eds and trans.) (1969) *Bede's Ecclesiastical History of the English People*, 3.25, p. 297, Oxford University Press. Bede's quotation from Galatians 2.2 implies that only one Easter reckoning is correct

14 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. lxi–lxiii, Liverpool University Press

15 McCluskey, S.C. (1998) *Astronomies and Cultures in Early Medieval Europe*, p. 94, note 68, Cambridge University Press

16 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. lxiii, Liverpool University Press

17 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. xxxiv–lxiii, Liverpool University Press, provides a comprehensive account of the complex development of the Christian calendar

18 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. xvii, Liverpool University Press

19 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. lxxxvi, Liverpool University Press. Many of the tables that Bede devised to assist his students were also widely copied. For example, the *pagina regularis*, used for finding the position of the moon, appears in at least 50 manuscripts according to Jones, C.W., ed. (1943) *Bedae Opera de Temporibus*, p. 354, Medieval Academy of America

20 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 3, Liverpool University Press

21 Quoted in Stevens, W.M. (1995) Bede's scientific achievement. *Cycles of Time and Scientific Learning in Medieval Europe*, II, p. 7, note 13, Varorium

22 Martin, I., ed. (1962) *De doctrina christiana*, Corpus Christianorum, Series Latina 32, Brepols. Refer to the translation by Shaw, J.F. (1990) *Great Books of the Western World: Saint Augustine: On Christian Doctrine* (2nd edn) (Vol. 16), Encyclopaedia Britannica

23 Shaw, J.F. (1990) *Great Books of the Western World: Saint Augustine: On Christian Doctrine* (2nd edn) (Vol. 16), Book 1 (esp. Chapter 11), Encyclopaedia Britannica

24 See the survey of Bede's sources in Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. lxxii–lxxxv, Liverpool University Press

25 Shaw, J.F. (trans.) (1990) *Great Books of the Western World: Saint Augustine: On Christian Doctrine*, 2.40.60 (2nd edn) (Vol. 16), Encyclopaedia Britannica

26 Bede's chapter on the month names of the English has been widely discussed. Whether it is evidence for the survival of the pre-Christian English calendar into Bede's lifetime is debatable. A recent balanced and thought-provoking study is Anderson, E.R. (1997) The seasons of the year in Old English. *Anglo-Saxon England* 26, 231–263

27 Shaw, J.F. (trans.) (1990) *Great Books of the Western World: Saint Augustine: On Christian Doctrine*, 4.4.6 (2nd edn) (Vol. 16), Encyclopaedia Britannica

28 Copeland, R. (1991) *Rhetoric, Hermeneutics and Translation in the Middle Ages: Academic Traditions and Vernacular Texts*, p. 60, Cambridge University Press

29 See the diagram and explanation by Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. 304–306, Liverpool University Press

30 McCluskey, S.C. (1998) *Astronomies and Cultures in Early Medieval Europe*, p. 95, Cambridge University Press. McCluskey notes that this proof tests the limits of perception available in Bede's time but says that the variation in the point at which the sun rises at the Spring equinox could be observable with the naked eye over a span of four years. If Bede carried out this proof in reality, therefore, he possessed a strong commitment to observation and measurement

31 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. 307–312, Liverpool University Press

32 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 85, Liverpool University Press

33 Stevens, W.M. (1995) Bede's scientific achievement. *Cycles of Time and Scientific Learning in Medieval Europe*, II, p. 41, Varorium

34 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 309, Liverpool University Press

35 Stevens, W.M. (1995) Bede's scientific achievement. *Cycles of Time and Scientific Learning in Medieval Europe*, II, pp. 26–33, Varorium

36 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 85, Liverpool University Press

37 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 311, Liverpool University Press

38 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, pp. 254–263, Liverpool University Press

39 Wallis, F. (trans.) (1999) *Bede: The Reckoning of Time*, p. 139, Liverpool University Press

40 See the section on arithmology in Baker, P.S. and Lapidge, M., eds (1995) *Byrhtferth's Enchiridion*, pp. lxi–lxxiv, Early English Text Society, second series 15, Oxford University Press

41 Jones, C.W., ed. (1943) *Bedae Opera de Temporibus*, p. 71, Medieval Academy of America

42 Baker, P.S. and Lapidge, M., eds (1995) *Byrhtferth's Enchiridion*, p. lxxxvii, Early English Text Society, second series 15, Oxford University Press

43 Baker, P.S. and Lapidge, M., eds (1995) *Byrhtferth's Enchiridion*, pp. lxi–lxxiv, Early English Text Society, second series 15, Oxford University Press

44 Henel, H., ed. (1942) *Ælfric's De Temporibus Anni*, pp. xlvi–li, Early English Text Society, original series 213, Humphrey Milford, Oxford University Press. Scholars agree that Aelfric's work was written before Byrhtferth's and was a source for the *Enchiridion*. See Baker, P.S. and Lapidge, M., eds (1995) *Byrhtferth's Enchiridion*, pp. xc–xci, Early English Text Society, second series 15, Oxford University Press

45 Henel, H., ed. (1942) *Ælfric's De Temporibus Anni*, p. 68, Early English Text Society, original series 213, Humphrey Milford, Oxford University Press

46 Henel, H., ed. (1942) *Ælfric's De Temporibus Anni*, p. 103, Early English Text Society, original series 213, Humphrey Milford, Oxford University Press

47 Whitfield, P. (1999) *Landmarks of Western Science: From Pre-history to the Atomic Age*, p. 70, British Library

48 Baker, P.S. and Lapidge, M., eds (1995) *Byrhtferth's Enchiridion*, pp. 255, 373–374, Early English Text Society, second series 15, Oxford University Press