

MATHEMATICS IN GEORGE ELIOT'S NOVELS

Thesis submitted for the degree of

Doctor of Philosophy

at the University of Leicester

by

Derek Ball MA

Victorian Studies Centre

University of Leicester

2016

Abstract

Derek Ball

‘Mathematics in George Eliot’s Novels’

The mid-Victorian novelist George Eliot had a keen interest and expertise in mathematics, which she studied throughout her life, and this had a profound influence on her work as a novelist. Not only does mathematics appear overtly in several of her novels, and particularly in the first two, but her mathematical way of thinking also informs the way in which she structures her novels and her arguments.

In the first novel, the eponymous hero, Adam Bede, is a mathematically-minded carpenter and his thoughts about mathematics recur throughout the novel. This novel and Eliot’s second novel, *The Mill on the Floss*, include discussions of mathematics education that demonstrate the author’s awareness of curricular and pedagogical issues.

Eliot’s imagery frequently makes use of mathematics and mathematical physics, which she offers the reader with the deftness and clarity of an expert. Her logical mathematical thinking helps her to structure her novels, and the epigraphs in her last two novels, which contribute to this structuring, frequently have a mathematical basis.

Eliot’s narrators continually philosophise, and the arguments they offer the reader are repeatedly informed by mathematical and logical thinking. This is particularly true of Eliot’s philosophising about gender, and about the way in which women are frequently seen as different from men, particularly in the context of education. Eliot has a notorious concern for truth, and mathematical argument enables her to distinguish the certain from the uncertain, and to mock absurd presuppositions.

Eliot was aware of current mathematical controversies regarding the teaching of mathematics and regarding non-Euclidean geometry; these appear in the novels. Mathematicians are often characterised as having a narrow and unimaginative view of the world – this view is counteracted by Eliot’s novels, which demonstrate how it is possible to use mathematics to engage our sympathy.

Acknowledgements

I want to thank my supervisor, Gowan Dawson, for giving me invaluable help during the writing of this thesis: in particular, for helping me to set off in a useful direction, for curbing my tendencies to indulge in diversions from the path, and for providing innumerable suggestions concerning the structure and content of the thesis.

I would also like to thank my wife, Barbara, who, although she is not officially a student of English literature, has read some of what I have read and everything I have written, told me when she did not understand it, and above all checked the accuracy of my writing.

Derek Ball

Contents

List of Illustrations	5
Abbreviations and Explanations	6
Introduction	7
Chapter One – ‘Put your face to one of the glass panes ... What do you see?’: noticing the mathematics in <i>Adam Bede</i>	31
Chapter Two – ‘Thick-rinded fruit of the tree of knowledge’: theoretical geometry and practical mathematics in <i>The Mill on the Floss</i>	62
Chapter Three – ‘Have you robbed somebody else, who is <i>not</i> dead?’: mathematics and logic in <i>Romola</i>	93
Chapter Four – Seeing things differently: Boolean algebra, logic and geometry in <i>Middlemarch</i>	124
Chapter Five – Binding the great with the small in <i>Middlemarch</i> and <i>Daniel Deronda</i>	158
Chapter Six – Conceiving the inconceivable: probability and geometry in <i>Daniel Deronda</i>	191
Conclusion	224
Bibliography	233

List of Illustrations

Arthur's birthday marquees and Euclid's fifth postulate	31
‘principally of two spheres’	34
‘thirteen times’	35
Difficult and easy estimating	49
‘Put your face to one of the glass panes’	52
The parallels postulate	71
An alternative to the parallels postulate	72
Virtual image and virtual observer	110
‘The light can be a curtain as well as the darkness’	119
‘The successive events inward and outward were there in one view’	120
‘Suppose you let me look at myself’	122
‘scratched in all directions’	143
‘flattering illusion of concentric arrangement’	144
‘our supreme selves’	150
‘the length of the sun's journeying’	159
The same from any one such point as from any other	170
Arrows and parabolas	182
‘curve that might be drawn through certain well-known points’	183
‘many improbable things will happen’	201

Abbreviations and Explanations

Throughout this thesis George Eliot's novels are referred to by title only. The *Impressions of Theophrastus Such* is referred to as simply *Impressions*. Information about the editions used is provided at the start of the Bibliography.

GEL is used throughout to refer to Gordon Haight's nine-volume edition of George Eliot's letters. Again, details of publication are provided at the start of the Bibliography.

Emphasis in quotations that is not commented upon is the original author's emphasis. Where emphasis has been added, this is noted in the reference.

Introduction

There is general agreement among literary historians that George Eliot was a polymath; in an introduction to *Middlemarch*, Felicia Bonaparte suggests that '[n]o other Victorian novelist [...] was as well equipped as Eliot' in this respect. Bonaparte extols Eliot's knowledge of 'history, music, art, theology' and describes Eliot as someone 'who had a love of all the sciences, especially physics, geology, chemistry and astronomy'. She also mentions that Eliot was an 'excellent mathematician', although she says nothing else in her introduction directly about mathematics.¹ This thesis will explore Eliot's relationship with mathematics and examine the effect her mathematical interest, knowledge and expertise had on her writing, and on her novels in particular. I shall argue that mathematics was not only an enduring interest of Eliot's, but also a crucial intellectual component in her understanding of the world, something that underpinned much of her thinking.

In this introduction I shall summarise what is known about Eliot's learning of mathematics, review the extent to which Eliot scholarship has engaged with her mathematics, and position Eliot's mathematics in the broader context of Victorian mathematics. A number of critics I shall mention in this thesis, including Gillian Beer and Sally Shuttleworth, have written at length about the science in Eliot's novels, with particular emphasis on the life sciences. Nobody has so far undertaken to consider systematically the influence of mathematics on her fiction. This introduction will end with an overview of how Eliot's engagement with mathematics influenced her approach to writing novels.

Eliot's mathematics

What we know of Eliot's knowledge of mathematics is largely inferential. Eliot spoke highly of her father's ability with practical mathematics and, in view of their close relationship, he might be responsible for having initiated a life-long interest in the subject. In his biography of Eliot, Gordon Haight writes about her apparent interest in

¹ Felicia Bonaparte, 'Introduction' to *Middlemarch* by George Eliot (Oxford: OUP, 1998), p.ix.

mathematics when, at the age of thirteen, she started at the Miss Franklins' School, given that she produced twenty pages in her school notebook about the 'single Rule of Three'.² In her early letters to Maria Lewis she manifested an interest in mathematics and the mathematical sciences, both through her interest in astronomy and through the metaphorical use of the language of mathematics; in 1839 she commented on a passage from Paul's second letter to the Corinthians: 'Here is the all-powerful lever or rather the magnet that can alone lift our souls heavenward.'³ Moments and magnetic fields, like all key concepts of nineteenth-century physics are underpinned by mathematics, and mathematical facility is required to work with them. Evans lapsed naturally into mathematics and mathematical physics when writing about unrelated matters in her letters, in much the same way that she lapsed naturally into French.

There is sporadic but repeated evidence that Eliot continued her study of mathematics throughout her life. In 1848-9 Eliot spent several months in Geneva, during which time she attended 'a course of lectures on Experimental Physics by M. le professeur de la Rive'; the course consisted of twenty-six lectures.⁴ She also apparently studied mathematics every day while in Geneva; more will be said about this shortly.⁵ Soon after moving to London in 1851 she attended a geometry course run by Francis Newman, about which more will be said in chapter one.⁶ She appears to have had an enduring interest in algebra, proposing studying it with her step-son in 1860, studying three algebra books with Lewes in 1871 and, late in her life in 1879, recording studying algebra on her own.⁷

Lord Acton remarks on Eliot's knowledge of the calculus, and Edith Simcox on Eliot's studying conic sections.⁸ And according to John Cross, Eliot esteemed her own ability in geometry highly, saying that 'she might have attained to some excellence in

² Gordon S. Haight, *George Eliot: A Biography* (Oxford: OUP, 1968), p.12.

³ GEL, 1: pp.106-7, 32.

⁴ GEL, 1: p.325

⁵ GEL, 1: p.321.

⁶ GEL 1: p.343.

⁷ GEL 3: p.216; John Clark Pratt and Victor A. Neufeldt, *George Eliot's Middlemarch Notebooks* (Berkeley and London: University of California Press, 1979), p.70; GEL 7: p.209.

⁸ Acton, 'George Eliot's "Life."1', *Nineteenth Century*, 17 (March, 1885), 464-85 (pp.471-2); GEL, 9: p.293.

[geometry] if she had been able to pursue it'.⁹ In spite of her twenty-six lectures in experimental physics, Eliot's principal mathematical interests seem to have been in pure mathematics.

Mathematics and Eliot's mental health

I shall argue that mathematics was not only an enduring interest of Eliot's, but also a crucial intellectual component in her understanding of the world, something that underpinned much of her thinking. Mathematics even kept her emotionally stable. In 1848 Evans wrote this to her friend Sara Hennell:

the poetry of girlhood goes for a season – the poetry of love and marriage – the poetry of maternity – and at last the very poetry of duty forsakes us and we see ourselves and all about us as nothing more than miserable agglomerations of atoms [...] I feel a sort of madness growing upon me - just the opposite of the delirium which makes people fancy that their bodies are filling the room. It seems to me as if I were shrinking into that mathematical abstraction, a point - so entirely am I destitute of contact that I am unconscious of length or breadth.¹⁰

This was written after Evans had relinquished her Christian faith, but she clearly had not relinquished her interest in mathematics, given that she chose to use theoretical geometrical imagery to describe her depression. Nearly thirty years later, Eliot used a similar image in her final novel, *Daniel Deronda*, when Gwendolen, about to be abandoned by Daniel, 'felt herself reduced to a mere speck'.¹¹ In a 2010 essay about some nineteenth-century views of mathematics and mental health, Alice Jenkins points to Wordsworth's account in *The Prelude* of being comforted by geometry.

[...] A single Volume, and no more,
A Treatise of Geometry [...]
[...] Mighty is the charm
Of those abstractions to a mind beset
With images, and haunted by itself;
And specially delightful unto me
Was that clear synthesis built up aloft

⁹ J. W. Cross, *George Eliot's Life as Related in her Letters and Journals*, 3 vols. (Edinburgh and London: Blackwood, 1885), 3: p.423.

¹⁰ GEL, 1: p.264.

¹¹ *Daniel Deronda*, p.689.

So gracefully! [...]
[...] an independent world,
Created out of pure Intelligence.¹²

But in the same essay Jenkins refers to remarks attributed to William Paley, himself senior wrangler (in other words, top mathematics graduate) in 1763, about the system of going for high honours in the Cambridge Mathematical Tripos: ‘the stimulus is too strong; two or three are cracked by it every year [...] some of them go mad’.¹³ Given that mathematics could apparently destroy some people’s mental health, did it have this effect on Marian Evans, or did she, like Wordsworth, find it *good* for her emotional well-being?

In 1849, the year after she described her low mood to Hennell, Evans spent nine months in Geneva, having fallen out with her family over her loss of Christian faith. In a letter to her friends the Brays she described her life in Geneva: ‘I take walks, play on the piano, read Voltaire, talk to my friends, and just take a dose of mathematics every day to prevent my brain from becoming quite soft.’¹⁴ Given Evans’s formidable brain, she must have learnt an impressive amount of mathematics during her nine months in Geneva, if what she told the Brays is true. Her use of the word ‘dose’ suggests that Evans might have been using mathematics as some form of therapeutic medicine, especially given that the low spirits she described to Hennell remained with her in Geneva. I was ‘one whom you knew when she was not very happy and when her life seemed to serve no purpose of much worth’, she told M. D’Albert, the man in whose house she stayed while in Geneva; she wrote this ten years later, during the year in which her first novel *Adam Bede* was published.¹⁵ In this novel, Adam tells himself, when he is grieving for his father who has just died: ‘The square o’ four is sixteen, and you must lengthen your lever in proportion to your weight, is as true when a man’s miserable as when he’s happy’.¹⁶ The fact that Adam uses the unchangeability of mathematics to console himself suggests that Eliot knew about the power of

¹² William Wordsworth, *The Thirteen-Book Prelude*, ed. by Mark L. Reed (Cornell: Ithaca and London: 1991), 6: lines 164-87 (p.96).

¹³ Alice Jenkins, ‘Mathematics and Mental Health in Early Nineteenth-Century England’, *BSHM Bulletin*, 25 (2010), 92-103 (pp.101-2, 95).

¹⁴ GEL, 1: p.321.

¹⁵ GEL, 3: p.187.

¹⁶ *Adam Bede*, p.115.

mathematics to soothe, and, while in Geneva, used learning mathematics (as well as walking and piano playing) as consolation.

And there is this from Edith Simcox's autobiography, describing a meeting with Eliot much later, in February 1880, in the last year of Eliot's life and just over a year after George Lewes, whom she had shared her life with for many years, had died: 'She told little Marks that she was doing conic sections every morning because "she didn't want to lose the power of learning".'¹⁷ Sarah Marks was a talented and socially active mathematician who read Mathematics at Cambridge between 1877 and 1881, sponsored by Eliot and Barbara Bodichon. Not wanting to 'lose the power of learning' echoes 'a dose of mathematics' stopping her 'brain from becoming quite soft'. Once more Eliot appears to have been using mathematics to console herself, this time in her grieving for Lewes. This all suggests the value Eliot placed on her engagement with mathematics.

The influence of mathematics on how Eliot saw the social world

Eliot's study of unchangeable abstract mathematics might be thought to indicate a very conservative stance. In *George Eliot and Nineteenth-Century Science*, Sally Shuttleworth describes Adam Bede's interest in mathematics as a 'mathesis', suggesting that for the socially unimaginative Adam, 'the whole equals the sum of its parts'.¹⁸ Charles Dickens satirised mathematics in this way, describing Thomas Gradgrind as a 'man who proceeds on the principle that two and two are four, and nothing over'.¹⁹ I shall suggest that Eliot sees mathematics quite differently and shall seek throughout this thesis to demonstrate how mathematics opened up her thinking about society rather than closing it down.

An incident in *Adam Bede* involving Miss Lyddy's screen exemplifies this. Adam's geometrical common sense enables him to comprehend Miss Lyddy's 'particular orders' and to build for her exactly the screen she wanted, but also, using his mathematics he 'calculated pretty close' the proper price for the screen. When the old squire challenges this price and suggests that his sister could get a better quality of work

¹⁷ GEL, 9: p.293.

¹⁸ Sally Shuttleworth, *George Eliot and Nineteenth-Century Science: The Make-Believe of a Beginning* (Cambridge: CUP, 1984), p.37.

¹⁹ Charles Dickens, *Hard Times* (London: Penguin, 2003), p.10.

cheaper 'at Rosseter', Adam refuses to accept the lower valuation and takes the moral high ground by presenting the screen as a gift.²⁰ Adam's apparently conservative respect for rank, admitting 'all established claims unless he saw very clear grounds for questioning them', is circumscribed by his mathematics.²¹ The mathematics is presented here as unquestionable. It does not induce deferential behaviour; instead, it does the reverse, which is to challenge what is not believable. Adam adheres to his mathematics, which places limits on his preparedness to accept his place within the predetermined social order. Mathematics does not make Eliot or her characters dogmatic, but it does make them prepared obstinately to go against social convention if necessary. One reason the mathematician and mathematics educationalist Augustus De Morgan suggests for pupils to study mathematics is 'that they may learn to raise objections, and how to raise them in the proper place, when false logic and absurd definitions make objections desirable'.²² Conic sections, which Eliot was studying in 1879 while grieving for Lewes, is the mathematics Newton used when providing a logical basis for the cosmology that upset the social order by removing the earth from the centre of the universe. This cosmology makes a brief but significant appearance in *Adam Bede*, and plays a greater role in Eliot's last novel, *Daniel Deronda*.

While Eliot roundly rejects the notion that mathematics is a means of cutting people off from their humanity, in her celebrated essay 'The Natural History of German Life' (1856) she pours scorn on the 'modern generalisation' that 'the relations of men to their neighbours may be settled by algebraic equations'.²³ This rejection has the more force coming from someone who understands and uses mathematics, a mathematical insider who knows very well how mathematics can be used to obfuscate and propagandise, and who, in *Middlemarch*, ridicules the meaningless use of a large number to impress: 'a statistical amount without a standard of comparison, but with a note of exclamation at the end'.²⁴ One of my tasks in this thesis is to show how Eliot uses mathematics, not to deny what it means to be human, but to connect people with their humanness. Eliot sets the permanence of mathematics against the transience of human life and social opinion.

²⁰ *Adam Bede*, pp.243-4.

²¹ *Ibid*, p.164.

²² [Augustus De Morgan], 'On Mathematical Instruction', *Quarterly Journal of Education* 1 (April, 1831), 264-279 (p.271).

²³ [George Eliot], 'The Natural History of German Life', *Westminster Review*, 10 n.s. (July, 1856), 51-79 (p.59).

²⁴ *Middlemarch*, p.416.

Eliot scholarship and mathematics

In spite of the evidence that mathematics played an important role in Eliot's life and work, few critics have considered the mathematics in Eliot's novels. Those that do, rarely consider in any detail the influence of mathematics on her intellectual development or on her style of writing. In *Darwin's Plots* Gillian Beer has placed Eliot's novels, and particularly her last two novels, in the context of the scientific upheaval happening in mid-Victorian Britain. As her title suggests, Beer emphasises the relationship between Eliot's novels and evolutionary biology, but she also considers the physical sciences, notably astronomy and physics. She also skirts around the edge of mathematics when she writes about 'relations', about the 'distances between people', without suggesting that these might be mathematical ideas. In *Daniel Deronda* she writes implicitly about probability in connection with predicting the future, and she quotes the mathematician William Kingdon Clifford, but does not mention his mathematics.²⁵ Those who invoke exact mathematics are often seen as suggesting simplifying what cannot be simplified; Beer describes evolution as 'a system that could not be resolved into a simple mathematical elegance'.²⁶ In this thesis I shall argue that Eliot uses mathematics to complicate rather than to simplify our view of the social world.

In *George Eliot and Nineteenth Century Science*, Sally Shuttleworth situates Eliot's novels among a range of sciences, from the very mathematical science of astronomy to physiology. However, even though Shuttleworth makes significant use of the astronomy in *Daniel Deronda* and mentions physics, sciences that are heavily dependent on mathematics, she appears to present mathematics as a limiting influence, as I have already mentioned.²⁷

Some critics, including Bonaparte writing about *Romola*, and Hillis Miller writing about *Middlemarch*, have made more than a passing mention of Eliot's mathematical ideas as we shall see in later chapters. This is also true of George Levine, particularly in

²⁵ Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (London: Ark, 1985), pp.154, 186-7.

²⁶ Beer, p.16.

²⁷ Shuttleworth, pp.177-9, 14.

his essay 'George Eliot's Hypothesis of Reality', where he writes about George Lewes's 'perfect ellipse' and William Kingdon Clifford's non-Euclidean geometry, and the use Eliot made of these in distinguishing between the 'real' and the 'ideal'.²⁸ In addition to making several references to the mathematics in Eliot's novels, most notably in *Space and the 'March of Mind'*, Alice Jenkins has written at length about Maggie Tulliver's engagement with Euclidean geometry in *The Mill on the Floss*.²⁹ As will become apparent later, Selma Brody writes about Eliot's use of the physical sciences in her novels, and sometimes strays into mathematics; Nancy Paxton has revealed the source of the mathematical pier-glass image in *Middlemarch*; and Felicia Bonaparte considers geometrical imagery in *Romola*. And there is a mathematical edge to Anna Henchman's account of the astronomy in *Daniel Deronda*. Mary Poovey is one critic who deals at length with a mathematical topic in an Eliot novel, providing a substantial account of the interaction between the 'financial' and 'sentimental' plots in one of Eliot novels, *The Mill on the Floss*, exploring the way Eliot manipulates the reader's attention to the different plots.³⁰

Mathematics does not receive any sustained attention in biographies of George Eliot. I mention here three significant biographies. Gordon Haight, Eliot's best-known biographer and editor of her letters, alludes to mathematics in the index to the letters, but makes scant reference to mathematics in his biography; the longest reference is perhaps to Eliot's writing 'more than twenty pages' on 'rules and problems' concerning 'The Single Rule of Three' when starting at the Miss Franklins' school.³¹ Later, Haight seems more interested in the fact that John Chapman offered to buy Marian Evans' ticket for 'Francis Newman's course in geometry' in 1851, than in what mathematics Eliot might have learnt on the course.³² And Nancy Henry, in a biography of Eliot published as late as 2012, suggests that 'the extension of the railways affected [Eliot]

²⁸ George Levine, 'George Eliot's Hypothesis of Reality', *Nineteenth-Century Fiction*, 35:1 (June, 1980), 1-28 (pp.3-6 et al).

