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Essay review

How Christiaan Huygens mathematized nature

Joella G. Yoder, *Unrolling Time. Christiaan Huygens and the Mathematization of Nature*. Cambridge: Cambridge University Press, 1988. Pp. xi + 238. ISBN 0-521-34140-X. £30.

This concise and modestly presented book offers exciting reading to a diverse audience. To the student of the Scientific Revolution in any of its manifold aspects, Joella Yoder's book has important insights to offer, in particular about how the 'mathematization of nature' went ahead in daily, sometimes hourly, practice. If one's appetite is whetted by a well-argued revision of current views on how seventeenth-century geometry and the onset of the calculus were connected, *Unrolling Time* is where one finds it. If one cares for a minutely detailed account of three months in the life of a great scientist caught in his most creative period, Yoder's book provides it. If one has experience of one's own in wrestling with the ghosts of the editors of Huygens' *Oeuvres Complètes*, a sympathetic and highly successful fellow-toiler is to be encountered here. In short, even if a lack of refined mathematical ability compels the reader to forego part of the pleasure of this book, a great deal remains to enjoy. Since the reviewer belongs to the latter category, I should like to place the comments that follow under the general heading of 'What *Unrolling Time* has to teach to the mathematically unskilled reader'.

Christiaan Huygens unrolled time in the sense that there is an intricate connection between his discovery (and subsequent application) of the isochronism of the cycloid and his theory of evolutes. The aggregate of ideas, discoveries, theories, theorems, concepts, proofs, etc., that centre around this topic was presented by Huygens to the world in his *Horologium Oscillatorium* of 1673 – one of the recognized masterpieces of the Scientific Revolution. Not until the appearance of Yoder's book has it become clear that almost all the research that went into Huygens' greatest book goes back to a tightly-knit period of three months in his life – October to December 1659. Once this concentrated outburst of creativity had subsided, no more than one topic (the compound pendulum) remained to be added by Huygens to a corpus that was eventually to see the light thirteen years later. His accomplishment during these three critical and exciting months is the essential subject of Yoder's research as reported here.

Compared with the other 'great men' of the Scientific Revolution, Huygens' work has not received a great deal of attention. As Yoder observes (pp. 61–2), this relative neglect applies in particular to his papers, which have frequently been ignored in favour of his finished works. Huygens' papers are accessible in two ways: through the 22 volumes of the *Oeuvres Complètes*, and through the manuscript 'Codices Hugeniorum' kept at Leyden University Library from which those *Oeuvres*, of course, are largely derived. The *Oeuvres Complètes* enjoy a great reputation for accuracy and completeness. Much of the praise that has been bestowed upon them is quite deserved, yet there is something about those volumes that makes them very hard to handle. The edition of the *Oeuvres Complètes* was carried out with great thoroughness, with a formidable erudition, and with a continuously increasing, specialized knowledge of Huygens' work. These resources were incorporated in the *Avertissements* preceding every piece as well as in the numerous, often quite lengthy, footnotes. None of the bulky and, on the face of it, authoritative editorial comments grew, or was meant to grow, into separately publishable studies. They occupy a difficult-to-define position half-way between editorial enlightenment and independent interpretation. As such, their very presence exudes discouragement to whomever dares approach. It is this feature of the editors' accomplishment that tends to lame in

advance the prospective Huygens student, who takes up the *Oeuvres Complètes* and finds himself torn by two contradictory sentiments, the one being: 'everything worth knowing about Huygens is already known', and the other: 'perhaps true Huygens research still has to begin'.

Add to this that the editors' concerns – naturally so for the years 1885–1950 when the edition appeared – betray prejudices quite different from those we hold today concerning the most interesting questions to ask about the history of science. No doubt the editors were, among other things, Huygens chauvinists, hoping to establish as many 'firsts' as they possibly could safeguard for their hero, and framing their questions and answers accordingly. Yet it would scarcely be possible for the present-day investigator simply to go ahead and do his own research in the *Oeuvres*, ignoring whatever has since become useless in the accompanying comments. One encounters the editors' traces at every step, for their spirit pervades the entire body of the enterprise. This is true of the overall arrangement of Huygens' treatises; it is no less true of what, from among Huygens' scrap papers, the editors decided to leave unpublished without recording that anything had been omitted. Again, I do not wish to disparage what the editors did, for in terms of their own time they did almost as splendid a job as could be expected. My concern here is the obstacles they unwittingly put in the way of present-day students of Huygens' thought and its advance over time.

