Adelard of Bath and Roger Bacon: early English natural philosophers and scientists

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The image of Roger Bacon as a 'modern' experimental scientist was propagated as historical truth in 19th century scientific historiography. Twentieth century criticisms attacked this tradition, arguing that Bacon was primarily a medieval philosopher with 'medieval' scientific interests. However, recent scholarship has provided a more careful and critical account of Bacon's science, and identifies his greatest achievement in terms of his successful attempt to assimilate the worlds of Greek and Islamic optics. It can be justly claimed that Roger Bacon was the first Western thinker in the middle ages to have mastered most of the Greek sources and the central Islamic source in optics. He made this scientific domain understandable for a Western Latin-reading audience. Yet, Bacon himself acknowledged Adelard of Bath, whose translations and commentary of Euclid's Elements set the foundations for a science of optics, as the true pioneer.

In popular writing on science in the 19th century, Roger Bacon (1220–1292) was depicted as the single exception to the absence of science in the Middle Ages. He was seen as 'an experimentalist' before his time, a veritable 'Philosophical Chancellor' in Friar's clothing. This 19th century image had a very long pre-history. Already in the 15th century the learned Oxford teacher and practitioner of medicine, John Cokkys, had made much use of Bacon's writings on philosophy and medicine[1]. The attribution to Bacon of countless alchemical and medical works in the later Middle Ages attests to his elevation as a hero of English medical and experimental concerns[2]. Bacon's role as an emblem of English scientific and experimental interests was established during the Renaissance and Reformation in the works of John Dee, who borrowed widely from Bacon's physics, geometry, optics and writings on the nature of science and magic. William Gilbert used the treatise on the magnet, the De magnete of Peter of Maricourt, the one who is lauded by Bacon as 'the best experimentalist' at Paris in the 13th century. Indeed, none other than Francis Bacon in *Temporis Partus Masculus* praised Roger Bacon as the one who avoided the theoretical excesses of the scholastics and who alone among the scholastics dedicated himself to the use of mechanical subtlety for the discovery of nature[3]. The dedication of John Dee, Sir Kenelm Digby and Thomas Allen, among others, to the preservation of the historical records of the past ensured that modern readers would have access to most of the works written by Roger Bacon.

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The interpretation of medieval science and philosophy by Francis Bacon, for which no medieval author but Roger Bacon was a true experimentalist, was given canonical status by William Whewell in his influential *History of the Inductive Sciences* (1859) and by Robert Adamson, *Roger Bacon: The Philosophy of Science in the Middle Ages* (1876).

In the early 20th century, however, Lynn Thorndike and Pierre Duhem raised serious concerns about the evidence for 'modern experimental science' in the works of Roger Bacon. Duhem took Bacon's account of experience to be a demand for the use of 'ordinary experience' for the verification of rational deductions, and argued with cogency that Bacon did not know experimental method in the 'modern' sense of that term[4]. Thorndike argued that Roger Bacon's experiments did little more than duplicate and confirm 'the medieval status of experimental method which we have already obtained from other earlier sources'[5]. And so, the *experimenta* provided by Roger Bacon were seen to be no different in kind from those found in Robert Grosseteste, Peter of Spain, Albertus Magnus and others. These are based on the 'Book Learning' gained from translations from Greek and Arabic (12–13th century), and from the recovery of Latin texts. In dealing with medieval science, it is absolutely necessary to emphasize the fundamental role of 'Book Learning'. It is not that the 12th and 13th century thinkers had no sense of experience, test and experiment. Rather, the sudden influx of works in science from the Greek and Arabic worlds forced the Latin Western society to institutionalize this new knowledge. Hence, one has the significant institution of the medieval universities on the basis of new curricula and new libraries. A level of reading competence would precede and accompany new efforts at an examination of the natural world.

Lynn Thorndike noticed a connection of some of the *experimenta* in Bacon's works to the medical and hermetic traditions, and acknowledged a definite experimental tendency in Roger Bacon.

