JHA, xvi (1985)

IN QUEST OF SACROBOSCO

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1. *Introduction*

A number of the greatest and most influential scientists in history have left to posterity nothing but their names and their writings. In Antiquity this was the case with both Euclid and Ptolemy, on whose lives all contemporary sources are completely silent, with the result that the only clue to their personal histories is the meagre information we can infer from their works. It is true that we are a little better off with respect to Archimedes, but – and this is one of the ironies of history – that is only because Plutarch found it worth while to devote a few pages to the great mathematician when he wrote the biography of the Roman general whose subaltern killed him when Syracuse was captured in the Second Punic War.[1] Perhaps Plutarch would have been more informative if he had suspected that the Principle of Archimedes was destined to outlive the passing fame of Marcellus.[2]

In later times many medieval scholars met with a similar fate, and among them was Johannes de Sacrobosco. Today Sacrobosco is a mere name attached to a few elementary mathematical and astronomical writings usually mentioned only in passing by historians of medieval science. Yet for hundreds of years this name was a household word to any student of the liberal arts, for the *Sphere of Sacrobosco* was the standard manual through which at least a dozen generations of scholars became first acquainted with astronomy, either directly or through one or another of the multitude of revised versions or commentaries produced by university professors who wished to add to Sacrobosco's lore or present it in their own way. Over the years the *Sphere* together with two other treatises by the same author became the kernel of an ever-growing collection of standard texts on astronomy which, taken as a whole, can be said to define that scientific world in which Copernicus lived and Kepler was brought up.[3]

Nevertheless, the name of Sacrobosco does not appear in university records or other historical documents from his own time.[4] Even today his life remains almost as obscure as that of Euclid although for centuries he shared the fame of the Alexandrian mathematician without, of course, partaking in his genius. No historian has ever attempted to write a comprehensive exposition of what he achieved, with due attention to all his writings.[5] In consequence his biography has always been restricted to a few remarks in the prefaces to his printed works, or to a succession of brief entries in dictionaries, all of them marred by serious errors and unsubstantiated assertions handed on uncritically from one writer to another. In consequence it is necessary to start right from the beginning when one ventures on an attempt to shed at least some light upon this enigmatic personality whose very name and works remain the only clue to the circumstances of his life. The problem is whether it is possible to develop any clear and consistent picture from such a thin negative.

2. *The Name*

One thing which we know for certain about Sacrobosco is that (in the words of

0021-8286/85/1603-0175 $4.00

Zacharias) his name is John. Unfortunately this tells us nothing since John was as popular and hackneyed a Christian name in the Middle Ages as it is today. More promising is the epithet "de Sacrobosco", or one of its numerous variant forms,[6] which he shares with no other medieval author. According to ordinary medieval usage such a 'surname' would in most cases derive from the place where the person in question was born, or perhaps the place where he received his first education. However, no medieval author or commentator ever tried to determine Sacrobosco's birthplace on the basis of his name. On the other hand, at a very early date the tradition arose that he was English by birth although he taught in Paris. As early as 1271 a certain Robertus Anglicus wrote (somewhere in France) one of the first commentaries on the *Sphere*, which he provided with a brief introduction in which he enumerated the four Aristotelian 'causes' of this work which must have become a well known text book by this time. Here Robert stated explicitly that the *causa efficiens* of the *Sphere* was "Johannes de Sacrobosco Anglicus".[7] He gave no particular reasons for this statement, but since he was an Englishman himself it is quite possible that he had some sort of direct information, or perhaps even personal memories, of a fellow countryman who lived, as we shall see, only thirty or forty years earlier. At least we have no positive reasons to doubt Robert's assertion, which was never seriously challenged during the Middle Ages, perhaps because questions of origin were of very little importance at a time when the truly international character of the scholastic community was still a matter of course.

This unambiguous medieval tradition was faithfully adopted by the first biographers in their prefaces to printed versions of the *Sphere*. In 1550 Elias Vinet maintained that "John of Sacrobosco's mother country was that which is now called the English island and formerly Albion and Britannia",[8] and in 1569 Schreckenfuchs simply spoke of "Joannes de Sacrobusto, natione Anglus",[9] being no more explicit than the greatest of all the commentators, Christoph Clavius, who in 1581 described our author as "Joannes de Sacro Bosco natione Anglus".[10] Obviously the precise place of Sacrobosco's birth was immaterial even to commentators who wrote extremely long and detailed expositions of his best-known work.

This situation was drastically changed through the efforts of the antiquarians of the sixteenth and seventeenth centuries. These pioneer scholars were inspired partly by a humanistic interest in history as such, partly by the desire to salvage as much as possible from the ruins of medieval civilisation. The harvest was great and the workers few so their scope had to be wide. Their great historical, topographical and biographical surveys became crammed with innumerable odd bits of information, neatly labelled and docketed, but often, it must be admitted, collected by uncritical and arbitrary methods reflecting much national and religious prejudice and inevitably leaving much confusion behind. In the case of Sacrobosco this led to the emergence of what might be the English, the Irish and the Scottish hypothesis, respectively.

The English hypothesis originated with John Leland who in the 1540s made the first attempt by an English author to write the rudiments of a biography of Sacrobosco. It began as follows:

> John Sacrobosco, so called from his birthplace which I interpret as the Saxon name of Haligwalde, or Halifex, which is the name of a very famous wool

> market in Yorkshire. From this conjecture I might easily believe that he came from there. Thomas Grynaeus, the chief among our British mathematicians, is of precisely the same opinion. In so far as I gather he studied in his youth at the academy which is so well known at the ford of the Isis.[11]

It is quite interesting to follow the line of thought behind these words. Leland begins in a sensible way by construing "de Sacrobosco" as referring to the birthplace of our author. Since there is no place in Britain called Sacrobosco he assumes it to be a latinised form of an English word which he in the literal way renders as "Haligwalde", or "Holywood" in more modern terms. So far, so good. But since Leland obviously knew no place called Holywood in England he identified his Holywood with the well known Yorkshire centre of the wool trade which is still known as Halifax. As Leland himself admits, this was purely conjectural and supported by no evidence at all. All he can offer is the assertion that the foremost British mathematician, Thomas Grynaeus, was of the same opinion.[12] In consequence, Leland found it easy to believe that Sacrobosco was a Yorkshireman born at Halifax.

The next step was to provide him with an academic education which according to Leland he acquired at Oxford University, described with typical 'humanistic' circumlocution as the "well known academy at the ford of the Isis". Again there is no evidence, but it seems unlikely that Leland's choice of Oxford rather than Cambridge was completely arbitrary. He himself was educated both at Christ College, Cambridge and at All Souls, Oxford, and so he was well acquainted with both universities. Furthermore, he uses the expression "quantum ego colligere possum" ("in so far as I can gather"), which seems to indicate that he had a specific reason for bringing Sacrobosco to Oxford instead of Cambridge. But we shall never know what it was that Leland gleaned since Sacrobosco is not mentioned in any of the surviving records of thirteenth-century Oxford.

Thus the English hypothesis was founded upon extremely shaky grounds. Nevertheless, it was uncritically adopted by John Bale[13] in 1557, from whom it passed to William Camden, who in his *Britannia* from 1586 described Halifax as a town of great renown both for its ancient privileges and for being the birthplace of Sacrobosco.[14] However, Camden knew more about place-names than Leland and remarked first, that Halifax was formerly called Horton, not Holywood, and second, that Holywood is not equivalent to Halifax. For north of the Trent the English equivalent of the word *fax* is not 'wood' but 'hair', as in the family name Fairfax, which means 'fair haired'. In consequence, if Sacrobosco means 'Halifax' it should be rendered 'Holyhair' instead of 'Holywood'.[15] Thus without mentioning his name Camden had revealed the weak point of Leland's argument. Nevertheless, the idea of Halifax being the birthplace of Sacrobosco was destined to enjoy a long life and it would be tedious here to enumerate the many authors who later took it for granted without hesitation.[16]

The Irish hypothesis had emerged even before Camden gave his rather qualified support to Leland's assertion. It appeared in 1577 in Richard Stanyhurst's *Description of Irelande* in the form of a brief note in the seventh chapter on "The names and surnames of the learned men and authors of Ireland" which includes "Joannes de sacro bosco, borne in Holywoode, and thereof surnamed de sacro bosco. He wrote an excellent introduction, De Sphæra."[17] Stanyhurst gave no source for this assertion, but his idea may well stem from the fact that Holywood is

a well known place-name in Ireland, although he did not say which Holywood he had in mind. One possibility would be Holywood, or Ardicnise, in Co. Down about five miles north-east of Belfast where in the thirteenth century an ancient religious settlement was transformed into a Franciscan house.[18] However, when in 1639 James Ware discussed the hypothesis he assumed with "Stanihurstus et alii" that the birthplace of Sacrobosco was Holywood near Dublin — "in agro Dubliniensi". Being aware that the Halifax hypothesis was impossible for the philological reasons already pointed out by Camden — "for Holyfax means sacred hair, not sacred wood[19]" — and also of the existence of the Scottish hypothesis mentioned below, Ware decided not to form any opinion of his own on this question, and the Irish hypothesis never had many adherents.

England and Ireland having thus staked their claims to Sacrobosco, it could only be a question of time before Scotland would follow suit. This actually happened in 1627 when a wandering scholar by the name of Thomas Dempster and son of the Laird of Muresk published his *Ecclesiastical history of the Scottish people*, a work which was printed at Bologna and did not appear in Britain until 1829. Dempster was an ardent polemicist who delighted in heaping scorn upon other scholars who happened to disagree with him. With respect to Sacrobosco this led him to brand Leland as a detestable person who had made an Englishman of Sacrobosco "by his usual kind of futile arguments and ridiculous reasons".[20] As a fervent Roman Catholic convert Dempster may well have nourished hateful feelings towards the antiquarian who one century earlier had stripped the English monasteries of books and manuscripts on behalf of the king. But his own rather perfidious form of scholarship is strikingly illustrated by what he goes on to say about Camden, whom he blames for making Sacrobosco a native of Halifax, although the original name of this town was not Holywood but Horton – without mentioning that it was Leland who first traced Sacrobosco back to Halifax, and that it was Camden who actually demolished this hypothesis by discovering the old name of Horton for this town. This example goes a long way towards justifying the severe judgement on Dempster as a scholar which posterity has so often expressed.[21] In consequence, it is tempting to brand Dempster's own account of Sacrobosco as unreliable speculation not worth consideration. On the other hand, he is the only one among the antiquarians who refers to a definite source of information, so one has to listen to what he had to say. Let us first consider the following three passages:

(1)"Johannes a Sacrobosco, or Halybush in the vernacular [was] a Scotsman of a family which still exists among us, preserving a most reliable memory of him."

(2)"The Acts of the German Nation in [the church of] St. Cosmas in Paris explicitly state that he was Scottish and that he was admitted into this university on the fifth of June 1221."

(3)"He was a canon in the monastery in Nithsdale [which is called] Haliwood in the vernacular, and was founded by countess Deo Virgilla of Gallovidia."[22]

The first passage shows that Dempster does not derive the name Sacrobosco from a place name, but from the name of a family called "Halybush" which is said to be still living in Scotland, preserving – in 1627 – a clear memory of its famous thirteenth-century member. It is impossible to verify this fantastic statement which certainly looks like one of the fabrications for which Dempster has

acquired his rather herostratic fame.

More interesting and certainly worth considering is the second passage, in which Sacrobosco is said to have been enrolled as a member of the German Nation in Paris, an event which is precisely dated to 5 June 1221 as it appears in the acts of this Nation which are preserved in the church of Saint-Côme in Paris. Now, if Sacrobosco was at one time a student in Paris he would have been a member of what Dempster calls the German Nation, that is, that fraction of the Faculty of Arts which is more usually known as the "Natio Anglicana"; and this would have been the case regardless of whether he was Scottish, English or Irish. Moreover, it is true that this English Nation had some connection with Saint-Côme where in the early fourteenth century it kept a chest containing what was necessary for celebrating mass, whereas the money and papers of the nation were kept in another chest placed in the church of Saint-Mathurin.[23] In consequence, the truth of Dempster's assertion presupposes, firstly, that the papers of the English Nation were moved from Saint-Mathurin to Saint-Côme sometime before 1627, and secondly, that the acts of the Nation went back at least to 1221. The first presupposition is possible, although I have been unable to verify it. As for the second it is almost certainly impossible. Matriculation lists were not in general use in Paris until the end of the thirteenth century,[24] and the extant records of the English Nation do not begin until 1333.[25] We know that Dempster was in Paris on more than one occasion; but it is impossible to say what he actually saw in Saint-Côme — if he did see anything at all. For, everything considered, it is impossible to verify any part of his statement, which may or may not be a fabrication.

In the third passage Dempster returns to Scotland with the assertion that Sacrobosco was a canon of the monastery of Holywood in Nithsdale (near Stranraer in Dumfriesshire), but it is obvious that he was not well acquainted with this religious house. Holywood, or St Cross, was a small Premonstratensian Abbey founded from Soulseat sometime before 1225 when we first hear about it. That Dempster assumes it to be founded by Deo Virgilla reveals that he is confusing it with Sweetheart Abbey which was founded much later (about 1275) by John Balliol's widow Devorgilla.[26] Of course, there is no proof that Sacrobosco was not a Premonstratensian, just as there is no proof to the contrary. On the other hand, Dempster's story is rather strange, considering that he first translates Sacrobosco as Halybush, construing this as a family name, and next connects it with a place called Holywood – a coincidence which must make any historian suspicious. In consequence, it is difficult to accept anything that Dempster says.

Nevertheless, despite its internal weakness, this Scottish hypothesis found a considerable number of supporters most of whom contributed to make the issue even more confused. Here we shall quote only the *Life of Joannes a Sacro Bosco, Professor of Mathematics at Paris*, as written in 1708 by George Mackenzie. It reads as follows:

> This Gentleman was born in Nithsdale, and, in his younger Years, apply'd himself very closely to the Study of the Belles-Lettres [*sic*!], Mathematics and Theology. Having finished the Course of his Studies, he entred into Holy Orders, and was made a Canon Regular of the Order of St. Augustin, in the Famous Monastery of Holywood in Nithsdale, from whence he has his name of Joannes a Sacro Bosco. After he had staid for some Years in this

> Monastery, he went over to Paris, where he was admitted a Member of that University, upon the 5th Day of June in the Year 1221 under the Syndic of the Scots Nation.[27]

Obviously relying upon Dempster, Mackenzie here gives an even more free rein to purely speculative conclusions with details of Sacrobosco's education more proper for a seventeenth-century 'Gentleman' than for a thirteenth-century scholar. We notice that both he and Dempster carefully avoid any reference to Oxford as if even such a modest English connection were repugnant to these champions of the North. Moreover, he assumes Sacrobosco to be born at Nithsdale although Dempster had said nothing about his birthplace; and finally, he makes him an Augustinian Canon Regular, obviously unaware that Holywood was a Premonstratensian foundation.

Dempster and Mackenzie seem to be jointly responsible for all the confusion which persists until our own time. Thus in 1936 the Premonstratensian historian A. Erens listed Sacrobosco among the authors of the Order, assuming his Scottish origin but showing some independence by letting him go to Oxford from Paris before finally placing him at Holywood Abbey.[28] More sceptical was another historian of the same religious affiliation, N. Backmund, who doubted that Sacrobosco was a monk at Holywood and stressed that all hypotheses about his nationality are without proof, "omnia carent probatione".[29] Unfortunately this healthy scepticism was unable to remove the confusion, with the result that even the most authoritative work on scientific biography in recent years presents Sacrobosco as an Augustinian canon [*sic*] at Holywood who went to Paris after 1220 and became a member of the Scottish [*sic*] nation on 5 June 1221.[30]

Before the time of the antiquarians there were a number of medieval authors or scribes who placed the birthplace of Sacrobosco outside the British Isles. In one manuscript from the fifteenth century he is described as a Catalonian,[31] while in another he is said to be of French origin.[32] Thus these medieval sources are confused and no importance can be attached to them since they are all of a rather late date and offer no evidence for their statements. Modern authors have added to this confusion by careless examination of the MS material, as when J. C. Russell found evidence of Sacrobosco being regarded as a Jewish convert who translated astronomical texts from Hebrew into Latin.[33] This was based on a codex originating from the monastery of Ruppin in Germany and containing a fifteenth-century copy of a treatise which begins "Me pudet audire iudeum talia scire" and is usually known as the *Computus iudaicus*.[34] It is provided with a preface maintaining that the "causa essencialis" [*sic*] of the work was "a certain student Johannes who was a former Jew but was at one time baptized wherefore he translated this science from Hebrew into Latin".[35] Here there is no mention of Sacrobosco, but there is a note in the margin saying "or, according to others, Johannes de Sacrobusco" ("vel secundum alios iohannes de sacrobusco"). In other words, the scribe assumed that the translator was either a Jewish convert by name of Johannes, or Sacrobosco, but was careful enough not to identify them.

We shall not here go further into the details of these purely hypothetical and unsubstantiated medieval ascriptions but return to the more important question of whether any conclusion can be drawn from the work of the antiquarians.

Here the Irish hypothesis is certainly the least interesting. It appears out of the blue as a pure invention by Stanyhurst and has no independent support whatever.