Consider how it is possible that no one before Yoder has ever recognized how closely the five Parts of *Horologium Oscillatorium* hang together; how narrowly defined was the time period during which Huygens made his pertinent discoveries, and in what precise manner and order he made them. One answer to that question is that the Huygens student must be prepared to put together once again what, three and a half centuries ago, *was* held together in Huygens' own mind but which was split up over separate volumes under quite distinct headings – 'Mathematics', 'Mechanics', 'Horology' – by his editors in the early decades of the present century. And the other answer is that one may not rest content with what has been printed in those volumes, but must consult the original manuscripts to find out what the editors omitted or tampered with in bringing them to the press.

True, there exist excellent studies of parts of Huygens' work written by authors who have not gone to such lengths – in-depth studies of his work in mathematics, in astronomy, in kinematics, in optics, etc. But it is also true that no picture of what Huygens stood for, scientifically speaking, has emerged from such studies. In 1979, summing up a symposium on the occasion of Huygens' 350th anniversary, the chairman could still suggest that in the very elusiveness of Huygens' personality, so often bemoaned, might lie his true personality. It is only now, in Yoder's book, that the veil is torn off and a clearly drawn portrait of Huygens the scientist begins to emerge. Her ability to draw such a portrait has everything to do with her insistence, and her courage, in undertaking what no one confronted with the *Oeuvres* had hitherto been ready to undertake – to put together what the editors had taken apart, to set right what they had misunderstood, and to include what they had left out.

What, then, *is* the picture of Huygens that emerges from Yoder's account? It is that of a full-blown scientist with no research programme of his own, but with a penchant for solving problems and an effortless command of the geometrical tools that he finds necessary to solve them. It is the picture of a man who almost never attacks a problem through an inner drive of his own. Invariably Huygens must feel persuaded at the outset that there is something more to a problem than the satisfaction of idle curiosity before he decides to engage with it, and invariably the necessary stimulus comes from outside. Among the most potent stimuli was the prospect of fame, reputation, glory. More substantive incentives, derived from the nature of the problem, could also present themselves, but Huygens would never engage himself in a piece of research merely to exercise his very considerable technical skills. However, once engaged, he clings to the problem with tenacity, and allows himself to be guided by a solution to a consequent problem, which in its turn yields a

successor solution, and so on. He continually accompanies his ongoing process of discovery with an array of mini-treatises, in which results attained so far are systematized, simplified, and made coherent – often such mini-treatises, although primarily prepared to further his own enlightenment, ultimately turn up, scarcely altered, in the final publication. Yoder readily grants that she is not the first to call Huygens a problem solver. However, she is the first to bring out the consequences of Huygens' scientific style, both for his own work and for his impact upon succeeding generations.

It is generally recognized that part of Huygens' unique accomplishment was obscured by the work of another generation – by Newton and Leibniz, in particular. On the one hand, Yoder of course agrees. Her summing-up of the case is as follows: 'His personality, his concentration on problems over technique, his need to retain the physical tie, his distaste for heroes – all conspired to lessen his impact' (p. 178). That is to say, Yoder shows in considerable detail how various features of Huygens' approach – his aptitude for problem solving, his lack of interest in devising algorithms lacking as yet a solid foundation, his refusal to address mathematical problems devoid of physical meaning, his abhorrence of scientific syntheses exemplified by Descartes – led to the incorporation of his achievements in later work that was greatly indebted to him, but without clearly betraying the original inspiration because the approach was now so different. But on the other hand is Yoder's insistence that, if we wish to regain a proper understanding of Huygens' achievement, we must stop requiring him to have done what we ask of no other member of his generation – to have preempted Newton and Leibniz. One refreshing aspect of Yoder's study is that it discusses Huygens without this perennial doom looming in the background – without these two giants of a later generation watching intently over the shoulders of author, reader and subject alike.