> Bacon's method is not, like modern experimentation, the source but the goal of all speculation. It is not so much an inductive method of discovering scientific truth, as it is applied science, the putting the results of the speculative sciences to the test of practical utility.[6]

Part of this utility was in the application of mathematics to the reading of the *Book of Nature* and the *Book of Scripture*. In Bacon's case, this primarily meant the mastery and use of Euclid's *Elements*. And in this respect, in 1266 at Paris, Roger Bacon could look back with pride to the primary works of both Adelard of Bath (1075–1160) and Robert of Chester (Ketton) in translating and commenting on Euclid's *Elements*. Indeed, as will be seen below, much of Roger Bacon's work in physics and optics could not be understood without these texts. And in the *Communia mathematica* and elsewhere, Bacon acknowledged the foundational nature of Adelard of Bath's works in natural philosophy.

Writing in Paris in around 1266 on astronomy and astrology, computistics, geography and the study of light (*perspectiva*), Bacon is essentially a retired professor in logic, mathematical arts and natural philosophy[7]. By 1257 he had become a Franciscan Friar. In the 1260s, in the context of debate at the University of Paris concerning the place of the 'new' Aristotelian and Islamic learning in the curriculum, Bacon used his spare time to carry on a propaganda war for the improvement of the Medieval Quadrivium (Mathematical Arts) in the medieval university. In Bacon's view, the over-emphasis on the language arts and especially the opposition by some theologians to both Aristotle, his Islamic commentators and the new sciences allowed little room for the development and application of mathematics. Without this development, Bacon believed, science in the Latin West would make little progress.

In more recent scholarship, Alasdair C. Crombie[8], David C. Lindberg[9] and Sabetai Unguru[10] point to a distinctive experimental interest on Bacon's part, but they are clear that by modern standards, it is a very limited interest, and certainly it is not a case of 'modern inductive method' before its time. Crombie correctly situated Roger Bacon in the context of the reflections on *episteme*/*scientia* in Grosseteste's all-important *Commentary on Aristotle's Posterior Analytics*, which of course has close connections with the geometry that came to fruition in Euclid. Crombie never did claim that Bacon developed the quantitative experimental techniques characteristic of post-Cartesian science. He simply pointed to the 'qualitative definition' of a science on the basis of the Aristotelian *episteme*/*scientia*, and to issues arising from the newly translated texts of the medical tradition. Lindberg clarified Bacon's dependence on Neo-Platonic (Pagan and Christian), Arabic and Jewish philosophical traditions for his understanding of Force in nature (*On the Multiplication of Species*). He also identified Bacon's *perspectiva*, with its synthesis of Greek, Latin and Arabic sciences, as the central reference point for Bacon's own definition of a 'science'. Further, Sabetai Unguru linked the *scientia experimentalis* of Bacon with the greater attention on 'manual' knowledge found in Peter of Maricourt, and some later medieval thinkers. I have pointed to Bacon's recognition that Islamic concerns with astronomy required the re-definition of the term 'experience/experiment/*empeiria*/*experimentum*' in the light of his reading of Ibn al-Haytham and other authors. In this way, he was led to a re-definition of the Aristotelian 'experiment' (*empeiria*/*experimentum*) in a more scientific direction[11]. Bacon makes this point clearly in his *Communia mathematica*, his medical works and in his works on '*scientia experimentalis*'. Indeed, as A.I. Sabra noted with respect to Ibn al-Haytham:

> Testing remains a form of proof, but a proof in which physical properties were directly investigated, sometimes with the aid of an experimental apparatus especially designed for the purpose. And the aim of the proof was to bring certainty or exactness and precision to an observation by subjecting it to an artificial situation in which conditions could be varied. To operate explicitly with such a distinct concept of experimental proof while regularly attaching it to a definite set of terms (*I'tibar* and its cognates), and thus dissociating it from the idea of accumulated experience or *empeiria*, was a significant conceptual development in the history of experimental science. It remains true, however, that the 'confirmatory experiments' in I.H.'s *Optics* differ in at least one respect from the 'discovery experiments' of seventeenth-century optics: they do not reveal new properties, such as diffraction, double refraction or the dispersion of light; and although some of them are supported in a remarkable way by geometrical arguments (e.g. I, 3 [48–67]), they lack measurement[12].