²⁹ Alice Jenkins, *Space and the 'March of Mind': Literature and the Physical Sciences in Britain, 1815-1880* (Oxford: OUP, 2007); Alice Jenkins, 'George Eliot, Geometry and Gender', in *Literature and Science*, ed. by Sharon Ruston (Cambridge: Brewer; The English Association, 2008), pp.72-90.

³⁰ Mary Poovey, 'Writing about Finance in Victorian England: Disclosure and Secrecy in the Culture of Investment', *Victorian Studies* 45:1 (2002) 17-41 (p.34 et seq).

³¹ Gordon S. Haight, *George Eliot: A Biography* (Oxford: OUP, 1968), p.12.

³² *Ibid*, p.82.

more practically than the Reform Bill or scientific theories'.³³ Writing about *Middlemarch*, she suggests that 'the application of scientific metaphors' was 'advanced by Lewes's research for *Problems of Life and Mind*', seemingly implying that Eliot's interest in science derived mainly from Lewes's work.³⁴ Much of the research by Lewes she refers to was in mathematics rather than in science, and Eliot did not get her mathematics from Lewes – the reverse was the case. Rather than enlarging on this, Henry refers us to Beer, Shuttleworth and Levine.³⁵ Henry makes no mention at all of mathematics throughout the biography. And Avrom Fleishman, in a biography explicitly exploring what George Eliot learned from her reading and what use she made of it in her writing, does not discuss her mathematics, even though there were many books about mathematics and the history of mathematics in the Leweses' library and even though Eliot's and Lewes's letters specify some of the mathematics books they read.³⁶

Bonaparte suggests that 'much of [Eliot's] sense of what it means to explore the world around her derives from [science's] methodology'.³⁷ I would add that, just as noticeably, it derives from the ways of thinking that characterise mathematics. And while some critics have sometimes addressed this implicitly, by focusing on particular aspects of one novel, none have engaged with the idea that, because mathematics was a part of Eliot's way of thinking, its influence can be traced throughout her novels.

Victorian pure mathematics

I shall now say something about the position of academic pure mathematics in Victorian England. I shall not discuss at the present Victorian mathematical physics, which was significant as a Victorian success story. Nor will I consider here the many Victorians who were not academics, but who either studied pure mathematics for their own recreation and enjoyment, or used mathematics in practical ways in pursuance of their professions or hobbies.

³³ Nancy Henry, *The Life of George Eliot: A Critical Biography* (Chichester: Wiley-Blackwell, 2012), p.15.

³⁴ Ibid, p.199.

³⁵ Ibid, p.206.

³⁶ See, for example, William Baker, *The George Eliot - George Henry Lewes library: An Annotated Catalogue* (New York and London: Garland, 1977); GEL, 5: p.150.

³⁷ Bonaparte, p.xiv.

According to Jeremy Gray, nineteenth-century pure mathematics in Britain was a ‘particular kind of failure’. Gray describes what he sees as British philistinism in mathematics; mathematics was disliked by the culture ‘except as an aid to science’.³⁸ Adrian Rice tells how the French dominated pure mathematics at the beginning of the century, particularly with their work on analysis – analysis means putting infinite processes on a logically rigorous basis – and how the Germans became dominant towards the end, with their developments in geometry and in formal mathematics generally.³⁹ The British were slow at assimilating the results of continental scholarship, partly through sticking patriotically to ‘Newton’s fluxional version of the calculus’ and also through distrusting purely formal developments in analysis and algebra, including the use of negative and complex numbers, and in geometry.⁴⁰ Rice refers to the ‘lack of a genuine research ethos at British Victorian universities’.⁴¹ British mathematicians were more concerned with doing – with developing computational techniques – than with proving; Rice gives the example of Cayley who proved his celebrated theorem about matrices – rectangular arrays of numbers – for small two-by-two matrices but reported that he had ‘not thought it necessary to undertake the labour of formal proof’ for larger matrices.⁴²

In spite of this down-beat assessment, some of the work by British pure mathematicians indicated that Britain was making its own contribution to developments. George Peacock’s *Treatise on Algebra* (1830), a copy of which was in the Eliot-Lewes library and which Eliot and Lewis studied together in 1871, is seen by Rice as initiating a ‘different, and more abstract, algebraic methodology that fundamentally altered the way the subject was perceived in Britain’. This spawned moves to see algebra as more than generalised arithmetic and paved the way for innovations such as Hamilton’s system of abstract algebra called quaternions, objects which unlike ordinary numbers did not obey the commutative law of multiplication. Quaternions were subsequently put to use by mathematical physicists, including James

³⁸ Jeremy Gray, ‘Overstating their Case? Reflections on British Pure Mathematics in the 19th Century’, in *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011), pp.397-414 (pp.414, 409).

³⁹ Adrian Rice, ‘Introduction’ to *Mathematics in Victorian Britain*, p.2.

⁴⁰ Ibid, pp.4, 12.

⁴¹ Ibid, p.12.

⁴² Ibid, p.6.

Clerk Maxwell, who stated his celebrated equations for electromagnetic fields in terms of quaternions.⁴³ Maxwell is one of a number of British mathematical physicists who were making their mark internationally; applied mathematics was Britain's 'indisputable forte'.⁴⁴ George Lewes quotes Maxwell in his writing and Eliot copied passages from Maxwell into one of her *Daniel Deronda notebooks*. Quaternions were further developed into what are now called Clifford algebras by William Kingdon Clifford, who is significant in this thesis as a friend of George Eliot.⁴⁵ Chapter four will provide evidence of Eliot's interest in such formal and abstract developments in algebra, the formality of which enable their broader application.

I now turn to geometry, which in Britain was dominated for much of the nineteenth-century by discussion of Euclid. Joan Richards describes how, for much of the century, geometry, in England in particular, was seen as embodying exact truth, based on the certain truth of Euclid's postulates, which could not be doubted by any reasonable person.⁴⁶ Early in the century, there was debate between Cambridge academics about how humans acquired this certainty. So-called 'nativists' like William Whewell believed that it was hard-wired into our human thinking; empiricists like John Hershel believed that it is our experience of space that ensures our certainty. By whatever route this certainty was obtained, there was more or less general agreement that there was no possibility for doubt, which puzzled empiricists, who found it difficult to understand how humans could have exact knowledge of absolute truth.⁴⁷ Because it was an example of certain knowledge, the geometry of space was of keen interest to philosophers and theologians as well as to mathematicians. These beliefs about geometry were 'institutionalised in the education system' in England, as a consequence of the fact that a large proportion of the 'educational elite' whose degrees were Cambridge degrees could not obtain an honours degree in any subject unless they proved themselves proficient in mathematics, and in Euclidean geometry in particular.⁴⁸ Geometry was seen as a model for sound reasoning to be emulated as far as possible by other subjects of study. Hershel thought that, in the quest to obtain unchallengeable

⁴³ Ibid, pp.4-5; Baker, p.60.

⁴⁴ Ibid, p.11.

⁴⁵ Rice, p.6

⁴⁶ Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (San Diego and London: Academic Press, 1988), p.2.

⁴⁷ Ibid, pp.24-5, 3.

⁴⁸ Ibid, p.7.

truth, the difference between mathematics and the empirical sciences was ‘one of degree’: truth in the sciences could be established, but with greater difficulty.⁴⁹ Eliot encountered these ideas, probably in Newman’s geometry course, and certainly when editing the *Westminster Review* in the early 1850s, as I shall explain in chapter two. One of the themes of this thesis is that Eliot was increasingly doubtful about the existence of unchallengeable truths.

These views about the certain truth of Euclidean geometry were not universally shared, even in the first half of the century. William Hamilton and Dugald Stuart adopted a formal stance with regard to Euclid’s postulates, believing that they were purely hypotheses, which needed to be assumed before the results of Euclidean geometry could be demonstrated. This position was firmly rebutted by William Whewell in 1837.⁵⁰ But things were set to change in the last third of the century, when the certain truth of Euclid’s postulates was more insistently questioned. In fact, this certainty had been conclusively disproved earlier in the century by mathematicians from continental Europe, including Lobachevski.⁵¹ And in the 1860s Hermann Helmholtz and William Kingdon Clifford became polemical advocates in Britain for the non-Euclidean geometries, which were logically consistent alternatives to the geometry deriving from Euclid, and which advocates believed could feasibly be regarded as candidates for the true description of the space we live in.⁵² What Clifford demonstrated in his lectures was that mathematics could be a force for increasing doubt rather than certainty, and I shall contend that this is how Eliot frequently uses mathematics in her novels. More will be said about this in chapters two and six.

The idea of non-Euclidean geometry can be confusing. Jonathan Smiths tells of ‘empiricists’ efforts to limit geometry to a study of our experience of space’, when referring to mathematicians like Clifford and J. J. Sylvester.⁵³ In fact, the complete opposite was the case. It would have been the empiricist John Herschel, early in the century, who would have seen himself studying geometry based on our experience of

⁴⁹ Ibid, pp.8, 25-6.

⁵⁰ Ibid, pp.5, 22.

⁵¹ The transliteration used by Victorians was Lobachewsky. I shall use Lobachevski, one of the three spellings in current use.

⁵² Ibid, pp.96 et seq, 109.

⁵³ Jonathan Smith, *Fact and Feeling: Baconian Science and the Nineteenth-Century Literary Imagination* (Madison and London: University of Wisconsin Press, 1994), p.201

space: through experience it is obvious that the plane can be covered with squares and therefore Euclid's postulates have to be true. For 'empiricists' like Clifford and Helmholtz, however, although our experience tells us about squares covering the plane, this experience might not be an exact representation of the situation. It is through looking at geometry formally and abstractly, that we discover there is no way of telling whether our apparent observations are true or not, because other assumptions than Euclid's are equally valid in fitting the facts that we approximately perceive. Eliot frequently challenges the truth of apparent observations about society.

Many British academics opposed any suggestion that non-Euclidean geometries were credible alternative descriptions of space, pouring scorn on their inconceivability.⁵⁴ The magnitude of this shaking of the Euclidean foundations is compared by Joan Richards with the earthquake caused by the publication of Darwin's *The Origin of Species*.⁵⁵ This was a time at which Euclid was still widely used as a text book for geometrical education in schools and universities in England, although this situation was beginning to change. Sylvester, also much involved with the promulgation of new geometries and seen by Jeremy Gray as an exceptional Victorian pure mathematician, suggested that Euclid should be 'honourably shelved and buried "deeper than did ever plummet sound" out of the schoolboy's reach'.⁵⁶ Interestingly, he sent Eliot a copy of Euclid as a present in 1875.⁵⁷ Eliot views on the use of Euclid in schools are expressed in *The Mill on the Floss*, as we shall see in chapter two.

Mathematics and logic

Why have I decided to include logic in my account of the mathematics in George Eliot's novels, even though logic has not been and is not always seen as part of mathematics? Adrian Rice remarks that, despite logic's long history, in the 1830s 'it was a relative newcomer as a mathematical discipline'.⁵⁸ Logic has always been involved with deduction and in the 1830s, in order to clarify the way logic was used in Euclid's *Elements*, Augustus De Morgan introduced algebra into logic. In contrast with

⁵⁴ Ibid, p.56; Daniel Brown, *The Poetry of Victorian Scientists: Style, Science and Nonsense* (Cambridge: CUP, 2013), pp.196-7.

⁵⁵ Richards, p.1.

⁵⁶ Gray, p.414; Smith, p.197.

⁵⁷ Baker, p.60.

⁵⁸ Rice, p.7.

the study of syllogisms, in which the validity of deductive arguments was inextricably bound to the truth of premises, De Morgan decided to ‘detach’ from his logic any discussion of the truth of premises and focus specifically on the *means* by which true conclusions could be inferred from true premises. In 1847 George Boole published a book in which he developed an algebra of logic based on the notion of classes of objects, which might be combined and which might intersect.⁵⁹ In an article about Lewis Carroll’s use of logic in his fiction, Andrea Henderson emphasises and perhaps celebrates this detachment by De Morgan and Boole of form from meaning; she quotes George Boole: the interpretation of elements of language ‘is purely conventional: we are permitted to employ them in whatever way we please’.⁶⁰ This is best illustrated in what we are told to regard as classes in De Morgan’s and Boole’s mathematical logic. As Henderson puts it: ‘The goal of classification is not the discovery of the essence of a thing but its distinction from other similar things.’⁶¹ In other words we can form classes at will, provided that their definition discriminates between objects within the classes and objects outside them. Eliot was an admirer of Augustus De Morgan and also familiar with Boole’s work, and she made use of their ideas. More is said about this in chapter four. It is possible to see a parallel between the genesis of mathematical logic in Victorian Britain and the genesis of non-Euclidean geometry. Both involve a move towards a more formal approach to mathematics. Looking at logic purely formally helps us to see alternative explanations for the same empirical observations, including social observations.

Not everybody is happy about the close association of mathematics with logic. Daniel Wright describes what he calls ‘George Eliot’s vagueness’ in a recent essay with this title, and explores and celebrates her use of ‘blurred concepts’ in her novels. He suggests that ‘we read Eliot not just as a novelist of ethical clarity or “sharpness” but also as an artist who registers the sheer difficulty of the kind of self-understanding required to give our erotic lives a meaningful shape’.⁶² Wright sees the use by mathematicians of the two-valued logic of Boole as a brake on allowing vagueness when exploring the relationship between ethical thinking and ‘erotic life’. Mathematics

⁵⁹ I. Grattan-Guinness, ‘Victorian Logic: From Whately to Russell’, in *Mathematics in Victorian Britain*, pp.359-376 (pp.361-2).

⁶⁰ Andrea Henderson, ‘Symbolic Logic and the Logic of Symbolism’, *Critical Inquiry* (Autumn 2014) 78-101 (p.83).

⁶¹ *Ibid*, p.84.

⁶² Daniel Wright, ‘George Eliot’s Vagueness’, *Victorian Studies*, 56:4 (Summer 2014), 625-648 (p.640).

is cast as the villain because of its precision; Wright points to the sorites paradox – if grains of sand are removed one by one from a heap of sand, at what exact point does the collection of sand cease to be a heap? – and atemporally presents Wittgenstein’s use of many-valued logic as a way of describing Eliot’s vagueness.⁶³ Wright’s view appears to be not only that mathematics is unhelpfully precise, but also that mathematicians are pedantic and narrow in their thinking.⁶⁴ This is reminiscent of a debate between Thomas Huxley and Sylvester in the late 1860s. Daniel Brown reports how Sylvester, in his address to the British Association for the Advancement of Science meeting in Exeter in 1869 defends mathematics against criticism made in ‘public utterances by Huxley’, in which Huxley identifies mathematics with Euclid and consequently ‘characterises it as dogmatic and deductive, fundamentally unprogressive’.⁶⁵ But Sylvester did not accept the assumption that, because mathematicians are capable of logical deductive thinking, they must always think in pedantically unimaginative ways. Sylvester declared mathematics to be ‘constantly invoking the aid of new principles, new ideas, and new methods, not capable of being defined by any form of words but springing direct from the inherent powers and activity of the human mind’.⁶⁶ He was arguing that effective and innovative mathematicians are of necessity creative thinkers. From this point of view Eliot’s mathematics can help her to be what Wright calls ethically sharp, while at the same time she embraces inevitable vagueness on matters about which mathematical reasoning or any other reasoning may have little to say.

And this brings me to my last reason, and perhaps the most significant reason, for including logic in an exploration of the mathematics in George Eliot’s novels. Henderson’s emphasis on the role of symbolic logic in separating content from the process of argument is echoed by De Morgan writing about school education: while the ‘same species of logic is used in all inquiries after truth’, mathematics is different from other subjects because ‘the data or assumptions of the first are few, understandable and known to the student from the beginning [...] they require no induction from facts which can be disputed.’⁶⁷ It is not that logical deduction is the exclusive domain of mathematics, but that mathematics is a subject in which, with few preliminary facts, we

⁶³ Ibid, pp.627-8.

⁶⁴ Ibid, pp.632-3.

⁶⁵ Brown, p.190.

⁶⁶ Ibid, p.186.

⁶⁷ Henderson, pp.89-90, 99-100; De Morgan, p.265.

can learn to think logically, and can then think logically about other subjects. Consequently, those who from a young age become confident with mathematics learn to think in the language of mathematics and of mathematical logic. Eliot exemplifies the use of mathematics as a language in her early letters. She lapses into mathematics in much the same way as she lapses into French. Mention has already been made of Marian Evans, when in a low mood, comparing herself to ‘that mathematical abstraction, a point’. This may or may not be an example of Eliot’s deliberate and mannered use of mathematics. Someone with a mathematical education is likely to think logically and in a patterned way without necessarily always being conscious of doing this. This is an example of Eliot’s specific use of mathematics, but in this thesis I am also interested, not only in her explicit use of mathematics in her novels, but also in her use of logical patterning which is often patently self-conscious but is likely sometimes not to be.

For the mathematician, mathematics can be used not only to insist on logical thinking; it can also challenge illogical thinking. Adam Bede’s awareness that the ‘square of four is always sixteen whether a man is happy or miserable’ is an indication of the need to be aware of when it is necessary to accept and when it is possible to dispute. In Eliot’s final publication *The Impressions of Theophrastus Such* (1878), Aquila miscalculates nine times thirteen, giving the answer as one hundred and two, for reasons that are explored in chapter one. What is ironically important here is not the inaccuracy of the result but the dazzlingly spurious statistical use that is made of it by the charismatic Aquila.⁶⁸ Arguments based on spurious or incorrect reasoning need to be challenged. In her novels Eliot repeatedly uses mathematical and logical argument to demolish certainties that were not certain – a notable example of which is that women were intellectually inferior to men.

Women and mathematics

There are a number of women competent in mathematics, whom Eliot either knew or had read. In 1840, Eliot told Maria Lewis that she was about to read Mary Somerville’s *Connection of the Physical Sciences*, which as its title suggests is an exposition of the

⁶⁸ *Impressions*, pp.88-9.

physical sciences and the relationships between them. Somerville was an able translator and expositor of the mathematical sciences and her books were ‘best sellers and did much to educate the general population’.⁶⁹ I shall return to Mary Somerville in chapter two.

Eliot knew of Ada Lovelace and presumably of her work; in 1852, when visiting a friend Eliot inadvertently met Lovelace’s mother who was nursing her ‘in this sad ending of her career – *cancer*’.⁷⁰ Lovelace wrote extensive notes about Charles Babbage’s analytic engine, notes that were published in 1843 and ‘which contain not only what is regarded as one of the earliest computer programs but also prescient comments about the future of such an engine, which have stood the test of time’.⁷¹ Thus she was a visionary thinker, who might provide an example of Sylvester’s claim, cited above, that mathematicians needed to be able to work with ‘new principles, new ideas, and new methods’.

Eliot was also acquainted with Harriet Martineau and her work. When in 1851 it was suggested that Martineau should undertake a condensed translation of Comte’s *Cours de Philosophie*, Eliot was sceptical: ‘Harriet Martineau’s style is admirably adapted to the people [...] I should have less confidence in the equal fitness of her calibre of mind for rendering a trustworthy account of Comte’s work’, she wrote to Hennell.⁷² In spite of Eliot’s doubts, *The Positive Philosophy of Auguste Comte* was published in 1853, a translation that at its start requires a good overview of difficult enough pure mathematics.

Eliot met ‘the mathematically inclined Florence Nightingale’ on more than one occasion.⁷³ At the first meeting in 1852 Eliot was more impressed by Nightingale’s aunt, but a year later Eliot told Hennell: ‘There is a loftiness of mind about her’.⁷⁴

⁶⁹ A. J. S. Mann and A. D. D. Craik, ‘Scotland: Land of Opportunity but Few Rewards’, in *Mathematics in Victorian Britain*, pp.77-102 (p.98).

⁷⁰ GEL, 2: p.66.

⁷¹ Betty Alexandra Toole, ‘Byron, (Augusta) Ada [*married name* (Augusta) Ada King, countess of Lovelace] (1815–1852)’, *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, Oct 2009 [http://www.oxforddnb.com/view/article/37253, accessed 6 Sept 2016]

⁷² GEL, 1: pp.360-1.

⁷³ M. Eileen Magnello, ‘Vital Statistics: The Measurement of Public Health’, in *Mathematics in Victorian Britain*, pp.261-282 (p.272).