The English hypothesis by Leland is supported by the fact that already in 1271 Sacrobosco was called "anglicus" by his English commentator Robertus Anglicus; but it suffers from the defect of being unable to explain the name "de Sacrobosco" since it is impossible to uphold Leland's identification of Holywood with Halifax. On the other hand, the Scottish hypothesis has the advantage of providing a reasonable explanation of the word Sacrobosco as derived from the name of the well known Scottish monastery of St Cross at Holywood in Nithsdale, although one would expect a monk from Holywood to latinize his name as "de Sancta Cruce" instead of "de Sacrobosco". But the hypothesis is contradicted by the epithet "anglicus" used in Robert's commentary, and also by the fact that, whereas scores of Scottish (and Irish) students underlined their nationality by adding a "Scotus" to their Christian names, there is – to the best of my knowledge – no medieval author who ever called Sacrobosco a Scotsman. In view, too, of the notorious carelessness and unreliability of Dempster's scholarship, his hypothesis must remain as controversial as that of Leland. When all is said and done one has to admit that all three hypotheses rest upon shaky foundations. In consequence, we simply do not know where Sacrobosco was born. On the strength of the evidence of his first commentator the presumption must be that he was English. But even of this we have no certainty, and it must be a matter of further research to find a place in England from the name of which the epithet "de Sacrobosco" can be reasonably explained.

However, if the name of Sacrobosco did not lead us to the place where he was born it certainly leads us to his grave which according to Vinet,[36] followed by Leland[37] and Riccioli,[38] was in the cloisters of the monastery of Saint-Mathurin in Paris. Here it could be seen at least until the end of the eighteenth century when it was described by Lalande[39] as adorned with an astrolabe and some verses in Latin. The tomb is no longer to be seen and was presumably destroyed during the upheavals caused by the French Revolution. Today it is impossible to say what the "astrolabe" mentioned by Lalande was, except that it must have been a figure engraved on the tombstone and representing some kind of astronomical instrument. Vinet and Riccioli described it as an engraved sphere, or a "sphaera insculpta". Whatever it was, it was obviously destined to commemorate Sacrobosco's work as an astronomer.

Fortunately we are in less doubt with regard to the inscription which Vinet transcribed as follows:

(a) De Sacrobosco qui computista Joannes
(b) Tempora discrevit, iacet hic a tempore raptus.
(c) Tempora qui sequeris, memor esto quod morieris.
(d) Si miser es, plora: miserans pro me precor ora.[40]

The two last lines of this epitaph is a *memento mori* of a very usual type and without particular reference to Sacrobosco, in contrast to the two opening lines which prove that this was in fact his grave, giving his name in full and commemorating his fame as a *computista*, that is, an expert on time-reckoning who "tempora discrevit", that is, who sorted out the different aspects of time. Thus Sacrobosco was here remembered in public with a reference to the subject he dealt with in his most comprehensive work, as we shall see in the next section. We notice that there is no date on the monument, at least not if Vinet's transcription is

complete. This raises a problem with which we shall have to deal in Section 4 of this paper. Here we shall only underline the important fact that Sacrobosco was not laid to rest in the church of the unknown parish in which he lived, but buried in a place of considerable distinction in the University. Originally St Mathurin was a hospital which in 1229 was handed over to the brothers of the Holy Trinity by the Bishop of Paris, the famous philosopher Guillaume d'Auvergne.[41] In the following years the chapel of this institution became as it were the headquarters of the University which had no buildings of its own, but usually held its plenary congregations here[42] and also kept its documents in a chest in the chapel.[43] We can therefore conclude that at the time of his death Sacrobosco must have been a well-known figure in the University since it decided to bury him in its 'own' church, and also to commemorate his name and his work with a rather spectacular monument, although this may have been erected sometime after his death, as we shall see. Another possibility would be that Sacrobosco himself was a brother of the Holy Trinity; but this can be ruled out since it would almost certainly have precluded his having a teaching position in the University.

Thus the final conclusion of this phase of the quest for Sacrobosco must be that his name is but a poor clue to his life. It leads only from an unknown origin – although possibly in England – to a grave in Paris with a monument revealing his fame as an astronomer with a particular interest in time-reckoning. In order to provide this shadowy picture with more details we must now take a brief and provisional look at his works.

3. *The Works*

When a medieval author gradually rose to such a degree of fame that his name became a household word in scholarly circles he usually became credited with more works than he ever produced. This happened already in the Middle Ages themselves when the science of bibliography was almost non-existent, with the result that an anonymous text of unknown origin would more often than not be ascribed to one or another of the more well-known authors in the same field. That also the first printed catalogues of the various collections of medieval MSS often suffer from the same defect is known to every student of medieval literature. Unfortunately Sacrobosco is no exception to this rule and several of the writings ascribed to him by medieval authors or more recent bibliographers must be rejected as spurious. However, there are three, or possibly four, treatises which on all accounts must be accepted as authentic. In the following we shall distinguish them by the sigla *A*, *S*, *C* and *Q*, without describing them in more detail than is necessary for the present purpose.

(*i*) *A*: *Algorismus*

This is a rather brief treatise comprising a total of about 5600 words. It has the incipit "Omnia quae a primaeva origine rerum" and explains in a rather dry but precise way how to perform ordinary, elementary arithmetical operations using 'Arabic' numerals. There are no mathematical errors in the text. The exposition has a very matter-of-fact character and is not embellished by the many quotations from classical authors which mark Sacrobosco's other works. The only author referred to by name is Boethius who is mentioned once[44] in the text while the incipit contains a hidden quotation from him.[45] Since the text does not deal with

fractions it was often given the title of *Algorismus de integris* to distinguish it from the later *Algorismus de minutiis* or *Algorismus minutiarum* which dealt with the handling of sexagesimal fractions. More commonly it was called the *Algorismus vulgaris*. Nothing in the text indicates where or when it was written.

No complete survey of the MSS of the *Algorismus* has ever been made, but it can be estimated that the number of extant MSS of pure or revised versions amounts to more than fifty copies. A small number of these are anonymous, but the great majority are unanimous in ascribing the text to Sacrobosco so that there is no reason to doubt his authorship. The text was also printed several times, the *editio princips* being produced in 1488 in the press of Johannes Pryss of Strasbourg. Later editions were fairly numerous, the work being printed in Venice, Paris, Vienna, Cracow, and Antwerp where what seems to be the last among the early editions appeared in 1582.[46] This reveals the popularity which this little textbook enjoyed even three hundred years after its first appearance. In more recent times it has been edited by J. O. Halliwell,[47] later by M. Curtze,[48] and at last in what seems to be a final, critical edition by F. Saaby Pedersen.[49]

(*ii*) *S*: *Tractatus de sphaera*

This is the work usually referred to as "The *Sphere* of Sacrobosco". It is much longer than *A* with a total of about 9000 words. It begins with a preface with the incipit "Tractatum de spera quattuor capitulis distinguimus", followed by the four chapters dealing with:

I The general structure of the universe
II The circles of the celestial sphere
III Phenomena caused by the daily rotation of the heavens as seen from the various 'climates' of the inhabitable world
IV Planetary motion, in particular with the elements of the theories of the Sun and Moon and the explanation of eclipses.

The style is pleasant, and while only Boethius was quoted in *A*, the *Sphere* is enlivened by numerous quotations taken not only from astronomical works, but also from classical authors and poets.

As in *A*, there is nothing in the text of *S* that allows us to determine where or when it was written. However, we have thirteenth-century evidence that it originated in Paris. When in 1297 Bartholomaeus de Parma wrote his great commentary on *S* he stated: "John of Sacrobosco said in his treatise on the *Sphere* which he composed while he lived in the University of Paris...",[50] and we have no reason to doubt that this is correct and that *S* was in fact written in Paris by an author who taught in the university. Actually this remark seems to be the first direct reference to Sacrobosco's connection with the University of Paris.

The number of extant MSS is unknown, but there is no doubt that it must be counted in hundreds. In his critical edition of *S*,[51] Thorndike described and used eighteen MSS of *S*, some of which are part of one or another of the many commentaries which were produced in the Middle Ages. Half of these MSS date from the second half of the thirteenth century. Among the MSS which were not noticed by Thorndike one must draw attention to a copy in the Royal Library of Copenhagen[52] which may be written about 1240 and thus may be considered the earliest MSS known at present.

The printing history of *S* is very long and complicated and not yet properly

investigated. The first edition appeared as early as 1472 from the press of Andreas Belfontis at Ferrara. This date means that *S* was the first astronomical work of all to be printed (if we ignore mere calendars and prognostications).[53] Soon other editions followed in great numbers. Thus the *Sphere* was printed no less than thirty-five times at Venice in the period from 1476 to 1620, and the same number of printed versions appeared from 1494 to 1619 in Paris. Also Cologne, Basel, Leiden, Antwerp and Wittenberg produced many editions, just as the book was occasionally printed at Bologna, Milano, Avignon, Dijon, Louvain, Frankfurt, Vienna, Augsburg and Cracow.[54] The last edition of this series seems to have been printed in 1673 at Antwerp. Thus the book was kept in print and available all over Europe for two complete centuries, a record which no other astronomical work has been able to break. The reason for this long span of life can only be that the *Sphere* was in constant use as a text-book not only in the Middle Ages but even long after its elementary contents had been overtaken by the general development of astronomy which already in the Middle Ages caused the book to appear old-fashioned and insufficient. However, its very obvious qualities of clarity and brevity guaranteed its survival, the insufficiencies being remedied by an ever-flowing stream of commentaries, perhaps beginning with the already mentioned commentary written in 1271 by Robertus Anglicus[55] and ending with such comprehensive works as the commentary by Schreckenfuchs (1569)[56] and Clavius,[57] the latter running to about 800 pages in its later editions. A further proof of the popularity of the Sphere lies in the many translations into the vernacular German, English, Italian and Spanish, which can be mentioned here only in passing.

(*iii*) *C*: *Compotus*

This treatise on time reckoning was by far the longest of Sacrobosco's works and in many ways the most original and interesting. It runs to about 19,000 words and opens with the words "Compotus est scientia considerans tempora". It deals in great detail with all aspects of time reckoning, both civil and ecclesiastical, although it is often given the title of the *Compotus ecclesiasticus*, or in some cases *De anni ratione*, or *Compotus philosophicus*.

We shall have much more to say about *C* below and here only notice that there is no modern edition of this important work. On the other hand it was often printed during the two centuries in which the *Sphere* was so popular, although it was not printed nearly as early.[58] From the first edition in 1531 at Wittenberg to the last one (1673) at Antwerp at least thirty-five printed versions are known; half of these appeared at Wittenberg, usually together with the *Sphere*, both works (which he found adequate despite their old-fashioned character) being promoted by Philip Melanchthon as part of his efforts to provide the reformed university with text-books.[59] No versions in the vernacular are reported.[60]

The lack of a modern edition enhances the importance of studying the early MSS of *C*. Without pretending to be complete, the following list presents a number of versions dating from the thirteenth and early fourteenth centuries, i.e. from the first hundred years of the existence of the text:[60]

Basel O.II.7, 23r – 38v, c. A.D. 1300
Bruges 522, 31v – 49r, saec. XIII-XIV
Bruxelles 2910-20, 42r – 76r, c. A.D. 1280

Cambridge McClean 166, 39v – 71v, c. A.D. 1280
Cambridge Univ.Libr. Ff.vi.13
Cambridge Univ.Libr. Ii.i.13, 18r – 25r, saec. XIV
Cambridge Univ.Libr. Ii.i.15, 25v – 38r, saec. XIV
Cambridge Univ.Libr. Ii.i.17, 30r – 52v, saec. XIV[1]
Cambridge Univ.Libr. Ii.III.3, 36r – 55v, saec. XIII-XIV
Colmar 414, 26r – 50r, saec. XIII
Copenhagen Add. 447, 2°, 58r – 77r, saec. XIV[1]
Copenhagen GKS 277, 2°, 89v – 98r, c. A.D. 1240
Copenhagen GKS 1810, 4°, 24r – 47v, saec. XIV
Copenhagen NKS 275[a], 4°, 31r – 63v, saec. XIII
London BM Egerton 844, 23v – 48v, c. A.D. 1300
London BM Harleian 3647, 33v – 54v, c. A.D. 1300
Lugano XXI, 20, 21v – 44r, A.D. 1281[60]
Madrid 8918, 15r – 31v, saec. XIII
Milan Ambros. H.75 sup. II, 16 ra – 34va, A.D. 1284
Montpellier Ec. Méd. H 323, 42v – 73r
Munich CLM 353, 8r – 20v, saec. XIII
Paris BN Lat. 7416 B, 31va – 50vb, saec. XIV[1]
Paris BN Lat. 7475, 10r – 55v, saec. XIII
Paris Ste Geneviève 1043, 12r – 28v, c. A.D. 1300
Stockholm X, 767, 42r – 66v, saec. XIV[1]
Vatican Lat. 3114, 33v – 55r, saec. XIV[1]

For the reasons already given above, the MSS Copenhagen GKS 277, 2°, can be dated to 1240 or a little later. This means that it is considerably earlier than any other known MSS and indeed copied within a few years of the composition of the original text, which can be dated fairly precisely to 1232 or 1235 as we shall see in the following section of this paper. Unless explicitly stated we shall refer to this manuscript in the following.

As in the case of *A* and *S* there is no evidence in the text of *C* as to where it was written; but since the epitaph of Sacrobosco in Paris commemorated him as a *computista* we can safely assume that his greatest work was composed in this city. In contrast to *A* and *S* it can be fairly accurately dated to the years 1232-35 as we shall see in the following section.[61]

(*iv*) *Q*: *Tractatus de quadrante*

This is a short text of only about 2,000 words describing the construction and use of the *quadrans vetus* or Old Quadrant. It is not preserved in nearly as many MSS as Sacrobosco's other treatises and cannot have enjoyed a similar popularity. Among the MSS are the following:

Copenhagen GKS 1810, 4°, 56r – 60r, saec. XIV
Munich CLM 353, 35 – 38, saec. XIII
New York Publ. Libr. 69, 70r – 79v, saec. XIII
Paris BN Lat. 7196, 25r – 27v, saec. XIII
Vatican Lat. 3099, 25ra – 28va, A.D. 1472

In the Paris MS the treatise has the title *Tractatus magistri Ioannis de Sacrobosco super compositione quadrantis simplicis et compositi et utilitatibus*

utriusque, and the incipit "Omnis scientia per instrumentum operativa". The same incipit is found in the other MSS although in some cases the last word reads "operative". The MSS listed above all give Sacrobosco as the author, with the exception of CLM 353 which ascribes the text to Arnoldus de Villanova. To the best of my knowledge this treatise has never been printed. That it was written in Paris is obvious from a numerical example stating that the colatitude of Paris is 42°.[62]

The authenticity of *Q* has never been as generally admitted as that of the other three treatises. On the other hand there is no reason to doubt the ascription to Sacrobosco in the majority of the MSS. It is no argument against his authorship that *Q* is written in a very dry style unlike the much more literary prose of *S* and *C*, since the text is concerned with the construction and use of an astronomical instrument, described in brief and precise terms, but without Sacrobosco's usual references to classical authors which would indeed have been out of place here. The text was first examined by Delambre[63] on the basis of the MS BN 7196. We shall return to it in a later section of this paper.

(v) Spurious works

It almost goes without saying that an author of Sacrobosco's renown would be credited with a number of works which cannot be accepted as genuine. Thus a number of usually late medieval MSS mention him as the author of the well-known *Theorica planetarum* with the incipit "Circulus eccentricus vel egresse cuspidis" which has also been ascribed to Gerard of Cremona or Gerard of Sabbioneta but is really the work of an author who has not yet been identified.[64] There are absolutely no reasons for connecting it with Sacrobosco, but it is easy to see how the misunderstanding may have arisen since the *Theorica* often follows directly after *A, S* and *C* in the medieval *Corpus astronomicum*.[65]

In an old catalogue of the Vatican MSS Sacrobosco is mentioned as the author of commentaries on Aristotle's *De caelo* and *De generatione et corruptione*.[66] No such commentaries have been mentioned elsewhere and it is quite certain that they never existed, in particular since Sacrobosco was in opposition to the Aristotelian approach to astronomy, as we shall see.

Finally there are a few references in the early literature to Sacrobosco as the author of a treatise on the astrolabe. This was first stated in 1550 by Elias Vinet[67] and later repeated by Riccioli[68] and Ger. Voss,[69] but once again no such treatise has materialized. Since Vinet said that Sacrobosco wrote "de sphæra mundi, de astrolabo, de algorithmo ... et de computo ecclesiastico" it is natural to assume that the treatise on the quadrant was here mistaken for a work on the most popular of all astronomical instruments of the Middle Ages.

In the following we shall disregard all these uncertain attributions, considering *A*, *S*, *C*, and *Q* to be the only works which can be safely ascribed to Sacrobosco and used as testimonies to his ideas on science in general and astronomy in particular. However, before we examine them from this point of view we must ask whether these four works contain any evidence as to the time when they were written.

