BJHS, 1999, **32**, 237–251

Book reviews

JOHN BROOKE and GEOFFREY CANTOR, **Reconstructing Nature. The Engagement of Science and Religion.** Edinburgh: T. & T. Clark, 1998. Pp. xii + 367. ISBN 0-567-08600-3. £24.95, $49.95.

If works on science and religion have been plagued by propaganda, this book is a happy exception. John Brooke and Geoffrey Cantor show how often science is rooted in theological considerations, and how frequently religion mirrors the science of its age. In the seventeenth century, Robert Boyle insisted that natural phenomena should be explained solely in terms of matter in motion. This may seem to sever the relations between God and nature, but he further argued that the more mechanical the world, the better for religion since it made it clear that the world had been designed. Machines do not spring into existence by themselves! In the nineteenth century Lord Kelvin grounded the principle of the conservation of energy in the belief that God alone can create and destroy energy, while his contemporary, Frederick Temple, the Archbishop of Canterbury, saw the extension of natural law into the biological world as a confirmation of the existence of laws governing moral behaviour. The notion that science and religion are competing rather than complementary world-views would have astonished Newton or Kepler, and it is only in the nineteenth century that it became commonplace. It received its canonical form in Andrew Dickson White's *History of the Warfare of Science with Theology in Christendom*, a reaction to the clerical battering that he had been administered for proposing a liberal charter for Cornell University. White battered in turn, but his conflict with the religious establishment should be dedramatized; instead of seeing it as a typical confrontation between 'science' and 'religion', it may more usefully be seen as reflecting the waning of the power of the clergy as cultural leaders and the rise of a scientific meritocracy. New professional standards were urged, although they were sometimes honoured more in the breach than in the practice. For instance, the chemist Marcellin Berthelot, one of the leading French scientists, justified his rejection of the concept of the atom as follows: 'I do not want chemistry to degenerate into a religion: I do not want chemists to believe in the

existence of atoms as Christians believe in the existence of Christ in the communion wafer'. It is clear that such an incident, and several others recounted in this book, cannot be captured by a master-narrative that relies on immutable definitions of science and religion.

In order to know how science and religion actually impinged on one another, we have to see them in the context in which they were constructed, modified or reconstructed. The history of science is not simply the history of progress in the acquisition of truth. It is also the story of the extent to which scientific practice depends on social and economic factors, intellectual tastes and, last but not least, religious sensibilities. The popular interpretation of Galileo's troubles with the Roman Curia is perhaps the best illustration of the pitfall of assuming that there is something essential to science and something essential to religion that keeps them perpetually at odds. Chapter 4 of this book, 'The contemporary relevance of the Galileo affair', is an excellent attempt at breaking this mould. Brooke and Cantor explain in lucid and non-polemical historical prose the genuine scientific difficulties that were raised concerning the Copernican system, and show that some high-ranking officials, such as Cardinal Robert Bellarmine, were open-minded and anxious to avoid unnecessary clashes with the new science. Galileo was right, of course: the Earth does go around the Sun. This much we can see from satellites in the twentieth century, but in the seventeenth century Galileo had only a telescope. With that instrument he was able to see and show to others that there were more stars than had ever been imagined, that Venus had phases and Jupiter satellites, and that the Moon appeared to have craters. What he could neither witness nor demonstrate was that the Earth was moving in space. No amount of looking could solve that question. This is why the vast majority of Catholic astronomers rallied to the system that the Protestant Tycho Brahe had devised, and taught that the planets circle the Sun, while the Sun itself goes around the Earth. In 1616 Bellarmine cautioned Galileo,

> I say that if there were a true demonstration that the sun is at the centre of the world and the earth in the third heaven, and that the sun does not circle the earth but the earth circles the sun, then one would have to proceed with great care in explaining the Scriptures that appear contrary, and say rather that we do not understand them than that what is demonstrated is false.

Galileo, however, thought he had a decisive proof, one *that we can see with our own eyes*: the tides. They occur, according to Galileo, because the Earth both rotates on its axis and revolves around the Sun. If Church officials cannot be approved for condemning a scientific theory, they can hardly be blamed for listening to the scientists who told them that this argument was bogus.

If Galileo is the first name that springs to mind when the relations between science and religion are mentioned, the next is Darwin. It is sometimes said that with Darwinism came the death of God. But whose God? The diversity of responses to the theory of evolution can only be understood if we consider the different images of the deity that were entertained in the nineteenth century. Two such images clearly took a beating from *The Origin of Species*. The first was that of the magician who conjured up new species out of primeval slime. The demise of this image was hailed by the Christian socialist Charles Kingsley: God was wise enough to make things make themselves. The second image was more sophisticated. It was the notion of God as artisan or mechanic, and had been given its classic formulation by Paley, who marvelled at the design and craftsmanship that could be observed in the human eye or ear. Darwin made the watchmaker-God redundant by providing an account of how such structures had come about by gradual refinement over immense periods of time. Although this appeared disastrous to some theologians, many felt that it was a much-needed corrective to an anthropomorphic conception of God that eschewed the darker side of creation and was insensitive to the poor and suffering. Long before Darwin appeared on the scene, Paley's construction of nature had been criticized for preferring a remote locksmith to the demanding God of Christianity.

The theory of evolution did not toll the knell of a departing God but was an invitation to

reconsider his image. The image of God the artisan gradually faded from European consciousness to be replaced by that of God the artist. This image left room for an evolving landscape with the artist entering into an intimate relationship with what was being made. The Jesuit modernist George Tyrrell, writing in the early years of the twentieth century, borrowed Darwin's metaphor of a branching tree:

> The universe is like a great tree, that pushes out its branches, however and wherever it can, seeking to realize its whole nature … in every one of them, but aiming at no collective effort. This is its play, this is its life, this is, if you will, its end.

Brooke and Cantor explore this kind of natural theology, but they also offer a case study of the Quakers, a distinctive social group that had several members elected to the Royal Society, including John Dalton in the nineteenth century and Arthur Stanley Eddington in our own.

The last chapter examines a number of questions that affected traditional conceptions of divine providence in the debate over the chemical reconstruction of vital processes. The controversy may be seen as heralding current discussions over biotechnological methods of improving nature by freezing embryos (to allow women to have their children when they want, even past the menopause) or isolating the gene for the ageing process (in the hope of developing a pill that would add fifty years to life expectancy). Will science reconstruct nature? And if it does will theology be its handmaiden?