What then is the central contribution of Roger Bacon to the history of an experimental science? Bacon is very much a child of his own times. He is not in any sense a modern research scientist. Born in England c. 1214/1220 and educated at Oxford, he spent most of his mature life in Paris (c. 1237/40 to c. 1280). He continued to write on the relation of philosophy of language to theology in his later life (c. 1292). Like any great emblem or hero, Bacon has been made to carry too heavy a burden. He is but one of the many known and anonymous English natural philosophers in the 13th century. Bacon's primary claim to scientific fame, as Lindberg argues, is that he was the first to write a comprehensive account of optics based on the newly available *Optics* of Ibn al-Haytham. In other words, he took this very important book in science and philosophy, interpreted it for a Latin-reading audience, and attempted to critically situate it in the context of all the important Greek and Latin works on 'optics', and the major Platonic, Aristotelian and Stoic philosophical ideas known to him. This was a massive undertaking. To understand the comprehensive scope of Bacon's task, one should note that whereas Grosseteste had only a few ancient sources, Bacon had available to him almost all of the

ancient works on optics. To gain an appreciation of the very fundamental quantitative and qualitative growth in the sources of knowledge from Adelard of Bath to Roger Bacon, it will be most helpful to cite the following comprehensive judgment of Professor David C. Lindberg.

> Bacon was the first to master the full corpus of translated Greek and Arabic works on the subject. In the first place, he was well acquainted (as any European scholar must be) with Plato's *Timaeus* and its discussion of light and vision. He was thoroughly familiar with the mathematical analysis of light and vision in Euclid's *Optica* and *Catoprtica*, translated as *De visu* (or *De aspectibus* in its Latin version) and Alkindi's *De aspectibus*, both of which went well beyond the mathematics of light and vision, but which, nonetheless, were frequently perceived as demonstration pieces of the mathematical program. … And he drew both inspiration and content from the works of Grosseteste, a distinguished Oxford Scholar from the previous generation, for whom Bacon had deep admiration.

Through his mastery and use of these sources, Bacon became a key transitional figure in the history of the science of *perspectiva* and one of the leading Western authors of the doctrine of the multiplication of species. It was Bacon, more than any other author in the Latin world, who taught Europeans how to think about light, vision and the emanation of force[13].

To this I would add that Roger Bacon tells us that his studies in *Perspectiva* were carried out so that he could give a better and more 'scientific' account of the processes found in the psychology of knowledge. Further, his account of experimental science was a complex effort to achieve the following: (1) An examination of the relation of reason to experience in epistemology, and (2) The provision of a 'practical method' concerning 'experiences of the world' analogous to 'formal logic' in regard to argument. That is, he sought to provide a method by which 'an art and science of nature' could be carefully distinguished from 'magic'. Bacon takes the explanation of the nature of a rainbow as the 'paradigm' (*exemplum*) of what he means by an experimental science. One is tempted to say his '*experimentum crucis*'. And he prefaces his account of the rainbow and related phenomena, such as the halo, by arguing that the natural philosophers such as Aristotle, Seneca, Avicenna and Averroes as well as the authors on *Perspectiva* have much to offer in a broad manner on how we see such phenomena. But in Bacon's view, they do not give an adequate direct physical account of these phenomena. He thinks we need a '*scientia experimentalis*' to provide us, not with 'general knowledge', but with a direct knowledge of the individual phenomena. And yet much of Bacon's description of the rainbow draws on these authors. What is Bacon getting at? I believe that his introduction of the calculation of the highest altitude of the rainbow at 42 degrees using an Astrolabe makes his point, as does his criticism of Grosseteste's account of refraction and reflection in the production of the rainbow. Bacon recognized that prior knowledge and authority had not solved the problem of how to explain the rainbow, and he projected that a newer method dealing with singular and particular experiences in much greater detail would be needed. Further, he knew from Peter of Maricourt that the uses of prizms and other optical instruments would be required. Hence, he understood the crucial role that observation, instruments and mathematics would play in opening new vistas in experience[14]. The fact that he was unable to accomplish the task, due, he tells us, to the limitations of his tasks as a busy Franciscan friar, should not detract from seeing the validity of his argument. Indeed, approximately 40 years later, Theodoric of Freiberg would work out a detailed geometrical account, one that would improve on Bacon's sketch and would have a continuity up to the works of Renee Descartes when the modern forms of experimental study would surpass those attempted in the Middle Ages. And yet, as Mark Smith has demonstrated, the 'Cartesian Method' has strong ties to these concerns of Bacon, Pecham and Witelo[15]. Whatever about the *Cogito*, Cartesian science did not just happen in a single act of self-illumination. It had to be the work of a lifetime. And the mastery of this medieval tradition is a major element of Descartes' achievement.