4. *The Dates*

The dating of Sacrobosco and his works presents a difficult problem. So far we

have only met with the date of 5 June 1221, the day he was made a member of the University of Paris according to the enigmatical Thomas Dempster. However, since it is impossible to verify this statement it is best here to disregard it, in order to see if more reliable dates can be determined by investigating Sacrobosco's own writings. There are here two different problems to be considered, and we must ask, firstly, if the works contain internal evidence for the time at which they were written.

As far as *A*, *S* and *Q* are concerned the answer is that there is nothing whatever to be found in these three treatises, neither in the form of numerical examples from which a date can be inferred, nor in the form of colophons stating when they were finished. However, we are in a more fortunate position with respect to *C*, as might be expected in a work concerned with time reckoning. In fact, scholars have been wrestling with the date of *C* for centuries, usually starting with a number of verses found at the end of the treatise in most of the MSS. They read as follows:

1 O qui perpetua mundum ratione gubernat
2 Terrarum celique sator qui tempus ab evo
3 Ire iubes, stabilisque manens das cuncta moveri
4 Tu stabilire velis opus hoc per temporis evum.
5 .M. Christi bis .CC. quarto deno quater anno
6 De sagero busco discrevit tempora ramus
7 Gratia cui nomen dederat divina iohannes
8 Annuat hoc nobis huius sic carpere fructum
9 Ecclesiae Christi quod nos hinc fructificemus.[70]

There are some reasons to doubt the authentic character of these lines, or at least of some of them. They are found in most of the MSS, but significantly omitted in the early Copenhagen MS GKS 277, 2°, which ends with the words "Dicitur evum etiam idem quod etas; unde homo magni evi dicitur".[71] However, the beautiful and poetic lines 1, 2 and 3 are a quotation from Boethius,[72] an author with whom Sacrobosco was well acquainted and whom he quoted on more than one occasion. In consequence, it is probable that he actually did finish his *Compotus* with this appropriate quotation, adding line 4 as a well-phrased prayer of his own for the preservation of his treatise throughout the ages. This hypothesis is supported by the fact that at least one fourteenth-century MS[73] has the words "Explicit compotus" inserted between lines 4 and 5, just as there is a thirteenth-century MS[74] which ends with line 4 after which the remaining five lines are added in a later hand of the fourteenth or fifteenth centuries. Moreover, it is difficult to believe that a lover of good poetry like Sacrobosco would quote Boethius only to supplement him by four lines which are really bad from a literary point of view, just as line 6 is difficult with respect to grammar.[75]

However, the real trouble is caused by line 5 which at first sight seems to provide the date on which Sacrobosco "discrevit tempora". Unfortunately the phrase is ambiguous since it can be construed in two different ways. If 'quater' qualifies the two preceding words 'quarto deno' = 14 we arrive at the date of A.D. 1256, but if 'quater' refers to 'deno' only we get the year A.D. 1244. In 1550 Vinet opted for 1256[76] and several later authors have adopted the same reading.[77] Others have felt that this was too late a date for Sacrobosco, who according to Clavius "floruit circa annum Domini M.CC.XXXII"[78] which is correct, as we shall see. Riccioli restricts himself to saying that "non omnes consentiunt", giving a long range of

dates from various authors in support of this non-committal statement.[79] Among more recent authors the majority have followed P. Tannery who in 1897 said that he "preferred to interpret the verses in question as indicating the date of 1244".[80] There is no reason to follow Duhem's suggestion of a scribal error[81] since line 5 is perfectly open to both constructions.

A new and interesting interpretation of line 5 has been suggested by Dr C. M. Taisbak (in a private communication) who construes *deno* as a 'tenth' of years, or a decade, so that "quarto deno quater" is taken to mean "in the fourth year of the fourth decade", resulting in the date 1234.

The next problem is what it was Sacrobosco did in 1234, 1244 or 1256? Although 6 is a difficult line it clearly refers to Sacrobosco's work in time reckoning, and to that only. It would seem, therefore, that the date would refer to the year in which the *Compotus* was finished. This was assumed by Vinet who also took 1256 to be the date of the *Algorismus*, the *Sphere*, and the spurious treatise on the astrolabe – an assumption which must be rejected at once since it presupposes an impossible literary output of a single author within only one year. Nevertheless, the damage was done and one or the other of the two dates 1244 and 1256 have been adopted by many later scholars as the date of one or another of Sacrobosco's works.

But there was even worse to come. It did not escape the attention of the early scholars and antiquarians that the expression "discrevit tempora" in line 6 is strongly reminiscent of the "Tempora discrevit" in line (b) of the epitaph in St Mathurin quoted above. This inevitably caused confusion. John Bale was careful enough to distinguish between the two poetic statements, mentioning the epitaph without quoting it and continuing by saying that "de eius tempore sunt hi versus", after which follows lines 5, 6 and 7 of the concluding verses of the *Compotus*;[82] but he only drew the conclusion that Sacrobosco "claruisse fertur ... 1256". Nevertheless, the two texts were not kept separate and in 1696 Gerard Voss maintained that the fatal lines 5, 6 and 7 of the *Compotus* were in fact the verses inscribed on Sacrobosco's tomb, with the result that he took 1256 to be the year of Sacrobosco's death.[83] In this he was followed by Mackenzie,[84] Lalande[85] and in more recent times by R. T. Gunther[86] and A. P. Youschkewitsch.[87] Other authors perpetuate the same kind of confusion by giving the year of Sacrobosco's death as either 1244 or 1256.[88]

Since the placing of the year of Sacrobosco's death in either 1244 or 1256 rests upon a confusion of his epitaph with the concluding verses of the *Compotus*, we must conclude that we have no evidence that Sacrobosco died in either of these years which have played such a great role for his historians. On the other hand his biographers in general seem to have overlooked the only known definite reference to the year of his death. It is found in the *Chronicon* written in 1608 by Miraeus who under the year 1236 noted that "Johannes a Sacrobosco, who wrote the book on the Sphere and the ecclesiastical compotus, dies in Paris".[89] This date was soon after adopted by Dempster, with direct reference to Miraeus[90] who did not quote the source from which he had this information. Accordingly it is impossible to verify it until eventually further evidence becomes available. All we can say is that the year 1236 does not conflict with anything else we know about Sacrobosco, and that it is quite possibly correct, although by no means certain.

We must now consider the question whether the years 1234, 1244 or 1256 may

refer to the time of the composition or completion of the *Computus*. Here we are on much more certain ground since this text contains a passage saying that "ab incarnatione domini elapsi sunt [*N*] anni".[91] The only difficulty is that the number *N* varies from one manuscript to another. There is no doubt that the majority of the MSS have $N = 1235$.[92] But one of the earliest MSS has $N = 1232$ and so have a number of the printed editions. Now 1235 may easily be a scribal error for 1232, or vice versa, particularly if Roman numerals are used, so it is impossible to say which of the two dates is the correct one. However, it is possible to investigate the question in more detail on the basis of the context in which the date occurs. Sacrobosco is here concerned with a small discrepancy between the two cycles upon which the ecclesiastical calendar is based. We shall return to this problem in more detail in a later section and only mention here the essential part of Sacrobosco's argument. He begins by stating that "According to Ptolemy in Book III of the *Almagest* 19 solar years are equal to 6939 days 18 hours although by a very crude computation".[93] Accordingly Sacrobosco is aware that the Ptolemaic year is somewhat different from the Julian Calendar year of 365 days 6 hours. Nevertheless he uses the Julian year in the following calculation, which accordingly must be regarded only as an example. Sacrobosco continues by saying that "according to Book IV of the *Almagest* the lunar *cyclus decemnovennalis* of 235 lunations is 6939 days 16 hours and nearly 2/3 hours".[94] The difference is $1 + 1/3$ of an hour, and Sacrobosco maintains that this amounts to 65 hours + 65/3 hours over the time which has elapsed since the Incarnation. This implies that this period of time equals 65 complete cycles of 19 years each. Therefore we must have $N = 65 \times 19 = 1235$. In consequence, the value 1235 must be correct — at least if we assume that we are not dealing with an approximative calculation.

Now Sacrobosco continues by saying that the $65 + 65/3$ hours amounts to 3 days 14 hours, where a more correct result would be 3 days 14 hours 40 minutes, a value which Sacrobosco obviously has rounded down to 3 days 14 hours — only to continue with rounding it further to "tres dies et dimidiam". In consequence, he is not averse to approximations as such. The problem then is whether the year $N = 1232$ can be explained as a result of his reasonably rounding off a number somewhere in the calculation. Now $1232 = 64 \times 19 + 16$, or, in other words, there are $(64 + 16/19)$ 19-year periods in 1232 years. In this span of time the discrepancy would amount to

$$(64 + 16/19) \cdot (1 + 1/3) \text{ hours} = 3 \text{ days } 14 \text{ hours } 28 \text{ minutes}$$

so that we here get a better approximation to the 3 days 14 hours of the text, by discarding only 28 minutes instead of 40 minutes. However, the result seems to be that both $N = 1235$ and $N = 1232$ are compatible with the calculation if we assume that Sacrobosco always rounded down to the nearest integral hour.

Everything considered, all we can say is that the passage analysed above must have been written by Sacrobosco either in 1232 or 1235, when already more than half of the *Compotus* was finished. This makes it unlikely that the whole work had to wait for its completion until 1244, not to speak of 1256. In consequence neither of these dates should be in any way connected with the *Compotus*. This conclusion is supported by the fact that at least the last five lines of the verses found at the end of the treatise in many MSS are a later addition to the original version of the text. This being so, there is still one problem left: What relation is

there between these concluding verses and the epitaph?

Here we must remember the significant fact that Sacrobosco was never mentioned in extant documents from his own time. This points to the conclusion that he was not of great fame among the scholars of Paris while he lived and worked among them, and therefore was unlikely to be honoured with a conspicuous epitaph. His fame grew, however, and is works gradually became accepted as standard textbooks both there and in other universities, and there is much to be said for the suggestion already made by Tannery[95] that the monument on his grave was not erected until the university at a later time realized that one of its members deserved to be commemorated in this way. It is impossible to say when this happened; but it may have been after a considerable span of time during which the precise year of Sacrobosco's death had been forgotten. Otherwise one would certainly have expected it to be mentioned in the inscription. But whether this inscription borrowed the characteristic words "tempora discrevit" from the additional verses to the *Compotus*, or whether the verses were composed with an eye to the inscription, seems to be one of the many insoluble problems in the history of Sacrobosco.

When we turn from the *Compotus* to the other works the problem of dating becomes even more difficult. Sacrobosco did not belong to that numerous tribe of authors who delight in quoting their own works, and neither *A*, *S*, *C* nor *Q* contains any reference to any of the other treatises. In consequence, there is nothing in the texts themselves which allows us to place them in their proper historical sequence. To do this one must have recourse to other criteria, all of which presupposes more or less arbitrary assumptions.

Thus one may apply what might be called 'the criterion of maturity', assuming that over the years a scholar must obtain an ever increasing mastery both of his subject matter and of the way in which he presents it. In consequence a more mature work must be dated later than a less perfect production. This sounds reasonable enough provided that the word 'mature' has a precise and acceptable meaning. One way of defining 'maturity' would be to connect it with scientific precision. However, this is not possible in the case of Sacrobosco. His writings are not, it is true, totally free from mistakes or imperfections, and later scholars of the Renaissance sometimes tried to score points for themselves by counting all the faults they were able to find in his works.[96] But, considering the elementary and introductory character of his works as well as the general scientific level of his time, one has to admit that they are remarkably free from serious errors. It follows that Sacrobosco did not 'mature' over the years in the sense of becoming more precise.

Lynn Thorndike applied the criterion of maturity in another way.[97] It is of course a reasonable assumption that during his active years as a scholar Sacrobosco must have become better and better acquainted with the literature on his subject and that this growing familiarity must be reflected in his own writings by a growing number of quotations from or references to other works. This principle is easily applied since we have only to compare the number of such references in the various treatises.

Such a count reveals, first, that there are no references to other authors in *Q*. Of course this does not mean that Sacrobosco invented the quadrant himself, but only that the treatise was written at a stage when he had not yet acquired the

scholarly habit of quoting his sources. There are also few references in *A*, where the only author quoted by name is Boethius although it is obvious that Sacrobosco must have had access to a treatise on 'Arabic' numerals the identity of which he did not reveal.

This situation changes drastically when we consider *S*. Here we find an abundance of references to both scientific and literary authors as shown in Table 1.[98] No doubt some of these references are, as it were, second-hand, as it is clearly the case with 'Almeon' which is the Latin form of the name of the Caliph al-Ma'mum who instigated astronomical research in ninth-century Baghdad without writing anything himself. Nevertheless, the list shows that Sacrobosco was fairly well acquainted with the literature on his subject at the time when he wrote the *Sphere*. Nevertheless, when he composed the *Compotus* his reading seems to have been much more extended since we here find references to many more names, as shown in Table 2.

TABLE 1. References in *S* to other authors.

Literary references	Scientific references
Ambrosius	Alfraganus
Lucanus	'Almeon'
Ovid	Aristotle
Vergil	Eratosthenes
The Bible	Euclid
——	Ptolemy
	Theodosius
	Macrobius
	Pseudo-Dionysius

TABLE 2. References in *C* to other authors.

Literary references	Scientific references	
The Bible	Alexander de Villa Dei	Gamaliel
Claudianus	Alfraganus	Gerlandus
Lucan	Anianus	Hieronymus
Ovid	Aristotle	Hippocrates
Vergil	Augustus Caesar	Josephus
	Bede	Martianus Capella
	Dionysius Exiguus	Plato
	Eusebius	Ptolemy
	Galen	Theophilus Alexandrinus

This analysis shows that if the criterion of familiarity with literature is strictly applied we must conclude that *C* is a later work than *S*, and that both these major works were written after both *Q* and *A*.

Finally we must consider the problem whether there is external evidence for the dates of Sacrobosco's writings; that is, if they show any influence from contemporary writers whose works can be dated more or less precisely. As far as Sacrobosco's *Sphere* is concerned this question has been dealt with at some length

by Thorndike[99] who tried to place this treatise in its possible relationship to the works of Robert Grosseteste and Michael Scot. It is well known that Grosseteste wrote a *De sphaera* which is about half the length of *S* but organized on rather similar lines and with some similarity of vocabulary.[100] The problem here is that it is impossible to give a precise date to Grosseteste's work and that the similarities of the two texts are not of such a nature that we can be certain whether Grosseteste depended on Sacrobosco or whether it was the other way round. There are also important differences. Thus Grosseteste quotes Aristotle's *De caelo*,[101] which is never mentioned by Sacrobosco. Furthermore Grosseteste has a trepidation theory of precession[102] in contrast to the linear theory adopted by Sacrobosco. In general there seems to be no serious reason to quarrel with Thorndike's impression that Sacrobosco's work is the earlier.

Michael Scot comes into the picture as the possible author of the earliest known commentary on the *Sphere* of Sacrobosco.[103] The text says explicitly that the *causa efficiens* of the work was "magister Ioannes de Sacrobosco et alii compilatores".[104] This commentary cannot be dated with any certainty, but Thorndike has drawn attention to the fact that it contains so many references to Aristotle that it must have been written either before Aristotle's works were banned in 1210 or after this ban was tacitly lifted in 1231. The former date seems unacceptable, and so Thorndike concludes that Michael Scot must have written after 1231 and before his death in 1235, at which time Sacrobosco's *Sphere* must have been available.[105] Since Sacrobosco was working on the *Compotus* in 1232 or 1235 it is most likely that his *Sphere* was written at least somewhat earlier and probably around 1230-31. Since in the *Sphere* he allowed himself a couple of references to Aristotle the latter year is perhaps to be preferred, although there is no evidence that the ban on Aristotle was very strictly observed during the years 1210-31; it only prohibited the use of Aristotle's philosophical works as textbooks, while the mere mentioning of his name must have been a minor offence which would have been easily overlooked, particularly in the prevailing intellectual climate of which more will be said below.

Everything considered, it seems that Sacrobosco's active period in Paris was quite short. In fact, there is nothing preventing us from placing it between the year 1221 when he arrived at the University (if there is any truth behind Thomas Dempster's remarkably precise date, however unsupported it is) and the year 1236 when he died (according to the equally unsupported claim of Miraeus). This is not to say that these two dates really marked these two events, but that it is very probable that they fairly accurately circumscribe the period in which he was active in Paris.

5. *The Background*

With John of Sacrobosco safely established in Paris around the end of the first quarter of the thirteenth century, it is now possible further to develop the picture, until the background of its central figure begins to appear.

At this time the scholars of Paris had already transformed the great schools flourishing in the previous century into a unified structure in the form of a *studium generale* — later called a 'university' — in which the various scholastic disciplines were pursued within the framework of four faculties each of which was governed by a corporation of its own masters. There were three 'higher' faculties

of canon law, medicine and theology to which no student was admitted unless he had previously acquired a basic education and obtained a master's degree in the great Faculty of Arts. Several characteristics of this structure are of importance for the proper evaluation of Sacrobosco's situation, if we suppose (as we must) that he taught in the University and that his writings were the outcome of his teaching.