Brooke and Cantor have written an outstanding book on a difficult subject. They provide lively and stimulating accounts of incidents that loomed large in the development of our modern idea of nature without slipping into facile generalizations about the respective roles of science and religion. Scientific inquiry and religious quest have travelled together, not always in the most companionable of moods, yet strangely aware that together they can help us keep faith with the future. *Reconstructing Nature* can be warmly recommended to anyone interested in knowing by what curious highways and byways science and religion have brought us where we are today. It would make an excellent textbook and should be reissued in paperback edition.

William Shea
University of Strasbourg

Marelene Rayner-Canham and Geoffrey Rayner-Canham, **Women in Chemistry: Their Changing Roles From Alchemical Times to the Mid-Twentieth Century.** Washington, D.C.: American Chemical Society and Chemical Heritage Foundation, 1998. Pp. xiv + 284. ISBN 0-8412-3522-8. $34.95.

Drawing primarily on individual accounts of the lives and scientific careers of around fifty women active in the chemical sciences from antiquity to the mid-twentieth century, Marelene and Geoffrey Rayner-Canham seek to outline the contributions made by women to the discipline of chemistry and to identify the barriers which prevented their more extensive participation. Their intended audience is a diverse one, including chemical educators, practising chemists, historians of chemistry and participants in women's studies programmes, and they have sought a style which will be accessible to all of these groups. This is primarily a biographical approach, which they suggest is a consequence of their status as historian scientists, that is, writers of the history of science who are primarily scientists. This does not mean, however, that their book is simply a collection of biographies of 'great women' chemists. Instead they insist on the importance of contextualizing the individual accounts in order to understand 'the forces that have circumscribed women's roles in the progress of chemistry' (p. xiii) and of including women whose limited achievements help to illustrate the prevailing constraints on women's participation. To this end each chapter begins with a brief contextual overview to draw out the themes implicit in the biographies which follow.

The first group of women to be considered are those who were involved in the practice of chemistry before the scientific revolution. Here Chinese women alchemists appear along with those of the classical period and medieval and Renaissance Europe. Women who played a role

in the birth of modern chemistry through the medium of the French *salons*, including Émile du Châtelet and Marie Anne Paulze-Lavoisier, are the subject of the next chapter. While many of these women acted as assistants to male chemists, the independent researchers of the eighteenth and nineteenth centuries, the focus of Chapter 3, worked alone. The remaining seven chapters are devoted to women who, armed with higher-level qualifications, sought professional careers in chemistry from the later nineteenth century onwards. First to be considered is the concentration of women in particular branches of the discipline, notably crystallography, radiochemistry and biochemistry. The participation of women in industrial chemistry, chemical education, analytical chemistry and the history of chemistry, represented by Hélène Metzger, follows. In the examination of the individual branches of chemistry there is an emphasis on the important role played by male mentors in creating the conditions which made it possible for women to pursue scientific research. The diverse range of biographical accounts includes not only women already well known to historians of science such as Marie Curie and Rosalind Franklin, but also hitherto little-known researchers such as the Canadian biochemist Maud Menten (1879–1960) or the industrial chemist Florence E. Wall (1893–1988), a leading expert in cosmetic chemistry. A brief epilogue looks to the participation of women in chemistry after the mid-twentieth century.

The main strength of this book lies in the diversity and depth of the biographical accounts which it presents. A considerable effort has been made to ensure that the selection of biographies includes women from a range of national origins who worked across the many branches of chemistry. The authors have made effective use of often fragmentary sources whilst readily acknowledging the constraints which the limited availability of material placed on their project. Unfortunately this diversity is not always sustained when discussing trends in women's participation in chemistry, where much of the evidence is drawn from the United States. Indeed there is a general failure to anchor the individual biographies sufficiently in their national contexts. Instead the limitations placed on women's participation in chemistry are presented largely as an international phenomenon, divorced from any specific national context and resulting from cultural frameworks which were specific to certain periods of history but which remained consistent across national boundaries. The national context does emerge as an issue in the case of those women who migrated to pursue their research careers, but receives little mention or detailed analysis elsewhere. Lack of sensitivity to these issues undermines the argument that certain branches of chemistry had shared intellectual characteristics which made them more amenable to accepting women researchers. Crystallography, for example, may well have been more generally open to women than other fields, but the bulk of material presented here points strongly to the crucial role played by the support of powerful mentors (W. H. and W. L. Bragg) in making crystallography in Britain uniquely accessible. Further investigation of the field as it developed elsewhere is needed if such an argument is to be convincingly sustained.

Within the limits which it sets itself this is a successful and readable book, although those familiar with recent scholarship on gender and the history of science will find little to challenge them in its methodology. Its main contribution is to supplement existing biographical sources concerning women as researchers in the chemical sciences. By seeking to draw out the common threads which linked individual experience it also suggests a number of questions worthy of further investigation.

Sally M. Horrocks
University of Leicester

John T. Ramsey and A. Lewis Licht, **The Comet of 44 BC and Caesar's Funeral Games,** American Philological Association: American Classical Studies, 39. Atlanta: The Scholars Press, 1997. Pp. xx + 236. ISBN 0-7885-0273-5. $27.95 (hardback); ISBN 0-7885-0274-3. $17.95 (paperback).

Interdisciplinarity is a buzzword in education today; the collaboration between J. T. Ramsey and A. Lewis Licht provides a powerful and effective example of it. This study comprises arguments that clarify the confusion that surrounds the celebration of Games in honour of

the mythical ancestress of the Julian family (of Caesar and Augustus), Venus Genetrix, in 45 BC, 44 BC and subsequently; central to this is the reconciliation of the sometimes confused and inconsistent reports in Classical and Chinese/Korean documents regarding the appearance of a comet in the summer of 44 BC. This, however, is not just a significant advance in reconciling records: the resolution sheds important light on the maturity of Octavian's (Augustus') powers of political manipulation, even at the early age of nineteen.