I shall now provide the reader with a chapter-by-chapter outline of Huygens' pertinent researches as set forth in *Unrolling Time*. After an introductory first chapter, to which I shall return, Chapter 2 'Accelerated motion: gravity' presents the problem from which Huygens started. Characteristically, he owed the problem to others – he wished to redress Mersenne's partial failure in 'determining an accurate value for the constant of gravitational acceleration', the existence of which had of course been discovered by Galileo (p. 12). The curtains raised, we see in Chapter 3 ('Accelerated motion: centrifugal force') the hero enter the stage on 21 October 1659. Here Yoder shows in an almost day-by-day account how Huygens transforms his rather limited and unassuming problem into one much more susceptible to mathematical treatment: 'Huygens' creative step was to realize that, because the two forces can be made mathematically equivalent, if one wishes to study gravity one can study centrifugal force instead' (p. 40). It is in this setting that the theorems of *De Vi Centrifuga* and the study of the conical pendulum are produced. In Chapter 4 'Accelerated motion: curvilinear fall', Huygens' key discovery is set forth in all the requisite detail that is usually omitted elsewhere – the derivation leading to the finding that, whereas the isochronism of the ordinary pendulum is only approximate for very small circle arcs, the cycloid is the truly isochronous curve. Yoder shows convincingly that this find was an unexpected bonus of Huygens' mastery in handling infinitesimal relations geometrically, rather than a property consciously sought by him (p. 63).

We have meanwhile reached the first of December 1659. The great find, if considered now in the light of Huygens' invention of the pendulum clock two years earlier, at once presented him with a new problem. That clock, as he had been well aware, was not really isochronous. He had therefore fitted it out, at the top of the cord, with metal 'cheeks' bent into an empirically determined curve so as to compel the bob to describe a more nearly isochronous curve slightly above its uninhibited, circular path. But now, unexpectedly, a chance had turned up to determine the shape to be given to the cheeks with rigorous precision. The question to be answered was: What curve, in being 'unrolled', can generate a cycloid? Chapter 5, 'Evolutes' (the centre-piece of the book in every sense) presents the story in all its suspense. Within two

weeks Huygens, aided by the same geometrical techniques that had put him in possession of the original discovery plus his instant recall of properties of the cycloid from Pascal's preceding challenge, discovers that the curve sought is, once again, a cycloid. The method by which this new discovery is made lends itself readily to generalization, and within a few more weeks Huygens has a generalized theory of the evolution of curves at his disposal. The year 1659 is over; three months have passed since Huygens set out to find the constant of gravitational acceleration, and virtually the entire substantive content of *Horologium Oscillatorium* lies ready, so it seems, for the press.

Before explaining why thirteen more years nonetheless elapsed before the great book finally appeared, Yoder makes two excursions into the historiography of mathematics. In Chapter 6, 'Curvature', she goes to great lengths to show that the theory of evolutes, although in later mathematics incorporated in the theory of curvature as a matter of course, was discovered by Huygens in a manner that rules out its habitual location, by historians of mathematics, as one developmental link in the ongoing history of curvature. Once again in the history of science the retrospectively 'logical' route is unmasked as the unconscious projection backwards of a present-day state of affairs. Chapter 7, 'Rectification', has an opposite thrust: it fits in Huygens' work on the theory of evolutes with his own preoccupations and those of a number of colleagues (van Schooten, van Heuraet, Sluse, Grégoire de Saint-Vincent, Wren, Wallis, and others) to rectify curves wherever they could find them.

Chapter 8, 'Diversions', takes up the thread again at late December 1659. It relates a somewhat tragicomical sequence of events – connected chiefly with ultimately elusive efforts at using the isochronism now attained for solving once and for all the problem of geographical longitude – that led to ongoing procrastination with a publication already envisaged from early 1660 onwards, and, with fitting irony, rounded off in 1673 with the appearance of a *Horologium Oscillatorium* dedicated to the very King Louis XIV who had just invaded Huygens' own fatherland.