First, it is important to remember that no medieval university had a special Faculty of Science. Science was cultivated only in the Faculty of Arts, which had its name from the ancient educational scheme of the 'liberal arts'. These seven disciplines comprised grammar, rhetoric and dialectics, which were known as the *trivium* and represented the 'humanistic' component of the curriculum, and the scientific subjects of arithmetics, geometry, astronomy and theory of music which together formed the *quadrivium*.[106] Thus all scientific education in the university took place within the *quadrivium* section of the Faculty of Arts. In consequence, this corner of the university was the intellectual home of any teacher with scientific proclivities. From this follow several important consequences.

The Faculty of Arts was the school of the beginners who in the Middle Ages began their university careers at a much earlier age than today. Typically a student would arrive at the university at the age of fourteen or fifteen in order to spend the following five or six years studying the Arts. This meant that beginning students were not only mere boys themselves but also that they were taught by Masters of Arts who might be not more than six years older, assisted by Bachelors of Arts only a couple of years younger than the Masters who were themselves often enrolled as students in one of the higher faculties. Thus the Faculty of Arts was a very youthful institution, and the low age of its students often led to serious social and human problems which the students themselves tried to solve by uniting into corporations called 'nations' organized on a geographical basis for the purpose of mutual aid. In Paris there were four such nations of which the Natio Anglicana (see Section 2 above) comprised students and masters from the British Isles, Scandinavia and Germany. There is no doubt that Sacrobosco belonged to this English Nation.

The students were not only young. They also arrived with a very slight intellectual baggage, acquired in a local grammar school. Its principal component was a knowledge of Latin which would be sufficient to enable them to profit by the teaching of a university, attending lectures given in Latin and taking part in disputations conducted in the same language. However, the grammar schools did not cater for scientific subjects, except perhaps in teaching the more elementary rules of arithmetic and the system of Roman numerals. In consequence the university teaching of the *quadrivium* had to start from scratch with introductory courses based on textbooks of an elementary character. Such text books are extant in hundreds of MSS, whereas more advanced treatises are more rare. This can easily lead to a distorted picture of medieval science. In fact, the elementary character of most of its literary remains does not reflect the true level of scientific knowledge of advanced students. It only reflects the fact that the Faculty of Arts – overcrowded as it was with students many of whom left the university without a degree – provided its young members with that kind of introductory education which was later taken over by the secondary school or the 'gymnasium'. All this gives an idea of the intellectually very innocent audience with which Sacrobosco

must have been confronted as a teacher of mathematics and astronomy.

Since a thirteenth-century scientist would in most cases have to earn his living by teaching the *quadrivium* it follows that his life as a scholar would be deeply influenced by the intellectual climate that prevailed in the Faculty of Arts. This climate varied considerably from place to place, just as it might change in the course of time. The situation in Paris was mainly conditioned by the fact that during the twelfth century a number of great Parisian schools had risen to European fame as centres of philosophical and theological thought which here clearly overshadowed the interest in natural philosophy or mathematics. Such scientific subjects were much more at home in the Cathedral School of Chartres where all the liberal arts flourished in the spirit of what has been called the "humanism of the twelfth century". Here everything was imbued by a deep love of classical learning nourished by an intimate knowledge of classical Latin literature. Cicero was the great philosopher above all others, but also the poets were made part of the curriculum and any teacher worth his salt would know how to flavour his lectures with more or less apt quotations from Virgil, Horace or Ovid. But it was characteristic of Chartres that natural philosophy was integrated into the curriculum and held in high esteem although it was nourished by a much more meagre diet than the *trivium*, consisting of Latin works on mathematics by Boethius, the *Naturalis historia* by Pliny, and the encyclopedias compiled in late Antiquity by authors like Macrobius and Martianus Capella. Such works were of secondary importance compared with the original sources of Greek science which were still unavailable to the Latin world. How far it was possible to proceed along such lines can be seen, for instance, in the *De philosophia mundi* and the *Dragmaticon* by the Chartres scholar William of Conches, or in the *Didascalicon* of Hugo of St Victor who was one of the rare Parisian scholars who shared the attitude of his colleagues at Chartres.

Greek titles like *Dragmaticon* and *Didascalicon* reveal that something new was in the offing when we approach the middle of the twelfth century, when some of the major works of Greek science began to invade the schools of Latin Europe in Latin translations produced on the Spanish border between the Latin and the Arabic world. They were often based on Arabic translations but increasingly also on Latin versions made directly from the Greek. Thus the fundamental works of Euclid, Apollonius, Ptolemy and Aristotle became available. The result was an explosion of knowledge which the existing small schools were unable to cope with and which, therefore, became one of the main driving forces behind the reorganization of the educational system marked by the emergence of the universities.[107]

In Paris this new wave was strongly felt in the first half of the thirteenth century when the Masters of Arts were trying to consolidate their Faculty as an independent and self-governing corporation with a more up-to-date curriculum than that of the earlier school. However, the strong philosophical tradition from the previous century meant that the attempts to innovate the arts curriculum were more aimed at the *trivium* than at the *quadrivium*, expressing themselves as a long struggle to introduce the philosophical works of Aristotle into the curriculum against the opposition from theologians and churchmen who regarded the Aristotelian doctrine of the eternity of the world and other tenets of 'The Philosopher' with suspicion or dismay. A synod held in 1210 in Paris decreed that

"the books of Aristotle on natural philosophy must not be read in Paris neither publicly nor in private".[108] This showed the strength of the conservative party which in the following years usually brought pressure to bear on the chancellor of the Chapter of Paris, who was the formal head of the University. In 1229 he failed to help his scholars in the skirmishes between 'town' and 'gown' with the result that the University suspended its teaching and went on strike; many of the English students returned to Oxford and the situation was not normal again until 1231, when Pope Gregor IX issued the Bull *Parens scientiarum*[109] in which the privileges of the University were defined and in which Aristotle was let in through the back door by a passage stating that the forbidden books should not be read until they were examined and cleansed from any suspicion of error. From then on the final victory was only a question of time, and in 1252 the English Nation openly put Aristotle's *De anima* on the list of standard texts.[110] In 1255 the Faculty as a whole authorized all Aristotle's works; but it is significant that the new curriculum did not mention any works on mathematics or astronomy, with the result that Aristotle's *De caelo* became the only work on astronomy and cosmology backed by the authority of the Faculty.[111] It must have seemed that the great wave of innovating the science curriculum by means of Euclid and Ptolemy would bypass Paris.

Such was the general situation in Paris at Sacrobosco's time. We do not know whether he arrived at the University as a young student intending to acquire a complete education in the Arts, or as an already 'formed' master who would be qualified to teach. As we shall see, the presumption is that his education was acquired elsewhere and that his intellect was already formed according to principles which were in many respects foreign to the tradition of Paris. Only two things are certain. As an *anglicus* he would have become a member of the English Nation, and as a teacher or 'regent master' his salary would have been paid by the Church in the form of a prebend from a chapter or a parish the whereabouts of which is unknown. This implies that he was at least a tonsured clerk like all other students and masters in Paris (except some of the medical students); it is possible, but by no means certain, that he followed the usual course and took higher orders as a deacon or priest. That we do not know. But what we can infer from the account of the University presented above is that in his intellectual life he must have encountered difficulties. Not only would he be faced with an audience of young boys with blank minds and no previous education; but he would also have to teach the comparatively neglected *quadrivium* along lines that were at variance with the general attitude of his Faculty. His writings reveal how he tried to solve these difficulties.

6. *The Independence of Mind*

As far as we know Sacrobosco wrote nothing on the great Parisian subjects of philosophy and theology. All his works are on science or, more precisely, what may be called pure and applied mathematics. For this reason he may well have been somewhat isolated among his colleagues in the Faculty, committed as they were to the common task of reorganizing their teaching along Aristotelian lines and making room for as many Aristotelian works as possible within the curriculum. In this effort they found very little support from Sacrobosco who seems to have been extremely uninterested in 'The Philosopher', whom he quoted

only four times. In *S* he admits the Aristotelian distinction between the elementary and the ethereal regions of the universe by a reference to the *Metheorologica*,[112] just as he ascribes to Aristotle the idea that elementary changes are caused by the varying position of the Sun along the ecliptic, referring to the *De generatione et corruptione*.[113] It follows that he was familiar with at least two of the forbidden books. In *C* he does not bother to give references at all, but credits Aristotle with the definition "dies est sol lucens super terram"[114] and with the statement that "sol unum duodecim signorum integro mense metitur".[115] Since Sacrobosco in general was very fond of quotations the very scarcity of his references to Aristotle is a sufficient proof that, unlike the majority of his colleagues, Sacrobosco did not regard the Stagirite as 'The Philosopher' over and above all other authorities.

The explanation of this general lack of interest in Aristotle seems to be that he did not share the Aristotelian concept of science or *philosophia naturalis*. The Greeks had caused a revolution of philosophical thought by their attempt to describe the phenomena of nature as produced by causes inherent in nature itself, linking all its several parts together by the metaphysical concepts of cause and effect, the logic of which had been worked out by Aristotle in his *Physics* and *Metaphysics*. This general belief in causality became for the Greeks the hallmark of scientific knowledge for "we conceive ourselves to know about a thing when we are acquainted with its ultimate causes and first principles".[116] Knowledge is, in general, the knowledge of causes with the corollary that natural science is the investigation of the various causes to which natural effects (the observable phenomena) are due. According to Aristotle causes can be divided into four different categories, comprising the material, formal, efficient and final causes respectively, a scheme well illustrated by his analysis of the way in which a sculptor produces a statue. The same four categories are, however, applied also to the workings of nature in general so that no natural phenomenon was thought to be satisfactorily explained until its final cause, or purpose, had also been found.

An entertaining example of how the Aristotelian scheme of causality captured the minds of thirteenth-century natural philosophers can be studied in Sacrobosco's commentators, who without hesitation gave 'causal' explanations of his works. Table 3 shows the results arrived at by Robert Anglicus[117] in 1271 with respect to *S* and by Peter Nightingale (Petrus Philomena de Dacia) in 1291 with respect to *A*.[118] It is difficult to say what Sacrobosco himself would have thought of such philosophical dissections of his works. But it is significant that no similar analyses are to be found in anything he wrote himself. On the contrary, his works are marked by a general conception of science which does not explicitly refer to causality. In fact, the very first lines of *A* read as follows: "Omnia, qua a primaeva rerum origine processerunt, ratione numerorum formata sunt; et quemadmodum sunt, sic cognosci habent; unde in universa rerum cognitione ars numerandi est operativa";[119] or, in translation, "Everything which has come forth since the beginning of the world has been formed by numerical relations; and as these are, so they must be known; in consequence the science of numbers is at work in the knowledge of things in general".

In other words, mathematics is a necessary instrument for the acquisition of knowledge of the natural world. The reason is that everything in nature is 'formed' by mathematical relations: "ratione numerorum formata sunt". The general idea

TABLE 3. The four 'causes' of *S* and *A*.

	Cause	Robertus Anglicus on the *Sphere*	Peter Nightingale on the *Algorismus*
1	Material	corpus celeste	numerus
2	Formal	sicut in aliis scientiis	in se: divisio ... tractatus in capitula et capitulorum in suas partes in modo tractande: divisivus definitivus exempla positiva probationes improbationes
3	Efficient	magister Johannes de Sacrobosco Anglicus	artis: Algus Philosophus Arabicus tractatus: Johannes de Sacrobosco
4	Final	utilitas eius	perfectior cognitio omnium

seems to be that nature is possessed of an underlying mathematical structure or a network of relations which can only be laid bare by a mathematical investigation: "quemadmodum sunt, sic cognosci habent". If this is Sacrobosco's general metaphysical and epistemological convictions it is clear that he must be ranked among the anti-Aristotelians in metaphysics since Aristotle would never admit that 'numbers' can be 'forms'.[120]

Considering Sacrobosco's English origins, it would be tempting here to link him with Grosseteste, who nourished very much the same idea of the role of mathematics as indispensable for natural knowledge "since it is impossible to learn natural philosophy without it. It is indeed absolutely valid in the whole universe and in all its parts",[121] although Grosseteste more had the lines, angles and figures of geometry than the *ars numerandi* in mind. However, in order to explain this similarity of ideas it is not necessary to make Sacrobosco an Oxford student of the later Bishop of Lincoln. For already in 1291 Peter Nightingale proved in his commentary on *A* that Sacrobosco's first proposition is taken from Boethius: "propositio prima scribitur in Arismetica Boecii et sub his verbis: 'Omnia quacumque a primaeva rerum natura constructa sunt, numerorum videntur esse ratione formata ... Hoc enim fuit principale in anima conditoris exemplar'".[122] Thus Sacrobosco simply quoted – a little imprecisely and perhaps from memory – the principal textbook on arithmetic known to the schools of the early Middle Ages, permeated as it was with the idea of the Creator as 'The Great Mathematician'. Despite the authority of Aristotle this idea never disappeared from medieval thought, perhaps to some extent because it could be supported by an often-quoted passage from Holy Scripture to the effect that "everything is

ordered by measure, number and weight".[123] Sacrobosco is, however, one of the few medieval natural philosophers who does not quote it.

In his other works Sacrobosco remains faithful to the general epistemological principle enunciated in the opening words of *A*. Avoiding all metaphysical prolegomena he usually goes straight on to a purely mathematical account of the natural phenomena he is about to consider. Thus *S* begins without further ado with two different, although equivalent, definitions of a sphere as a geometrical structure, culled from Euclid and Theodosius respectively,[124] and proceeds with a clear and lucid description of the circles of the celestial sphere. In a similar vein the Prohemium to *C* underlines that time reckoning is a quantitative, mathematical discipline based on the motions of the Sun and Moon, stressing that the word *compotus* stems from *computando*, not because the science of *compotus* teaches how to compute, but because it is taught by means of precise and subtly related numbers: "quoniam numeris certis et subtiliter coniunctis doceatur".[125]

But if natural science is an account of nature in mathematical terms, the question must be how we obtain the numerical values, or geometrical structures, on which the account must be based? One possible answer would be that the properties of nature lie hidden in the properties of numbers and can be derived from the latter without reference to external experience. Already the Pythagoreans toyed with this idea, thereby provoking Aristotle's vehement protest that numbers cannot be 'forms'. All through Antiquity and the Middle Ages , and even further, this idea was kept alive, with a torrent of numerological speculations about nature as the inevitable result. But of this there is nothing in Sacrobosco, who never adheres to the view that the underlying mathematical structure of nature is directly accessible to the human mind. On the contrary, this structure has to be disclosed and revealed, and for that purpose we have no other means than measurements. The opening words of *Q* assert that "omnis scientia per instrumentum operativa instrumenti sui noticiam de necessitate preexigit",[126] which means that any science operating by instruments presupposes the knowledge of its instrumental equipment. But Sacrobosco does not here say what place such sciences have in the acquisition of knowledge as a whole. Nevertheless, he refers to a number of scientific instruments, among which the quadrant itself serves to determining by measurement ("ad mensurationem discernendum") such quantities as the altitude of the Sun and the stars, the geographical latitudes of places and regions, the different climates, the precise hour of the day or the night, and the height of an inaccessible object. Another instrument is the astrolabe which is mentioned in *S* as a means of determining an arc of one degree on the meridian.[127] Finally, in the same treatise Sacrobosco mentions a *horologium*, or sundial.[128] In consequence, we have to admit that his instrumental equipment is rather limited, although not more so than that of contemporary astronomers in general; but at least it allows us to draw the conclusion that astronomy is a "scientia operativa per instrumenta", and that its numerical data have to be extracted from the phenomena themselves by means of quantitative observations. Whether he would extend this principle to other natural sciences is impossible to say since he wrote nothing about them. And had he had a clear idea of, say, physics as a mathematical science based on measurements he would certainly have been much in advance of his time.

7. *The Youthful Innovator*

Just as Sacrobosco in his conception of science differed from the Aristotelians among his colleagues on the Faculty, so he showed his intellectual independence by making it clear from the beginning that he had something new to tell his students. Of course the Aristotelians were at the forefront of a 'modernistic' movement in philosophy and in opposition to many trends still prevailing from the previous century. But when all is said and done they fought for a philosophy which could be presented as novel only because it had laid dormant for centuries. In contrast to this Sacrobosco presented something which was really new, in the sense that it represented one of the latest achievements in the development of European mathematics. He did this in the *Algorismus* which, as we have seen, may well be his first written work. It is dry and unadorned and looks very much like a set of lecture notes by a young master at the beginning of his career. Yet this little book has conspicuous merits which are sufficient for its author to deserve a place of his own in the history of mathematics.

Now the mathematical part of the *quadrivium* included both arithmetic and geometry, and we can safely assume that Sacrobosco taught both disciplines. This raises the question of why he wrote his own textbook on one of these subjects, but not on the other? The answer is not that he considered geometry an inferior subject, since it was the theoretical basis for his treatment of astronomy in the *Sphere*. The answer is more likely that there already was a textbook of geometry which he found satisfactory – although we do not know if the Faculty had already switched to Euclid or still used the traditional *Geometria* ascribed to Boethius – but that the corresponding *Arithmetica* by the same Boethius was of no use to him since it did not provide the new mathematical methods he wished to make known to his students.