⁷⁴ GEL. 2: pp.39, 45.

Nightingale's interest in statistics began during her childhood; she regarded statistics as 'the most important science in the world' and she believed that 'we learn the purpose of God by studying statistics'.⁷⁵ As a consequence of the statistical work she did on elucidating the causes and prevention of disease through sanitation, and particularly on the standardisation of the collection of statistical data, she was the first woman to become a fellow of the Royal Statistical Society in 1858.⁷⁶ Nightingale popularised the use of statistical diagrams for presenting data with her polar area graphs, popularly known as 'rose diagrams'.⁷⁷ Eliot may have been alluding to these in *Daniel Deronda* when she describes Mordecai as 'more poetical than a social reformer with coloured views of the new moral world in parallelograms, or than an enthusiast in sewage', even though the regions in the rose diagram were trapezia rather than parallelograms.⁷⁸

The most prestigious female mathematician whom Eliot knew was the Russian Sonja Kovalevskaya, who admired Eliot's novels and visited her on several occasions. More will be said about her in chapter four.

Mathematics education in Eliot's novels

Eliot had an active interest in education and in how human beings learn. She and Lewes gave considerable thought to how to educate Lewes's two eldest boys, deciding in the end to send them to Hofwyl school in Switzerland, a progressive school which adopted methods similar to those advocated by Pestalozzi, giving pupils a measure of freedom and responsibility concerning their own education.⁷⁹ Her interest in the practicalities of both learning and teaching is evident in all her novels and particularly in her first two. Evidence from her novels suggests that she was especially interested in mathematics education. It is true, of course, that other mid-Victorian novelists allude to teaching in their novels. Some of Charles Dickens' schoolmasters are violent and worse: Whackford Squeers in *Nicholas Nickelby* and Bradley Headstone in *Our Mutual Friend* are extreme examples. And in *David Copperfield* there is the sadistic Mr

⁷⁵ Magnello, pp.273-4.

⁷⁶ Ibid, p.276.

⁷⁷ Ibid, pp.275-6.

⁷⁸ *Daniel Deronda*, p.435.

⁷⁹ GEL, 2: p.236.

Creakle with his ‘craving appetite’⁸⁰ for caning, while the ironically named school proprietor Dr Strong is weak. In *Hard Times*, Dickens satirises teaching that is based on a mathematical way of seeing the world: ‘With a ruler and a pair of scales, and the multiplication tables always in his pocket’ Mr Gradgrind is ‘ready to weigh and measure any parcel of human nature, and tell you exactly what it comes to’,⁸¹ so that when he teaches the children in his school he refers to them by numbers in preference to names. Eliot writing about the teaching of mathematics is rarely satirical, although she can be ironic, for example when describing Mr Stelling’s teaching. Pictures of education painted by Dickens and other novelists are not always negative or critical. Dickens has the pupil teacher Biddy in *Great Expectations* battling to keep order in the chaotic school run by Mr Wopsle’s great-aunt, and doing her best to teach Pip to read and to teach him also some sense concerning Estella.⁸² Charlotte Brontë’s Jane Eyre, when teaching in the village school, works hard and effectively at discovering how ‘heavy-looking, gaping rustics wake up into sharp-witted girls’.⁸³ But Brontë does not provide details of what Jane teaches and how she teaches it. What makes Eliot distinctive is that she writes about mathematics teaching, and writes about it as a mathematical insider: she repeatedly engages with curricular and pedagogical issues, in connection with Bartle Massey in *Adam Bede*, and Tom Tulliver and Mr Stelling in *The Mill on the Floss*, and with mathematics at Cambridge University in *Daniel Deronda*.

Eliot’s imagery and Lewis Carroll’s imagery

Eliot can be usefully compared not only with mid-Victorian realist novelists such as Dickens and Brontë, but also with Lewis Carroll. Both Eliot and Carroll were mathematicians before they were novelists, and both used mathematical imagery in their novels, often absurd imagery. Several of Eliot’s sometimes bathetic images will be described in this thesis. The link between mathematics and playfulness with language is evident in both Carroll’s Alice novels and in Eliot’s novels, sometimes through the use of similar examples. In *Alice’s Adventures in Wonderland* (1865) in response to Alice’s suggestion that ‘I say what I mean’ is the same thing as ‘I mean what I say’, the March Hare tells Alice: ‘You might just as well say [...] that “I like what I get” is the same

⁸⁰ Charles Dickens, *David Copperfield* (London: Penguin, 2004), p.100.

⁸¹ Dickens, *Hard Times*, p.10.

⁸² Charles Dickens, *Great Expectations* (Oxford: OUP, 1994), pp.71-2, 126-7.

⁸³ Charlotte Brontë, *Jane Eyre* (Oxford: OUP, 2000), p.366.

thing as “I get what I like”!’⁸⁴ Eliot offers almost exactly the same remark in an epigraph in *Middlemarch*, presented as a Spanish proverb: ‘Since we cannot get what we like, let us like what we can get.’⁸⁵ This is an example of mathematical logic: ‘p implies q’ does not imply ‘q implies p’; or, a theorem is not equivalent to its converse. Getting something and therefore liking it is not the same as liking something and therefore getting it. Unlike Carroll, Eliot explores some of the implications of this in the chapter that follows the epigraph. Will Ladislaw is not able to get what he likes, which is to communicate with Dorothea; instead he stays near her in Middlemarch, ‘beginning thoroughly to like’ working for Mr Brooke.⁸⁶

Both Carroll and Eliot associate some of their absurd imagery with spurious counting. The contrived logic of Wonderland results in the King and Queen of Hearts having ten royal children, who come ‘jumping merrily along’ in the procession: ten, not because of any suggestion that the King and Queen are fecund, but simply because, in a pack of cards, there are ten hearts cards that are not picture cards.⁸⁷ In *Middlemarch*, Mary Garth frequently makes satirical comments underpinned by mathematics or mathematical logic. This is part of a conversation between Mary and her sister Letty, when Mary is embroidering handkerchiefs for Rosamond’s wedding:

‘It is for Rosamond Vincy: she is to be married next week, and she can’t be married without this handkerchief.’ Mary ended merrily, amused with the last notion.

‘Why can’t she, Mary,’ said Letty, seriously interested in this mystery[...]

‘Because this is one of a dozen, and without it there would only be eleven,’ said Mary, with a grave air of explanation, so that Letty sank back with a sense of knowledge.’⁸⁸

This excerpt illustrates how Eliot’s use of mathematics is often associated with humour, and in particular the humour that arises from gently mocking what Eliot saw as absurd social assumptions, or less gently mocking absurd philosophical ones, which are supposedly supported by scientific evidence for which extravagant claims are made.

⁸⁴ Lewis Carroll, *The Annotated Alice*, ed. by Martin Gardner (Harmondsworth: Penguin, 1970), p.95.

⁸⁵ *Middlemarch*, p.431.

⁸⁶ *Ibid*, p.433.

⁸⁷ Carroll, *Alice*, p.107.

⁸⁸ *Middlemarch*, p.374.

Martin Gardner, in his introduction to *An Annotated Alice* (1970), notes how ‘the Alice books lend themselves readily to any type of symbolic interpretation – political, metaphysical, or Freudian’.⁸⁹ With this reservation in mind, it is worth noting that Melanie Bayley interprets some of the images in the Alice books as a satire on new developments in mathematics which might challenge the pre-eminent position of Euclid. She suggests that turning the Duchess’s baby into a pig is the conservative Carroll’s satire on the new projective geometry, which studies the properties of shapes that remain the same when one shape is transformed into another.⁹⁰ In *Adam Bede* the narrator turns the publican Mr Casson into two spheres. Eliot’s position is diametrically opposed to that of Carroll; her images often mock intellectual and social conservatism. In *Euclid and his Modern Rivals* (1879), the aim of which is ‘the vindication of Euclid’s masterpiece’, Carroll derides those textbook writers who claimed to have improved on Euclid.⁹¹ When Humpty Dumpty, in *Through the Looking Glass*, says ‘When *I* use a word [...] it means just what I choose it to mean’, Carroll might be seen as parodying what he saw as the elastic and imprecise use of mathematical language and conceptualisation by these writers.⁹² On the other hand, when in *Middlemarch* Dorothea tells Mrs Cadwallader ‘I never called everything by the same name that all the people about me did’, Eliot is protesting against stultified social beliefs, which are also sometimes stultified mathematical beliefs, and arguing for a recognition of the absurdity of what is assumed to be socially – and intellectually – self-evident.⁹³

The action in one of the Alice novels is on the other side of a looking-glass. The mathematical science of optics occurs in several of Eliot’s novels. Bonaparte describes one way Eliot uses optics: Eliot depicts egoists ‘regarding themselves with admiration in a mirror. Altruists look through windows instead.’⁹⁴ For Eliot, though, looking through windows is not entirely without complications. Windows allow light to pass through them, but they also reflect light, and Eliot capitalises on this fact in several of her novels. Optics and astronomy are closely allied mathematical sciences and I explore

⁸⁹ Martin Gardner, ‘Introduction’ to *The Annotated Alice*, p.8.

⁹⁰ Melanie Bayley, ‘Mathematics and Literature in Victorian England’(unpublished doctoral thesis, University of Oxford, 2010), p.147. The whole of chapter two of her thesis develops the theory that *Alice’s Adventures in Wonderland* is a satire on new mathematics.

⁹¹ Lewis Carroll, *Euclid and his Modern Rivals* (London: Constable, 1973), p.x.

⁹² Carroll, *Alice*, p.269.

⁹³ *Middlemarch*, p.505.

⁹⁴ Bonaparte, p.xvii.

Eliot's use of astronomy and cosmology imagistically in several of her novels. Light is required if we are to see things, but we sometimes need to restrict it if we are to see what we want to see, and we will sometimes interpret what we see wrongly, as people did, before Copernicus and Galileo put them right. Galileo, whom Eliot was 'fond of quoting', makes an appearance in Eliot's first and last novels.⁹⁵

Structuring the novels

All Eliot's novels make use of mathematical ways of thinking, and Eliot uses analogies and structures based on mathematical or logical understanding. Jules Law writes about Eliot's use of the syntactic device of chiasmus in *The Mill on the Floss*. The Oxford English Dictionary describes chiasmus as a 'grammatical figure by which the words of one of two *parallel* clauses is *inverted* in the other'. Law's essay describes chiasmus as 'the figure of syntactical *reversal* or *symmetrical* crossing'; and also describes how the uses of rhetorical devices in the novel involve '*isomorphic*' rhetorical patterns, or a '*postulate*', or 'highly ideological notions of *continuity* and *discontinuity*, *identity* and *difference*', for example.⁹⁶ The words I have italicised are all mathematical terms and are suggestive of the strong link between mathematical ways of thinking and Eliot's use of rhetorical language generally. Analogical thinking recurs throughout Eliot's novels, and her use of imagery is frequently either overtly mathematical or based on the reasoning characteristic of mathematical logic. There is certainly plenty of parallel thinking in *Middlemarch*.

Bonaparte describes how many of Eliot's metaphors 'act like a scaffolding on which poetic structures are erected'.⁹⁷ Bonaparte suggests an example of poetic scaffolding that 'draws on mythological imagery'.⁹⁸ I shall demonstrate how in her novels Eliot frequently uses mathematics to provide such scaffolding; this is particularly noticeable in *Middlemarch*. Many of the epigraphs in the last two novels are mathematically based. In 'The Natural History of German Life', Eliot suggests that she saw mathematics in this way: she writes about the advance of social science 'from the

⁹⁵ GEL 4; p.401.

⁹⁶ Jules Law, 'Water Rights and the Crossing of Breeds' in *Rewriting the Victorians: Theory, History and the Politics of Gender*, ed. By Linda Shires (New York and London: Routledge, 1992), pp.52-69 (throughout).

⁹⁷ Bonaparte, p.xxxvi.

⁹⁸ Ibid.

general to the special, from the simple to the complex, analogous with that which is found in the series of sciences from Mathematics to Biology'.⁹⁹ This idea is analogous to Herbert Spencer's assertion that 'we shall find that the transformation of the homogeneous into the heterogeneous, is that in which Progress essentially consists', except that Eliot specifically includes mathematics in her account.¹⁰⁰

In a lecture given in 1870, which Eliot read in *Nature* and quoted from in one of her *Daniel Deronda* notebooks, James Clerk Maxwell declared that 'the mathematical processes and trains of reasoning in one science resemble those in another so much that [...] knowledge of one science may be made a most useful help in the study of the other'.¹⁰¹ Peter Allan Dale describes such analogical thinking like this: 'the later George Eliot everywhere encourages us to read her "realism," in parabolic terms'.¹⁰² I shall discuss the two 'parables' in *Middlemarch*, and the parallel between alternative Jewish culture and alternative non-Euclidean geometries in *Daniel Deronda*. Eliot's ability to handle chains of reasoning is evident in the facility with which she plots her novels. In *Middlemarch* in particular, a genogram showing how characters are linked by birth and marriage would be an unusually multiply-connected network, broken into two almost disconnected networks: one for the squirearchy, and the other for the merchant middle-class. These are tenuously linked by a thread running through Mr Bulstrode, who, in this sense, becomes pivotal to the novel.

When discussing how Eliot uses language to describe Tom Tulliver's sense of his own stupidity when with Mr Stelling, which makes him become 'more like a girl than he had ever been in his life before', Law observes that '[d]ifference and femininity, by this equation, are constituted as negatives'.¹⁰³ Eliot, of course, repeatedly uses irony when addressing issues concerning the different treatments of and attitudes towards males and females, but more than this, she frequently discusses such differences either in the context of mathematics, or framed, as Law suggests, as negative. She does both

⁹⁹ 'The Natural History of German Life', p.71.

¹⁰⁰ Herbert Spencer 'Progress: Its Law and Cause', *Westminster Review*, 11 n.s. (April, 1857), 445-485 (p.447).

¹⁰¹ James Clerk Maxwell, 'Sectional Proceedings: Section A, Mathematics and Physical Science, BAAS', *Nature*, 2 (1870), 419-422 (p.420).

¹⁰² Peter Alan Dale, *In Pursuit of a Scientific Culture: Science, Art, and Society in the Victorian Age* (Wisconsin: University of Wisconsin Press, 1989), p.142.

¹⁰³ *The Mill on the Floss*, p.141; Law, p.62.

when Adam Bede observes, in connection with the new rector, that ‘as for math’ematics and the natur o’ things, he was as ignorant as a woman’.¹⁰⁴ I shall show how Eliot employs mathematics as a useful device for challenging faulty gender reasoning.

Melanie Bayley has written more than other critics about George Eliot’s mathematics, allocating two chapters in her DPhil thesis to it; one of these chapters is about statistics in *Middlemarch* and the other about non-Euclidean geometry in *Daniel Deronda*. Like Bayley, I discuss particular mathematical topics; but I am also interested in how Eliot’s novelistic style is affected by mathematical ways of thinking. The fact that the eponymous heroes of Eliot’s first and last novels are mathematicians is perhaps an indication of the significance of mathematics in Eliot’s thinking. However, I am not solely concerned with the mathematics with which characters engage. One result of Eliot’s philosophical style of writing is that her novels can reveal her attitude to mathematics and demonstrate how mathematics influenced other aspects of her thinking, as the following chapters will show. Each of the chapters, with the exception of chapter five, focuses on one of five novels and is organised around mathematical themes that are significant in that novel, but that may also have relevance for other novels. Chapter five is concerned with the mathematical sciences that are used analogically and imagistically in Eliot’s last two novels. I have omitted detailed consideration of *Silas Marner* and *Felix Holt* from this thesis for reasons of space. This does not imply that Eliot’s mathematics was not in evidence in these novels. The chapters are arranged so that the novels considered appear in chronological order.

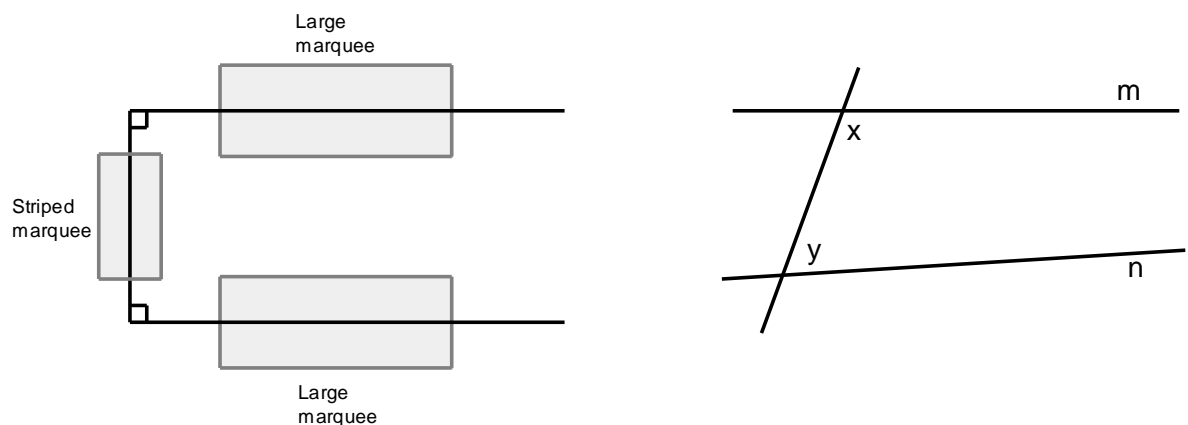
¹⁰⁴ *Adam Bede*, p.180.

Chapter One

‘Put your face to one of the glass panes ... What do you see?’: noticing the mathematics in *Adam Bede*

Eliot’s first novel, *Adam Bede* (1859), set at the very end of the eighteenth century and the beginning of the nineteenth, has more overt references to mathematics than her other novels. The eponymous hero, who is a mathematically adept carpenter, uses mathematics, solves mathematical problems, thinks in terms of mathematical metaphors and muses about mathematical education, providing Eliot with the opportunity to address these issues in her novel. But the appearance of mathematics in the novel has a broader significance. As mentioned in the introduction in connection with Miss Lyddy’s cabinet, mathematics is used to carry messages about reassessment of and challenge to beliefs about Victorian society, messages which gather force in later novels.

Eliot uses mathematical language and concepts naturally in her descriptions, often telling the reader the geometrical shape of things. These descriptions may have deeper significance than is at first apparent, introducing ideas that will be indicate Eliot’s thinking and which are sometimes developed in later novels.



Arthur’s birthday marquees and Euclid’s fifth postulate

For example, at Arthur Donnithorne’s birthday party, the narrator of *Adam Bede* tells us, with geometrical precision, that the ‘striped marquee’ is ‘standing at right angles with two larger marquees’. ¹ This geometrical configuration is close to that used by Euclid when he stated his problematic fifth postulate for plane geometry: this postulate

¹ *Adam Bede*, p.253.

asserts that if the sum of the angles x and y is less than two right angles then the lines m and n will meet when extended. For the marquees, the sum of these angles is not less than, but equal to two right angles and so we deduce that the marquees are parallel. The significance of Euclid's fifth postulate for Eliot is discussed in chapters two and six.

Use of mathematical detail begins early in the novel. In the second chapter, when the horseman stranger meets Mr Casson, the landlord of the Hayslope inn, having passed Adam Bede on the road, he describes Adam as a 'fine [...] broad-shouldered fellow'. Mr Casson agrees that Adam is 'wonderful strong'.² And being a publican no doubt in the habit of moving barrels of beer around, he is not only impressed by Adam's strength but is also able to quantify it, using the language of weights and measures and telling his listener: 'he can walk forty mile a-day, an' lift a matter o' sixty ston'.³ We soon discover that Adam is even better than Mr Casson at using mathematical language, because Adam has 'an eye at measuring, and a head-piece for figures'.⁴ These are the words of Adam's night-school teacher, Bartle Massey. Adam's childhood friend, Arthur, who is the squire's grandson, also recognises Adam's prowess with mathematics, giving him a 'two-foot ruler', bought with his pocket-money, in gratitude for 'Adam's lessons in carpentering and turning'.⁵

Adam's mathematical abilities are repeatedly mentioned in association with his physical strength and his manliness. Adam is more impressed by the pretty Hetty than she is with him, but she does perceive him to be manly, because he can know, 'with only looking at it, the value of the chestnut tree that was blown down'.⁶ The narrator tells us that, when Adam is looking at beech trees, his 'perceptions' enable him to calculate 'the height and contents of a trunk to a nicety, as he stood looking at it'.⁷ John Cross, Eliot's widower, wrote of Eliot's father's ability to 'calculate with almost absolute precision the quantity of available timber in a standing tree'.⁸ In September 1859, seven months after *Adam Bede* was published, Eliot told Charles Bray that her

² Ibid, p.17.