First, the issue of the timing and nature of the Games themselves. It is shown convincingly that the Games in honour of Venus Genetrix, established by Caesar and held for the first time in September 46 BC, were repeated in September 45 BC, but that the timing was altered to July by Octavian in 44 BC, when the Games were 'twinned' with Funeral Games in honour of the dead Julius (pp. 41ff). Octavian's reasons were typical of his political manoeuvring during this period: the new date brought these Games closely adjacent to the traditional *Ludi Apollinares* (organized in 44 BC by Marcus Brutus, Caesar's 'chief assassin'), and it pointedly and openly established Octavian's position as Caesar's heir, highlighting the fact that Marcus Antonius had signally failed in his duty (*pietas*) to Caesar, his former friend and faction-leader. The change of date was also appropriate in view of the renaming, as *July*, of the former month of *Quintilis*, in honour of the dead Dictator. Octavian was thus shrewdly exploiting the popular enthusiasm for the memory of his dead adoptive father. As so often in his life, chance dealt Octavian another favourable hand – the appearance of a comet during the rescheduled Games.

At this point, the scientific evidence comes into play. A comet was normally taken as a 'baleful' sign, but a number of factors combined to make this appearance different even from sightings of the same phenomenon earlier in the summer in China. It is convincingly established that the July sighting in Rome was of the same object as that seen in China, and that its unusual appearance in the Rome sighting (as a star, which was subsequently used in literature, statuary and on the coinage as a symbol of Caesar's deification) was due to 'anomalous brightening' and to the fact that the atmosphere was full of volcanic gas and debris released earlier in 44 BC during a major eruption, probably of Mount Etna – an event which incidentally offers a plausible explanation of other 'portents' and phenomena reported that year.

In this way, the contributions of a Roman historian and a physicist provide a unique and cogent account of events, the details of which have long had Roman historians in considerable difficulties. Along the way, the authors produce some useful reinterpretations of puzzling problems, for example, the dating of Cicero's letter to Atticus, XIII. 44 (pp. 19–40), and inconsistencies in the sources, even though most of them appear to derive their accounts from Augustus' own memoirs. They are right, for example, to point out (pp. 53–4) inconsistencies within Suetonius' *Lives of the Caesars*, but might also have added the totally different slant which the author gave to Caligula's 'campaigns in Germany' as recounted in the *Life of Caligula* and the *Life of Galba*.

The question that has always hung over the events of this study has been one of '*cui bono?*' We are left in no doubt that it was the cynical opportunist, Octavian: sharp, fresh evidence is added through this reinterpretation of the extent of his ruthless ambition. In this particular, it is surprising that, although the authors show that the Games were still being held in 34 BC in honour of Venus Genetrix (p. 56), they do not suggest that the change of title to *Ludi Victoriae Caesaris* probably occurred after Octavian's final victory over Antonius at Actium in 31 BC, again demonstrating his opportunistic use of a designation that had long been accepted unofficially, and intended for Julius Caesar. There can be no doubt that although Octavian outwardly was ostentatiously honouring his dead father's memory, in fact he was preparing the ground for his own future.

The book is equipped with simplified statements of the main pieces of scientific evidence, and a series of Appendices which include the texts of all relevant source passages (with English translations), and another which provides a fresh and persuasive explanation of Cicero's odd description of Caesar as 'Victory's neighbour'.

In all, the authors' collaboration produces a book that is refreshing and cogent; it is also a fascinating piece of 'detective work' and eminently readable, an addition of considerable significance to the bibliography of that most tumultuous of years — 44 BC, the year of Julius Caesar's assassination and of 'Comet Caesar'.

DAVID SHOTTER
University of Lancaster

ROGER FRENCH and ANDREW CUNNINGHAM, **Before Science: The Invention of the Friars' Natural Philosophy.** Aldershot: Scolar Press, 1996. Pp. x + 298. ISBN 1-85928-287-3. No price given.

This book considers the development of natural philosophy in the thought of medieval Dominicans and Franciscans. By focusing on the circumstances in which the Friars' natural philosophy arose, as well as on the content of this philosophy, the authors aim to show that the Friars engaged in the study of nature because of their politico-religious concerns (p. 3), and that their specific approaches to natural philosophy 'were created as a weapon to defend Christianity … and to promote particular religious practices' (p. 6). This study thus belongs to the growing body of literature which seeks to take seriously the context within which specific approaches to nature were developed, rather than considering certain features of the Friars' natural philosophy simply as precursors to modern science.

In pursuit of this laudable aim, the authors discuss Dominican and Franciscan natural philosophies as two essentially different projects. Dominican natural philosophy was developed in the context of the establishment of the Dominican order and the attempts of the Catholic Church to combat the Cathars. It arose, the authors argue, as a response to the heretical teachings of the Cathars, whose dualist doctrine of creation held that the natural world had been created by 'an Evil Principle that rivalled the Catholic God in power and even eternity' (p. 127). This Cathar understanding of creation, nature and causality, which here is taken largely from the treatise *De Duobus Principiis*, contradicted orthodox understandings of creation, and the Dominican Order thus had an interest in demonstrating that the created world had been created by God and should be held to be good. Dominicans appealed to Aristotle's treatises on natural philosophy as offering a philosophical basis for arguments for this view. Thus, the authors argue, both the development of Dominican natural philosophy and the particular form which it took can and should be understood as an integral part of Dominican efforts to counter the Cathars both by force and by superior argument.

In a similar way, the authors believe that the Franciscan interest in light and perspective 'was not simply either a mystical or an academic study, but one of very practical value to help the townsfolk live good, Christian lives' (p. 251), and as such integral to Franciscan spirituality. The discussions of perspective found in the work of, for instance, Grosseteste, did not comprise 'a random mishmash, or even a bastard science, which was due to a simple lack of decent Greek or Arabic texts in the thirteenth century', but were '*thirteenth*-century discussions of a thirteenth-century science, *perspectiva*' (p. 249), which had to do not only with light but with natures and species. The Franciscans' discussions of light cannot simply be integrated into the history of optics. The authors show convincingly that the natural philosophies developed by the Friars were shaped by the contexts in which they arose and by the interests of the different orders, although they perhaps underestimate both the differences between various Cathar groups and the fact that the Dominican order was not established solely to combat the Cathars. These interests were not part of a 'scientific project' which was separate from the Friars' religious interests. Moreover, if unintentionally, French and Cunningham's study provides an interesting example of the way in which orthodoxy and heresy influence each other (and indirectly of the inadequacy of their definition of a heresy as the 'opposite of an orthodoxy' (p. 49)). The interdisciplinary approach could well yield results for church historians as well as for historians of science and philosophy.