Briefly told, the *Algorismus* had the merit of being the first widely adopted university textbook which introduced into the curriculum both Hindi ('Arabic') numerals and algorithmic procedures. Boethius had of course used Roman numerals, with all the ensuing limitations and complications of practical calculation which had been only slightly remedied by the introduction of the abacus in the tenth century. The first problem here is, how did Sacrobosco himself become acquainted with the new methods? It is well known that they were first introduced to the Latin world by a translation, made one hundred years earlier by Adelard of Bath, of a manual of the liberal arts called *Liber ysagogarum Alchorismi*, the first three books of which are on arithmetic and based on Arabic sources, the *Alchorismus* of the title being no other than the famous Persian scholar al-Khwarizmi who worked in ninth-century Baghdad. Now Sacrobosco tells us that the "scientia numerandi" was described by "quidam philosophus nomine Algus".[129] This points to this or another work by al-Khwarizmi as the ultimate source. On the other hand, Sacrobosco cannot have been deeply familiar with al-Khwarizmi's writings, since he explicitly ascribes the invention of the new system to the Arabs, since numbers are here written "more Arabum" from right to left.[130] This misunderstanding would have been impossible if he had known another work by al-Khwarizmi, which in Adelard's translation was called *De numero Indorum* and clearly stated that the 'Arabic' numerals originated in India. Another work using the new numerals was the *Liber abbaci* by Leonardo Fibonacci of Pisa, the first version of which appeared in 1202 without being

widely used, whereas the revised version of 1228 may well have been too late to have influenced Sacrobosco. In consequence, the problem of his immediate sources remains to be solved.

Sacrobosco divided his "ars numerandi" into nine different operations, viz.:[131]

1	Numeratio	(§§ 12-24)
2	Additio	(§§ 25-37)
3	Subtractio	(§§ 38-54)
4	Mediatio	(§§ 55-69)
5	Duplatio	(§§ 70-80)
6	Multiplicatio	(§§ 81-111)
7	Divisio	(§§ 112-24)
8	Progressio	(§§ 125-30)
9	Radicum extractio	(§§ 131-79)

Section 1 contains the description and explanation of the nine *digiti* or numerals 1, 2, ... 9, supplemented by a zero called by various names such as *theta*, *circulus*, *cifra*, or *figura nihili* because it signifies nothing in itself, but gives significance to the other numerals according to their position. Sacrobosco stresses the fact that any number, however large, can be written by these ten figures only, so that it will be unnecessary ever to invent others (contrary to what is the case in the Roman system).

In Section 4 *mediatio* means finding the arithmetical mean; other mean values are not mentioned here but the geometrical mean or *medium proportionale* is introduced later in the paragraphs on square roots, while the two means, a^2b and ab^2, between a^3 and b^3 are used in connection with cubic roots. No fewer than six rules for multiplication are given; the first corresponds to the formula

$$a \cdot b = 10a - a(10 - b)$$

whereas §§ 93-105 describe the algorithmic procedure which we still use today. The algorithm for division is explained in §§ 112-23. These two sections clearly demonstrate the advantage of the general algorithmic methods made possible by the positional system of numeration. Any modern schoolchild ought to be grateful to Sacrobosco for having first paved the way for these simple and general procedures which are now taken for granted but must have appeared as fascinating novelties when they were first revealed. Among other topics we notice that Section 8 on *progressio* gives the correct procedure for finding the sum of an arithmetical series, while the final section explains the algorithm for extracting square and cubic roots. The only weak point of the *Algorismus* is that it has nothing on fractions. In division only integer quotients are considered, the procedure being stopped when the remainder becomes less than the divisor. The same applies to root extraction. There is only one exception, viz. the special symbol used for one half when an uneven integer is 'mediated'. But one half is also said to be equal to 30 minutes, from which we conclude that at the back of his mind Sacrobosco had a sexagesimal system of fractions, the details of which he decided had better be left out of a book which was meant to propagate the advantages of the positional decimal system.

Such was the modest, but nevertheless revolutionary arithmetical *pensum* that Sacrobosco wanted his young students to digest. What was his purpose? Noticing that the text gives clear definitions and rules of procedure, but no proofs at all, we

may conclude that Sacrobosco aimed more at computational skill than mathematical insight. This agrees with the opening words of the text, on the *ars numerandi* as an instrument for the acquisition of knowledge applicable to any and all parts of the natural world. However, there are no hints in the text of how the new procedures might be applied outside the pale of pure mathematics. On the other hand, one must ask which discipline would profit most by a new technique of calculation in which large numbers would present no particular difficulty. This question was raised already in 1291 when Peter Nightingale wrote his commentary and stated his personal opinion that Sacrobosco wrote the *Algorismus* to the benefit of astronomy: "I believe that his more immediate purpose is astronomy itself, for it is the practice of this art as a means of investigating the magnitudes of the celestial motions".[132] This ingenious suggestion he does not support by further arguments. In particular Peter does not comment on the brief appearance in *A* of a sexagesimal system of the kind used by astronomers. Nevertheless, it was an intelligent guess that Sacrobosco wrote his only mathematical work with an eye to astronomical applications. In consequence, the *Algorismus* points forward to the two major works by the author.

8. *The Discerning Professor*

The composition of the *Sphere* must have presented Sacrobosco with several problems. With respect to the Faculty he would have to decide what kind of astronomy his students should learn. Should he comply with the general trend of his time and base his teaching on the *De caelo* of Aristotle, or choose his own way at the risk of alienating himself from his colleagues? And with respect to the students he would have to decide on how to present his subject matter to an audience to which it was completely new. We cannot say precisely in what way he turned such problems over in his own mind; but his work clearly reveals the outcome of his private deliberations.

As already remarked, Sacrobosco begins his exposition of astronomy with two purely geometrical definitions of a sphere, one of them taken from the *Elements* of Euclid[133] and the other from Theodosius's *Sphaerica*, a manual of spherical astronomy dating from about 100 B.C.,[134] both of which were available in Latin translations from the twelfth century. This abrupt start certainly underlined Sacrobosco's conception of astronomy as a mathematical science, in agreement with his general epistemological ideas. It also reveals a slightly polemical attitude towards the Aristotelians since Sacrobosco never alluded to the *De caelo* by so much as a single word, almost as if he wished to show his contempt for a work the primitive and non-mathematical cosmology of which would seem hopelessly out of date to an astronomer who knew the tradition stemming from the *Almagest*.

However, this is not to say that Sacrobosco did not share the central tenets of Aristotelian cosmology such as the central position of an immovable Earth,[135] or the sharp distinction between the elementary and celestial spheres[136] composed of different forms of matter obeying different physical laws. Such ideas were commonplace and Sacrobosco did not question them, but to him they were not astronomy of the kind he wished to impart to his students. We have already seen the list of authorities he quoted with its significant series of astronomical works that were without exception of a mathematical and technical character. It was

such works he chose as the basis of his teaching, and not the book that his Aristotelian colleagues would have preferred.

Another question is how Sacrobosco used his sources. Often he has been slandered by historians as nothing more than a miserable compilator who took his information from books in the usual 'scholastic' manner without consulting nature itself[137] by performing his own observations,[138] and who in consequence was able to present only unoriginal and outdated opinions.[139] No doubt such criticisms tell more about their authors than about Sacrobosco. It is true that there are no references to personal observations in the *Sphere*; but this is certainly immaterial since it is not always the case that the best textbooks for beginners are written by those scientists who do the original research in the field.

Most textbooks are in fact compilations and no one can blame Sacrobosco for borrowing from other authors. Moreover, behind the criticisms of Sacrobosco for not being an observer lies a completely unhistorical and indeed stupid view of the scientific situation of his time, as if the scholars of the thirteenth century ought to have begun the reform of astronomy by building observatories and making fresh observations. Their task was different and approached in a more intelligent way. For before it would be possible to develop astronomy beyond the stage where it had been left by the astronomers of Antiquity, it was clearly necessary to catch up with the delay and ascertain the actual contents of astronomical knowledge in order to know the point from where a fresh start might be made. It is precisely in this perspective that we must view the efforts of Sacrobosco.

We shall not here go into all the details of the contents of the *Sphere* but content ourselves with mentioning a few points which may serve to illustrate some of the more significant features of his work. Firstly, in the cosmological Chapter 1 Sacrobosco takes a great step forward relative to his predecessors in the schools by describing the phenomenon of precession. This is done in connection with the problem of the number of the celestial spheres. In all previous Latin treatises on cosmology it was assumed that there were eight spheres of relevance to astronomy apart from the scientifically irrelevant crystalline and empyreal spheres, viz. seven spheres for the planets within an eighth sphere containing the fixed stars and called the 'firmament' or the 'primum mobile'. But in Sacrobosco we find a ninth sphere outside the firmament, empty of stars, but producing the daily rotation of the heavens and taking over the role of *primum mobile*. Relative to this ninth sphere the eighth sphere of the fixed stars is said to perform an eastward motion at the rate of 1° in 100 years.[140] In this way the 'precession of the fixed stars' made its entry into Latin astronomy.[141] For although the phenomenon of precession is described as a direct (i.e. eastward) motion of the fixed stars relative to the ninth sphere, and not as a retrograde motion of the equinoctial points, the phenomenon itself is clearly recognized. We notice that Sacrobosco assumes a constant rate of precession equal to the Ptolemaic value in the *Almagest* without mentioning the non-linear theories of 'trepidation' propagated by various Muslim astronomers.[142]

In Chapter 2 we find a detailed description of the circles of the celestial sphere such as the equator or *circulus equinoctialis*, the zodiac or *circulus zodiacus* conceived as a zone with a width of 12° carrying the twelve zodiacal constellations and therefore also called *signifer*. Its middle line is a circle called *linea ecliptica* on which the Sun is moving. Next come the *colures*, the *meridianus*, and the *orizon*

which has the zenith as pole and occupies different positions relative to the equator according to the *distantia zenith ab aequinoctiali* which is equal to the *elevatio poli*, i.e. the altitude of the pole of the equator. All this is traditional but Sacrobosco has a small original contribution with respect to the Arctic Circles. In Antiquity these two circles had been defined by Geminus[143] as the circles limiting the areas of the circumpolar stars in the northern and the always invisible stars in the southern sky. In consequence their radii must depend on the geographical latitude of the observer. However, Sacrobosco defines the Arctic Circle as the circle described by the pole of the zodiac around the pole of the world.[144] It follows that it has a constant radius equal to the obliquity of the ecliptic, which is said to be 23°51′ according to Ptolemy, but 23°33′ according to Almeon, i.e. the Baghdad astronomers of al-Ma'mun.[145] Later Sacrobosco usually quotes the Ptolemaic value.[146] In this way the Arctic Circle and its antarctic counterpart came to occupy the fixed positions on the heavenly sphere where they still are.

Having defined the circles Sacrobosco has all the necessary material for introducing proper systems of celestial coordinates. However, he fails to do so, mentioning only in passing such concepts as zenith distances, polar distances, solar declinations, and altitudes. He may not himself have been sufficiently familiar with them, or he more likely considered the subject to be too advanced.

In Chapter 3 Sacrobosco describes some of the observable consequences of the theories proposed in the two first chapters. He begins with the rising and setting of the fixed stars in two different senses of the words. First there are the first and last visibilities of a given star caused by the annual motion of the Sun. They are somewhat incompletely classified as cosmical risings in the morning, chronical settings in the evening, and heliacal risings and settings out of or into the rays of the Sun. Such phenomena were of great importance to ancient astronomy, but since Sacrobosco qualifies them as "phenomena quantum ad poetas" one gets the impression that he only dealt with them for traditional reasons. What interested him more were the phenomena caused by the daily rotation of the heavens, in particular the problem of the *ortus alicuius signi*, that is, how to find the time in which a complete sign (equal to an interval of 30° on the ecliptic) rises above the horizon of a given observer.

The exact solution of this problem had been worked out by Ptolemy by means of spherical trigonometry. It was clearly too advanced for an introductory textbook and Sacrobosco restricts himself to stating a rather obvious rule of symmetry. This section is only a kind of introduction to the following account of the variation of the length of daylight for observers with different geographical latitudes. He first takes an overall view of how the length of the day will vary when the observer (as it were) moves from a position on the terrestrial equator to a position on the north pole. Next he subjects the 'habitable world' to a more detailed scrutiny. It is a zone on the northern hemisphere, divided into seven *climata* or parallel strips each of which is wide enough to make the variation of (the time measured by) a sundial perceptible: "dicitur autem climatum tantum spatium terrae per quantum sensibiliter variatur horologium".[147] This is a vague definition which is not up to Sacrobosco's usual standard; but since it is omitted in several MSS it may well be a later interpolation by a badly informed scribe. For when we come to the following table of climates there is no lack of precision. To quote a single example, Sacrobosco gives the following data for the climate of

Alexandria:

Climata 3ª Dialexandrias
Extension 350 milliaria from south to north
Longest day at southern limit 13 3/4 hours. Latitude 27 1/2°.
Longest day at middle line 14 hours. Latitude 30 3/4°.
Longest day at northern limit 14 1/4 hours. Latitude 33 2/3°.

Since the 350 milliaria corresponds to an arc of 6 1/6° on the meridian it follows that 1° = 56.8 milliaria, which is close to the value of 1° = 56 2/3 milliaria ascribed to the astronomers of al-Ma'mun.[148] In fact, Sacrobosco's account of the *climata* is not derived from the corresponding account of Ptolemy,[149] but from Alfraganus, the Muslim astronomer whose work *Liber 30 differentiarum*, or *Rudimenta astronomica*, he quoted more frequently than any other source. However, contrary to what has often been said, Sacrobosco was no slavish copier of Alfraganus, whose material he arranged in a very different way and often supplemented – for instance in the case of the climates, where he quoted their Greek names which are not found in Alfraganus.[150]

Another procedure was used at the *disputationes* where a definite *quaestio* was formulated, a number of objections stated, a solution given by the master, and the objections finally refuted. This was the famous 'Scholastic Method' which was immensely useful in cases where it was important to reduce a great number of more or less tenable opinions to order by placing them in a logical framework with which all were familiar. It was less appropriate when the subject matter was not a matter of opinion to be discussed but a body of positive knowledge to be absorbed. Nevertheless, the *quaestio*-genre became more and more dominant, taking over the *lectiones* and transforming them from commentaries into minor disputations with the master as the sole participant. This happened also to the *Sphere* when Michael Scot asked such questions as "Whether day and night can be equal all over the Earth?",[162] or "Whether summer nights are longer than winter nights?",[163] and many others which might have been answered without much of the discussion *pro et contra* which he presented.

Neither of these manners of exposition seems to have satisfied Sacrobosco who decided to avoid both the *lectio*- and the *quaestio*-genre in favour of a simple manual which in a straightforward way and without pseudo-intellectual glitter tried to convey as much factual knowledge as possible. This characteristic of the *Sphere* did not pass unnoticed. There is a MS of *S* to which an unknown scribe has added a series of marginal glosses explaining that the science of astronomy is partly *naturalis* and partly *mathematica* so that it forms a link between mathematics and natural philosophy, or physics; in other words it is what medieval scholars called a *scientia media*. But mathematical astronomy can be presented in two ways, says the author –*demonstrative* as in Ptolemy, Geber and Thabit, and *narrative* as in Alfraganus, Martianus [Capella] and Sacrobosco.[164] In 1317 the same characteristic was noted by Thadeo da Parma in his bibliographical introduction to the *Theorica planetarum* where he said that astronomy was first dealt with in a narrative form without demonstrations by "Alfraganus ... and to some extent by Thebit ... and by John of Sacrobosco in the treatise on the *Sphere*".[165] Thus Sacrobosco did not invent a new literary genre but

chose to follow an already existing tradition of 'narrative astronomy' which was well suited to his purpose. The fact that he adopted the same style for his *Compotus* is another proof that he made a deliberate choice of a style that contrasted strongly with that which was increasingly preferred by his colleagues.

A characteristic feature of Sacrobosco's 'narrative' art is the many quotations from non-scientific authors, and first and foremost the classical poets. In the *Sphere* there are ten quotations from the *Georgica* of Vergil, four from the *Metamorphoses* of Ovid, and nine from the *Pharsalia* of Lucanus. In the *Compotus* we meet again the same three poets, but now supplemented by Claudianus's *De raptu Proserpinae*, from which Sacrobosco quoted the lines

> Ambit et eternis mortalia separat astris
> Luna subiecta globo qui septimus auras[166]

in order to make it clear that there are seven planets in the celestial regions separated from the mortals by the sphere of the Moon. Of course there is no compelling reason for quoting the tragic poem of Claudianus for this purpose, and one would like to think that Sacrobosco was a lover of literature who could not help quoting such beautiful verses as came to his mind. But there is no doubt that the quotations also served a pedagogical purpose. It must have been easier to make 'green' students digest a difficult point or acquaint them with an unusual phenomenon if it could be illustrated by a couple of verses with which they had become familiar through the teaching of rhetoric in the *trivium*, if not already at school. However, Sacrobosco must have seemed to be somewhat old-fashioned in holding on to this manner of exposition which had been common among twelfth-century authors with humanistic proclivities. By using it Sacrobosco formed a link with the past at the same time as the contents of his treatises pointed towards the future. He lived in a period of transition and realized the necessity of modernizing the astronomical curriculum; but he also wished to do this in a way that gave room for that love of the classical world which had been so strongly expressed by the School of Chartres. We do not know what Sacrobosco's direct relationship with this tradition was, but it is no doubt significant that the only 'modern' work on natural philosophy he ever referred to was the *De mundi universitate* by the Chartres scholar Bernardus Silvestris.[167]

Another advantage of the narrative method was that it permitted Sacrobosco to make asides and occasional remarks which increased the value of the exposition in a secondary way without disturbing the general trend of what he was primarily explaining. These asides are frequently remarks on the etymology of one or another of the many new technical terms with which he had to acquaint his audience. Thus he correctly explains that *orizon* is a Greek word meaning 'terminator visus'.[168] He is also right in deriving *arcticus* from *arthos* (*cf.* Greek ἄρκτος) meaning 'ursa maior', although his Greek is here slightly faulty.[169] Concerning *zodiacus*, or *signifer* in Latin, he admits to be in doubt whether this word stems from *zoe* meaning 'vita', or from *zodias* meaning 'animal'.[170] But when he explains that *colurus* is composed of two Greek words, viz. *colon* meaning 'membrum' and *uros* meaning 'bos sylvester',[171] he obviously mistakes κόλον for κόλος and οὖρος for οὐρά. We must conclude, therefore, that Sacrobosco knew but little Greek and that not all his etymologies are to be trusted. Nevertheless, they served to underline the Greek origin of astronomy, reminding his audience of

the existence of the Greek language which was sadly ignored in the universities of the thirteenth century. In this way a smattering of general education was smuggled into a course of astronomy in a way which must have stimulated the interest of his students.