³ Ibid.

⁴ Ibid, p.259.

⁵ Ibid, p.163.

⁶ Ibid, p.97.

⁷ Ibid, p.295.

⁸ J. W. Cross, *George Eliot's Life as Related in her Letters and Journals*, 3 vols. (Edinburgh and London: Blackwood, 1885), 1: p.11.

father ‘had large knowledge of building, of mines, of plantations, of various branches of valuation and measurement;’ this was in response to misinformation that her father was a ‘mere farmer.’⁹ Hetty was also impressed that Adam could ‘do figures in his head – a degree of accomplishment totally unknown among the richest farmers of that country-side’;¹⁰ the narrator takes pride in the social status of Adam’s achievement, rather as Eliot did in her father’s achievement when she told Bray that her father ‘was held by those competent to judge as *unique* among land-agents for his manifold knowledge and experience’.¹¹ Eliot included these passages in her novel, not only as a tribute to her father, but also as a way of declaring her own interest and expertise in the use of practical mathematics. She demonstrates her own understanding of the problem concerning the bulk of a tree by the way she transplants it into *Adam Bede*: the narrator could have told us simply that Adam could value the wood in standing trees. Instead, we are told that Adam could calculate ‘the height and contents of a trunk’.¹² This greater detail indicates Eliot’s level of insight and also provides a more specific challenge for interested readers to attempt the same computation.

A mathematical description of Mr Casson

Eliot’s use of mathematics to help make points about society is instanced early in the novel, when the reader first encounters Mr Casson, the publican in Hayslope. Eliot uses the bathetic humour of a streetwise journalist to present him as a figure of fun. By subsequently giving this mathematical image wider social significance Eliot is signalling a stance she intends to adopt through all her novels.

Mr Casson’s person was by no means of that common type which can be allowed to pass without description. On a front view it appeared to consist principally of two spheres, bearing the same relation to each other as the earth and the moon: that is to say, the lower sphere might be said, at a rough guess, to be thirteen times larger than the upper [...] But here the resemblance ceased, for Mr Casson’s head was not at all a melancholy-looking satellite, nor was it a ‘spotty globe’, as Milton has irreverently called the moon.¹³

⁹ GEL, 3: pp.168-9.

¹⁰ *Adam Bede*, p.97.

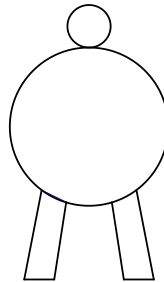
¹¹ GEL, 3: p.168.

¹² *Adam Bede*, p.295.

¹³ *Adam Bede*, p.14.

This description is simultaneously amusing and puzzling: it presents the attentive reader with a mathematical problem: how does the number thirteen connect the earth to the moon?

The crafting of the Mr Casson image provides an example of an elaborate process. To begin with, Eliot not only had to think of relating Mr Casson's body and head to the earth and the moon respectively, but had to consider whether the ratios involved corresponded to a believable reality about the human body. The diagram below, in which the circles are drawn using the ratio of the diameters of the earth and the moon, suggests that perhaps they do. This is arguably the most ingenious and impressive part of the whole process. This then provides a context in which Eliot could refer to Galileo's revolutionary astronomy, as will be discussed shortly.



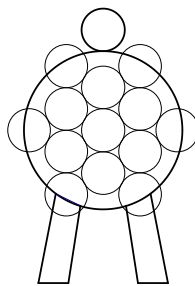
‘principally of two spheres’

Having cleverly described Mr Casson using an astronomical parallel, Eliot presents the mathematics to the reader in the form of a mathematical puzzle: ‘the lower sphere might be said, at a rough guess, to be thirteen times larger than the upper.’¹⁴ The puzzle is to ascertain how Eliot arrives at the number thirteen. There is economy of language here: Eliot is able to state the puzzle in eighteen words, so that it does not intrude clumsily into the narrative. Readers who set about solving the problem can discover that the ratio of the diameters of the earth and the moon is about 3.7. So the puzzle is to decide in what way the earth, or Mr Casson's body, is thirteen times the size of the moon, or Mr Casson's head. Given that the ratio of the diameters is 3.7, the volume of one sphere is about fifty times that of the other; so it is not volumes that are being compared. We might obtain the clue by looking at the picture of Mr Casson; when comparing the relative sizes of body and head, our brains automatically compare surface areas, rather than diameters or volumes. This awareness is reinforced by the

¹⁴ Ibid.

narrator's reference to the 'spotty globe': it is surfaces which are of interest here. Perhaps the surface of the larger sphere is thirteen times that of the smaller sphere.. This can be confirmed by calculation: the ratio of the surface areas is obtained by squaring the ratio of the diameters and so is about 3.7^2 , which is approximately 13.7, or indeed, 'at a rough guess', thirteen.

Why does Eliot choose thirteen rather than fourteen, which is closer to 13.7? One reason is that when greater astronomical accuracy is adopted, the diameter of the earth is 7926 miles and that of the moon 2159 miles, and this gives the ratio of the diameters an approximate value of 3.671. When this ratio is squared the answer obtained is 13.476, which is so close to 13.5 that, in order to be sure that the ratio is closer to thirteen than fourteen, this degree of accuracy is required. So the pedantically assiduous reader is faced with a calculation which, before the advent of calculating machines would have been arduous. Of course, the numerate mathematician knows that this level of accuracy is a spurious response in the context of this problem; the narrator is able to make only 'a rough guess' when assessing Mr Casson's appearance and it would indeed be surprising if Mr Casson's body and head bore exactly the same relation as the earth to the moon.



'thirteen times'

There is another reason why Eliot may have been very content with thirteen. As has already been suggested, a more geometrical way of seeing that the area of the larger sphere, pictured as a circle, is about thirteen times the area of the smaller, is to fit the smaller circles on top of the larger, since the ratio of the areas of the circles will be the same as that of the surface areas of the spheres. When we do this, a pattern of thirteen circles yields a symmetrical image, and thus is much tidier and more satisfying than a pattern of fourteen circles. Would it have been likely that Eliot would think of this pattern? One of the books in the library of George Eliot and George Lewes was

Inventional Geometry, a collection of geometrical problems, the author of which was Herbert Spencer's father, George Spencer. Eliot had met this 'large-brained, highly informed man [...] altogether very pleasing', in 1852.¹⁵ Although his book was published in 1860, too late to directly inform Eliot's writing of *Adam Bede*, the problems in the book might be indicative of the kind of recreational geometry being pursued by mathematical amateurs, including Eliot.

142 Show how many circles may be made to touch one point without overlapping, and compare that number with the number of hexagons, the number of squares, and the number of equilateral triangles.

366 Find the surface of a sphere whose diameter is 1, and also the surface of a sphere whose diameter is 2. Compare the two surfaces together, and say whether the ratio the less has to the greater accords to the law, "The areas of similar figures are to each other as the squares of their homologous sides."¹⁶

Problem 142 suggests that the idea of fitting shapes together was familiar to interested mid-Victorians. Problem 366 in Spencer's book suggests the other, the algebraic method for obtaining the solution; it is in fact a much easier version of Eliot's problem, because the diameters of the spheres are provided, and the result asked for can be obtained by the relatively straightforward method of calculating the surfaces of the spheres by means of a formula. The mathematics educationalist Michael Price judges that Spencer's book 'on practical geometry was over thirty years ahead of its time in England' in encouraging 'active rather than passive learning to promote understanding' of geometry.¹⁷ This remark indicates the impressiveness of Eliot's achievement in constructing an ingenious mathematical problem that could be inserted seamlessly into her novel.

Crafting other mathematics

Several critics have remarked on the care with which Eliot crafts the images in her fiction. U. C. Knoepfelmacher, for example, describes at length the allusions that lie behind the description of the incident in *Middlemarch* in which Lydgate and Rosamond

¹⁵ GEL, 2: p.37.

¹⁶ W. G. Spencer, *Inventional Geometry: A Series of Questions, Problems and Explanations* (London: Mozley, 1860), pp.43, 81-2.

¹⁷ Michael H. Price, 'Spencer, (William) George (bap. 1790, d. 1866)', *Oxford Dictionary of National Biography*, Oxford University Press, online edn (2004) <doi:10.1093/ref:odnb/26139>

ridicule Ned Plymdale's 'Keepsake'.¹⁸ This care is shown in her crafting of mathematical images, of which the Mr Casson description is just one example. An early example occurs in 'Janet's Repentance', when the narrator is describing how, for the Utilitarians, 'thirteen happy lives are a set-off against twelve miserable lives, which leaves a clear balance on the side of satisfaction'.¹⁹ Why does the narrator choose thirteen and twelve, when it could have been twelve and eleven, for example? It would seem that these particular numbers are chosen by this mathematically-minded novelist, because they result in a tidy percentage of satisfaction: fifty-two per cent, in fact, whereas other numbers would not yield such a readily calculable 'arithmetical proportion'.²⁰

Much later, in *Theophrastus Such*, the narrator points up the ignorant arrogance of the 'agreeable' Aquila by attributing to him 'a hasty reckoning that nine thirteens made a hundred and two'.²¹ This is not a mistake that could be made by anybody with a feeling for numbers: to start with, such a person would know that the product of two odd numbers is odd. But the choice by Eliot of this particular incorrect answer of 'a hundred and two' is surely not random. My explanation is this: the product of nine and thirteen can be calculated by first multiplying nine by ten and then by three, and then adding the results. Nine tens are ninety, and nine threes are twenty-seven, if you forget you are multiplying and instead add the numbers. Ninety plus twenty-seven gives a hundred and twenty-six. Eliot may have been familiar with errors like this from helping others, possibly her step-sons, learn arithmetic. In one of her *Middlemarch* notebooks Eliot writes this:

$2/5 \text{ of } 1 = 1/5 \text{ of } 2$

Let 5 dominoes be laid side by side. Lay 5 more on these. Then it is evident that 2 fifths (i.e. dominoes) in the first row are equal to 2 dominoes taken perpendicularly, which are seen to make 1 fifth of two rows.²²

¹⁸ U. C. Knoepfelmacher, 'Fusing Fact and Myth: The New Reality of *Middlemarch*' in *This Particular Web*, ed. by Ian Adam (Toronto, University of Toronto Press, 1971), pp.43-72 (pp.43-4). The reference is to *Middlemarch*, p.254.

¹⁹ *Scenes of Clerical Life*, p.270.

²⁰ Ibid.

²¹ *Impressions*, p.88.

²² John Clark Pratt and Victor A. Neufeldt, *George Eliot's Middlemarch Notebooks* (Berkeley and London: University of California Press, 1979), p.70.

This example illustrates Eliot's interest in mathematics education, and suggests the way Eliot collected her mathematical images for possible use in novels. The editors of these notebooks comment that 'we do not know the source of [these] notes', and it is likely that the source of the excerpt above was not a book at all, but an incident, perhaps of teaching, in which Eliot was involved.²³ It is a particular characteristic of mathematics, as opposed to almost any other subject, that mathematics may be acquired informally; where books are used, it may not seem appropriate or necessary to name them. One book used for the study of algebra, for example, may be just as appropriate as another. It is perhaps for this reason that Eliot's study of mathematics can be overlooked by biographers, and that, for example, Avrom Fleishman can write about George Eliot's 'intellectual life' with scarcely a mention of mathematics, because he is basing his work on the books Eliot read and discussed.²⁴ Having said this, there are references to lists of mathematics books read by Eliot and Lewes; a list referred to by Pratt and Neufeldt includes three algebra books, for example.²⁵

Mr Casson and Galileo

I now turn to how Eliot interprets her Mr Casson image. When, in Thomas Hardy's *The Return of the Native* (1878), the rustics light a bonfire on the top of the barrow, the bonfires being simultaneously lit on other distant hills are described as 'planets'. The transgressive heroine Eustacia has lit a much smaller bonfire close to the barrow, in order to attract her illicit lover, and the narrator describes this bonfire, 'the nearest of any', as the 'moon' and 'its nearness was such that, notwithstanding its actual smallness, its glow infinitely transcended theirs'.²⁶ While this image makes no pretence to being astronomically exact, particularly regarding the size of the bonfires, there is a stronger sense of correspondence between the bonfires and the actual moon and planets: Eustacia's 'moon' is much nearer and so appears much brighter than the much larger but distant 'planet' bonfires. Applying lunar imagery to a transgressive female is something the reader might well expect; the inconsistent female is often associated with the changeable moon.

²³ Ibid, p.153.

²⁴ Avrom Fleishman, *George Eliot's Intellectual Life* (Cambridge: CUP, 2010).

²⁵ Pratt and Neufeldt, pp.153-4.

²⁶ Thomas Hardy, *The Return of the Native* (London: Macmillan, 1974), pp.50-1.

Eliot, on the other hand, makes no attempt to use astronomical imagery in this semi-realistic way. Mr Casson's description is the creation of a pure mathematician. The ratio of a body to a head could not naturally 'appear' to anybody to be roughly that of the earth to the moon. Mr Casson is a most unlikely target for lunar imagery, and Eliot's earth and moon are clearly introduced as a context for a mathematics problem. And Eliot has another reason for including this image: she wants to make a point concerning the nature of mathematics and science. While making fun of the round and superficial Mr Casson, Eliot introduces Milton's 'spotty globe', which is a reference to *Paradise Lost*.

He scarce had ceas't when the superieur fiend
 Was moving toward the shore; his ponderous shield
 Ethereal temper, massy, large and round,
 Behind him cast; the broad circumference
 Hung on his shoulders like the Moon, whose orb
 Through optic glass the Tuscan artist views
 At evening from the top of Fesole,
 Or in Valdarno, to descry new lands,
 Rivers or mountains in her spotty globe.²⁷

The 'Tuscan artist' is Galileo, here apparently being associated with Satan, and the 'optic glass' is his telescope. But the 'irreverent' puritan Milton 'visited Galileo and entertained the highest opinion of his philosophy', according to the *Penny Cyclopaedia* in 1834.²⁸ In a review of a Milton biography in 1855 Eliot too mentions how Milton went to Italy and 'found and visited the famous Galileo, grown old, a prisoner.'²⁹

Eliot and Lewes both shared Milton's positive opinion of Galileo. In October 1858, Lewes offered Eliot's publisher, John Blackwood, an article about Galileo and three other mathematicians for *Blackwood's Magazine*.³⁰ A letter to friends in 1861 indicates Lewes's imperative need to acquire 'the new edition of Galileo'.³¹ The Leweses had at

²⁷ John Milton, *Paradise Lost* (London: Penguin 2000), 1: lines 283-91 (p.10).

²⁸ [Augustus De Morgan], 'Galileo Galilei', in Society for the Diffusion of Useful Knowledge, *The Penny Cyclopaedia*, 30 vols. (London: Charles Knight, 1833-1843), 11: pp.44-47 (p.45).

²⁹ [George Eliot], 'Life and Opinions of Milton', *Leader*, 6 (4 August 1855), p.750.

³⁰ GEL, 2: p.491.

³¹ GEL, 3: p.471.

least four biographies of Galileo in their library, and also his complete works.³² Eliot made significant reference to Galileo in her last novel *Daniel Deronda*, as well as in *Adam Bede*. She was apparently ‘fond of quoting’ Galileo’s dictum: ‘Si muove’, or ‘It moves, for all that’, apocryphally what Galileo said at the end of his abjuration of his belief in heliocentrism before the Inquisition.³³ This apocryphal story is treated as fact by *The Penny Cyclopaedia* and other nineteenth-century biographies.³⁴ Eliot used this Italian phrase in a letter to Sara Hennell in 1867, to indicate how the world would never be the same after the establishment of Girton College, the first women’s college ‘in connection with the Cambridge university’.³⁵

Using mathematics to challenge

It was, of course, Galileo’s astronomical discoveries and the mathematical theory he built around them which interested the world and provided a challenge to the authority of the Catholic Church. When Galileo invited people to look through his telescope and see the moon, ‘stripped of the character of geometrical perfection, absurdly attributed to all the celestial bodies by the schoolmen’, he was, like many mathematicians before and after him, challenging the accepted view of the universe.³⁶ This is what Eliot is also doing by means of her mathematical image of Mr Casson. Galileo got things right mathematically, when he wrote his book, *Dialogue Concerning the Two Chief World Systems*, in which he was asked by the pope to set out even-handedly the case for a geocentric universe and the case for a heliocentric universe. Even though Galileo’s mathematics was correct, he was brought before the Italian Inquisition because he was mischievously and provocatively subversive – poking fun at supporters of the geocentric theory.

Eliot’s narrator draws parallels when poking fun at Mr Casson.³⁷ Mr Casson, the narrator declares, is not a ‘spotty globe’; his face could not ‘look more sleek and

³² William Baker, *The George Eliot - George Henry Lewes library* (New York and London: Garland, 1977), pp. 36, 38, 58, 70. The Leweses also had histories of science which would have included Galileo.

³³ GEL, 4: p.401.

³⁴ De Morgan, ‘Galileo Galilei’, p.46.

³⁵ GEL, 4: p.401.

³⁶ De Morgan, ‘Galileo Galilei’, p.45.

³⁷ In a letter in 1871, George Lewes recommends a book by John Drinkwater, *The Life of Galileo Galilei* (London: 1830), to a colleague (GEL 9: pp.29-30). Drinkwater writes: ‘This very flimsy veil [the

healthy'; his face is as close as possible to the schoolman's description of the moon: 'round, self-luminous and uncorrupted by any terrestrial tarnish'.³⁸ What preserves Mr Casson from 'terrestrial tarnish' is his 'personal dignity', which is not 'excessive in a man who had been butler to "the family", for fifteen years'.³⁹ Eliot here equates the outdated scholastic view of the solar system with the outdated respect Mr Casson shows for the gentry. Through her use of the Mr Casson image Eliot associates mathematics with scientific and social revolution. The unchangeability of mathematics is just as likely to inspire radical change as prevent it: Galileo's moons of Jupiter, whose existence was so disturbing to the Italian Church, were still unchangeably there in Galileo's telescope, whether or not the schoolman would look 'through his glass to be convinced'.⁴⁰

Clocks and relative time

Clocks, like telescopes, are powerful tools that make significant appearances in Eliot's novels. In highlighting the role of watches and clocks in the Alice books, Gillian Beer has pointed to how they 'controlled industrial labour', adding that '[r]egularising time and defining ever smaller units [...] chime[d] with [...] time-anxieties'.⁴¹ Eliot uses the topic of time and its measurement, in order not only to discuss and challenge how technological measurement was controlling everyday life, but also to debate, with increasing sophistication, how developments in science and technology were influencing beliefs about society and progress. *Adam Bede* opens with a controlling clock.

All hands worked on in silence for some minutes, until the church clock began to strike six. Before the first stroke had died away, Sandy Jim had loosed his plane and was reaching his jacket; Wiry Ben had left a screw half driven in, and thrown his screw-driver into his tool-basket; Mum Taft [...] had flung down his hammer as he was in the act of lifting it.⁴²

introduction to the *Dialogue*] could scarcely blind any one as to Galileo's real views [...] nor does it seem probable that he framed it with any expectations of appearing neutral'. (p.56).

³⁸ *Adam Bede*, p.9; De Morgan, 'Galileo Galilei', p.45.

³⁹ *Adam Bede*, pp.14-5.

⁴⁰ De Morgan, 'Galileo Galilei', p.45.

⁴¹ Gillian Beer, 'Alice in Time', *Modern Language Review* 106: 4 (October 2011), xxvii-xxxviii (xxix, xxx).

⁴² *Adam Bede*, p.10.