However, this book has some shortcomings which highlight the problems of an inter-

disciplinary approach. Of minor significance are a number of terminological irritations; why, for instance, is the Bible frequently referred to as the 'Sacred Page'? If a particular hermeneutical point is intended, it is not made with any clarity. More seriously, the opening chapter, which purports to be a brief history of the relationship between theology and philosophy, is profoundly flawed. The assertion that 'Christianity was, from the start, a revealed religion, with a set of doctrines which had been given authoritatively and which one had to believe in order to be a Christian' (p. 14) is quite simply false, as the struggles to define doctrine and to establish orthodoxy during the first centuries CE demonstrate. Approaches to philosophy, and especially the acceptance of (Neo-)Platonism and Stoicism, certainly played an important role in the establishment of Christianity, but French and Cunningham's distinction between Judaism and Greek philosophy is extremely misleading; Hellenic Judaism had an important role to play. Further, the New Testament cannot really be said to be 'Plato-based' (p. 62), although this might well be said of early medieval Christianity. The acceptance of Platonism in Christianity is a complicated question which the authors might have done well to consider in greater detail. Finally, what justification can there be for quoting from the Authorized Version of the Bible (1611) and an 1838 translation of Augustine's *Confessions*, as if no modern, scholarly translations were available? Interdisciplinary work at the interface between the histories of science, philosophy and theology is essential, but it must draw on modern editions and translations and represent accurately the findings of recent research in all three disciplines.

Perhaps the paucity of this opening chapter is a reflection of a certain lack of focus in this study. The authors seem not to be clear what they wish to establish in the first chapter, and there is no obvious connection between their discussions of the Dominicans and the Franciscans. It might have proved fruitful to trace Christian attitudes to asceticism as illuminating approaches to dualism. Augustine, the Christian Neo-Platonic ex-Manichee, struggled with the question of attitudes to the body, and Platonic Christianity often came perilously close to dualism. Opponents of the Cathars found it difficult to use Plato against them, and this was surely one reason why the Dominicans appealed to Aristotle. The Franciscans, on the other hand, drew heavily on Plato; what does this say about their understanding of nature in contrast to that of the Dominicans?

Despite these caveats, there is much to be gained from French and Cunningham's study. It offers a vivid reminder that neither investigations of nature nor deliberations about doctrine can be divorced from their context. It is certainly neither a work of Christian apologetics nor an attempt to 'rehabilitate the reputation of the Medieval Roman Catholic Church', as one early reader apparently assumed (p. ix). It is an attempt to take seriously the fact that the Friars were not modern scientists who were somehow ahead of their time, but were committed theologians who sought to use all the weapons at their disposal to teach the truth about the world as they saw it, and to understand how this endeavour shaped the Friars' natural philosophy. Much more work needs to be done to give this picture more detail, but French and Cunningham offer a thought-provoking beginning.

CHARLOTTE METHUEN
Ruhr-Universität, Bochum

J. V. FIELD, **The Invention of Infinity: Mathematics and Art in the Renaissance.** Oxford: Oxford University Press, 1997. Pp. 264. ISBN 0-19-852394-7. £29.50, $35.00.

This is an extremely well-produced and well-written book on the history of perspective geometry in the Renaissance. But it is more than just an essay on how a practical piece of mathematics developed. It shows how the artistic skill of drawing and painting pictures in a naturalistic, convincing way is intertwined with the practical mathematical skill of projective geometry. Hence the historical narrative that unfolds is one where the practical mathematics of the craftsmen-painters was still very much at one with the skilful works of art produced by these very same mathematically trained artists.

The story starts by pointing out that medieval mathematics, as studied at the university as part

of the *quadrivium*, is to be distinguished from the practical mathematics taught at abacus schools. These schools were visited by prospective merchants and prospective craftsmen alike and taught 'commercial arithematic', algebra and a little geometry. In the first half of the book Field tells in a convincing story how Brunelleschi's invention of 'artificial perspective' shortly before 1413 – related to his drawings of the Baptistery of Florence – were taken up by his fellow artisans to produce more convincing naturalistic pictures; how in 1435 the humanist Alberti wrote the first account of a method of constructing pictures in correct perspective (in his short treatise *On Painting*), and how this finally culminates in Piero della Francesca's treatise *On Perspective Painting* (date of publication unknown). Field shows an impressive command of the development of the mathematics of perspective and the way this skill is put to use in various paintings. Here some new ground is broken in the history of mathematics in that much attention is paid to the actual setting of the practical mathematics of the abacus school. This part of mathematics is not normally dealt with by historians of mathematics for the simple reason that the mathematics is not very advanced and stands outside the high university of mathematics. Up to this point the book is eminently readable.

The second part of the book deals with the story of perspective and Girard Desargues's 1639 *Rough Draft of an Essay*, with which modern projective geometry is born. This part of the book is more technical – the mathematics becomes more important and hence more attention is paid to the proof of particular theorems – but this change of focus also reflects the fact that after della Francesca the subject of perspective geometry becomes more and more one where 'professionals' dominate. Or, to put it differently, the subject leaves the realm of practical mathematics and enters the realm where only the happy few – those who are gifted in and have an ability for mathematics – can understand it. Part of the reason why I believe this second part is not as successful as the first is that the stated intention of Field – to write a social history of mathematics – gets lost. This part is more in the well-known tradition of highly technical books on the history of mathematics that still dominate the field.