Finally, Sacrobosco often profited by the occasion to make his students acquainted with the historical background of his subject matter. This happens most frequently in the *Compotus*, as one might expect from a work which is explicitly concerned with time. Thus he correctly narrates how the ancient Romans, Hebrews and Arabs each had their own convention of when the day begins,[172] just as he explains how the pagan philosophers named the days of the week after the planets whereas the simple ferial numbers of the days were introduced by the Christians.[173] Similarly he gives an account of the ancient Roman calendar, said to be instituted by Romulus with March as the first month, because the Roman kings usually went to war at this time of the year.[174] He is also aware that the Romans called the first day of the month *kalenda*, deriving from "clamo quod est voco" because the first day of the month was officially proclaimed from a high locality in the city,[175] although he also offers two other etymologies for the choice of his readers. With respect to the unlucky 'Egyptian Days' in the calendar he stresses the fact that Augustus prohibited their observance, but that it is necessary, nevertheless, to explain how to determine them since they are still observed by common people.[176] Such examples could be supplemented by many others, particularly with regard to the ecclesiastical calendar; but they are sufficient to show that Sacrobosco realized the value of the history of science for the purposes of teaching.

9. *The Modest Reformer*

We shall now turn to the *Compotus* which is in many respects the most interesting among Sacrobosco's works, as well as being the longest. It is not quite certain how it originated. Time reckoning as such was not usually counted as one of the liberal arts and there was no obligation to include it into the curriculum of the Faculty. However, it was a common subject in the schools of the early Middle Ages as a prerequisite for the proper formation of a priest, according to a frequently repeated saying attributed to St Augustine: "In the House of the Lord four things are necessary – grammar, music, canon law and *compotus*."[177] The importance of the subject was obvious since it taught one how to understand the civil and the ecclesiastical calendars by which everyday life was regulated, explaining in particular the difficult business of determining the date of Easter and other movable feasts. Accordingly, it was of particular importance to students who were looking forward to an ecclesiastical career and it may well have been a required subject in a theologically oriented university like Paris. It is, therefore, reasonable to regard the *Compotus* as the outcome of Sacrobosco's work as a teacher, but not as a scientific treatise written for more disinterested purposes. This is in agreement with the fact that it was the only one among his works to be commemorated when his tomb was provided with the inscription quoted above. We shall not here discuss all the details of this rich and pleasant work which, more than any of the other writings, permits us to have a glimpse of what occupied the mind of its author towards the end of his active life.

The *Compotus* was planned on a large scale, revealing a very logical and orderly

mind. The following analytical table gives a general idea of what it contains, roughly – but not completely – in the order in which the various subjects are expounded in the treatise.

1 PREFACE
Definition of the subject and its relation to astronomy.

2 UNITS OF TIME
(a) The day – natural and artificial
(b) Units smaller than one day
the *quadra*
the hour – natural or equinoctial, divided into
(1) *puncta*
momenta
unciae
atomos, or
(2) sexagesimal parts
(c) Units larger than one day
the week
the month – solar, lunar, calendaric
the year – solar or lunar
the planetary periods
the 'Great Year'

3 THE SOLAR COMPOTUS: The Sun and the civil calendar
(a) The solar year
its length
its beginning
the seasons
leap years
(b) The *cyclus solaris* of 28 years
dominical and calendaric letters
the change of weekdays from year to year.

4 THE LUNAR COMPOTUS: The Moon and the ecclesiastical calendar
(a) The lunar phases and the lunar month
(b) The lunar year – common or embolismic
(c) The *cyclus lunaris* of 19 years
the *epactae*
the *regulares*
(d) The movable feasts
Septuagesima
Quadragesima
Pascha
Rogationes
Pentecosta
the *termini* and *claves*.

5 ARBITRARY PERIODS OF TIME
the *lustrum* of 5 years

the *indictio* of 15 years
the *saeculum* of 100 years
the *aevum* or *aetas* of 1000 years.

In the Preface Sacrobosco begins with a general definition of his subject, saying that *compotus* is a science considering periods of time distinguished by the motions of the Sun and Moon and their mutual relationships,[178] and continuing by saying that astronomers study the motion of the stars in general whereas the *computistae* are only interested in the motions of the Sun and Moon. The Church, says Sacrobosco, is not interested in the other planets, thereby implying that time reckoning is an ecclesiastical discipline. Furthermore, the *compotus* differs from astronomy also by disregarding the inequalities of the motions of the Sun and Moon, being, as we would say, based exclusively on the mean motions or mean periods of the two luminaries. Finally he ventures to give a general definition of time as an effect of the motion of the heavenly bodies from which the measure and numerical value of a quantity or the alteration of a quality is derived[179] – if that is the meaning of the text which here seems to be corrupt.

In his sections on the hour Sacrobosco distinguishes between the natural hour defined as one-twelfth of the length of daylight and thus varying according to the seasons of the year, and the equinoctial hour defined as the 24th part of the artificial day (comprising one day and one night). In the treatise he usually bases everything upon the equinoctial hours. The hour can be subdivided in various ways. There is a traditional system according to which one hour is 4 *puncta* in the solar *compotus* but 5 in the lunar *compotus*. One *punctus* is made up of 10 *momenta*, one *momentum* of 12 *unciae*, and one *uncia* of 47 *atomos* – 47 being a strange factor of conversion which has, to the best of my knowledge, never been sufficiently explained.[180] However, this antiquated system plays no further role in the *Compotus* since Sacrobosco always uses the sexagesimal division into minutes and seconds.

One of the fundamental questions with regard to the *Compotus* is about the origin of Sacrobosco's numerical parameters, among which is the length of the year. Already in the *Sphere* we find the approximate value of "365 days and a quarter of a day apart from a small and imperceptible amount".[181] Here there is no indication of which kind of year Sacrobosco has in mind. This becomes clear in the *Compotus* where the *annus solaris* or 'solar year' is defined as the interval of time in which the Sun moves by its own motion around the whole zodiac from any one of the four equinoctial or solsticial points and back to the same point again.[182] It follows that Sacrobosco's solar year is the same as what we now call the tropical year; in fact, despite his knowledge of the phenomenon of precession he never mentions the sidereal year as such, perhaps because it is of little interest for calendaric purposes.

It is more difficult to understand why Sacrobosco did not explicitly provide the *Compotus* with a more precise value of the length of the calendarically important tropical year than that found in the *Sphere*. Continuing the passage just quoted, all he says is that a complete revolution of the Sun comes to an end in 365 ¼ days apart from a small amount. This is very much the same as in the *Sphere*. But then Sacrobosco goes on by saying, first that it is impossible to find this small amount, and secondly that Ptolemy has stated this in Book IV of the *Almagest*.[183] Here the

second statement is wrong since Book IV of Ptolemy's great work is concerned with lunar theory and contains no mention of the length of the tropical year, the Ptolemaic value of which

$$365;14,48^{d} = 365^{d}5^{h}55^{m}12^{s}$$

is found in *Almagest* III,2 but is never quoted by Sacrobosco. As for the first assertion, Sacrobosco implicitly denies it himself by indicating how the precise length of the year may be found by 'measuring' (i.e. dividing) the complete length of the zodiac (i.e. the 360° of the ecliptic) by the (mean) daily motion of the Sun, which he gives as

$$59'08''17''' 13^{iv}10^{v}04^{vi} \text{ per day.}$$

The division is not carried out and the result is only said to prove that the solar year deviates from the Julian year by not quite one-twelfth of an hour.

However, it is possible to get a little closer to the elusive solar year of the *Compotus* since Sacrobosco now explains that if one year is divided into 12 equal parts one obtains a *mensis solaris* or 'solar month', the length of which is said to be

$$30^{d}10^{h}29^{m}36^{s}.$$

Multiplying this value by 12 we get precisely

$$365^{d}5^{h}55^{m}12^{s}$$

which is, to the second, the length of the tropical year according to the *Almagest*. So when all is said and done it is the Ptolemaic year that is lurking behind the scenes in the *Compotus*. This is another example of his intention of basing his astronomy on Ptolemaic principles, the first being the planetary theories outlined in Book IV of the *Sphere*. But it also seems to indicate that Sacrobosco had no first hand knowledge of the *Almagest* itself. For not only was the reference to Book IV erroneous, but also Sacrobosco's value of the mean solar motion differs from the Ptolemaic value of

$$59'08''20'''13^{iv}12^{v}31^{vi} \text{ per day}$$

although the discrepancy only appears in the two last sexagesimal places. I have not been able to identify the immediate source of Sacrobosco's value. It cannot stem from his often used authority al-Farghani who only gives the rough value of "about 59 minutes".[184] In al-Battani we find a value of

$$59'08''20'''46^{iv}56^{v}14^{vi} \text{ per day}$$

which differs considerably from the values of either Sacrobosco or Ptolemy.[185] Finally Sacrobosco might have consulted Jabir Ibn Aflah's paraphrase of the *Almagest*; but here we find the Ptolemaic value.[186] Thus this problem still awaits its solution.

Having established Sacrobosco's Ptolemaic credentials we must now discuss the problem why he decided to write a comprehensive exposition of the *compotus* when the Middle Ages had already an excellent manual on the same subject in the form of the *De temporum ratione* by the Venerable Bede which Sacrobosco knew and quoted on at least two occasions.[187] One reason may be indicated by a passage in which Sacrobosco states that modern scholars are in doubt with respect to the dates of the equinoxes and solstices, since the ancients said that the Sun enters a new sign of the ecliptic on the 15th kalends of the month (i.e. on the 15th day before the first day of the following month) and that both the solstices and the equinoxes occur on the eighth day thereafter.[188]

This is a correct reference to a well known norm in ancient astronomy

according to which the zero point of the ecliptic is at Aries 8°, instead of Aries 0° as in Hipparchus and Ptolemy.[189] It implies that if the vernal equinox is on 8.Kal.Aprilis (= March 25) as assumed by the Romans and the early Latin Church the Sun must enter Aries on 15.Kal.Aprilis (= March 18). For the same reason the winter solstice would be on 8.Kal.Januarii (= December 25) and the summer solstice on 8.Kal.Julii (= June 24). But Sacrobosco explains that this is no longer the case, and that the reason is that we assume the motion of the Sun to be slower than it actually is: "But that the winter solstice would be on the sixth day before the Nativity of our Lord, and the summer solstice on the sixth day before St. John is seen to appear from the fact that too much time is attributed to the course of the Sun."[190] The effect of this error is then calculated from the value of the *mensis solaris* quoted above, viz.

$$30^{d}10^{h}29^{m}36^{s},$$

whereas the mean value of a Julian calendar month is

$$30^{d}10^{h}30^{m}$$

or 24^{s} more than the true *mensis solaris*. Thus the Julian calendar lets the mean Sun dwell 24 seconds too long in each sign of the ecliptic, which is the same as to say that it uses 288 seconds too much for a complete revolution. The investigation of the consequences of this error occupies a central position in the *Compotus* and may well have been the reason why Sacrobosco embarked upon the composition of a completely new treatise on time reckoning. He proceeds in the following way.

First the 288 seconds are taken to be $^{1}/_{12}$ of an hour; this is a rather careless approximation since the correct fraction is $^{2}/_{25}$, but in consequence Sacrobosco maintains that the error amounts to one hour in 12 years and therefore to one day in 288 years. Had he used the fraction $^{2}/_{25}$ he would have found 300 years; however, this is a minor point which affects neither the gist nor the outcome of the argument, which runs as follows: We know that at the present time the winter solstice comes ten days before the Nativity; this appears "from various reasons" on the nature of which Sacrobosco unfortunately keeps silent. Since the number of years elapsed since the birth of Christ comprises no more than four complete periods of 288 years the error must amount to no more than four days during the Christian era. In consequence, we must conclude that there was an original error of 10 – 4 = 6 days in the dates of the solstices, as adopted by the ancients at the time of Christ, so that they did not occur on the 25th of the month but six days earlier.[191]

Having shown this, Sacrobosco is now able to offer a proposal for a calendar reform by which the accumulated effects of the error might be eliminated at the same time as it would prevent the dates of the equinoxes from wandering. The elimination of the actual error obviously means that ten days must be left out of the calendar, but Sacrobosco does not indicate how this might be done in a suitable way. He is more explicit with regard to the second step, which he proposes to achieve by leaving one day out of the calendar every 288 years, for instance the last day of February or, even better, the preceding leap day. The year in which this adjustment is made might be truly called an *annus jubilationis*.[192]

As far as I know this is the first explicit proposal for a reform of the Julian Calendar, made about 350 years before the Gregorian Reform actually took place. It is interesting to see that the two steps of the reform proposed by Sacrobosco were very similar to those taken by the Gregorian reformers, although

the basic parameters were different. Sacrobosco assumed that the Ptolemaic year of 365;14,48 days was the true solar year whereas the Gregorian committee adopted the value of 365;14,33 days. The result was the removal, not of one day in 288 years, but of three days in 400 years. Otherwise the fundamental principle was the same. It is worth noticing that Sacrobosco published his proposal in a textbook for the use of students without ever submitting it to the proper authorities, at least as far as we know. It may be that he considered himself to be only a modest scholar who had no intention of meddling in the affairs of his superiors. On the other hand there may also have been another reason, which will appear when we now consider his remarks on the errors of the ecclesiastical calendar, as distinct from those of the civil calendar with which he has been dealing so far.

The *Sphere* ends with the brief Chapter 4 in which Sacrobosco gives a few elements of the theory of motion of the planets. It has often been said that this account of theoretical astronomy is so short as to be practically useless; this is true enough and already in the thirteenth century it was felt necessary to supplement it by adding a much more detailed *Theorica planetarum* to the *Corpus astronomicum* immediately after Sacrobosco's own treatises.[151] Nevertheless, Chapter 4 is important in so far as it reveals Sacrobosco's intention of basing theoretical astronomy on Ptolemaic principles. This must have been a deliberate decision, for in 1217 Michael Scot had translated al-Bitruji's *De motibus celorum* into Latin with its vehement attack on the Ptolemaic models. If Sacrobosco knew this work – and he may have met Michael Scot in person in Paris after 1230[152] – he chose to pass it over in silence in order to provide an account of the deferent, equant and epicyclic circles of the Ptolemaic models. That he was here approaching the limits of his own knowledge appears from the only factual error of the exposition, viz. that the stationary points of the five planets are determined by tangents drawn from the centre of the Earth to the epicycle,[153] an error that was repeated in the popular version of the *Theorica planetarum* and first removed from Latin astronomy in 1460 by the *Theoricae novae planetarum* of George Peurbach.[154] As for the other details, Sacrobosco explains that the Sun has no epicycle, and that the Moon has a concentric equant in the plane of the ecliptic, and no retrograde motion "propter velocitatem motus eius in epicyclo".[155] It is not clear whether Sacrobosco realized that, unlike the five planets, the Moon has a retrograde motion on its epicycle. The motion of the Sun takes place on an eccentric circle with an apogee called by the 'Arabic' word *aux* and a perigee called *oppositum augis*, two terms which from now on were universally adopted in Latin astronomy until the Renaissance. These two points are said – as in Ptolemy – to follow the motion of the fixed stars at a rate of 1° per century, another testimony that Sacrobosco was well acquainted with Ptolemaic precession.

On this basis Sacrobosco is able to give a brief but correct account of eclipses of the Sun and Moon, stressing that lunar eclipses are seen at the same time from all over the Earth, while solar eclipses depend on the climate of the observer "propter diversitatem aspectus [lunae] in diversis climatibus"[156] which is the medieval way of referring to the daily parallax of the Moon. In his concluding remarks Sacrobosco defines his position on a point which was much debated by both the Fathers and the Scholastics: Was the eclipse which happened at the time of the Passion of Christ a miracle or a natural phenomenon? On this question Albertus

Magnus was later to waste a lot of time trying to calculate the possible visibility of a solar eclipse at Jerusalem.[157] Sacrobosco realizes at once that since an eclipse happens at a new moon and Christ died at the Passover when the Moon was full, the phenomenon must have been miraculous and against nature[158] – an insight which enables him to close the *Sphere* with a quotation from Pseudo-Dionysius: "Aut deus nature patitur, aut machina mundi dissolvetur."