Adam rather sanctimoniously remonstrates with his work-mates for having no pleasure in their work, and is accused of preaching at them. E. P. Thompson describes how employers used ‘time-measurement as a means of labour exploitation’, a means of measuring the work done by employees for their wages, rather than paying for ‘taken-work’, in other words, for the completed job rather than for the hours worked. But, by the end of the eighteenth century employees were striking for overtime: ‘They had learned their lesson, that time is money, only too well’.⁴³ Eliot alludes to the tension between ‘time-measurement’ and ‘taken-work’ in *Adam Bede*: Adam muses that ‘he and Seth might carry on a little business for themselves in addition to their journeyman’s work’.⁴⁴

A bit later, when for the first time we meet Mrs Poyser who runs the Hall Farm, before we even make her acquaintance, we make the acquaintance of her clock. The narrator tells us that ‘it is close upon three by the sun, and it is half-past three by Mrs Poyser’s handsome eight-day clock’.⁴⁵ At this point nothing more is said about this discrepancy, and there is a delay of eight chapters before this statement is decoded. This is when wayward Hetty arrives home late, and the reader gains further insight into what is going on. Hetty tells Mrs Poyser she has inadvertently forgotten about the problem of Mrs Poyser’s clock: ‘I did set out before eight [...] But this clock’s so much before the clock at the Chase, there’s no telling what time it’ll be when I get here.’ This outrages Mrs Poyser, who replies: ‘What, you’d be wanting the clock set by gentlefolk’s time, would you? [...] The clock hasn’t been put forrard for the first time to-day, I reckon.’⁴⁶ It suddenly becomes clear that Mrs Poyser deliberately and imperiously creates her own time zone at the farm, set up for people who need to rise early and go to bed early to enable the work of the farm to be done well. By creating her own time zone Mrs Poyser demonstrates her determination not to be imposed on by the tyranny of ‘gentlefolk’s time’. This may seem an admirable and creative solution on her part, but as an employer she is using the clock as an instrument of control over Hetty, among others. Hetty is no doubt genuinely confused by the discrepancy between the times shown on Mrs Poyser’s clock and the clocks possessed by richer and more powerful people. A

⁴³ E. P. Thompson, ‘Time, Work-Discipline, and Industrial Capitalism’, *Past and Present*, 38 (December, 1967), 56-97 (pp.80, 78, 86).

⁴⁴ *Adam Bede*, p.210.

⁴⁵ *Ibid*, p.72.

⁴⁶ *Ibid*, p.145.

watch is too costly for Hetty – at the turn of the century only the ‘best-paid urban artisan’ could afford one; nevertheless ‘even cottagers may have wooden clocks’ at this date: Adam’s household possesses an ‘old day-clock’, which is also, like Mrs Poyser’s clock, ‘in advance of the day’.⁴⁷ Hetty is clearly not the only inhabitant of Hayslope likely to be confused by other people’s time-keeping.

Other characters in Eliot’s novels also create their own time zones. In Eliot’s second novel, *The Mill on the Floss*, published in 1860, Maggie Tulliver’s Aunt Pullet also has her own time zone, and with the same time difference as Mrs Poyser’s. At Aunt Pullet’s they ‘took tea at half-past four by the sun, and at five by the kitchen clock’.⁴⁸ Here is another character who evidently can’t wait for the day to begin; in this case it is never made clear why. And Aunt Pullet’s sister Aunt Glegg, when going to the Tulliver’s for a family dinner makes it sound as though she has her own ideas for setting the time, but is really sarcastically using the tyranny of clock time to protest about the slovenly habits of her sisters, who have not yet arrived for the meal: ‘Mrs Glegg held her large gold watch in her hand with the many-doubled chain round her fingers, and observed to Mrs Tulliver [...] that whatever it might be by other people’s clocks and watches, it was gone half-past twelve by hers.’⁴⁹ Aunt Glegg claims her moral superiority through the measurement of time.

In creating her own time zone, Mrs Poyser is only doing at a very local level what happened regionally anyway; in 1800, when the novel is set, different parts of Britain set their clocks to the sun, and therefore to different times. Mrs Poyser does not set her clock to the sun, but instead sets it to the requirements of her business. She and Aunt Pullet are living in times preceding the advent and expansion of the railways, when it became increasingly clear that regional time zones were confusing for rail operators and rail travellers. So in ‘1847 the Railway Clearing House in Great Britain adopted Greenwich Mean Time as “railway time”, which was used by most railways and eventually became the universal standard’.⁵⁰ In 1859 when *Adam Bede* was published, standardising time would still have been a talking point, and it was not until 1880 that

⁴⁷ Thompson, pp.67, 69; *Adam Bede*, pp.47, 43.

⁴⁸ *The Mill on the Floss*, p.106.

⁴⁹ Ibid, p.54.

⁵⁰ Christian Wolmar, *Blood, Iron and Gold: How the Railways Transformed the World* (London: Atlantic, 2009), p.231

the Statutes (Definition of Time) Act came into force, providing that Greenwich Mean Time shall be used in all official documents. Back in 1848, *Blackwood's Edinburgh Magazine* published an article by William Aytoun on 'Greenwich Time':

We are no friends to modern miracles [...] The interference of modern town-councils, to which we have all long been accustomed, has at last reached a point which borders on absolute impiety [...] they have at last aspired to control the sun, and to regulate the motions of the heavenly bodies according to their delectable will.

[...] At twelve of the night of Saturday the thirteenth day of January, one thousand eight hundred and forty-eight, the public clocks of the city of Edinburgh were altered from their actual time by command of the Town Council, and advanced by twelve minutes and a half. To that extent, therefore, the clocks were made to lie.⁵¹

Dickens, in *Dombey and Son* (1848), takes a diametrically opposite view of exactly the same issue: 'There was even railway time observed in clocks, as if the sun itself had given in',⁵² the narrator rhapsodises as he describes the beneficial changes to Staggs's Gardens. Aytoun is protesting against the deceit, as he describes it, of adopting Greenwich Time in place of 'actual' time; moving away from sun time meant marking time with the rest of Britain. But for Mrs Poyser back in 1800, moving away from sun time meant being different from the ruling classes around her. At this date Mrs Poyser can argue, as mathematicians often do, that if time is an arbitrary convention, adjusted in different regions to meet regional needs, there is no reason why she should not adjust it further to suit her very local needs.

Time zones repeatedly raise the issue, beloved of Eliot, concerning who is being radical and who conservative. Mrs Poyser appears conservative in adjusting her time to suit the requirements of a traditional farm, but less so in her implicit challenge to hierarchy, when she tells Hetty: 'you'd be wanting the clock set by gentlefolk's time'.⁵³ The mathematics itself is neutral. Mathematics points to the possibility of changing the clocks, but does not resolve issues regarding the social significance of such change.

⁵¹ [William Aytoun], 'Greenwich Time', *Blackwood's Edinburgh Magazine*, 63 (March, 1848), 354-61 (p.354).

⁵² Charles Dickens, *Dombey and Son* (Oxford: OUP, 2001), p.233.

⁵³ *Adam Bede*, p.145.

In her novel *Cousin Phillis*, Elizabeth Gaskell uses time variability in a different way. Some people live life at a quicker pace than others. The railway, signifier of social change, is coming to Heathbridge, but at Hope Farm, the ‘double tick of the old clock’ suggests the occupants living the traditional country life in the same way for ever.⁵⁴ When Holdsworth, the railway engineer Phillis loves, arrives in Canada after his fast voyage across the Atlantic, which Phillis and her family expect to take at least a month, he writes in a letter: ‘It seems a year since I left Hornby. Longer since I was at the farm.’⁵⁵ And in no time at all for Phillis, only ten months she finds when she counts it ‘on her fingers’, Holdsworth has moved on from Phillis and married a Canadian woman.⁵⁶ Eliot uses time variability in a similar way in *Middlemarch*.

A great historian, as he insisted on calling himself, [...] seems to bring his arm-chair to the proscenium and chat with us in all the lusty ease of his fine English [...] But Fielding lived when the days were longer (for time, like money, is measured by our needs), when summer afternoons were spacious, and the clock ticked slowly in the winter evenings. We belated historians must not linger after his example; and if we did so, it is probable that our chat would be thin and eager, as if delivered from a camp-stool in a parrot-house.⁵⁷

Time moved more slowly, apparently, in the previous century. Whose side is Eliot on here? Ostensibly the narrator is satirising the novelist Henry Fielding for his eighteenth-century arrogance and his expansiveness, which would not do in the more enlightened society of 1871 when *Middlemarch* appeared. But we need always to beware of the comparisons Eliot’s narrators repeatedly make between then and now, with the apparent implication that now, thank goodness, we are enlightened. Surely there is something intentionally endearing about the reference to spacious summer afternoons and winter evenings. ‘The gardens of the Zoological Society of London were opened in 1829’ and Edward Lear was given permission to make drawings of parrots in the parrot-house in 1830, the time at which *Middlemarch* is set. It was the third edition of Lear’s *Book of Nonsense* (1861) that brought him wide acclaim.⁵⁸ I read Eliot’s reference to the ‘parrot-house’ as a satire on those Victorian historians, scientists, philosophers, and

⁵⁴ Elizabeth Gaskell, *Cranford and Cousin Phillis* (Harmondsworth: Penguin, 1976), p.242.

⁵⁵ *Ibid.*, p.280.

⁵⁶ *Ibid.*, p.301.

⁵⁷ *Middlemarch*, p.132.

⁵⁸ Vivien Noakes, ‘Lear, Edward (1812–1888)’, *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, Oct 2006 [<http://www.oxforddnb.com/view/article/16247>, accessed 14 Feb 2016]

indeed novelists, who are hasty in their judgements and claim to provide definitive answers about the whole world.

So Eliot moves from using time zones in *Adam Bede* for discussion of issues of independence, power and control, to using time in *Middlemarch* as a signifier of the spirit of the age she lives in, an age which was sometimes apt to come to hasty conclusions about the social world.

Speed, time and distance

Beginning with *Adam Bede*, Eliot's novels reflect, with increasing sophistication, how '[s]pace and time were coming to be understood more and more as being in intricate relations'.⁵⁹ Such developments were challenging cherished scientific certainties. In *Adam Bede* Eliot makes a start with her exploration of this issue.

At the time when Adam is developing a romantic interest in Dinah, but Dinah is determined to get back to her work at Snowfield, Mrs Poyser declares: 'She's no call to be in a hurry [...] Scarceness o' victual 'ull keep: there's no need to be hasty wi' the cooking.'⁶⁰ Throughout *Adam Bede*, the speed with which Dinah leaves the Hall Farm and returns to Snowfield is a repeated source of irritation to Mrs Poyser. The speed at which such things are done is not the sort of speed that relates to distance covered. Where distance is involved, it is almost invariably measured in terms of time and implicitly speed, the way it still is in colloquial speech, another example of the dominance of the clock. Adam will know how to turn such times into distances measured in miles, because he will know how fast he walks. We are provided with the information to do this too, since we can guess how fast a fit young man like Adam would walk; it would be at least four miles an hour if, as Mr Casson asserts, he can walk forty miles in a day. After his mother has delayed him on his way to the Hall Farm to see Hetty, 'Adam walked so fast that he was at the yard gate before seven.'⁶¹ Since he has originally set out 'when it still wanted a quarter to seven' we can infer that the distance from the Bede's house is such that Adam would cover it in a quarter of an hour

⁵⁹ Beer, p.xxx.

⁶⁰ *Adam Bede*, p.512.

⁶¹ *Ibid*, p.215.

walking at his normal pace, and therefore about a mile.⁶² Incidentally, although the narrator does not remind us of the Hall Farm time zone here, Adam's time of arrival is presumably half past seven, measured in the local Hall Farm time, and to further complicate the situation, the clock in Adam's house is itself 'always in advance of the day'.⁶³

Hetty wants to know how long it takes to get to Eagledale, where her lover Arthur has gone for a short visit. Adam, who has been to Eagledale, highlights the relative speed of travel by gentry and others, telling Hetty: 'it took us the best part of two days' walking. But it's nothing of a day's journey for anybody as has got a first-rate nag'; this is a contrast that Hetty, sadly, does not seem to hear.⁶⁴ The contrast between walking and riding to Eagledale is paralleled by the contrast between Hetty's walking, even if interspersed with lifts, and Arthur's riding, to Windsor. Hetty arrives tragically too late to catch up with Arthur. This is one of many occasions in Eliot's novels where mathematics plays a crucial part in dramatic events.

Another such occasion concerns Adam's discovery of the love affair between Hetty and Arthur. The day on which this happens is recorded with precision as the 'eighteenth of August'.⁶⁵ This is surely one of Eliot's occasional careless lapses; this day should be a Thursday, the day Hetty goes 'to the Chase to sew with the lady's-maid', but the eighteenth of August 1799 was in fact a Sunday.⁶⁶ Adam's discovery and his subsequent fight with Arthur are the culmination of Adam's movements on that afternoon and evening chronicled by the narrator with forensic attention to timing. Because of Jonathan Burge's sloth in finding a new foreman for his carpentering business, Adam 'of late had done almost double work,' and in consequence Adam does not arrive at the Chase Farm, where he is carrying out repairs, 'till late in the afternoon.'⁶⁷ Adam discovers on arriving, that some roofing, 'which he had calculated on preserving, had given way.'⁶⁸ As a consequence, Adam 'busied himself with

⁶² Ibid, p.214.

⁶³ Ibid, p.43.

⁶⁴ Ibid, p.222.

⁶⁵ Ibid, p.291.

⁶⁶ Ibid, pp.293, 135.

⁶⁷ Ibid, p.292, 293.

⁶⁸ Ibid, p.293.

sketching a plan, and making a specification of the expenses'.⁶⁹ This makes him later than he intended to be and it 'was nearly seven before he had finished'.⁷⁰ He then notices that his brother Seth who has also been working at the Chase Farm has forgotten to take his tools home, which delays him further.

Adam wants to return his pony to the Abbey; the narrator tells us that the 'buildings of the Chase Farm lay [...] at about ten minutes' walking distance from the Abbey', but we can infer that Adam would be quicker having 'come thither on his pony'.⁷¹ He is then detained by Mr Craig. He leaves the Abbey as 'the sun was on the point of setting', perhaps about half past seven on the date given. As he is late, Adam wishes 'to shorten his way home,' and so he decides to go through the Grove, 'where he had never been for years,' and it is because of this that he happens to see Arthur kissing Hetty.⁷² All this discussion of time, speed and implicitly distance emphasises the fact that Adam meets Arthur and Hetty 'twenty yards before him' purely by chance; had any one of many things been different, the meeting would not have happened.⁷³ And yet it is, in another sense, not by chance. George Levine, in an essay about George Eliot's determinism, quotes *The Mill on the Floss*: 'there is nothing petty to the mind that has a large vision of relations, and to which every single object suggests a vast sum of conditions,' which implies, Levine suggests, that 'the most apparently unimportant act may have important ramifications.'⁷⁴ Had Jonathan Burge, or Seth, or Mr Craig, or Adam himself behaved differently, Adam may never have encountered Arthur and Hetty and events may have been very different. But he did. Eliot's use of chance and probability in her novels will be discussed in chapter six.

There are no actual distances in the narrator's account of the eighteenth of August. Distances are difficult to estimate; it is far easier simply to rely on time taken. When Adam goes to Snowfield to propose to Dinah, she is preaching in a neighbouring village. Adam goes to the village to find her and, realising she has not finished preaching, climbs back up the hill she will need to cross to wait for her.

⁶⁹ Ibid, p.294.

⁷⁰ Ibid.

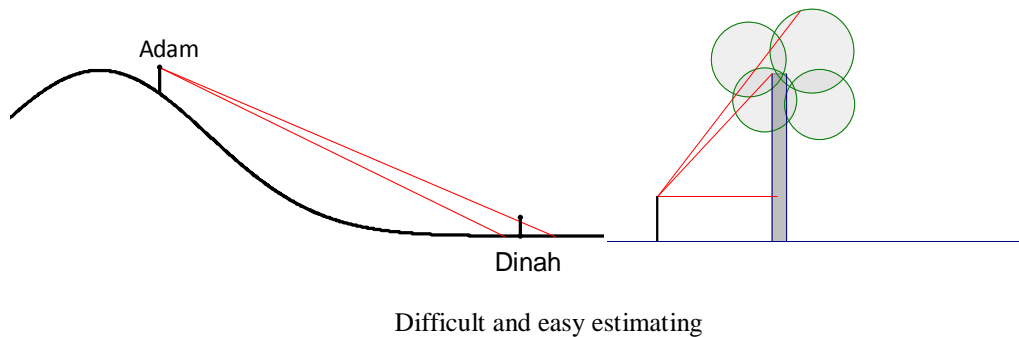
⁷¹ Ibid.

⁷² Ibid, pp.294-5.

⁷³ Ibid, p.296.

⁷⁴ *The Mill on the Floss*, p.273; George Levine, 'Determinism and Responsibility in the Works of George Eliot', *PMLA*, 77:3 (June. 1962), 268-279 (p.272).

He walked back till he got nearly to the top of the hill again, and seated himself on a loose stone, against the low wall, to watch till he should see the little black figure leaving the hamlet and winding up the hill [...] he waited an hour at least [...] At last he saw the little black figure [...] gradually approaching the foot of the hill. Slowly, Adam thought; but Dinah was really walking at her usual pace, with a light quiet step.⁷⁵



While Adam's impatience is quite likely to impair his judgment about Dinah's speed, it is also the case that it is much harder to estimate the speed of distant objects from the top of a hill than it is to estimate the height of a tree, for example, which we know Adam can do to a nicety. One way Adam can judge the height of the tree is to compare its height with his own and use ratio. But measuring a far-away distance covered by Dinah when coming up the hill involves estimating small changes in angle, either consciously or intuitively. Lack of accuracy of observation and over-claiming for the results of experiments, particularly experiments concerning society, is a repeated theme in Eliot's novels.

Surveying

Surveying is a mathematically-focused activity that tells us how the world actually is, something that continually demanded Eliot's attention. Surveying features most notably in *Adam Bede* and *Middlemarch*, and is associated with discovering how things really are.

As a practical man Adam makes frequent use of approximate mathematics. At the Hall Farm, the narrator emphasises the 'superfluity of broad beans' by providing a measure of the length of the plot they grow in, which is 'nine or ten of Adam's

⁷⁵ *Adam Bede*, p.531.

strides'.⁷⁶ Just as Adam can estimate the volume of timber in a trunk, so he would be able to translate a length measured in strides into a serviceable quantity, either because he knows the length of his stride in feet, or because he can perceive the whole of his immediate environment in terms of stride lengths.

The novel abounds with estimates of length, which sometimes use rough-and-ready units of measurement, just the kind of estimates a surveyor might make. Adam has opportunity for exploring the countryside when his 'work [...] lay at a country house about three miles off [...] This little walk was a rest to Adam.'⁷⁷ The narrator suggests that Adam has a surveyor's eye when we are told of his disdain of counties further south, because he has learnt that they are flat, so that 'you can see nothing of a distance, without climbing up the highest trees;' by contrast, because he lives in a hilly county, Adam takes pleasure in the fact that he can 'go to work [...] up a bit of a hill, and see the fields for miles round me.'⁷⁸

Many readers would have been aware of the work of the Ordnance Survey, which had begun mapping England accurately in 1842. George Hemming described the mathematical precision with which the work was carried out in an article in *Bentley's Quarterly Review* in 1860, the year following the publication of *Adam Bede*.⁷⁹ The previous issue of the *Review* published what Eliot judged the best review she had read of *Adam Bede*.⁸⁰ The mapping carried out by the Ordnance Survey made use of triangulation: by accurately measuring angles, triangles can be drawn to show the relative positions of three points within the area being mapped and then those points can be used as the basis for further triangles. What is required to start the process off, so that accurate maps can be produced is a very precise measure of the distance between two points, called a baseline measurement by surveyors. After Adam discovers Hetty's sexual relationship with Arthur, he tells himself: 'I don't know whether I feel the same towards anybody: I seem as if I'd been measuring my work from a false line.'⁸¹ All his distances have been wrong. Adam's use of this metaphor, even in a moment of crisis,

⁷⁶ Ibid, p.218.

⁷⁷ Ibid, pp.207-8.

⁷⁸ Ibid, p.120.

⁷⁹ George Hemming, 'The Ordnance Survey', *Bentley's Quarterly Review*, 2 (January, 1860), 335-68.

⁸⁰ GEL, 3: pp.148, 213-4; [Anne Mozley], 'Adam Bede and recent novels', *Bentley's Quarterly Review*, 1 (July, 1859), 433-472 (pp.434-7).

⁸¹ *Adam Bede*, p.317.

demonstrates his deep familiarity with the technicalities of surveying: if the baseline is measured badly, then all the subsequent calculations based on it are falsified.