This brings me to my main criticism. What the book deals with is the coming together of particular social strata in the Renaissance (artisans, humanists and, to a lesser degree, university scholars), how they together developed the naturalistic tradition in art, and how after a number of generations these different social strata again parted company. One group of people became known as natural philosophers and were later to be known as scientists, and the other group became known as architects, painters, artists and so on. The humanists slowly withered away. This is what makes the book fascinating reading in a number of places. However, what makes it disappointing at the same time is that it never really deals with this theme in any substantial depth. It is, I believe, telling that the very name of Edgar Zilsel – who after all is one of the first to have probed this theme in any detail – is not even mentioned in the book. This omission is all the more striking in that Zilsel has suggested a mechanism for the erosion of the social barriers between the people who laboured with their hands and those who worked with their heads: emerging capitalism and the growing importance of technological innovation in manufacturing. The process highlighted by Zilsel may or may not be the mechanism responsible but at least it is a useful analytical tool. What Field does is simply pass over the question. She tells us that Alberti provided a written account of a method for constructing pictures in correct perspective, but that is not something that can be so easily taken for granted in a social historical narrative. Why was Alberti interested in the things craftsmen did? The same goes for the separation process that is the subject of the second part of the book. What was it that made projective geometry respectable enough to become part of real mathematicians' mathematics? There is nothing self-evident in this process and I for one expected Field to address the question.

I would nevertheless like to claim that this is a very valuable book, highly entertaining and showing an admirable grasp of both the history of practical mathematics and the history of art. All the mathematical elements are presented

skilfully and concisely while at the same time Field is able to present a highly readable and accessible narrative. Anyone who ever had to write about mathematics will know how difficult this is. Field is to be congratulated on the way she is able to tell her history of mathematics. The many diagrams are most helpful and I feel that even the less mathematically inclined reader will easily find his way through the text. The numerous reproductions of paintings and frescos are all very well chosen and made the book most enjoyable. There is, however, one final critical remark I would like to make: the title is most puzzling. The idea of infinity was well known in Greek and Islamic mathematics and philosophy. So what was it that was invented? It turns out that Desargues's 'point at infinity' is the intended referent. The title should be altered to reflect this.

Diederick Raven
Utrecht University

Lynette Hunter and Sarah Hutton (eds.), **Women, Science and Medicine 1500–1700: Mothers and Sisters of the Royal Society.** Stroud: Sutton Publishing, 1997. Pp. xx + 292. ISBN 0-7509-1334-7. £40.00, $72.00 (hardback); 0-7509-1343-6. £14.99, $22.95 (paperback).

Studies of the history of women and early modern European science have concentrated much of their energy on the identification of individuals, intellectual arenas and modes of discourse in order to create an adequate framework within which to place women's contributions and participation in science. However, the full range of women's involvement in the early modern scientific enterprise remains to be explored. The volume edited by Lynette Hunter and Sarah Hutton takes strides to rectify that situation by offering an interdisciplinary perspective on women and science in England between 1500 and 1700. Hunter and Hutton bring together scholars from several fields in an effort to rethink the way we conceptualize the history of women and science. They note that past efforts to reintroduce women into the history of science have drawn successfully on feminist theory but with the result that they often focus on the 'question of whether science is and has been intrinsically biased against women' (p. 4). Hunter and Hutton want their volume to redefine the boundaries of historical inquiry through an examination of the different materials and kinds of activities that constituted female scientific practice.

The contributions are roughly balanced between literary and historical analysis, history of scientific ideas and social history, biography and group practices. Hutton, for example, presents two essays. The first discusses Francis Bacon and Evelyn Fox Keller's suggestion that Bacon's use of metaphor was strictly and purposefully masculine. Hutton questions whether or not Baconian science was necessarily misogynistic and antithetical to women and emphasizes instead the broad range of images, both masculine and feminine, that Bacon appropriated in his writings. Hutton's second essay offers a comparison between the lives and contributions of two seventeenth-century female savants, Anne Conway and Margaret Cavendish. Her examination of these two remarkable women illustrates the complexity of scientific practice and the methods used by women to engage with the ideas of their time. Other essays, such as Margaret Hannay's on the Countess of Pembroke, Reid Barbour's exploration of Lucy Hutchinson's atomism and Frances Harris's examination of women such as Mary Evelyn, all combine elements of biography and literary analysis with a healthy dose of historicism that nicely contextualizes the works of these individuals. Other case studies include Adrian Wilson's on the midwife Eleanor Willoughby and the essay by Rob Iliffe and Frances Willmoth on two women, Margaret Flamsteed and Caroline Herschel, who worked as assistant-astronomers to their husband and brother respectively. Iliffe and Willmoth illustrate some of the most concrete connections between women and the Royal Society and at the same time extend the argument of the volume into the nineteenth century.

Not all of the essays in this volume deal strictly with the intellectual work of specific female savants. In the first of two essays, Lynette Hunter examines several scientific books written by women. Her dual analysis attempts to explain

the dearth of medical and science books either by or for women between 1617 and 1652 and the sudden appearance of science books penned by women after that period. At the same time, Hunter does examine the authors themselves (Elizabeth Grey, Alethea Talbot and Queen Henrietta Maria) and their place in the intellectual and political history of the English Civil War and Restoration. She concludes that the aristocratic women who wrote these books did so both because it was useful and instructive to engage in such activities on a country estate and also because it was an enjoyable leisure activity. Hunter's second essay examines the intellectual and social circle of Katherine Jones, an aristocrat living in London in the 1640s and 1650s. Jones met and corresponded with a number of aristocratic women interested in science as well as a fair number of English savants such as Robert Boyle, Kenelm Digby and John Evelyn. She and her associates provided the context that allowed for the successful publication, discussed in Hunter's first essay, technical books by and for women.

Other essays take a broader view of things and seek to contextualize the participation of women in science within the general milieu of books and the development of medical stereotypes. Elizabeth Tebeaux's discussion of women, literacy and scientific writings and Margaret Pelling's discussion of the medical role of older women in early modern London probe the connections between women *and* science instead of looking just at women *in* science. Tebeaux looks both at popular scientific books written for women during the Renaissance and at the sudden appearance in the second half of the seventeenth century of technical books written by women. She identifies a number of books for women on topics such as cookery, medicine, midwifery, silkworm propagation (considered an exclusively female occupation until about 1650), estate management and gardening. Based on her reading of these books she concludes that women readers had roughly the same level of literary comprehension skills as men, even if there were fewer literate women overall. Differences in scientific books, she suggests, existed only in terms of the length and extensiveness of content rather than in their complexity or difficulty of style. Pelling utilizes the records of the College of Physicians in London to delve into early modern attitudes towards older women and the creation of stereotypes. She addresses this difficult topic through an analysis of the College's attacks on female 'irregulars', ubiquitous practitioners of medicine who worked outside the officially sanctioned hierarchy of the medical establishment. Her reading of these documents provides insight into the work of these women, the broad range of men and women who utilized their medical expertise, and the way in which members of the College of Physicians constructed their own personal identities *vis-à-vis* the stereotype of these 'older women'.