Such in brief was the astronomical knowledge which Sacrobosco presented to his students and arranged for them in the *Sphere* in a neat and logical manner which completely belies Delambre's strange accusation of a *défaut d'ordre* of the exposition.[159] We shall conclude this section by reflecting a little on the manner of exposition which Sacrobosco chose to adopt, no doubt having considered and rejected a number of possibilities. The ordinary teaching of most of his colleagues would consist in a series of *lectiones* based on an already existing text which was cut into small sections on each of which the Master provided as much commentary as could be delivered within the stipulated hour. Since Sacrobosco had no prescribed text but wrote his own manual this method was out of the question. But it is characteristic that as soon as his book became a standard text book the commentators immediately cut it into sections and *lectiones*. This was the case already with the commentary ascribed to Michael Scot who found material in the *Sphere* for eighteen *lectiones*,[160] whereas Robert Anglicus in 1271 spent only fifteen lectures on it.[161]

The ecclesiastical calendar was based on the mean motion of the Moon and aimed at determining the times of new and full moons so that the time of Easter, and the other movable feasts dependent on Easter, could be established. This was in a way a simple matter since the remarkably precise value of the mean synodic month found in Ptolemy was well known. But the problem was complicated by the fact that the times of the lunations had to be determined as dates in the Julian calendar which, as we have seen, gave a rather poor account of the motion of the Sun. In a special chapter "On the verification of the new moon"[193] Sacrobosco raises the general question whether the ecclesiastical method of determining the dates of the *primationes*, or new moons, is correct. He has already explained that the method is based on the assumption that 19 solar years equal 235 complete lunations, forming the so-called *cyclus lunaris* or *cyclus decemnovenalis*. He now argues that this is not the case, showing – as we have already seen – that the two periods differ by $1^1/_3$ of an hour if the Julian year is made the basis of the calculation instead of the Ptolemaic year. This led him to recognise an error of about $3^1/_2$ days in the dates of the lunations of his own time compared with those happening at the time of Christ. This again has obvious consequences for the value of the so-called Golden Number, that is, the number of the actual year within the actual 19-year cycle. Here Sacrobosco first calls Eusebius and St Jerome to witness in support of the assumption that in the first year of that cycle within which Christ was born there was a new moon on March 23, and accordingly also on January 23, since these two dates are separated by 59 days (equal to two mean synodic months of $29^1/_2$ days). In consequence, January 23 ought to be marked in the calendar by the Golden Number one, indicating that in the first year of each 19-year cycle there is a new moon on January 23. Now, he continues, it is a fact that during the Christian era the 19-year cycles have

accumulated an error of three or perhaps four days relative to the Julian years, with the consequence that the date of the January new moon in the first year of a cycle has changed from January 23 to January 20. It follows that the Golden Numbers ought to be adjusted accordingly. If this is not done the dates of the full moons in general, and the Easter moon in particular, will be wrong and Easter will be celebrated on a wrong date. However, Sacrobosco has no hopes that this adjustment will ever be performed since the Ecumenical Council has forbidden any change of the calendar.[194] It is not clear which council Sacrobosco had in mind since the reform of the calendar had not yet appeared on the agenda of any general council. Perhaps he merely intended the Council of Nicaea in A.D. 325, which was usually thought to have fixed the principles of the ecclesiastical calendar once and for all.[195] However, he had made his point – the ecclesiastical calendar is wrong, but this is something we have to live with. Already Bede had suspected that not all was well and that the phases of the Moon were sometimes ahead of the calculated dates;[196] but it seems that it was Sacrobosco who made the first estimate of the magnitude of the error and proposed a remedy for it.

On one other point Sacrobosco proposed an idea which was more practicable than the adjustment of the Golden Numbers. As we have seen above, the 19 Julian years of the lunar cycle comprise 6939¾ days. The problem was whether this period could be made equal to 235 calendar months. Since Antiquity the Christian computists had tried to solve this problem by piecing the 235 lunations together from

	114 hollow months	$= 114\times29^{d}$	$= 3306^{d}$
+	114 full months	$= 114\times30^{d}$	$= 3420^{d}$
+	7 embolismic months	$= 7\times30^{d}$	$= 210^{d}$
+	the leap days in 19 years		$= 4\frac{3}{4}^{d}$
		totalling	$6940\frac{3}{4}^{d}$.

This is precisely one day more than 19 Julian Years, an error which could be suppressed by leaving out one day somewhere in the cycle of lunations. This so-called *saltus lunae* was usually placed in the month of July in the 19th year of the cycle, as Sacrobosco correctly explains.[197] However, even with the device of the *saltus* we get a period which is not an integer number of days and therefore impossible as a calendar period, which must necessarily comprise a whole number of days without fractions. Accordingly Sacrobosco proposes to use a succession of four 19-year cycles comprising a total of 25,759 days as the fundamental calendaric period.[198] Such a *cyclus cyclorum* would actually make the lunations repeat themselves on the same dates within a period of 76 years. This suggestion was less offensive than that of tampering with the Golden Numbers and was in fact adopted by several calendar makers in the thirteenth century. Thus the calendar of Grosseteste covered the 76 years from 1216 to 1292,[199] being succeeded by a calendar by Peter Nightingale valid for another 76-year period 1292–1368.[200] This raises once more the question of the possible relationship between Grosseteste and Sacrobosco. If Grosseteste's calendar was composed in the year 1216 in which it started, it may well have been known to Sacrobosco. On the other hand the *Compotus* contains some evidence for the plausible assumption that the two authors worked independently. Thus Sacrobosco maintained that the error of

the Golden Numbers amounted to $3^1/_2$ days in 1232 years, as explained above, which is equivalent to one day in 352 years. On the other hand Grosseteste said that in 304 years the Moon would be $1^d6^m40^s$ ahead of its calculated phase, which corresponds to one day in 274 years.[201] This makes it unlikely that the Parisian scholar was influenced by his more famous Oxford colleague.

10. *Conclusion*

It would probably be unwise to try further to develop the picture of John of Sacrobosco. But even if we stop at this stage and proceed with the process of fixating the picture, it would seem that we have been able to learn more about him that might have been expected from the poor state of the negative. Admitting that both his origin somewhere in Britain and the precise dates of his birth and death must remain unknown to us, neither his personality as a scholar nor his achievements as a teacher are any longer clouded in total obscurity.

Firstly, we have seen him performing his work in an academic environment which was not deeply interested in those particular sciences to which he devoted all his energy. But in a Faculty eagerly committed to promoting the Aristotelian conception of science as an investigation of causal relations framed in a predominantly metaphysical language, he nevertheless succeeded in presenting his student with an alternative idea of science as the disclosure of mathematical relationships between observable phenomena of nature.

Secondly, for this purpose he displayed much pedagogical ingenuity in his dealings with young and immature students, to whom his course of lectures must have formed a marked and perhaps pleasant contrast to what they were confronted with in the more philosophical approach to the *artes liberales*. In his class there was no schematic marshalling of scholastic *quaestiones* and *responsiones*, and no slavish dependence on prescribed textbooks. Instead we may imagine John in his chair simply telling his students about mathematics, astronomy and time reckoning in his 'narrative' manner, flavouring his talk with etymological explanations which were no less interesting for being wrong (in many cases), and with bits of ancient history, glimpses of the historical development of his subject matter, and copious quotations from the Latin poets he knew so well and loved so much. He must have been a very popular professor indeed.

Thirdly, he wished to give to his students the very best of what he knew himself, first and foremost precise definitions of scientific concepts, easy to remember and not to be forgotten or 'unlearned' by those who later passed on to more advanced studies. In mathematics he introduced the new 'Arabic' numerals into the university curriculum, showing how these strange symbols adapted themselves to algorithmic procedures of calculation of much greater ease and elegance than those to which earlier generations had been accustomed. In astronomy he made the immensely significant transition from the stellar lore of Macrobius and Martianus to the astronomy of Ptolemy. Although the *Almagest* itself was too difficult for his students, and perhaps even somewhat above his own level of understanding, he was able to convey at least the elements of spherical astronomy and planetary theory to his audience, including such features as the phenomenon of precession which appeared as a real novelty in elementary teaching in Paris. Finally, his great exposition of time reckoning showed how simple calculations

based on improved parameters would illuminate calendaric problems of immediate importance to society, and point the way towards future reforms.

All these features are easily discernible in the works of Sacrobosco and sufficient to present him as a sympathetic figure who reacted to the scientific challenges of his time in an intelligent and conscious way. As such he greatly contributed to the rebirth of science in Europe, since his modest legacy of mathematical and astronomical texts were destined to become the kernel of that collection of treatises which is known as the *Corpus astronomicum* and which so largely contributed to keep the idea of a mathematical description of nature alive until the time arrived when the great pioneers of the sixteenth and seventeenth centuries were able to proceed so much further on the track along which Sacrobosco had taken the first resolute steps, however modest they must seem to later generations.

REFERENCES

1. Plutarch, *Marcellus*, 15-17.
2. See Pliny's pungent remarks on that strange twist of the human mind which makes it more interested in tales of war and slaughter than in the story of the true benefactors of mankind, *Naturalis historia* II, 6, 43.
3. See O. Pedersen, "The *Corpus astronomicum* and the traditions of medieval Latin astronomy", *Colloquia Copernicana*, iii (1975), 57-96.
4. Thus Sacrobosco is not mentioned in the *Chartularium* of the University of Paris edited by Denifle and Châtelain (see ref. 24). Also the famous *De scriptoribus ecclesiasticis* by Johannes Trithemius passed him over in silence, and this was also the case of Bulaeus in his great *Historia Universitatis Parisiensis*.
5. The best approach is found in the introduction to Lynn Thorndike, *The Sphere of Sacrobosco* (Chicago, 1949), cited in the following as "Thorndike".
6. Such as Sacro Bosco, Sacro Busco, Sacro Busto, Sager busco, Sagero Busco.
7. Quoted from the printed edition of Robert's commentary in Thorndike, 143. See also below in the present paper.
8. "Joanni de Sacrobosco patria fuit, quæ nunc Anglia insula, olim Albion et Brettannia appellata", *Sphaera Joannis de Sacro Bosco ... cum annotationibus et scholiis doctissimi viri Eliæ Vineti ...* (Parisiis, 1550); here quoted from the following edition (Paris, 1552), fol. 2r.
9. *Erasmi Oswaldi Schreckenfuchsii Commentaria in Sphæram Joannis de Sacrobusto* (Basileae, 1569), Epistola dedicatoria, fol. a3r.
10. *Christophori Clavii Bambergensis ex Societate Iesu in Sphæram Joannis de Sacro Bosco Commentarius* (Romae, 1581); here quoted from the later edition, Romae, 1606, Praefatio, p. 2.
11. "Ioannes Sacroboscus, a loco natali dictus, quod ego nomen Saxonice interpretor Haligwalde, vel Halifex, cuius appellationis et emporium apud Brigantes lanicio celeberrimum: unde et hunc, conjectura ductus, ortum facile crediderim. Thomas Grynaeus, mathematicarum Britanniæ nostræ decus, unicum idem sentit. — Studuit adolescens, quantum ego colligere possum, in academia, quæ ad Isidis Vadum notissima est", Ioannes Lelandus, in *Commentarii de scriptoribus Britannicis*, ed. by A. Hall (Oxford, 1729), i, 353. This was the first printed edition, but the work can be roughly dated from the fact that Leland's manuscript was used by Bale in 1548.
12. I have been unable to find any British mathematician by the name of Thomas Grynaeus, or Green (?). Did Leland confuse him with the well known Tübingen mathematician Simon Grynaeus to whom Melanchthon dedicated his edition of the *Sphere*?
13. In Bale's original notebook there are a few notes on Sacrobosco as a *vir anglicus* who wrote a *De sphaera mundi* and also was an *Iudiciarius astrologus*, or astrologer, who in 1233 published a *spherae armillaris utilitates* in Paris; see his *Index Britanniæ Scriptorum*, ed. by R. Lane Poole and Mary Bateson (Oxford, 1902), 244. These confused notes were not included in the first edition of Bale's *Illustrium maioris Britanniae scriptorum ... summarium* (London, 1548)

which was silent about Sacrobosco, whereas in the enlarged second edition (Basileae, 1557-59), i, 502, Bale quoted Leland almost verbatim.

14. "Oppidum celebratissimum cum suis privilegiis quæ magna, et admodum antiqua sunt, tum authore de Sphæra Joanne de Sacro Bosco, quem suum fuisse alumnum prædicat", Wm Camdem, *Britannia sive florentissimorum regnorum, Angliæ, Scotiæ, Hiberniæ, et Insularum adiacentium ex intima antiquitate Chorographica Descriptio* (London, 1586), 400.
15. "Horton ... nomenque novum Halegfex sive Halifex, id est, sacri capilli acceperit. Fax enim Transtrentanis Anglis capillum signicat. Unde etiam nobilium familia in hoc agro Faierfax, a pulchro capellitio nominatur", *ibid.*, 401.
16. The entry on Holywood or Halifax, John, in the *Dictionary of national biography*, by C. L. Kingsford, maintains that Sacrobosco was "probably born at Halifax in Yorkshire" and educated at Oxford before he went to Paris. Also E. B. Emden included Sacrobosco in his *Biographical register of the University of Oxford to A.D. 1500* (Oxford, 1959), iii, 1621, without offering direct evidence.
17. Richard Stanyhurst, *A Treatise contayning a playne and perfect Description of Irelande ... compyled by Richard Stanyhurst* (London, 1577), fol. 26 vb. This work was printed and published (with its own foliation) as part of Holinshed's *Chronicles*, i.
18. See A. Gwynn and R. N. Hadcock, *Medieval religious houses in Ireland* (London, 1970), 271.
19. "Nam Haly-fax sacrum capillum significat, non sacrum Boscum", *De scriptoribus Hiberniæ authore Jacobo Waraeo* (Dublin, 1639), 59.
20. "Maledicentissimus Lelandus, qui futili argumento et ridicula, ut solet, ratione Anglum fuisse et Oxoniam studuisse affirmat", *Thomae Dempsteri Historia Ecclesiastica Gentis Scotorum, I-II*, editio altera (Edinburgh, 1829), 579.
21. Thus in the *Dictionary of national biography*, v, 785-90, Henry Bradley said that "Although displaying great industry, the book is chiefly remarkable for its extraordinary dishonesty, the author supporting himself often by quotations from imaginary sources".
22. "Joannes a Sacrobosco Scotus, vulgo Halybush, quae familia adhuc durat apud nostras, et certissimam de eo memoriam conservat.
    Acta nationis Germanicae ad D. Cosmi Parisiis, et Scotum fuisse diserte loquuntur, et venisse in eam academiam adoptatumque .v. Junii anno MCCXXI.
    Fuit canonicus in monasterio Nithisdaliae, vulgo Haliwud, quod fundavit Deo Virgilla comitissa Gallovidiae" (*op. cit.* (ref. 20), 578-9).
23. See the *Liber procuratorum nationis anglicanae (alemanniae) in Universitate Parisiensi*, ed. by H. Denifle et A. Châtelain (Paris, 1894), p. xv.
24. Matriculation lists were first introduced by a statute of the Faculty of Arts, dated 14 October 1289; see *Chartularium Universitatis Parisiensis*, ed. by H. Denifle and A. Châtelain (4 vols, Paris, 1889-97), ii, no. 561, pp. 35f. In the following this work is cited as *Chartularium*.
25. See *op. cit.* (ref. 23).
26. J. B. Cowan and D. E. Easson, *Medieval religious houses in Scotland* (2nd edn, London, 1976), 78 and 102.
27. George Mackenzie, M.D., *The lives and characters of the most eminent writers of the Scots nation* (Edinburgh, 1708), i, 161.
28. A. Erens, Prémontrés, *Dictionnaire de Théologie Catholique*, xiii (1936), col. 23.
29. Norbert Backmund, *Monasticon Praemonstratense*, ii (Straubing, 1954), 41 and 106.
30. John F. Daly, s.j., "Sacrobosco, Johannes de", *Dictionary of scientific biography*, xii (1975), 60 seq.
31. MS Trinity College Cambridge R.2.86 (James 567) fol. 14v: "Explicit algorissmus [sic] de integris et minutiis secundum venerabilem virum magistrum Johannnem de Sacro bosco de cathelonia [sic]. Amen." Quoted from M. R. James, *The western manuscripts in the library of Trinity College Cambridge*, ii (Cambridge, 1901), 43.
32. MS Bodleian Add. A.2.
33. See J. C. Russell, *Dictionary of writers of thirteenth century England* (London, 1936), 73 (= *Bulletin of the Institute of Historical Research*, special supplement no. 3).
34. See L. Thorndike and P. Kibre, *A catalogue of incipits of mediaeval scientific writings in Latin*, 2nd edn (London, 1963), col. 854.
35. "Quidam studens iohannes qui olim fuit iudeus et quondam baptisatus ideo transtulit istam scienciam de iudaico in latinum." The MS is now Berlin 959, lat. 4° 23. The quotation is from V. Rose, *Verzeichnis der lateinischen Handschriften der Königl. Bibl. zu Berlin*, ii/3 (Berlin, 1905), 1188.
36. "Lutetiæ sepultus est, in sodalium Maturinalium claustris: cuius medio tumulo insculpta

sphaera, ac circum illum epitaphium hoc, etc.", *op. cit.* (ref. 8), 122.