The repeated references to times and distances in the novel give readers a surveyor's sense of the layout of Hayslope and the surrounding area. In discussing the 'landscape of reality', Levine tells us how the 'landscape painter must begin by lying on the ground and learning to draw a blade of grass accurately'.⁸² Eliot's first novel intimates realism by the care taken by Adam to 'map' his environment; this includes his human environment, even though he sometimes gets this fatally wrong. This sense of landscape realism is enhanced by the narrator's habit of conducting the reader to the geographical location of the next scene. 'Let me take you into that dining-room' of Rev. Adolphus Irwine, is one invitation the narrator gives the reader. 'We will enter very softly, and stand still in the open doorway.'⁸³ This may well make the reader feel like a trespasser, but a little later, the narrator assures the reader that 'imagination is a licensed trespasser', and in consequence, both narrator and reader are apparently entitled to 'climb over walls and peep in at windows' at the Hall Farm.⁸⁴ If readers in 1859 imagined themselves to be professional surveyors then they were entitled to trespass: the Survey Act of 1841 facilitated the conduct of the Ordnance Survey by licensing any 'person appointed by [...] the board of ordnance [...] to enter into [...] any land, ground or heritages of any person or persons whomsoever'.⁸⁵ This right to survey was often contested, as Eliot intimates: 'The submarine railway may have its difficulties; but the bed of the sea is not divided among various landed proprietors'. The railway surveyors in *Middlemarch* were set upon by local farm workers encouraged by the landowner Solomon Featherstone.⁸⁶

Optics

Eliot alludes to optics in several of her novels. There are a number of instances in Eliot's novels to support Bonaparte's suggestion, mentioned in my introduction, that

⁸² George Levine, *The Realistic Imagination: English Fiction from Frankenstein to Lady Chatterley* (Chicago and London: University of Chicago Press, 1981), p.211.

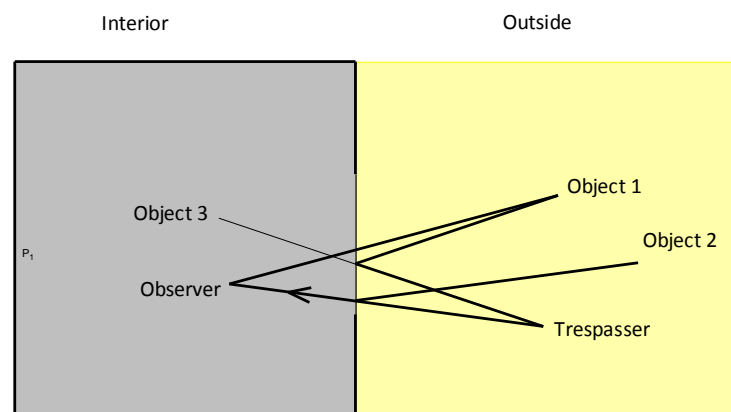
⁸³ *Adam Bede*, p.54.

⁸⁴ *Ibid*, pp.71-2.

⁸⁵ 'Survey Act 1841', <http://www.legislation.gov.uk/ukpga/Vict/4-5/30/section/2> (Accessed: 3-2-14).

⁸⁶ *Middlemarch*, p.519 et seq.

altruists, like Dinah, look through windows and egoists, like Hetty, look in mirrors. However, this equation needs to be qualified somewhat, given the wide variety of ways in which Eliot uses windows, and for that matter mirrors, in her novels. When readers of *Adam Bede* first make their acquaintance with the Hall Farm, they are given the instruction: ‘Put your face to one of the glass panes in the right-hand window’.⁸⁷ Here the narrator is inviting the reader to conduct a scientific experiment in mathematical optics. Why do readers need to put their faces to the window, in a manner that might produce cold noses and smudges from their breath on the pane? Because, on a bright day, observers will not see into the interior of a room through a window unless they do this; instead they will see reflections of what is outside.



‘Put your face to one of the glass panes’

The explanation is as follows. All objects that can be seen reflect light, which is why we can see them. But ordinary window glass allows most light to pass through it; about five per cent of the light is reflected. So if you are inside a room that is darker than the daylight outside, the light coming from outside is much stronger than the light coming from objects in the room and being reflected by the window. Consequently a person inside the room will see a person outside, for example: an imagined observer standing in the front room of the Hall Farm can see the imagined reader trespassing. The arrow in the diagram indicates the light coming from the Trespasser outside to the Observer inside. Similarly, light comes from Object 1 to the Observer (and from Object 2). However, if the light outside is significantly brighter than the light inside, then although some light is transmitted from the Observer or from Object 3 to the Trespasser, even the five percent of the light reflected by the window from the outside Objects 1 and 2 will

⁸⁷ *Adam Bede*, p.72.

dwarf the light coming from within the room, and consequently these objects prevent the Trespasser from seeing what is in the room. By looking from a position up against the glass, trespassers prevent light from outside entering their eyes and so they do see what is within. There is a similar instance in *Felix Holt*, when the narrator tells the reader what happens when we are not close to the window, by describing ‘little dingy windows telling, like thick-filmed eyes, of nothing but the darkness within’.⁸⁸ I have given this explanation in some detail, because variations on this arrangement appear in other of Eliot’s novels, in *Romola* and *Middlemarch* in particular, as we shall see later.

The view through the window of the Hall Farm seen by the trespasser is of an abandoned ‘parlour’ and the true function of the building can only be ascertained by changing our point of view and focusing from where life now radiates, which is no longer the parlour, but ‘the kitchen and the farmyard’.⁸⁹ To excuse the ‘impropriety’ in one of his novels, Stendhal describes a novel as ‘a mirror going along a main road. Sometimes it reflects [...] the azure of the sky, sometimes the mud.’⁹⁰ This is deliberately disingenuous: what the mirror reflects will depend as much on how it is angled as on what is there to be reflected: change your point of view and you will see something different. This is true when Hetty looks at herself in her mirror. The ‘old-fashioned’ blotched glass in Hetty’s bedroom is fixed down. Hetty cannot angle it as she will, and so, although this mirror provides all that is ‘needful’ for what Hetty has to do: ‘brush her hair and put on her nightcap’, Hetty chooses instead to use a small ‘shilling looking-glass, without blotches’, to help her let down her hair.⁹¹ Mirrors were relatively expensive in 1900: a shilling, in today’s terms perhaps five pounds, is the cost of Hetty’s small looking-glass. When Hetty wants to see more of herself she has to revert to the ‘old mottled glass’, since it is a mathematical fact that, whatever your point of view, when you look in a small glass, you can only see the same limited amount of yourself at one time. By contrast, affluent Arthur is able to see ‘his well-looking British person reflected in the old-fashioned mirrors’.⁹² ‘Old-fashioned’ here is a completely different signifier, pointing to prestige rather than damage and limited usefulness. Arthur, literally and metaphorically, can see all of himself at once; he is aware of his

⁸⁸ *Felix Holt*, p.6.

⁸⁹ *Adam Bede*, p.72.

⁹⁰ Stendhal, *The Red and the Black*, trans. by Catherine Slater (Oxford: OUP, 1991), pp.370-1.

⁹¹ *Adam Bede*, pp.149-50.

⁹² *Ibid*, p.124.

lust for Hetty and he is aware that he should be fighting it. And so he is more responsible than Hetty, who can only see part of herself, for what befalls them.

The *Adam Bede* narrator describes events ‘as they have mirrored themselves in my mind’. Given what we have already been told about Hetty’s mirrors, we are not surprised to be told that the mirror being used to tell the story is ‘doubtless defective’; however, the narrator tells us that he is ‘bound to tell you, as precisely as I can, what that reflection is’. The description of the defective mirror is reminiscent of, and could well be a satire on, Stendhal’s mirror. But the narrator is like Stendhal’s narrator to the extent that there is no intention to touch up the image to make it more ‘accordant with those correct views which it is our privilege to possess’.⁹³ This is surely ironic; the narrator is warning the reader that the novel will satirise mid-Victorian Britain too, whose point of view is no less defective than that at the start of the century.

In order to see what we need to see, we sometimes need not only to change our point of view, but also to see things in a different light; Galileo could not look through his telescope at the moon when the sun was shining. Hetty, whom Adam is in love with, and Dinah are both living at the Hall Farm; but Dinah, good Methodist that she is, visits Adam’s mother in their home after his father dies. This is how the narrator describes Adam’s reaction to Dinah during the visit.

It was like dreaming of the sunshine, and awaking in moonlight. Adam had seen Dinah several times, but always at the Hall Farm, where he was not very vividly conscious of any woman’s presence except Hetty’s [...] But now her slim figure, her plain black gown, and her pale serene face, impressed him with all the force that belongs to a reality contrasted with a preoccupying fancy.⁹⁴

Like Galileo, Adam discovers new worlds when sunshine is replaced by moonlight. The sunlight attracts him to his beloved Hetty, but it is Dinah that Adam sees by moonlight, light long associated with romance and sexual attraction. And this is what Adam and Dinah both experience in spite of themselves: ‘Dinah, for the first time in her life, felt a painful self-consciousness [...] A faint blush came, which deepened as she wondered at it.’⁹⁵ And for Adam, a surreal sunlit dream is here superseded by gentle moonlit reality.

⁹³ Ibid, pp.175-6.

⁹⁴ Ibid, p.116.

⁹⁵ Ibid, p.117.

In her other novels, too, Eliot repeatedly suggests seeing things from a different point of view or in a different light. One chapter of *The Mill on the Floss*, for example, is entitled ‘Wakem in a New Light’, a chapter that encourages the reader to see in the lawyer something other than the unmitigated scoundrel Mr Tulliver sees. Eliot’s enjoinder to change how you look at things culminates, as will be discussed later, in the pier-glass image in *Middlemarch*.

Mathematics education

What Eliot says about mathematics education in *Adam Bede* provides an insight into both how Eliot learnt mathematics and what Eliot thinks mathematics and mathematics education are. When Adam meets Arthur on the road, they discuss the education each of them has had, and Arthur tells Adam: ‘I think your life has been a better school to you than college has been to me.’ In reply, Adam tells Arthur something Bartle Massey the night-school master has told him: ‘college mostly makes people like bladders - just good for nothing but t’ hold the stuff as is poured into ’em.’⁹⁶ This conversation raises two issues about education. The first is the value of practical and autodidactic education in comparison with college or university education, and from this viewpoint it is worth noting that even on the day he met Adam, Arthur was not in a frame of mind to learn, since unconsciously he was preparing himself to avoid taking the rector’s advice about giving up his sexual interest in Hetty. The second is a related pedagogical insight: people do not learn very well if they are simply told things or made to practise procedures they do not understand. Augustus De Morgan sees this as applying particularly to the learning of mathematics in schools:

the pupil having worked unmeaning and useless questions by slatesful for some four or five years, comes out master of a few methods, provided he knows what rule a question falls under, which is not always sure to be the case, for in all probability, the first application which it is necessary he should make will be a combination of more rules than one, and, therefore, not exactly to be solved by the rule in his book.⁹⁷

⁹⁶ Ibid, pp.167-8.

⁹⁷ [Augustus De Morgan], ‘On Mathematical Instruction’, *Quarterly Journal of Education*, 1 (April, 1831), 264-269 (p.268).

Bartle Massey expresses a similar point of view when lambasting the two youths who are learning accounts: ‘you’ll come and pay Bartle Massey sixpence a-week, and he’ll make you clever at figures without your taking any trouble. But knowledge isn’t to be got with paying sixpence, let me tell you: if you’re to know figures, you must turn ’em over in your own heads [...] There’s nothing you can’t turn into a sum’. Massey challenges the youths to invent questions such as this: ‘if my fool’s head weighed four pound, and Jack’s three pound three ounces and three-quarters, how many penny-weights heavier would my head be than Jack’s?’ This is not only Massey challenging the youths: it is also Eliot challenging the reader. Here is another mathematics problem in *Adam Bede* for the reader to solve; and, of course, the reader is to solve the problem ‘in his head’.⁹⁸ Readers would need to know that a troy pound, in common use in 1799, but not in use at all by 1859, any more than today, has twelve ounces and that there are twenty pennyweights to the troy ounce. This is one of several mathematics problems Eliot sets readers of *Adam Bede*.⁹⁹ In doing this, Eliot is seemingly manifesting the beliefs of her Bartle Massey character that ‘[t]here’s nothing you can’t turn into a sum’, and is providing a mathematical education for her interested readership!

Mention has already been made of how Adam’s practical ability with mathematics is similar to that of Eliot’s father. John Cross describes what the young Mary Anne Evans learnt in the home. Although, in her ‘baby-days’ she was not ‘precocious in learning [...] because she liked playing so much better’, by the time she was five, her father, ‘already proud of the astonishing and growing intelligence of his little girl’, took her ‘with him in his drives about the neighbourhood’.¹⁰⁰ It was doubtless during such excursions that Eliot became acquainted with her father’s mathematical abilities and, equally significantly, extended her own abilities. De Morgan criticises the way in which young children are often introduced to numbers: ‘A child learns from his nurse or his mother our method of representing numbers, by a plan of teaching which makes two symbols such as 16 and 25 nearly as independent of one another in his head as the ideas attached to the words “book” and “steam engine”’.¹⁰¹ In other words, the number

⁹⁸ *Adam Bede*, p.236.

⁹⁹ Two others are: the problem concerning Mr Casson, the earth and the moon; and estimating the volume of wood in a tree trunk.

¹⁰⁰ Cross, 1: pp.14-15, 18.

¹⁰¹ De Morgan, p.266.

sequence is not introduced in a way that makes sense of it. Eliot will have learned about numbers in a very different way from her relationship with her practical father.

Eliot built on the basis of the mathematics she obtained from her conversations with her father and from a moderate amount of schooling, largely by means of her own reading and study. In an essay in the *Nineteenth Century* about George Eliot, Lord Acton relates how ‘the mathematician who came to give her lessons found she was already in the differential calculus.’ Acton comments that, being an autodidact, Eliot sometimes got Latin, Italian and history slightly wrong.¹⁰² This would not have been the case with her mathematics: De Morgan tells us that while the ‘same species of logic is used in all inquiries after truth’, mathematics is different from other subjects because ‘the data or assumptions of the first are few, understandable and known to the student from the beginning [...] they require no induction from facts which can be disputed.’¹⁰³ In other words, mathematics particularly lends itself to being well understood, even by those who are self-taught.

Playing with mathematics

A thorny and confused problem in mathematics education, as much now as in Victorian Britain, is the extent to which learners should be encouraged to develop their own understanding of mathematics. Clearly, Mr Stelling in *The Mill on the Floss* does not think they should, and more will be said about that in the next chapter. Alice Jenkins points out that Tom Tulliver does develop his own understanding of mathematics, prior to and in spite of Mr Stelling.¹⁰⁴ Jenkins refers to Hannah More, a writer on the education of girls, about whom Eliot changed her mind quite dramatically, describing her to Maria Lewis as ‘so blessed a character’ in 1838, but by 1848 telling John Sibree that she is ‘that most disagreeable of all monsters, a blue-stocking’ with ‘a smattering of learning’.¹⁰⁵ Jenkins quotes More’s book about girls’ education, published in 1799, the same year in which *Adam Bede* was set, suggesting that More would not have approved of the informal way in which Tom first acquired his

¹⁰² Acton, ‘George Eliot’s “Life.”1’, *Nineteenth Century*, 17 (March, 1885), 464-85 (pp.471-2).

¹⁰³ De Morgan, p.265.

¹⁰⁴ Alice Jenkins, ‘George Eliot, Geometry and Gender’, in *Literature and Science*, ed. by Sharon Ruston (Cambridge: Brewer; The English Association, 2008), pp.72-90 (p.88).

¹⁰⁵ GEL, 1:pp.7, 245.

mathematical knowledge: ‘we cannot cheat children into learning or play them into knowledge according to the smoothness of the modern creed’.¹⁰⁶ Interpreting this statement as supportive of the education offered by Mr Stelling may not be an accurate representation of More’s position. The sentence quoted is preceded by this passage, about pupils being spoon-fed by instructors and books:

Where so much is done for them, may they not be led to do too little for themselves? May there not be a moral disadvantage in possessing them with the notion that learning may be acquired without diligence and labour? Sound education never *can* be made a “primrose path of dalliance.”¹⁰⁷

By quoting Ophelia, who herself alludes implicitly to the New Testament reference about the ‘wide’ gate and the ‘broad’ way ‘that leads to destruction,’¹⁰⁸ More suggests that a pupil’s progress is ensured only if the pupil ‘strive[s] to enter by the strait gate.’¹⁰⁹ This is about self-control and not control by another. It is a belief closer to Bartle Massey’s views about colleges treating learners as bladders, and his advice to his youths, than to Mr Stelling’s teaching, and is in keeping with Tom Tulliver’s determined self-education: nobody could strive harder than Tom. That More is writing at least partly about mathematics education is suggested by her subsequent referral to Euclid’s apocryphal reply to Ptolemy that there is ‘no royal road to geometry’.¹¹⁰

Eliot would surely have agreed with More about not cheating children into learning. Adam is echoing More when he says: ‘It’s the same with the notions in religion as it is with math’ematics, – a man may be able to work problems straight off in ’s head [...] but if he has to make a machine or a building, he must have a will and a resolution’.¹¹¹ One possible source of confusion when interpreting More’s remark arises from different meanings of the word ‘play’. Ophelia does not want Laertes to be allowed to play his time and money away. But Bartle Massey does want his youths to play with mathematical ideas in their heads. As has already been noted, John Cross tells us that Eliot’s play in her ‘baby days’ resulted in her exhibiting ‘astonishing and growing

¹⁰⁶ Jenkins, p.86.

¹⁰⁷ Hannah More, *Strictures on the Modern System of Female Education*, 2 vols. (London: Cadell and Davies, 1799), p.155. More is quoting *Hamlet*, Act 1, Scene 3, 47-51.

¹⁰⁸ Matthew 7. 13-14.

¹⁰⁹ Luke 13. 24.

¹¹⁰ More, p.155.

¹¹¹ *Adam Bede*, p.180.

intelligence' by the age of five.¹¹² Although Cross perhaps does not see it as clearly as this, so-called play is a vital part of the learning of young children. Eliot believed that the kind of play that is creative self-motivated exploration remains an important tool for learning at a later stage. In Geneva, Marian Evans's daily regime was to 'play on the piano [...] and just take a dose of mathematics every day to prevent my brain from becoming quite soft.'¹¹³ Play is here associated with serious work. No doubt Eliot taught herself mathematics by playing around with it, just as she played around with mathematics when writing her novels.

Learning and teaching for men and women

On the other hand, Eliot did not believe that self-directed play was the only way or necessarily the best way of learning. Eliot valued being taught and believed that some teaching was indispensable, and should be available for women as well as for men. Writing to Maria Lewis in 1841, during her evangelical Christian period, she insisted that it was 'folly to talk of educating children without giving their opinions a bias.'¹¹⁴ Later, in 1847 she told Sara Hennell: 'I think "Live and Teach" should be a proverb as well as "Live and Learn". We must teach either for good or evil, and if we use our inward light as the Quaker tells us, always taking care to feed and trim it well our teaching must in the end be for good.'¹¹⁵ In 1851 Eliot attended a course of lectures on geometry 'every Monday and Thursday. You will say that I can't afford this, which is "dreadful true",' she told the Brays in a letter, indicating that she judged this an important thing for her to do.¹¹⁶

The trade-off between needing the support of others and learning for yourself is illustrated in *Adam Bede* through Adam's relationship with Bartle Massey. Adam visits his old night-school teacher to debate issues with him; he needs the teaching and advice Bartle gives him: for example, he tells Bartle: 'There is a good deal o' sense in what you say,' when he is advised not to turn 'your nose at every opportunity, because it's

¹¹² Cross, p.13.

¹¹³ GEL, 1: p.321.

¹¹⁴ GEL, 1: p.91.

¹¹⁵ GEL 1: p.242.

¹¹⁶ GEL 1: p.343.

got a bit of a smell about it.’¹¹⁷ On the other hand, he is happy to challenge Bartle about Bartle’s lack of reasonableness, as exemplified by his extreme views about women: ‘don’t be so hard on the creaturs God has made to be companions for us.’¹¹⁸ According to De Morgan, Adam as a mathematics student of Bartle’s is in a particularly strong position to do this, since pupils should study mathematics ‘[p]recisely that they may learn to raise objections, and how to raise them in the proper place, when false logic and absurd definitions make objections desirable.’¹¹⁹ Mathematics can give pupils the will, the resolution and the equipment to think for themselves.

One early reader of *Adam Bede* who appreciated the mathematics, and indeed the mathematics education, in the novel was Thomas Tate, who sent Eliot via her publisher a copy of one of his books on *The Philosophy of Education*.¹²⁰ Tate was an educationalist interested in how we learn mathematics. The historian of mathematics Geoffrey Howson singles him out as particularly influential on elementary mathematics education in the Victorian period: Tate edited a weekly column in the *York Courant* between 1828 and 1846, setting mathematics problems that became increasingly harder; and a course of classes he gave for boys between the ages of twelve and fifteen included such topics as the best kind of gravel for making a path, the properties of the lever, and the use and construction of a wheelbarrow, a course of which Adam Bede and Eliot’s father would both have thoroughly approved.¹²¹

That Eliot and her partner George Lewes believed learners need to take a large measure of responsibility for what they learn at school is further evidenced by the Leweses sending two of their sons to Hofwyl School in Switzerland: in 1856, Eliot thanked Hennell for sending a brochure about Hofwyl School and told her they had ‘almost decided to send the two eldest boys there’.¹²² In 1818, Henry Brougham described how, in this school, procedures where teachers are ‘preserving [...] watchful attention, and at the same time leaving the pupil free from any sense of restraint, are

¹¹⁷ *Adam Bede*, p.245.