The much more interesting issue is the following: how did European scholars, and in particular, how did Roger Bacon manage to get from very little knowledge of geometrical optics in the Latin tradition prior to Adelard of Bath to the very comprehensive knowledge displayed in the 1260s? With Bacon, Pecham and Witelo in this period, one has scholars who can critically handle this material. The answer to this question has to do, of course, with the leadership of Robert Grosseteste in English University education, but more fundamentally in one respect, it has to do with the pioneering works of Adelard of Bath and his contemporaries.

In modern scholarship, Charles Burnett and his colleagues have done a very great service to medieval scholarship by critically recovering the life, education and works of Adelard of Bath. Under the title *Adelard of Bath, Conversations with his Nephew*, he has provided a critical edition with an introduction, translation and notes of *On the Same and the Different*, *Questions on Natural Science*, *On Birds*[16]. When these works are read in the light of Burnett's enlightening and very careful scholarship in *The Introduction of Arabic Learning into England* (The Panizzi Lectures, The British Library)[17], and his edition of *Adelard of Bath: An English Scientist and Arabist of the Early Twelfth Century*[18], it is now possible to appreciate the central importance of Adelard of Bath.

Briefly, it can be stated that Adelard of Bath helped transform the teaching of the mathematical arts in 12th century England. Indeed, he initiated with others, such as Daniel of Morely and Robert of Chester, a tradition of learning in which Greek learning, including Aristotle, and Islamic developments of Greek philosophy and science would interact with and transform the older Latin learning beyond recognition. Further, this English tradition of philosophy and science would be well established and institutionalized for a century before the early condemnations of Aristotle and Islamic learning at the University

of Paris in 1210 and 1215. So, when Roger Bacon looks back from 1266 at the various Condemnations of Aristotle and Islamic commentators at Paris, he is able to use Adelard of Bath's ideas of authority as a 'halter' (*capistrum*) to polemically criticize the scholars at Paris. Further, in the *Opus tertium*, when he writes to the Pope to request a research grant for the training of young mathematicians and scientists, he speaks as one who was trained in this English tradition. Indeed, he presents himself as a representative of this tradition, taking Robert Grosseteste as his ideal of scholarship and science.

From the point of view of the applications of mathematics, Bacon's main concern in *Opus maius*, part four, Adelard of Bath's translation of Abu Ma'shar's *Abbreviation of the Introduction to Astrology* and of al-Khwarizmi's *Astronomical Tables* are very important. In the light of Bacon's major achievement in *Opus maius*, part five on *Perspectiva* and part six on *Scientia experimentalis*, Adelard of Bath's translation and comments on Euclid's *Elements* is fundamental. Roger Bacon especially recognizes this debt in his *Communia mathematica* and in the *Geometria speculativa*.

Marshall Claggett, writing on Adelard's translations of Euclid, divided them into three parts[19]. (a) Version I: a 'close translation of the whole work (including the non-Euclidian Books XIV and XV) from the Arabic text, probably that of al-Hajjaj.' (b) Version II is a very different text. The enunciations are expressed differently; the proofs are replaced by instructions for proofs or outlines for proofs. This version came to be the most popular translation used in the schools. In the light of their edition of this text, Hubert L.L. Busard and Menso Folkerts argue that 'a comparison of the text of version II with those of version I and III yields little or no reason to assume that Adelard was the author of version II' [20]. They attribute the writing of this version with some probability to Robert of Chester. (c) Version III: This work is not a translation but rather a commentary on Euclid. It is attributed to Adelard in a few manuscripts, and Roger Bacon refers to it many times as Adelard's *editio specialis*.