The final chapter, 'Conclusions', draws the lines together in presenting an overall picture of Huygens at work, from which I have already selected some features. Some others may now also be taken up. Let me first address the place Yoder assigns to Huygens' geometrical methods in the history of the calculus. Although I am not qualified to pronounce judgment on the ultimate validity of her key point that 'the rise of the calculus was not a revolution *against* geometry but rather a slow evolution within the new geometry' (p. 145), it does seem to me that in her preceding account she has assembled powerful evidence in favour of such a view. At the very least, with Huygens' derivations of the isochronism of the cycloid and of the evolution of the same curve in particular, Yoder has demonstrated beyond doubt that Huygens' geometrical handling of infinitesimal magnitudes *yielded*, rather than *stood in the way of*, his proudest discoveries.

One very attractive feature of the method by which she discusses these matters is her undisguised purism. Huygens' mathematics are presented in the very same idiom in which he himself presented his results and in which, even more importantly, he himself always thought about his problems. This feature may well make the book hard going for present-day mathematical adepts, to whom no concessions are made in this respect. For opposite reasons, it is occasionally hard going for the less adept among her readers, although for those Yoder has in store the genuine consolation that they may 'skip or at least skim' the derivations 'without loss of the underlying story' (p. 7). Her insistence on handling mathematical matters in the context of their own time equally informs her masterful discussion of the issue of curvature – her point that from *later* equivalence in *mathematical terms* one ought not to infer *contemporary* equivalence of *conceptual meaning* seems to me a most important and valid one, fruitful far beyond its application in the present book.

Beside its programmatic purism I should also like to heap praise on the care with which the book is presented to the reader. Here and there it is hard going, but Yoder has gone out of her way to present her themes as lucidly as one could wish. She explains in an easy-to-grasp fashion

what evolutes are, how problems of curvature have been defined over the ages, what is meant by quadrature and by rectification, and so on. She provides recapitulation and neat summing-up passages at the very spots where the reader begins to look for relief. She writes in an engaging, pithy, clear-cut style, humorous, almost deceptively simple, every sentence brimming with information, and devoid of anything that might smack of bombast. The referencing is exemplary in that the reader is placed in a position to check the conclusions reached without being bothered, in the main text, with scores the author has to settle with previous commentators, among whom the editors of the *Oeuvres Complètes* take pride of place. All quotations refer to notes which both indicate provenance and provide the original language wherever translations are offered. Yoder's command of Huygens' three languages – Latin, French, Dutch – seems flawless, with the sole exception of the word '*éloigné*', which is rendered as 'elongated' rather than as 'removed from' (p. 71). To such nitpicking details one has to stoop if one wishes to find fault with this beautiful book. Great care has also been bestowed on the figures, some of which are inserted so as to show up pertinent discrepancies between manuscript notes and their rendition in the *Oeuvres Complètes*.

Yoder presents her book as a 'case study'. A case study of what? The larger entity, of which this book aims to discuss one case, is that famous attribute of the Scientific Revolution, the 'mathematization of nature' mentioned in the subtitle. It is Yoder's contention that 'the development of this interrelationship between mathematics and physics has remained too long in the realm of vague generalizations, whose validity has yet to be substantiated by a careful comparison with actual events' (p. 1). If our talk about the Scientific Revolution is to acquire true substance, she implies, it is crucial to find out how the mathematization of nature went ahead as a matter of daily practice. Therefore she defines her own effort as 'a modest endeavor, designed not to explain the greater phenomenon but to provide a case study that any general account must encompass'. I concur wholeheartedly with the latter statement if it is taken to mean that no interpretation of the Scientific Revolution can be called complete that does not include a detailed picture of the scientific style of a protagonist of the stature of Christiaan Huygens. But I do not think it entirely fair to assert or at least imply that, as yet, we lack an insight into how nature was truly and factually mathematized by Galileo and Kepler and Descartes and Newton, to mention only the key examples. Each of these men had his own style, just as Huygens had, and important as it now is to know in revealing detail how precisely Huygens went ahead in mathematizing nature, this is not equivalent to providing the first study of a mathematizer of nature at work. Neither do I think that the 'generalizations' expressed by those men who shaped the concept of the Scientific Revolution in the first place were all that 'vague'.