The volume as a whole is well constructed with a very useful comprehensive bibliography and a general index. Despite the subtitle, which suggests that much of the discussion will centre on 'mothers and sisters of the Royal Society', the authors generally treat women as independent individuals rather than as dependent kinfolk, with only the one essay (on Francis Bacon) concentrating solely on male scientific views. Some of the essays do draw on similar subjects for their discussions and the index reveals that several of the same women appear in multiple essays. While this does tend towards some repetition, the volume does not suffer greatly since the result is a more nuanced portrait of female scientific culture from a variety of points of view. The various contributions to this volume reveal women's scientific work in Tudor–Stuart England to be vibrant, engaging and complex, and show that female savants had much to offer both their contemporaries and modern historians of science and medicine.

Michael R. Lynn
Agnes Scott College, *Decatur*

E. A. Davis (ed.), **Science in the Making: Scientific Development as Chronicled by Historic Papers in the *Philosophical Magazine* – with Commentaries and Illustrations, Volume 2: 1850–1900.** London: Taylor & Francis, 1997. Pp. xix + 406, 16 plates. ISBN 0-7484-0642-5. £59.95.

This is the second of three volumes which aim to illustrate 'science in the making' by providing a

collection of facsimile reproductions of original scientific papers. The bulk of the volume (368 pages) is taken up by the facsimiles. There are also short commentaries by E. A. Davis on the scientists involved and the importance of the papers selected for reproduction, and a foreword by W. H. Brock discussing the development of specialized, laboratory-based physics in the late nineteenth century. There is a nice set of black and white plates inserted at the front of the volume (but not subsequently referred to), mostly studio portraits of the scientists but including a few in their laboratories. Davis has selected just over thirty papers, and devotes sections to William Thomson (Lord Kelvin), James Clerk Maxwell and J. J. Thomson. Papers by John Tyndall, James Dewar and Lord Rayleigh appear under 'Professors at the Royal Institution', while those by Oliver Heaviside, Oliver Lodge and Heinrich Hertz represent 'The Maxwellians'. A 'Miscellany' section includes Foucault's pendulum, Bunsen's burner and Michaelson and Morley's ether-drift experiment, amongst others. The volume is strongest on thermodynamics, spectroscopy, the ether, electromagnetism and cathode rays, but unfortunately there is no index or detailed contents list. The organization of the volume is such that Rayleigh's paper on black-body radiation (1900) is in Section 2, while Kirchoff's suggestion that there might be such objects as black-bodies (1861) does not appear until Section 3, and papers dealing with the ether are similarly separated and out of chronological order.

The observant reader will have noticed that only a certain sort of 'science' is being dealt with here – the book would be more accurately titled 'Modern Physics in the Making'. In his foreword, Brock describes the book as chronicling the separation of experimental physics from chemistry in the course of the nineteenth century, and this is indeed what it does, although the strategy of reproducing whole pages leaves some tantalizing vestiges of fossil fish, cyclones and sunspots, and coal-preserved vegetation. This concentration on physics is presumably more a consequence of the decision to select papers from the *Philosophical Magazine* (over 80% of which was physics by the late nineteenth century, according to Brock), than a comment on what sort of subjects are 'scientific', but this is one of several historiographical issues that the commentaries fail to address. The restriction to the *Philosophical Magazine* alone is never explained, but the fact that it was published by Taylor & Francis, who are also the publishers of the current volume, might be reason enough.

I presume that this volume must be intended for students who are taking a course in the history of nineteenth-century physics, and whose lecturers would like them to read some of the original papers in a convenient format. The papers are too technical and the commentaries too sparse to appeal to a more general reader, while the more advanced researcher will get little benefit from the commentaries and will find only a few of the papers here relevant. With a student audience in mind, the commentaries might have been put to better use. The volume presents science as if it were something that originated in the minds or laboratories of a few individuals, and 'made' simply by committing it to print. Brock notes that the members of the X-Club 'exploited the powers of their speech and writing to argue for the supremacy of science' (p. ix), but we are left to assume that there was no such deployment of rhetoric in their scientific papers. As far as one can tell, getting published in the *Philosophical Magazine* was unproblematic, and simply doing so constituted the 'making of science'. Some comment on rhetorical strategies in writing scientific papers would have been welcome.

The relevance of publishing history to the sciences has become a subject of great interest recently, and Brock has been one of the major contributors to this field. Yet we are treated to no discussion of the *Philosophical Magazine* itself, of what the implications of choosing it as sole representative of the making of science might be, or even of the more mundane issues such as who read it, what it meant to be published there, or how it related to other scientific journals (although an extremely brief outline of the history of the journal appeared in Volume 1 of the series). J. J. Thomson's thoughts on the subject, quoted late in the volume, are as close as we get to a discussion on these matters. He wrote, 'I think myself that the *Philosophical Magazine* is a better means of

publication than even the Royal Society as the circulation is larger and the delay very much less. I only send papers to the R.S. occasionally as it is usually so long before they are in print that one almost forgets what they are about' (p. 311). From reading the rest of this volume, you could be forgiven for not realizing that there were other ways of publishing science, each with its own set of advantages and disadvantages. Brock's foreword to the current volume places the papers in their scientific context, but it is a shame that issues such as the use of rhetoric and the constraints or implications of the journal format, all of which are very much part of 'science in the making', are omitted. Such discussions would have made the volume of far more use to the student audience.

Aileen Fyfe
University of Cambridge

Michael Springford (ed.), **Electron: A Centenary Volume.** Cambridge: Cambridge University Press, 1997. Pp. xii + 330. ISBN 0-521-56130-2. £37.50, $49.95.
Per F. Dahl, **Flash of the Cathode Rays: A History of J. J. Thomson's Electron.** Bristol: Institute of Physics Publishing, 1997. Pp. xvii + 526. ISBN 0-705-0453-7. £29.50, $49.50.
Edward A. Davis and Isobel J. Falconer, **J. J. Thomson and the Discovery of the Electron.** London: Taylor & Francis, 1997. Pp. xxvii + 243. ISBN 0-7484-0696-4. £45.00, $135.00 (hardback); 0-7484-0720-0. £16.95, $45.00 (paperback).