¹¹⁸ *Ibid*, p.239.

¹¹⁹ De Morgan, p.271.

¹²⁰ GEL, 8:226.

¹²¹ Geoffrey Howson, *A History of Mathematics Education in England* (Cambridge: CUP, 1982), pp.98-100.

¹²² GEL, 2:236.

among those processes which no description can adequately represent'.¹²³ Doubtless changes were made in the school between 1818 and 1856, but the prevailing ethos is unlikely to have altered much: Mr Fellenberg, the director in 1818, did not retire until 1855.¹²⁴

Hannah More's 1799 book was about the shortcomings of the education of girls, even though, in her introduction, More conceded to hypothetical objectors to her book 'that many errors are here ascribed to women which by no means belong to them *exclusively*, and that it has seemed to confine to the sex those faults which are common to the species.'¹²⁵ Exactly the opposite can be said of *Adam Bede*, which presents strengths and weaknesses in the mathematics education of men, but makes little mention of women. Indeed, Bartle Massey, in a discursive diatribe against women, suggests that educating women in mathematics would be a futile enterprise: women have 'no head pieces to nourish,' and are incapable of learning mathematically-based truths from experience – 'a woman 'ull bake you a pie every week of her life, and never come to see that the hotter th' oven the shorter the time.'¹²⁶ This explosion of vitriol is sufficiently extreme to be taken by the reader as a satire on Bartle Massey rather than on women's ability to learn mathematics. Eliot's views on the educability of girls could not have been more different from Bartle Massey's: education, and particularly the education of girls, was one of Eliot's enduring passions.

This chapter has demonstrated how Eliot introduces mathematical themes: time and speed, optics, mathematical education, data handling, geometry – themes which reappear in later novels and contribute to Eliot's aim of examining society and challenging some of the beliefs about it. The neglect of women's mathematical education in *Adam Bede* is remedied by its treatment in Eliot's second novel, *The Mill on the Floss*, to which I shall now turn.

¹²³ [Henry Brougham], 'Mr Fellenberg's establishments at Hofwyl', *Edinburgh Review*, 31 (December, 1818), 150-165 (p.153).

¹²⁴ GEL, 2: p.236.

¹²⁵ More, p.x.

¹²⁶ *Adam Bede*, pp.238-246, especially pp.239, 240.

Chapter Two

‘Thick-rinded fruit of the tree of knowledge’: theoretical geometry and practical mathematics in *The Mill on the Floss*

Geometry is the branch of mathematics most concerned with reasoning from postulates. What mattered to Victorians were the believability of the postulates and the soundness of the reasoning. In her novel writing Eliot increasingly uses geometry as a metaphor for discussing the reasoning involved in what is known about society and what is merely conjectured. This chapter will consider how, in *The Mill on the Floss*, Eliot uses logical patterning and logical reasoning to raise social issues, one of which is the teaching of geometry – to girls as well as to boys.

When Mr Riley visits Mr Tulliver on business, Mr Tulliver takes the opportunity to get Mr Riley’s advice about a suitable education for his son Tom, but they are distracted by the presence of his daughter Maggie, the central character of George Eliot’s second novel, *The Mill on the Floss* (1860). Maggie shows off her ability to read Daniel Defoe’s *The History of the Devil*, which Mr Riley regards as unsuitable literature for a little girl. ‘Have you no prettier books?’ he asks Maggie. When told that *The Pilgrim’s Progress* is a far more suitable book for her, Maggie triumphantly points out to Mr Riley that this book also has ‘a great deal about the devil’ in it, at which point she is sent away by her father to ‘see after [her] mother’.¹ The problem for Maggie is that, because of her considerable intellectual abilities and because of the way she uses them, her family sees ‘a great deal about the devil’ in Maggie; her education is a major theme in the novel. Maggie’s logical argumentation exemplifies a strand of thinking in the novel, a novel which addresses the teaching of geometry, and also the logic of social class and of human inheritance, especially in relation to gender.

The first conversation in the novel, which is between Mr and Mrs Tulliver, concerns the problem, as Mr Tulliver sees it, of providing a suitable education for their son Tom.

¹ *The Mill on the Floss*, pp.18-9.

What rapidly becomes clear is the inappropriateness of the education received by both the siblings, and we become increasingly aware of the consequences of this. This is a novel about knowledge and ignorance, about wisdom and worldly wisdom. It is also a novel about reasoning and faulty reasoning, and about education, which might or might not include teaching reasoning. Since, for a while, both Tom's and Maggie's educations include Euclid, this is another novel in which George Eliot writes about the learning of mathematics, but with the focus moving to embrace the complexities of geometry education, and also the education of girls. I shall address issues concerning the nature of geometry, and look at different ways people acquire a geometrical education. The novel also uses descriptions of mathematics education as a means of commenting on explicit and implicit social education more generally, and on the implications of the separate spheres in which middle-class men and women operated, particularly in provincial society.

Ladder of ignorance

Eliot makes frequent, often ironic, use of logical structuring within her novels, in order to overturn easy assumptions. Avrom Fleishman suggests that in *The Mill on the Floss* George Eliot has a keen sense of 'class distinctions, even within the bourgeoisie'.² Each of the Dodson sisters - Maggie's mother and aunts - has a different position on a hierarchical class ladder, with Maggie's mother at the bottom. Late in the novel Maggie ascends this ladder by spending periods of time with different aunts; ending up at the top of the Dodson ladder with Aunt Deane turns out to be her downfall.³ Eliot constructs a similar hierarchical ladder concerning Tom's education: again it is a hierarchy of class distinction, which is also a hierarchy of charlatanism. This ladder, which I am about to describe, sets out exactly what Eliot thinks education is not, while, ironically, Maggie's interruptions concerning the devil, which come from the inquiring and interested mind of an autodidact, provide an indication of what education is or should be. This sets the stage for Eliot's depiction of the teaching of Euclidean geometry according to the methods of Mr Stelling.

² Avrom Fleishman, *George Eliot's Intellectual Life* (Cambridge: CUP, 2010), pp.102-3.

³ Ibid.

In the opening conversation between Mr and Mrs Tulliver already alluded to, Mr Tulliver is frustrated by his wife's obtuseness on the subject of finding a suitable school for Tom. He tells her 'I should like Tom to be a bit of a scholar, so as he might be up to the tricks o' these fellows as talk fine and write with a flourish', while her concern is that he should 'go where I can wash him and mend him'.⁴ At first we are seduced into taking Mr Tulliver's side in this debate, and sharing his opinion that his wife's thinking is somewhat shallow. However, as events unfold we realise that Mr Tulliver's thinking about Tom's education is not much deeper than his wife's, and that she has a point when she expresses concern about an education requiring boarding too far from home, or even boarding at all. For Mr Tulliver, it is 'an uncommon puzzling thing to know what school to pick [...] I'll talk it over wi' Riley'.⁵ Mr Tulliver's puzzle was not at all uncommon, as Augustus De Morgan explained:

Why are so many proprietary schools erected? The reason is, that parents, who have neither time to choose, nor knowledge to guide them in the choice, of a place of instruction for their children, find it easier to found a school, and make it good, than run the doubtful chance of placing their sons where they may learn nothing to any purpose.⁶

The novel's narrator later declares that education 'was almost entirely a matter of luck - usually of ill luck' for those 'old-fashioned fathers, like Mr Tulliver, when they selected a school or a tutor for their sons'.⁷ The Mr Riley alluded to, who provides professional services for Mr Tulliver, is 'rather highly educated for an auctioneer and appraiser'.⁸ Mr Tulliver is impressed by Mr Riley for the not necessarily helpful reason that Mr Riley 'knows a good lot o' words as don't mean much, so as you can't lay hold of 'em i' law'; Mr Tulliver whose loathing of lawyers is based on 'questionable conclusions' about them, clearly wants Tom to learn Mr Riley's art in combating them.⁹ Mr Tulliver's description of Mr Riley is all too accurate, since it aptly describes the advice Mr Riley offers about Tom's schooling - it 'don't mean much'. In responding to Mr Tulliver's request, Mr Riley takes the opportunity to advance the prospects of a

⁴ *The Mill on the Floss*, pp.9, 10.

⁵ *Ibid*, p.11.

⁶⁶ [Augustus De Morgan], 'On Mathematical Instruction', *Quarterly Journal of Education*, 1 (April 1831), 264-269 (pp.264-5); quoted in Geoffrey Howson, *A History of Mathematics Education in England* (Cambridge: CUP, 1982), p.88. It is notable that there are several echoes of this essay of De Morgan in Eliot's first two novels.

⁷ *The Mill on the Floss*, p.168.

⁸ *Ibid*, p.14.

⁹ *Ibid*, pp.11-12, 15.

clergyman friend, Mr Stelling, whose wife he has known since childhood. If Mr Riley does not know much about education, he is more aware of the workings of the world than Mr Tulliver, and does know how to provide advice which is to his own best advantage. He begins by genuinely believing that his recommendation for Tom's education is sensible and worth the outlay: 'there's no greater advantage you can give him than a good education', is his clichéd advice, later retailed by Mr Tulliver to Mr Glegg: 'Tom's eddication 'ull be so much capital to him', which, as we learn later, is just what it will not be.¹⁰ As Mr Tulliver raises further objections, Mr Riley becomes increasingly duplicitous, adopting the patter of a sales representative: 'I wouldn't mention the chance to everybody', he avers. Mr Riley explains to Mr Tulliver that Mr Stelling knows about mathematics because he is 'an Oxford man' and he will suit Tom because he is 'fond of teaching, and wishes to keep up his studies'. This last statement is patently pure invention, but apparently goes some way to mollifying Mr Tulliver. When Mr Tulliver objects that an Oxford clergyman might be 'too high-learnt to bring up a lad to be a man o' business', who will 'know 'rethmetic' he responds by declaring that 'when you get a thoroughly educated man like Stelling, he's at no loss to take up any branch of instruction', which is the exact opposite of the truth, because Mr Stelling knows 'the only right way' to teach Tom; 'he had not wasted his time in the acquirement of anything abnormal'.¹¹ After he has left Mr Tulliver Mr Riley appears to feel some remorse, remembering that it is not Oxford but 'Cambridge men who were always good mathematicians' but consoling himself with the observation that 'if you deliver an opinion at all, it is mere stupidity not to do it with an air of conviction'; the narrator remarks ironically that it would be unreasonable to expect 'scrupulosity which is not always exhibited [...] even in our present advanced state of morality'.¹² When Mr Tulliver does finally meet Mr Stelling, he - unlike the reader - is inappropriately impressed by Mr Stelling's 'off-hand, matter-of-fact way' of talking and is fobbed off with meaningless generalised reassurance: 'You want your son to be a man who will make his way in the world.'¹³

¹⁰ Ibid, pp.16, 71.

¹¹ Ibid, pp.20-23, 139.

¹² Ibid, pp.26-7.

¹³ Ibid, p.136.

In the end, even Mrs Tulliver is persuaded by ‘Mrs Stelling’s views as to the airing of linen’ that the educational arrangement is satisfactory for Tom.¹⁴ Previously, she has been troubled by Mr Riley’s information that Mr Stelling is ‘fifteen miles’ from Dorlcote Mill. Mrs Tulliver’s practical geometry is very different from the theoretical geometry Mr Stelling will offer Tom. It consists of mentally drawing a circle around Dorlcote Mill; if Tom went to school inside that circle it would be near enough for her to ‘wash him and mend him’, but fifteen miles is ‘too far off for the linen’.¹⁵ In an article about the geometry in *The Mill on the Floss*, Alice Jenkins points to a passage in the novel that describes the practical mathematical abilities possessed by Tom and, as we shall see, ignored by Mr Stelling:

Tom could predict with accuracy what number of horses were cantering behind him, he could throw a stone right into the centre of a given ripple, he could guess to a fraction how many lengths of his stick it would take to reach across the playground, and could draw almost perfect squares on his slate without any measurement.¹⁶

Since Mr Stelling will take no notice of Tom’s practical geometrical ability, but instead will provide an education that fails to educate Tom, it may be that, far from being the silliest person at the bottom of the ladder of advice about Tom’s education, Mrs Tulliver should be at the top: Mr Tulliver might have heeded her from the start and Tom might have stayed at home where she could ‘wash him and mend him’.

Mr Stelling’s inappropriate geometry

Mr Stelling’s teaching of geometry is a vehicle for Eliot to explore societal assumptions about how we learn about the world. Tom’s practical geometrical abilities require mathematical intuition, which would prove useful in applying mathematics in a number of real-life contexts, and is precisely what Mr Tulliver hopes Mr Stelling will enhance. Mr Tulliver recognises that Tom’s abilities do not indicate an education involving difficult reading or abstract reasoning, but that Tom nevertheless has the persistence to learn, and to be ‘a sort o’ engineer, or a surveyor’, for example.¹⁷ The

¹⁴ Ibid, p.137.

¹⁵ Ibid, pp.10, 24.

¹⁶ Ibid, p.139; Alice Jenkins, ‘George Eliot, Geometry and Gender’, in *Literature and Science*, ed. by Sharon Ruston (Cambridge: Brewer; The English Association, 2008), pp.72-90 (p.81).

¹⁷ *The Mill on the Floss*, p.9.

narrator suggests that Tom's powers of perception are 'quite as strong as those of the Rev. Mr. Stelling'; Tom 'had never found any difficulty in discerning a pointer from a setter, when once he had been told the distinction'.¹⁸ An education for the middle classes which included an emphasis on the practical application of geometry and which might have suited Tom was no new idea; in 1752 Isaac Watts suggested that youths should 'know something of geometry, so far at least as to understand the names of various lines and angles, surfaces and solids' and 'some of the most general properties', because 'this sort of language is often used in common writings and in conversation' and also because this is needed to make 'an acquaintance with the arts of surveying, measuring, geography and astronomy'.¹⁹ It is likely that Tom would have taken such a curriculum seriously and benefited from it. After all, Tom is a boy of serious intent, whose intention is not only to please Mr Stelling but also to learn, praying: 'please to make me always remember my Latin', even though Latin is as much a mystery to him as Mr Stelling's geometry.²⁰

As it is, Mr Stelling 'took no note' of Tom's actual ability, in spite of reportedly telling Mr Tulliver that 'teaching comes natural to him'.²¹ He does not recognise what Mr Tulliver recognises, that Tom has 'got a notion o' things out o' door, an' a sort o' common-sense, as he'd lay hold o' things by the right handle. But [...] he reads but poorly, and can't abide the books'.²² Instead, Mr Stelling presents Tom with his version of an education in Euclid. This version makes great demands on Tom's memory and his ability to reproduce what he is told rather than understand it. When Tom's sister Maggie visits Tom, she picks up his copy of Euclid and suggests she would understand it 'if I'd learned what goes before, as you have'. Tom puts Maggie right: 'it's all the harder when you know what goes before: for then you've got to say what definition 3 is and what axiom V. is.'²³ De Morgan satirises this ineffective style of teaching geometry:

The propositions are also said by rote, for the convenience of those who find their memory in a better state than their reason [...] But the prime feature of the system, though now somewhat obliterated, was

¹⁸ Ibid, p.139.

¹⁹ Quoted in Howson, pp.50-1.

²⁰ *The Mill on the Floss*, p.142.

²¹ Ibid, pp.139, 138.

²² Ibid, p.20.

²³ Ibid, p.147.

the necessity of recollecting the numbers of all the propositions; for it could clearly be of no advantage to know, that three angles of a triangle are equal to two right angles, unless it was also known that this is the thirty-second of the first book.²⁴

Tom, who in no way sets out to be a reluctant scholar, tells his father that Euclid is ‘a book I’ve got to learn in - there’s no sense in it’.²⁵ Mr Stelling makes no change in his approach, even when he realises that Tom is not learning: a ‘method of education sanctioned by the long practice of our venerable ancestors was not to give way before the exceptional dulness of a boy’.²⁶ But De Morgan warns teachers that ‘the boy ought never to be suffered to imagine that he is stupid, because he does not immediately see what is put before him’; the teacher’s methods should not be such as ‘to dishearten the well disposed, or to give the indifferent pupil an excuse for making no progress, by laying the blame on his faculties’.²⁷ George Spencer makes a similar remark in his introduction to his *Inventional Geometry* (about which more will be said shortly), using a horticultural metaphor that portrays the learner as a semi-hardy plant to be protected from harmful treatment: ‘The inventive power grows best in the sun shine of encouragement. Upbraiding a pupil for his want of skill, acts like a frost upon them, and materially checks their growth.’²⁸

So is Eliot suggesting that Tom’s problem arises from the use of Euclid to teach geometry, an approach which would be unsatisfactory for any pupil? Jenkins suggests in her essay that this is one message of the novel, and yet Philip Wakem would appear to be a counter-example.²⁹ Philip joins Tom at Mr Stelling’s, having already ‘been taught Latin, and Greek, and mathematics’. When questioned about this by Tom, Philip tells Tom ‘I like to know what everybody else knows’; he clearly puts it in this way because he cannot quite bring himself to tell Tom he actually enjoys Euclid.³⁰ And we are told, even before we engage with Tom’s learning of geometry, about Mr Stelling’s views of Euclid: ‘no opinion could have been freer from personal partiality’.³¹ That Mr Stelling himself does not enjoy Euclid, nor presumably geometry at all, might be a

²⁴ De Morgan, p.269.

²⁵ *The Mill on the Floss*, p.144.

²⁶ *Ibid*, p.169.

²⁷ De Morgan, p.274.

²⁸ W. G. Spencer, *Inventional Geometry: A Series of Questions, Problems and Explanations* (London: Mozley, 1860), pp.9-10.

²⁹ Jenkins, p.80.

³⁰ *The Mill on the Floss*, pp.162-3.

³¹ *Ibid*, p.138.

significant factor in his inability to teach geometry effectively, and could suggest that a more enthusiastic exponent of Euclid might possibly obtain better results. As so often, Eliot is wanting to indicate that people are different, and that what may be true of one person is not necessarily true of all people.

Euclidean geometry and what early Victorians made of it

In her essay on the geometry in *The Mill on the Floss*, Alice Jenkins describes different types of geometry by using terms that include ‘Euclidean geometry’, ‘applied geometry’, ‘practical geometry’, ‘theoretical geometry’ and ‘textbook geometry’.³² It will be useful to clarify the variety of overlapping meanings that can attach to the term ‘geometry’, meanings that are particularly relevant to the Victorian context and to the context of Eliot’s novels. In the twenty-first century, ‘Euclidean geometry’ has a number of different meanings that may easily become confused. First, the term is used to denote the geometry which was formalised by Euclid in his *Elements* more than two millennia ago. Since then, when people have used geometry, when people have reasoned about geometry, they have routinely assumed the geometry that Euclid described, even if they were unacquainted with the fact that Euclid described it. This is still the case: we all, those of us who are not either professional pure mathematicians or cosmologists or fundamental-particle physicists, reason using the assumptions of Euclidean geometry: we assume that space is infinite; we assume that cubes exist and squares are possible to construct; we assume that squares can be fitted together to cover the plane; we assume that the sum of the angles of a triangle is two right angles; and so on. We may not be interested in the formulation of Euclid’s geometry, but we make use of its results.

But since the early nineteenth century it has been known that the space we live in might not exactly have these properties and that it is impossible to reason logically that it does. The several alternative non-Euclidean geometries that might instead be the true description of our space were invented in the nineteenth century and became subjects of discussion in Victorian Britain during the late 1860s, introduced there by the essays of Hermann Helmholtz and the lectures of William Kingdon Clifford. If these alternative

³² Jenkins, p.88.

geometries prove to be better descriptions of the space we live in, then space may not be infinite, the sum of the angles of a triangle may not be two right angles, and so on. But for the practical uses of geometry, for geometry in school education, for recreational theoretical geometry, for geometry as applied to almost all sciences except those that deal with the cosmologically large or the atomically small, squares always exist and cover the plane; we still live in Euclidean space. And in 1860, when non-Euclidean geometry had not yet arrived in Britain, geometry still indisputably meant Euclidean geometry, even though those who did not know about Euclid's work might not have called it by that name.