In the course of his comments on the nature of geometry, Bacon makes use of this latter text as an authoritative treatment that is ignored by the 'common teachers' at Paris (*vulgus*). Bacon also makes use of Version II, and refers to the other translation (*alia translatio*), that of Gerard of Cremona that accompanied the text of the Commentary by Anaritius (al-Nayrizi). This latter commentary is also used extensively by Roger Bacon. It is not impossible that Bacon also knew the Medieval Latin translation made directly from Greek in the 12th century.

The following two examples from *Geometria speculativa* and *Communia mathematica* will provide a sense of Bacon's usage of Adelard's account of Euclid's *Elements*.

> Propositions, as Adelard of Bath says in his special edition, are explicated in the indicative mood, proposita in the infinitive, and he adds that propositions propose that something is or is not, proposita that something is to be done or not to be done. But Anaritius, wishing to reduce this doing to theory and distinguish it from practical geometry, says that demonstrations of theoretical geometry are either towards doing…or they are for showing and knowing without finding and doing…[21]

In an example that displays Bacon's awareness of the close importance of Euclid's *Elements* for the interpretation of the ideal of *episteme*/*scientia* in Aristotle's *Posterior Analytics*, he remarks:

> An axiom, as Adelard of Bath says in his edition, is interpreted as a dignity, for it explicates the definitions of things. And this is especially true when axiom is taken strictly, although in a wide sense all principles are called axioms, as Adelard of Bath's epilogue at the end of the book supposes. And Aristotle employs dignity thus in the *Posterior Analytics*. A postulate is, as Adelard of Bath says, that which being conceded nothing inconvenient follows from the hypothesis. A conception is, as the name says, that which also occurs to human intelligence, in which the 'wherefore' is not to be demanded.[22]

Bacon very clearly connects Adelard's and Robert of Chester's works on Euclid with the new ideal of proof in logic and epistemology, namely, the *Posterior Analytics* of Aristotle. This emphasis on the close connection between formal proof, geometry and experience would set the basis for the developments in calculus and formal analysis in the 14th century Mertonians at Oxford. It is for this that Bacon and Adelard should be honored, and not for some imaginary mythical image of them as modern scientists before their time.

In the *Geometria speculative*[22], Bacon uses Adelard as his authority to account for the historical origins of Geometry as an art in the measurement of the land to recover fields from the flooding of the Nile. The borrowing from Adelard is constant and extensive. And this alone would be enough to claim that Adelard exercised a strong influence on the work of Roger Bacon. But there is much more. As noted above with reference to the parts of the *Opus maius*, the influence of Adelard's research program is apparent in each part. Whether in the polemic on useless custom and authority, the importance of Hebrew, Greek and Arabic for Latin wisdom, the applications of mathematics, the study of optics and experimental science, and indeed the astrological account of civilizations from Abu Ma'shar in the *Moralis philosophia*, the varied concerns of Adelard's works are apparent in Bacon's formal presentation of these matters.

In his *On the Same and the Different*, Adelard of Bath presents common Neo-Platonic themes, especially in the light of Boethius's concern with the reconciliation of Plato and Aristotle. This concern with things, species, individuals, with Plato as a representative of the forms and Aristotle who is concerned with things in the world and with rhetorical speech, all of this is echoed in Bacon's concerns in the *Opus maius*. Again, the account of the Liberal Arts in this work of Adelard is made explicit in Bacon's later works.

In the text called *Questiones naturales* (*Questions on Natural Science*), one has concerns about physiology

which is found later in Bacon's works, including those on medicine. One also finds that topics on meteorological phenomena are given careful treatment by Bacon. There is also found some treatment of *spiritus*, animate life and the relation of intelligence and memory. Again, these items are reflected in Bacon's later concerns. Although Grosseteste is presented by Bacon as his model for translation and science, Adelard of Bath exercised a strong influence on Bacon's philosophy and science. It is not just that there is some borrowing of sources. Indeed, the very philosophical framework, that of uniting the best of the Latin tradition, such as Boethius, with the best of the Greek and Islamic traditions, is fundamental for both authors. They are two significant authors on the road leading to an English tradition of Natural Philosophy and Science[22].

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