The closing years of the nineteenth century saw a sequence of discoveries which revolutionized physics. They banished the notion, voiced by some eminent practitioners, that physics was almost a 'closed' subject with little left to do but measure with ever greater accuracy, and ushered in the new worlds of atomic and nuclear physics and quantum mechanics. Three events stand out: Wilhelm Röntgen's discovery of X-rays late in 1895, Henri Becquerel's discovery of radioactivity in 1896 and J. J. Thomson's discovery of the electron in 1897. A hundred years later their centenaries were celebrated in ways which bore curious resemblance to the reactions to the initial discoveries. Röntgen's X-rays burst upon the world with articles in the popular press as well as papers in learned journals, and within weeks progressive doctors were using X-rays to aid diagnosis. In 1995 it was the users of X-rays, predominantly the medical profession, who celebrated, and the various books published were mainly about applications. Becquerel's discovery lay almost dormant for two years until the Curies isolated two new radioactive elements, radium and polonium. The centenary passed with little fanfare, perhaps because of modern fears about radiation. Thomson's 'corpuscle' – he avoided calling it the electron for many years – fuelled existing discussions and disputes among scientists but impinged little upon the layman, and a hundred years later it was the physicists who celebrated. The three books reviewed here, written to mark that centenary, are aimed predominantly at the physicist and historian, even though it can be argued that our understanding of the electron, more than anything else, underpins the lifestyle of all of us at the end of the twentieth century.

Per F. Dahl's *Flash of the Cathode Rays* is the widest ranging of the three books and will appeal to the broadest readership. The book begins in Würzburg with Röntgen and X-rays, then discusses Thomson, his contemporaries and the Cavendish Laboratory in Cambridge up to the time of Thomson's appointment as Cavendish Professor in 1884. Dahl then returns to an earlier era and pens a brief history of electricity from the Ancient Greeks to Volta, Ørsted, Ampère and Faraday, before backtracking again to begin a more detailed look at investigations of electrical discharges in gases. This proceeds by way of Faraday, Plücker, Goldstein, Lenard and other German scientists, Spottiswoode, Crookes and other British scientists, and Perrin in France. Becquerel's discovery of radioactivity is also recounted. Only then, getting on for half way through the text, does Dahl describe the measurement of e/m for cathode ray particles by Thomson (and others), and Thomson's estimation of the charge e and the mass m separately. The second half of the book continues in a similar vein, starting with the measurements of e/m for other particles: those involved in the Zeeman effect and in photoelectricity and β-particles. It continues

with the work of Rutherford and others on α-particles, Blondlot's spurious N-rays and positive rays, where Thomson features strongly again. The final chapters cover Millikan's definitive measurement of the electron charge *e*, various atomic models proposed by Thomson and others, the Rutherford-Bohr atom and a glance at Moseley's explanation of X-ray spectra and events after the First World War up to Chadwick's discovery of the neutron in 1932.

The scope is vast, the treatment is largely descriptive and the style tends towards the journalistic with the chapter headings suggesting the action moving rapidly from one city or country to another and sometimes back again in the build-up to the 'race' for e/m. One does not have to subscribe to any myth that science is untainted by personal ambition to feel that the competitiveness is exaggerated. Equally, one has to admit that it makes it an easier and more interesting work for the more casual reader, without the time or inclination to plough through a more academic tome, who will thereby gain considerable insight into this important period of scientific history. It is not intended to be a definitive historical work, but it is a valuable introduction, even for the serious historian. The many notes and references, and a lengthy bibliography, point the way to deeper studies but there is at least one strange omission. There is no reference to the *Proceedings of the Royal Institution* for the seminal paper of April 1897 in which Thomson first suggested the existence of a lightweight charged corpuscle, only to the *Electrician*. Both printed the full text, and the report in the *Electrician* appeared first, but the paper was given as a Friday Evening Discourse at the Royal Institution and the report in the Institution's own publication ought to be cited. The book also is marred by poor proof-reading, with too many proper names misspelt. More diagrams would help in some of the early chapters, and there is no good reason why some of them should have been copied from secondary sources when they are accessible in primary sources. The author's grasp of the idiosyncrasies of scientific work in Britain in the late nineteenth century, particularly of Cambridge and the Cavendish Laboratory, and of the motivations of an aristocrat such as Lord Rayleigh, leaves something to be desired, but that is an understandable failing. For all these faults the book has a lot to commend it. Because it ranges so widely it brings out the connections between different pieces of work, the influence of one upon another, the contradictions and occasionally the controversies and the links between the many personalities who enter the story, including practically every physicist of note in this period. No other book does this, and this is its strength.

Electron, edited by Michael Springfield, goes to the other extreme. The concepts and the mathematics are graduate-level, and there is much specialized vocabulary. It is a difficult book to read even for physicists, unless they are working actively in the field of electron physics. Only the first chapter, a lucid account of Thomson's work by one of his successors at the Cavendish Laboratory, Brian Pippard, is more accessible. Pippard is careful to give due credit to Kaufmann, Wiechert and Zeeman for their measurements of e/m while maintaining Thomson's claim to pre-eminence because he demonstrated that the same particle was found in different gases and metals and went on to measure the charge *e*. Pippard also discusses two important topics not considered by Dahl: Thomson's theories about electrons in metals, and Richardson's work on thermionics, begun under Thomson's supervision.