One example where one might be led astray is in the handling of Alexandre Koyré's insights. It is well known that, on the topic of Galileo's experiments, Koyré has been proved simply wrong – to the extent that he declined to take literally in Galileo's own statements what we now know should indeed be taken literally. Granting so much does not, however, render all Koyré had to say on the mathematization of nature worthless. It is far from Yoder's brief to share in such cheap condemnation of a man who did so much to shape present-day insights on the Scientific Revolution. Yet she is remarkably grudging in giving Koyré his due on the topic of the balance held between mathematical treatment and experimental effort in Huygens' research leading up to the *Horologium Oscillatorium*. Yoder's findings concur almost entirely with Koyré's pertinent statements in 'An experiment in measurement', yet she finds fault with him because he based his assertions, not on a painstaking examination of the relevant manuscripts but rather on his overall conception of how physics ought to be done. Commonly, when historians of science deal with a *scientist* of the past whose insights have proven right for not quite the right reasons we have learnt to be more generous in our sympathetic understanding of his point of view.

While thus diverging somewhat from the overall perspective in which Yoder wishes her

own work to be seen, I have no quarrel with the picture of Huygens' mathematizing style that emerges from her study. No metaphysical commitment reigns there, yet his research style is pervaded by the persistent conviction that the primary interest of science lies at the boundary line where geometric concepts also acquire a physical meaning. 'Is it the cycloid that is isochronous or the clock whose bob follows its path? The terminology can be loose because the pairing of mathematical entity and physical object is so precise. A complete mathematical description suffices as the solution of a physical problem' (p. 167). Yoder makes a case for the idea that, at least in the research that went into the *Horologium Oscillatorium*, both experimentation and the corpuscular conception of things were entirely subservient to the mathematical approach. Corpuscularianism provided a language that made possible a point-by-point correspondence between mathematical entities and their counterparts in the physical microworld, whereas Huygens' experiments typically served a confirmatory rather than an heuristic purpose. 'If Bruce belittled the theory incarnate in his clock, he would bind it in still more theory and repossess the prize. If Hooke objected to the omission of physical parameters, he would absorb them into the mathematics and remove them from Hooke's dominion of trial and error' (p. 171). What remains to be seen is the extent to which the picture thus arising of Huygens at work holds true when other of his investigations, in which the mechanical philosophy seems to play a more conspicuous, independent part, are examined with as much care and precision as has now been done for the three final months of that fateful year, 1659.

It is here that the very excellence of this book gives rise to a somewhat disturbing reflection. In implicitly setting new standards for future Huygens research Yoder raises the historian's requirements to a new level of perfection particularly hard to emulate, let alone surpass. This would be all to the good, were it not for the almost impossible combination of resources that must be brought to bear on research of this kind if one wishes to comply with the new standards. Not only must one be able to play around with seventeenth-century mathematics, command a number of languages, and possess all those other resources already mentioned – one also needs generous amounts of sheer time. Given the very peculiar way the *Oeuvres Complètes* were set up, three *months* in the life of Christiaan Huygens have taken three times as many, equally well-spent *years* to reconstruct. True, not each quarter-year of his life was so crammed with happy finds, nor is it to be expected that each comparable period would require similar detective-like efforts. Yet one wonders how we are ever going to receive that outstanding *desideratum* in the historiography of the Scientific Revolution – a full 'life and works' of Christiaan Huygens. What has so far been attempted in this regard falls hopelessly short of the standard now set by *Unrolling Time*. Hopefully, the reception of the book that lies before us will help persuade the author that it is up to her to go ahead and write that larger book. Gold is hidden inside the *Oeuvres Complètes*, but it is fine gold dust, evenly spread out over 22 solid volumes. Yoder has already forged part of the dust into one fine nugget – what we eagerly await now is that full, 24-carat book to crown the entire effort.

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