37. "Sepultus in fano Maturini, insculpto saxo sepulchrali astrolabio, signo mathematico", Leland, *op. cit.* (ref. 11), 354.
38. J.-B. Riccioli, *Almagestum novum* (Bologna, 1651), p. xxxix a.
39. "Il fut enterré dans le cloitre des Mathurins, où l'on voit encore un astrolabe sur son tombeau avec des vers latins", J. Lalande, *Astronomie*, i (Paris, 1792), 143.
40. The beginning of the fourth line is given as "Si miseres, plora", etc., in Dempster who may have seen the monument; see *op. cit.* (ref. 19), 579.
41. *Chartularium*, i, no. 63, p. 118.
42. *Ibid.*, no. 136, p. 177.
43. *Op. cit.*. (ref. 23), p. xv.
44. *Op. cit.* (ref. 49).
45. "Omnia quaecunque a primaeva rerum natura constructa sunt, numerorum videntur ratione formata", Boethius, *De institutione arithmetica* I, 2; ed. by G. Friedlein (Leipzig, 1867), 12.
46. D. E. Smith, *Rara arithmetica* (Boston and London, 1908), 31-33, lists a total of 14 editions.
47. J. O. Halliwell, *Rara arithmetica* (London, 1841), 1-26.
48. M. Curtze, *Petri Philomeni de Dacia in Algorismum vulgarem Johannis de Sacrobosco Commentarius, una cum Algorismo ipso* (Hauniae, 1897), 1-19.
49. *Petri Philomenae de Dacia et Petri de S. Audomaro opera Quadrivalia*, ed. by Fridericus Saaby Pedersen, i (Hauniae, 1983), 174-201 (*Corpus philosophorum Danicorum Medii Aevi*, x/1).
50. "Johannes de Sacro boscho dixit in suo tractatu quem composuit de spera, existens in studio parisiensi", Bartholomeus Parmenensis, *Tractatus spere*, ed. by E. Narducci, in E. Narducci, "Intorno al 'Tractatus Sphaerae' di Bartolomeno da Parma", *Bullettino de bibliographia e di storia delle scienze*, xvii (1884), 1-42, 43-120 and 165-218, p. 73.
51. Thorndike, pp. ix and 57-75.
52. MS Copenhagen GKS 277, 2°, 169r – 173v. It is part of a codex written for the most part in the same hand and containing a gloss, fol. 91vb, referring to the year which "nunc habemus ... nunc scilicet anno domini .M°.CC.xl", a date which is repeated in another gloss on fol. 92ra where we read "hodie autem scilicet .M°.CC.xl gratie anno".
53. See e.g. A. C. Klebs, "Incunabula scientifica et medica", *Osiris*, iv (1938), 1 – 359. A possible competitor was Manilius's poem *Astronomicon* which was printed at about the same time.
54. The figures quoted here have been calculated from the list of editions in J. C. Houzeau and A. Lancaster, *Bibliographie générale de l'astronomie*, new edn by D. W. Dewhirst (London, 1964), but there is but little doubt that this list could be considerably increased by further research. The only modern, critical edition is by Thorndike, *op. cit.* (ref. 5), 76-117; it is followed by an English translation.
55. This commentary was edited by Thorndike, *ibid.*, 143-98. It should be noticed that the date of Johannes's work is given as 1267 in the anonymous version found in the Erfurt MS Amplon. Q. 188, fol. 34r, see Thorndike, 74. Thorndike also edited the commentaries of Michael Scot (pp. 287-342), Cecco d'Ascoli (pp. 344-411), and an anonymous series of glosses (pp. 412-44).
56. *Op. cit.* (ref. 9).
57. *Op. cit.* (ref. 10).
58. See Houzeau et Lancaster, *op. cit.* (ref. 54), 54.
59. Melanchthon provided the Wittenberg edition of 1537 with a preface which was often printed in editions appearing elsewhere. The importance he attached to Sacrobosco's works is underlined in his academic *orationes* on the exact sciences, e.g. in his *Oratio de Alfragano et mathematicis disciplinis Ioannis Regiomontani*, in *Philippi Melanthonis Opera quae supersunt omnia*, ed. by C. G. Bretschneider, xi (Halle, 1843), col. 543.
60. I have not seen this MS which is listed in Thorndike and Kibre, *op. cit.* (ref. 34), col. 243. The early MS Tournai 87 perished in a fire in May 1940.
61. The "Icelandic translation" mentioned by G. Sarton, *Introduction to the history of science* (Baltimore, 1927-48), ii, 618 was not a translation, but an original work with some references to Sacrobosco; *cf. Alfrædr Islenzk*, ed. by N. Beckman and Kr. Kålund (Copenhagen, 1914-16), 257.
62. MS Copenhagen GKS 1810, 4°, 57r.
63. J. B. J. Delambre, *Histoire de l'astronomie du Moyen Age* (Paris, 1819), 243 ff.
64. O. Pedersen, "The origin of the *Theorica planetarum*", *Journal for the history of astronomy*, xii (1981), 113-23, espec. p. 119.
65. See Pedersen, *op. cit.* (ref. 3).

66. The MSS are Ottob. 3024 and 3290, see Thorndike, 5.
67. *Op. cit.* (ref. 8), fol. 2r.
68. *Op. cit.* (ref. 38), p. xxxix a.
69. *Gerardi Joannis Vossii De artium et scientiarum natura ac constitutione libri quinque* (Amsterdam, 1696), 122.
70. Quoted from the MS Basel O.II.7, 38v.
71. Copenhagen GKS 277, 2°, 98rb.
72. Boethius, *De consolatione philosophiae* III, 9.
73. Copenhagen Add. 447, 2°, 79ra.
74. Paris BN Lat. 7475, 55v.
75. In line 6 the word *ramus* is 'emended' to *ramis* in the Cambridge MSS McClean 166, 71v, and CUL Ii.iii.3, 55v, which shows that already some of the early scribes felt this difficulty and tried to remedy it, although not very successfully.
76. *Cf.* Ovid, *Metaph.* 7, 293, where *quater deni* means 'forty'.
77. *Op. cit.* (ref. 8).
78. *Op. cit.* (ref. 10), Praefatio, p. 2.
79. Riccioli, *op. cit.* (ref. 38), p. xxxix a.
80. P. Tannery, "Le traité du Quadrant de Maître Robert Anglès", *Notices et extraits*, xxxv (1897), 561-640; here quoted after his *Mémoires scientifiques*, v (Toulouse and Paris, 1922), 140, note 1.
81. P. Duhem, *Le système du monde*, iii (Paris, 1954), 240, note 3.
82. John Bale, *Scriptorum illustrium maioris Brytanniae summarium*, i (Basileae, 1557), 503.
83. *Op. cit.* (ref. 69), 122.
84. Mackenzie, *op. cit.* (ref. 27), 167; according to Mackenzie the epitaph consisted of line 5 from the *Compotus* poem followed by the four authentic lines quoted by Vinet.
85. Lalande, *op. cit.* (ref. 39), 142.
86. R. T. Gunther, *Early science in Oxford*, ii (Oxford, 1923), 27.
87. A. P. Youschkewitsch, *Geschichte der Mathematik im Mittelalter* (Leipzig, 1964), 353.
88. Thus C. L. Kingsford in the *Dictionary of national biography*, Emden (*op. cit.* (ref. 15)), and Daly (*op. cit.* (ref. 30)) who also quotes lines 5, 6 and 7 of the *Compotus* poem as the epitaph of Sacrobosco.
89. "Joannes a Sacro-bosco, qui librum de Sphæra et computum ecclesiasticum conscripsit, Lutetiæ moritur", Albert Miraeus, *Rerum toto orbe gestarum chronicon ab anno Christi M.CC. ad nostra usque tempora* (Antwerpiae, 1608), 283.
90. *Op. cit.* (ref. 19), 578.
91. MS Copenhagen GKS 277, 2°, 95rb.
92. That Copenhagen Add. 447, 2°, 70va has $N = 1335$ is certainly a scribal error.
93. "Sed in 19 annis solaribus secundum Ptolemeum in tertia dictione Almagesti sunt 6939 dies et 18 hore licet nimis prodige fiat calculatio", GKS 277, 2°, 95rb; *cf.* the *Almagest* III,1, where the 19-year Metonic cycle is mentioned (Toomer's translation, 139) without its value in days and hours being calculated.
94. Actually the period of 235 lunations is not mentioned in Book IV of the *Almagest*, although it can be derived from the value of the mean synodic month quoted in IV, 3 (Toomer's translation, 179).
95. Tannery, *Mémoires scientifiques*, v (ref. 80), 317.
96. *Cf.* Franciscus Barochius, *Cosmographia in quatuor libros distributa ... in qua perfecta quidem astrologiae divisio ... Joannis de Sacrobosco vero 84 errores* (Venetiis, 1570); see L. Thorndike, *A history of magic and experimental science*, vi (New York, 1941), 154 ff.
97. Thorndike, 8-10.
98. All these references have been verified by Thorndike in his edition of *S.*
99. Thorndike, 10-14.
100. Grosseteste's *Sphere* was edited by L. Baur, *Die philosophischen Werke des Robert Grosseteste* (Münster i.W., 1912), 10-32 (*Beiträge zur Geschichte der Philosophie im Mittelalter*, ix).
101. Ed. by Baur, 12.
102. Ed. by Baur, 26f.
103. Edited in Thorndike, 247-342.
104. Thorndike, 249.

105. Thorndike, 22.
106. A historical survey of the development of this scheme is found in J. E. Wise, *The nature of the liberal arts* (Milwaukee, 1947). See also J. Koch (ed.), *Artes liberales* (Leiden and Cologne, 1959), and *Arts libéraux et philosophie au Moyen-Age* (Actes du IVe Congrès Intern. de Philosophie Médiévale, Montreal and Paris, 1969).
107. See the list of translations and translators in A. C. Crombie, *From Augustine to Galileo* (London, 1952), 23-30, to which should be added, for instance, the important Archimedes translations made in 1269 by William of Moerbeke.
108. *Chartularium*, i, 70 f.
109. *Chartularium*, i, 136-9.
110. *Chartularium*, i, 227-32.
111. *Chartularium*, i, 277 ff.
112. Thorndike, 78; *cf. Metheor.* I, 2; 339 a 11.
113. Thorndike, 87 f.; *cf. De gen. et corr.* II, 10; 336 a 32.
114. MS GKS 277, 2°, 89vb.
115. MS GKS 277, 2°, 90va.
116. *Phys.* I, 1, 184 a 14.
117. Thorndike, 143.
118. Ed. by F. Saaby Pedersen, *op. cit.* (ref. 49), 81-85.
119. *Ibid.*, 174.
120. *Metaph.* I, 9, 991 b 69 ff. and 992 b 7-9.
121. "Quoniam impossibile est sciri naturalem philosophiam sine illis. Valent autem in toto universo et in partibus eis absolute", Robert Grosseteste, *De lineis, angulis et figuris*, in Bauer, *op. cit.* (ref. 100), 59 f.
122. Ed. by F. Saaby Pedersen, *op. cit.* (ref. 49), 81.
123. "Omnia in mensura et numero et pondere disposuisti", *Liber sapientiae* XI, 32.
124. Thorndike, 76-77.
125. "Quoniam numeris certis et subtiliter coniunctis doceatur", GKS 277, 2°, 89vb.
126. MS Copenhagen GKS 1810, 4°, 56 r.
127. Thorndike, 127. It may be this passage which gave rise to the legend that Sacrobosco wrote a treatise on the astrolabe.
128. Thorndike, 110, note 57. The passage in question does not occur in all MSS and may be a later addition. However, there is of course no reason to doubt that Sacrobosco knew about sundials.
129. A §2; ed. by Saaby Pedersen, 174.
130. A §24; ed. by Saaby Pedersen, 177.
131. The division of the texts in §§ is due to F. Saaby Pedersen in his recent edition.
132. "Ego credo quod finis immediator eius est ipsa astronomia: est enim practica huius artis, sicut instrumentum inquirendi quantitates motuum caelestium"; ed. by Saaby Pedersen, 82.
133. Euclid, *Elements* XI, 14.
134. Theodosius, *Sphaerica* I,1.
135. Thorndike, 84 f.
136. Thorndike, 78.
137. Thus Delambre called the *Sphere* "un extrait superficiel" and "une production médiocre" compiled by an author who "n'avait jamais pratiqué l'Astronomie", *op. cit.* (ref. 63), 241-3.
138. "The author was unfortunately not a practical observer", said Gunther, *op. cit.* (ref. 86), 271, although he admitted that "Sacrobosco gave a fresh impetus to the science by abstracting from the writings of Alfraganus and Albatignius [*sic*]", obviously without being aware that Sacrobosco never quotes al-Battani.
139. Duhem went as far as to say that the first three books of the *Sphere* contain nothing which might not be learned from Pythagoras, *op. cit.* (ref. 81), 239 — as if 'Pythagoras' knew about the precession of the equinoxes.
140. Thorndike, 79.
141. It is difficult to see how Duhem (*op. cit.* (ref. 81), 240) could maintain that "Sacrobosco ne fait pas la moindre allusion au phénomène de la précession des équinoxes".
142. See R. Mercier, "Studies in the medieval conception of precession", *Archives internationales d'histoire des sciences*, xxvi (1976), 197-220, and xxvii (1977), 33-71.
143. Geminus, *Isagoge* V, 2.

144. Thorndike, 92.
145. Thorndike, 90.
146. Thorndike, 93.
147. Thorndike, 110. On the theory of climates in general, see E. Honigman, *Die sieben Klimata* (Heidelberg, 1929).
148. See T. Bychawski, "Measurement of one geographical degree undertaken an [*sic*] carried out by Arabs in the IXth century", *Actes IX^e Congrès Intern. d'Hist. des Sci.*, i (Barcelona and Paris, 1960), 635-8.
149. *Almagest* II, 6
150. Alfraganus, *Rudimenta Astronomica* (Norimbergae, 1537).
151. See *op. cit.* (ref. 3).
152. Thorndike, 23.
153. Thorndike, 114.
154. See O. Pedersen, "The decline and fall of the *Theorica planetarum*", *Studia Copernicana*, xvi (Warsaw, 1978), 157-85, espec. p. 167.
155. Thorndike, 115.
156. Thorndike, 116.
157. Albertus Magnus, "In VII epistolam Dionysii", *Opera omnia* (ed. Colon.), xxxvii/2.
158. Thorndike, 117.
159. *Op. cit.* (ref. 63), 243.
160. Thorndike, 248-342
161. Thorndike, 143-98.
162. Thorndike, 304.
163. Thorndike, 306.
164. Thorndike, 413.
165. "Narrative sine demonstrative primo est tradita ab Alfragano ... et a Johanne de Sacrobosco in tractatu spere", Bibl. Laur. Firenze, MS Plut. 29, 7, 106v.
166. GKS 277, 2°, 91vb.
167. See the *Compotus*, GKS 277, 2°, 90rb; *cf.* the edition by Barach and Wrobel (Innsbruck, 1876), 19, lines 135-6 (Thorndike, 9, note 40).
168. Thorndike, 91.
169. Thorndike, 87.
170. Thorndike, 87.
171. Thorndike, 90.
172. GKS 277, 2°, 89vb-90ra.
173. *Ibid.*, 90r a-b.
174. *Ibid.*, 90va.
175. *Ibid.*, 91rb.
176. GKS 277, 2°, 91va.
177. "In domo Domini quattuor sunt necessaria, scilicet grammatica, musica, canones et compotus." I have been unable to find this phrase in the works of St Augustine. It has an unmistakably monastic ring and must be of a later date.
178. "Compotus est scientia considerans tempora ex solis et lunae motibus et eorum ad invicem coequatione distincta", GKS 277, 2°, 89vb.
179. "Tempus igitur est effectus corporum supercelestium motus, ex quo quantitatis dimensionem et numerum et qualitatis alterationem sortitur", GKS 277, 89v; *cf.* MS Basel O.II.7, 23ra, CLM 353, 8va, and Vat.Lat. 3114, 33v.
180. It is found already in Antiquity and became known to the Middle Ages through Isidore of Seville's *Libri etymologiarum xx*.
181. "365 diebus et quarta unius diei preter rem modicam que nullius est sensibilitatis", Thorndike, 114.
182. "Est igitur annus solaris spatium temporis quo sol a quocumque quatuor punctorum zodiaci equalitatis vel conversionis movetur circuens totum zodiacum motu proprio, rediens iterum ad idem punctum", GKS 277, 2°, 92ra.
183. "... neque defectus illius quantitatem secundum veritatem propter diversitatis parvitatem possibile est inveniri sicut in Almagesti dictione quarta a Ptolomeo reperitur", *ibid.*