The rest of *Electron* is a discussion of the current state of knowledge about the electron, snapshots of what has been learnt over a hundred years, in ten chapters by different authors, beginning with 'The isolated electron' and ending with 'The electron in the cosmos'. There are occasional historical details but many of the references are to papers published within the last decade or so; it is primarily about where we are now, not how we got here. It is salutary to compare what Thomson knew about the electron with what we know now. Thomson's estimates of *m* and *e* were correct to within a factor of two, and Millikan's measurement of *e* was precise to one part in a thousand (ignoring the systematic error caused by the wrong value for the viscosity of air). The precision claimed for modern measurements is more like one part in a hundred million. Thomson's corpuscle had two proper-

ties, mass and charge; the modern electron also spins, in other words it has a magnetic dipole moment, and should it turn out also to have a non-zero electric dipole moment it may yet trigger another revolution in the theory of physics comparable to that occasioned by its discovery. Thomson's 'plum pudding' model of the atom, with discrete electrons distributed throughout a sea of positive charge, is almost the inverse of current perceptions of an electron 'glue' holding the positive ions together in condensed matter, or the electron 'fluid' as the means of electrical conduction in metals. Electrons in pairs underlie the explanation of superconductivity, a phenomenon not known until some years after the discovery of the electron. Thomson's work seemed to have demonstrated conclusively that cathode rays were streams of particles – electrons – not the waves many continental physicists believed they were. How ironic it must have seemed to him when Louis de Broglie and his own son G. P. Thomson demonstrated that electrons also have a wave nature. He cannot have conceived the explanatory power of this concept in modern physics. It is also ironic that the electron, through its interactions with matter and magnetic fields, has led to many of the most important discoveries in modern astronomy and cosmology, on a scale as many orders of magnitude larger than ordinary human perception as the electron is smaller. Indeed, electron phenomena were revealing some of the secrets of the universe before the electron itself was known, through solar and stellar spectroscopy.

Electron illustrates strongly the difficulty historians will have with modern theoretical physics. The author of one chapter comments, on the physics of the electron, that 'each time "complete" understanding is around the corner, the paradigm shifts a little, and new surprises appear in experiments, the interpretation of which is often painful to those attached to the earlier view'. The passage of time will ease the pain but unravelling the different strands and weaving them into a coherent story will require a depth of understanding of physics that has not been demanded of historians before. Thomson's work is accessible to those with a modicum of mathematics, but nowadays one branch of physics is not readily comprehensible even to other physicists if they work in different areas. How will historians cope, or will we become dependent on the memoirs of retired scientists with no formal training in historical analysis?

J. J. Thomson and the Discovery of the Electron is the shortest of the three books and the most narrowly focused. As the authors point out, it is not a complete biography, nor does it attempt to do justice to the many others who contributed to the discovery of the electron. Its stated purpose is to provide a readable account of Thomson's work on the electron in the context of his life and other scientific work, and to give enough background information to help the reader to interpret the original papers. It is indeed a readable account, but it is also the most critically detailed, as might be expected given the authors' closeness to the source material. E. A. Davis is one of the current editors of the *Philosophical Magazine*, in which so many of Thomson's papers were published. Over half the book is taken up with facsimile reproductions of all or part of nine of Thomson's key papers on the electron and on electrical discharges in gases. I. J. Falconer was formerly curator of the Cavendish Laboratory Museum, which preserves relics of Thomson's time at the laboratory. She is well known for her studies of his work, which formed the subject of her doctoral thesis and of a paper in this journal in 1981. Despite being relatively short and precisely directed, this book does give a good impression of the human side of Thomson and his life and work, thanks largely to a foreword by his grandson, but also to an account, in the first chapter, of his formative years at Manchester and Cambridge. Thomson's later life, including his role during the First World War as a member of the Board for Invention and Research and as President of the Royal Society, followed by his twenty years as Master of Trinity College, Cambridge, is discussed very briefly. A short final chapter sketches the consequences of the discovery of the electron in the physics of elementary particles and in the technology of electronics.

To understand Thomson's work one needs to get to grips with the concepts which underpinned his thought throughout most of his life, but which seem very strange many decades later –

concepts such as vortex atoms, Faraday tubes and Grotthus chains. They all receive due attention in this volume. Electrical discharge in gases was an unfashionable research topic for a professional scientist, and Thomson only took it up after he became Cavendish Professor, when his position was almost unassailable. The discovery of X-rays facilitated Thomson's work, because the ionization produced by X-rays provided the means to increase and stabilize the conductivity of gases, and it also led him into cathode ray work. The authors emphasize that Thomson was speculating far beyond the limits of the experimental data when he first proposed the existence of a charged corpuscle much smaller than an atom. It is a curious but well-known fact that the experiments that are nowadays cited as marking the discovery of the electron were performed and published several months after the initial announcement at the Royal Institution, which presented results obtained by a different method. Other theorists quickly linked Thomson's corpuscle with the electron proposed by Johnson Stoney some years previously. For many years Thomson was careful to distinguish the two, because he saw his corpuscle as not just a particle of charge but as an essential component of matter. The experiments which led him to this conclusion are covered, and his later work on positive rays is mentioned.

One of the strongest impressions gained from reading the reproductions of Thomson's papers is how much he relied on visual images and models such as the vortex atom, and sometimes even on analogies with real models such as Mayer's magnets. This is a little surprising from a Second Wrangler steeped in the uncompromisingly analytical tradition of the Cambridge Mathematics Tripos, and a man at ease with the intricacies of Maxwell's *Electricity and Magnetism*. His mathematical powers are apparent, but verbal and qualitative reasoning features very strongly in his electron papers. This is also seen in his 'plum pudding' model of the atom, which in its day was a more sophisticated and powerful concept than we now realize. Another strong impression from this book is of the support and loyalty of his students at the Cavendish Laboratory, well-deserved support as so many who started their scientific careers working with him went on to achieve great things.

Each of these books has its strengths and its limitations. *Electron* is a book by physicists for physicists, but as a general review of the state of the art at the present time it may not be a book many physicists will feel impelled to buy. *J. J. Thomson and the Discovery of the Electron* will appeal most to historians and should also be of interest to a much wider readership but it does only consider Thomson's work. *Flash of the Cathode Rays* has by far the broadest coverage but not the deepest. What the three works do reveal is that there is plenty of work left to do before the bicentenary of the electron. We have no full and definitive biography of Thomson because the fourth Lord Rayleigh, who wrote the existing major biography, was too close both personally and in time. We also need a definitive analytical history of the discovery of the electron, covering the whole of the story, not just Thomson's work, even though that is the major part of it.

Neil Brown
Science Museum, London

Correction

In the article "Politics by other means: Justus von Liebig and the German translation of John Stuart Mill's Logic" by Pat Munday, published in our December 1998 number, an unfortunate proof reading error occurred on p. 403. The third sentence should have read "Chemical methods, popular and professional publications about chemistry, technological applications, promoting the careers of former students and even politics – all were central concerns stemming from Liebig's notion of chemistry as *the* central science." We apologize to Professor Munday for this error.