But there are other meanings attached to the term 'Euclidean geometry', and to explain these we need to consider Euclid's *Elements* in more detail. This work, intended as a description of the geometrical space we live in, provided a logical development of geometrical theorems - theorems that would have been considered by early Victorians to be geometrical 'truths' - truths based on a number of assumptions that were considered self-evident. This was the position of William Whewell, an influential Cambridge mathematician, philosopher of science and theologian. Whewell, often described as a nativist, set out his beliefs about the truth of Euclid's axioms succinctly in notes he appended to some editions of his book *The Mechanical Euclid*. Euclid's postulates are to be seen not 'as something which the reader is to learn, but as something which he already knows'.³³ In an earlier paragraph, Whewell wrote that our thinking about lines 'resides in *the idea of space* [...] we cannot contemplate [objects] geometrically, without conceiving them in space which is subjected to geometrical conditions'.³⁴ So, for Whewell, Euclid's postulates are the intuited consequence of the way we *have* to think about space, and so are not known like the 'laws of nature learnt by observation'.³⁵ Observation is unnecessary, because it is inconceivable to human beings that Euclid's postulates could be anything other than as they are; there is no other way in which our brains could conceive space.

One reason that the certainty of geometrical truths was so important to Whewell is that they were examples of certain knowledge; such knowledge told us about God and,

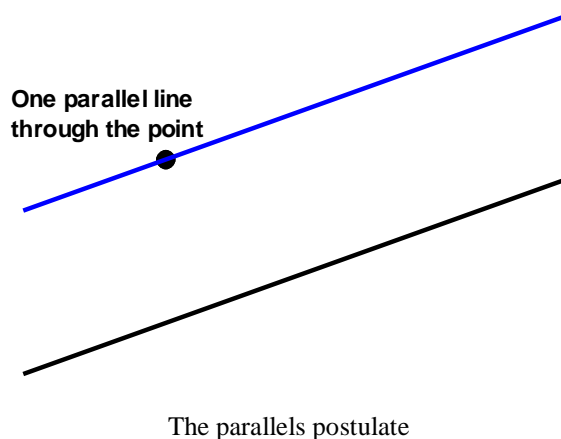
³³ William Whewell, *The Mechanical Euclid*, 3rd edn (Cambridge: CUP, 1838), p.160.

³⁴ Ibid, pp.159-60.

³⁵ Ibid, p.162.

equally importantly, about social morality. Whewell wrote: ‘Since man can know, certainly and clearly, about straight and curved in the world of space, he ought to know [...] no less clearly and certainly, about right and wrong in the world of human action’.³⁶ Whewell, in his *Bridgewater Treatise*, presented his nomological natural theology: he believed that incontrovertible facts about geometrical space were evidence for the existence of a law-giving God.³⁷

One geometrical ‘truth’ is that the sum of the angles of a triangle is equal to two right angles, but its incontrovertible truth depends on starting with self-evident assumptions. One of these, which is known variously as Euclid’s fifth postulate, Euclid’s twelfth axiom or the parallels postulate, was considered by mathematicians less self-evident than the others. This postulate was given at the start of chapter one of this thesis in the form Euclid gave it, but it may also be formulated in this equivalent way: given a line and given a point not on that line, exactly one line can be drawn through the given point and parallel to the given line.



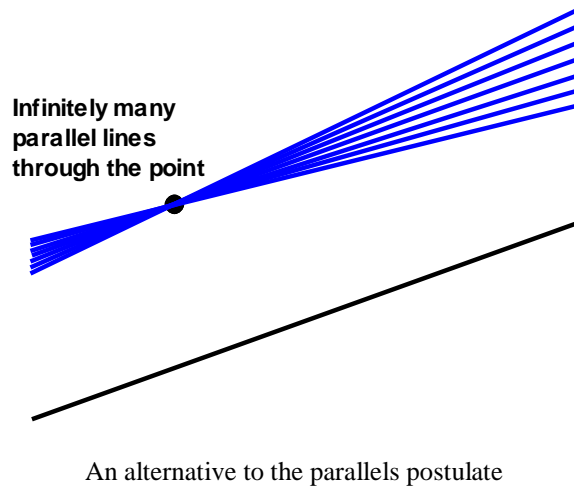
Over the centuries several mathematicians tried to prove this postulate by assuming only the other postulates.³⁸ All such attempts had to fail because, early in the nineteenth century, Gauss, Lobachevski and other Eastern European mathematicians explored the

³⁶ William Whewell, ‘On the Influence of the History of Science upon Intellectual Education’, in *Lectures on Education* (London: Parker, 1855), pp.3-36 (p.12). Quoted in Alice Jenkins, ‘*Space and the March of Mind*’ (Oxford: OUP, 2007), pp.162-3.

³⁷ William Whewell, *Astronomy and General Physics with Reference to Natural Theology* (London: Bohn, 1852).

³⁸ Richard J. Trudeau, *The Non-Euclidean Revolution* (Boston: Birkhäuser, 1987) pp.118-147.

possibility of a geometry that used an alternative to the parallels postulate: that there are infinitely many lines through a given point and parallel to a given line.



They discovered that the geometry they created was logically consistent; and this geometry provided one version of what came to be known as non-Euclidean geometry.³⁹ As far as these continental mathematicians were concerned, it was possible that the space we live in conformed to one of these non-Euclidean models. There will be further discussion of non-Euclidean geometry in chapter six. But none of this was known to or noticed by British mathematicians in the first half of the nineteenth century; they continued to believe that Euclid's postulates, including the parallels postulate, provide the true description of space. And even by 1860, when *The Mill on the Floss* was published, William Whewell's certainty about this was almost universally shared in Britain, even though not everybody shared Whewell's 'nativist' assumptions when explaining their certainty.

Early Victorians predominantly learnt theoretical geometry from 'various editions of the Books of Euclid'.⁴⁰ Euclid provided the preferred method of logical development of geometry from the self-evident assumptions; and was also used as a text book from which school pupils and university students learned geometry. These are two distinct aspects of the use of the *Elements*, even though they are related, and both came to be questioned during the early- and mid-Victorian period.

³⁹ Ibid, pp.157-9.

⁴⁰ Michael H. Price, *Mathematics for the Multitude?* (Leicester: The Mathematical Association, 1994), p.19.

Some mathematicians were questioning, not the propositions of Euclidean geometry, but the narrow use of Euclid to discuss them and teach them. They were questioning whether Euclid's logical development was the easiest to understand, the most elegant or the most logically sound, a debate which will be explored further in chapter six. Sometimes rethinking involved developing different definitions of fundamental geometrical objects such as 'line' and 'plane'; sometimes it involved arranging and proving theorems in a different order; and sometimes using different proofs for the theorems. Augustus De Morgan was a geometer who fully accepted the self-evident nature of the postulates of geometry; his 1839 entry on 'Geometry' in the *Penny Cyclopaedia* explained that 'discussion has arisen upon the question whether those primary propositions [of geometry] which, from our clear apprehension and willing admission of them are called self-evident, are notions inherent in the mind, or deductions from early experience. Except to mention the controversy, we have nothing to do with it. The certainty of these propositions is all we want, and this is conceded by both sides'.⁴¹

But writing elsewhere and for a different audience, De Morgan was scathing about the sanctity afforded to the *Elements*, and particularly to the version of the *Elements* translated and edited by Robert Simson, an eighteenth-century mathematician whose translation remained very popular into the nineteenth century. De Morgan suggested ironically that there were two Euclids: one from Alexandria; and the 'other a native of Utopia'.⁴² The Utopian Euclid, unlike the human one, wrote a perfect geometry text book, and the 'perfect Euclid is better known in our country [...] according to the perfection of Robert Simson'.⁴³ So when De Morgan wrote about the teaching of geometry he urged a flexible approach, which challenged the methods used by those who adhered strictly to Euclid as a text book. He recommended an early but informal introduction to geometrical ideas: 'The study of geometry should [...] not be deferred one moment later than is absolutely necessary.' De Morgan suggested acquainting the pupil 'with the leading facts of the first three books of Euclid. It is easy to give ocular

⁴¹ [Augustus De Morgan], 'Mathematics', in *The Penny Cyclopaedia*, 30 vols. (London: Charles Knight, 1833-1843), 15: pp.11-14 (p.11).

⁴² [Augustus De Morgan], 'The Elements of Euclid', *Dublin Review*, 11 (November, 1841), 330-355 (pp.330-1).

⁴³ *Ibid*, p.331.

demonstration of them all'.⁴⁴ Thus he differed from traditional adherents of Euclid in suggesting that the *teacher* is to select the facts to be discussed, that there is initially to be no systematic logical development from the axioms, and that the pupil is to be convinced by seeing for himself, using diagrams. But De Morgan was not backing away from advocating the teaching of geometrical proof in schools: had use of the 'treatise of Euclid' not already been 'established', geometry might have been reduced to 'calculating the area of squares and triangles', he suggested scathingly.⁴⁵

Francis Newman was an amateur mathematician and De Morgan's successor in providing a course on geometry at the Ladies' College in London, a course which Eliot attended in 1851.⁴⁶ Nothing is known about the course he offered, but Jenkins points to the geometry book he wrote in 1841, the preface of which demonstrates that he agreed with De Morgan in seeing 'no reason why the beaten track should be held sacred': in other words, he saw no reason why the development of geometry provided in the *Elements* (and in Simson's version of the *Elements*) should necessarily be followed either by the mathematics scholar or by the mathematics pupil.⁴⁷ Newman, like many other professional and amateur mathematicians, concerned himself with the 'logical flaws in Euclid's *Elements*'.⁴⁸ Specifically, he seemed to believe he had provided a convincing demonstration of the truth of the parallels postulate, which, of course, non-Euclidean geometers had shown to be impossible.⁴⁹ Newman's method, or rather Legendre's method which Newman employed, is to show that if the parallels postulate is false then one consequence is that, by knowing the angles of a triangle (the sum of which would not be two right angles) we should also know the lengths of the sides, which is absurd. The error, as with most other 'proofs' offered over the centuries, lies in the claim of absurdity: Newman is effectively saying: 'I have not disproved this logically, but can you really believe what I *have* proved as a consequence?' Well, yes we can.

⁴⁴ De Morgan, 'On Mathematical Instruction', p.275.

⁴⁵ Ibid, pp.269.

⁴⁶ Jenkins, p.78.

⁴⁷ Jenkins, p.79; Francis William Newman, *The Difficulties of Elementary Geometry: Especially Those which Concern the Straight Line, the Plane, and the Theory of Parallels* (London: Ball, 1841), p.2.

⁴⁸ Jenkins, p.78.

⁴⁹ Newman, pp.141-3.

There certainly are logical flaws in the *Elements*, but Newman did not uncover them. What he may have been more justified in claiming is that his book provides a treatment of geometry developed ‘in such a way as to prepare the mind for that large view which must be taken in the higher mathematics; for which, naturally and necessarily, the works of a Greek geometer are wholly unfit’.⁵⁰ Increasingly, the value of using Euclid as a text book for beginners in formal geometry was questioned in the mid-Victorian period. Matthew Arnold, one of the Taunton Commissioners, reporting in 1867 on measures for the improvement of secondary education, described how the French, Germans and Swiss told him that Euclid was ‘quite out of date, and was a thoroughly unfit text-book to teach geometry from’.⁵¹ A few years later a rash of alternative geometry texts appeared, the Association for the Improvement of Geometry Teaching was founded, and Lewis Carroll was fighting a rearguard action when he wrote *Euclid and his Modern Rivals* (1879), in order to defend the use of Euclid in schools.

Teaching and learning geometry in other ways

Whatever Eliot thought of the use of Euclid’s *Elements* in particular, or of the teaching of theoretical geometry in general, she was clearly aware of, and interested in other approaches to learning geometry. For Eliot there is rarely only one way of understanding things or one way of doing things. Tom’s practical understanding of mathematics is valued by the narrator, if not by Mr Stelling. Adam Bede makes use of practical geometry in ‘sketching a plan’ for a new building at the Chase Farm.⁵² He also uses geometry to calculate the volume of a tree trunk, a sophisticated extension of ‘calculating the area of squares and triangles’ that De Morgan appeared to deride. The narrator of *Adam Bede* makes similar use of methods for calculating and comparing areas when proposing the problem concerning Mr Casson’s body and head. These examples were all discussed in chapter one. This last example is of a somewhat different kind mathematically: it is a mathematical problem or puzzle to solve for the sake of it, not directly linked to any practical physical application. *Inventional Geometry*, the book by George Spencer referred to in chapter one, contains four hundred and forty-six mathematical problems for the sake of it, examples of which were

⁵⁰ Newman, p.8.

⁵¹ Quoted in Price, p.19.

⁵² *Adam Bede*, p.294.

given in chapter one. In his introduction, Spencer suggested that any ‘true geometrician who will teach practical geometry by definitions and questions thereon [as exemplified in Spencer’s book], will find that he can thus create a far greater interest in the science than he can in the usual course’, which is the ‘didactic method’, because Spencer’s problems will ‘lead the pupil to rely on his own resources [...] and gradually induce a degree of self-reliance as enables him to prosecute his subsequent studies with satisfaction’.⁵³ De Morgan made a similar point, alluded to in the introduction, explaining why self-reliance is likely to be developed by studying mathematics, because ‘the data or assumptions [...] are few, understandable and known to the student from the beginning’.⁵⁴

In fact, giving a learner geometrical problems, as Spencer did, where, for example, the areas of two shapes are to be compared, or where a geometrical result has to be proved or a method of solution invented, is frequently the way in which young pupils are taught geometry now, and the way in which many pupils and almost all interested adults outside of formal education would have learned geometry then. Spencer argued that his geometrical problems should ‘claim a place in the education of all, not excepting women’.⁵⁵ Interestingly, in April 1851, the year before Eliot (or Marian Evans) took over the editorship of the *Westminster Review*, a review article appeared in that journal that advocated the use of problem solving in learning and developing mathematics: ‘the history of mathematical science in this country soon convinces us of the great advantages to be derived from the individual efforts of the student himself, when duly exercised upon the solution of mathematical questions’.⁵⁶ Eliot, in the process of orientating herself so as to assume the editorship, is likely to have read this article, particularly since it was about mathematics and she was taking a course of geometry at the time. Eight years later she was setting readers of her first novel mathematical problems of her own invention to solve.

Many people learnt geometry so as to apply it in other fields. Scientists, engineers, architects and other professionals would have needed to use it in their work: ‘by

⁵³ W. G. Spencer, pp.7, 8.

⁵⁴ De Morgan, ‘On Mathematical Instruction’, p.265.

⁵⁵ W. G. Spencer, p.9.

⁵⁶ [Thomas Turner Wilkinson], ‘English mathematical literature [mainly on T. S. Davies]’, *Westminster Review*, 55 (April 1851), 70-83 (p.71).

geometry the architect constructs our buildings, the civil engineer our railways; [...] by a higher kind of geometry, the surveyor makes a map [...] a geometry still higher is the foundation of the noble science of the astronomer'.⁵⁷ Spencer suggested that the methods he advocated provide a suitable foundation on which the more vocationally-oriented geometrical learning required may be built.

George Eliot's geometry

What geometry did Marian Evans herself learn? Her 'dose of mathematics every day' while in Geneva, would have been a dose of difficult mathematics, given Evans's formidable intellect, and it is quite likely to have included geometry.⁵⁸ But this was not enough for Eliot's needs: when Evans arrived in London a year or so later, she more or less immediately enrolled on a geometry course at the Ladies' College, the course that Francis Newman had just taken over from De Morgan. She told the Brays:

I am attending Professor Newman's course of lectures on Geometry at the Ladies' College every Monday and Thursday. You will say that I can't afford this, which is "dreadful true" - but the fact is I happened to say I should like to do so and good-natured Mr. Chapman went straightway and bought me a ticket [...] I refused to accept it - and have paid for it - wherefore I must stint myself in some direction - clearly in white gloves and probably in clean collars.⁵⁹

Why did Evans decide to take this geometry course and manage without new white gloves? To find the reason we need to consider the intellectual requirements of Evans in 1851. She was about to take on the editorship of a journal, the most prestigious articles in which were frequently about science and philosophy; and understanding some of the thinking behind many of these articles required knowledge of that prestigious male subject: Euclid. What has already been said about Newman's geometry would suggest that his course was ideally suited to Evans's needs. He would have dealt with theoretical geometry, but in a way that questioned some of the conventional presuppositions behind the established geometrical education. This would have left Evans in no doubt about the significance of theoretical geometry for her role as editor and as a philosopher in her own right, and it would have made her more able to question

⁵⁷ W. G. Spencer, p.5.

⁵⁸ GEL, 1: p.321.

⁵⁹ GEL, 1: p.343.

some of the certainties that, as we shall see later in this chapter and in chapter six, men like Whewell espoused.

What use then did Evans make of her enhanced geometrical understanding in her role as editor of the *Westminster*? I shall discuss the ideas of John Stuart Mill and also of Herbert Spencer, George Spencer's son, who was a member of the bohemian group that gathered around the publisher John Chapman, and whom Eliot was in love with for a while. Fleishman draws attention to George Eliot's assertion in 1873 that her thinking about philosophical issues was largely original and not dependent on famous philosophers she had known:

[...] though I have studied [Mill's] books, especially his *Logic* and *Political Economy*, with much benefit, I have no consciousness of their having made any marked epoch in my life. Of Mr Herbert Spencer's friendship I have had the honour and advantage for twenty years, but I believe that every main bias of my mind had been taken before I knew him.⁶⁰

Eliot was certainly impressed by Mill's *Logic*: 'I wish you would ask Mr Bray to send Mill's *System of Logic* [...] I shall be glad to have it by me for reference', she wrote to Cara Bray in October 1851.⁶¹ Fleishman demonstrates at some length substantial points of agreement between Eliot's thinking and Mill's final book in the *Logic*, which is 'devoted to the "Logic of the Moral Sciences"', but he does not mention earlier books, such as the second, which is 'On Reasoning' and which includes Mill's remarks on the 'deductive sciences'.⁶² Evans would have needed to engage with Mill's ideas about the deductive sciences in due course, if she had not already done so, in order to edit Spencer's 1853 article for the *Westminster*, which will shortly be discussed. But before this she edited Mill's 1852 article on 'Whewell's Moral Philosophy', for which she would have been pleased that she knew what she had learned, either from Newman or previously, about the *a priori* nature of geometrical 'truths'.⁶³ Mill wrote:

⁶⁰ Fleishman, p.1; GEL, 6: pp.163-4.

⁶¹ GEL, 1: p.363.

⁶² Fleishman, pp.52-56; John Stuart Mill, *A System of Logic, Ratiocinative and Inductive* (Longmans, Green: London, 1925), pp.545-622, 103-184.

⁶³ [J. S. Mill], 'Whewell's moral philosophy', *Westminster Review*, 2 n.s. (October, 1852), 349-385 (pp.350-1).

A writer who has gone beyond all his predecessors in the manufacture of necessary truths, that is, of propositions which, according to him, may be known to be true independently of proof; who ascribes this self-evidence to the larger generalities of all sciences (however little obvious at first) as soon as they have become familiar – was still more certain to regard all moral propositions familiar to him from his early years, as self-evident truths.⁶⁴

What particularly incensed Mill was Whewell's undertaking to 'characterise and criticise, from his own point of view, all other English writers on moral philosophy; and particularly those who derive their ethical conclusions, not from internal intuition, but from an external standard'.⁶⁵ Evans would have needed to know about necessary truths and self-evident truths, concepts modelled on beliefs about Euclidean geometry.

A year later, she was editing Herbert Spencer's article, 'The Universal Postulate' in which Spencer quotes and criticises Mill; once again what Spencer is writing about are necessary truths, this time geometrical ones. In the *Logic*, Mill has been scathing about so-called necessary truths in the 'exact sciences' (mathematics), obtained from axioms that are apparently known *a priori* to be true. Spencer quotes this passage from the *Logic*:

The results of these sciences are indeed necessary, in the sense of necessarily following from certain first principles, called axioms and definitions; of being certainly true, if these axioms and definitions are so. But their claim to the character of necessity in any sense beyond this [...] must depend on the previous establishment of such a claim in favour of the definitions and axioms themselves.⁶⁶

Spencer's argument against Mill is a subtle one. He objects that while Mill does not accept the truth of axioms *a priori*, he does assume that there is 'some necessary truth in the steps of our reasoning, which is not possessed by the axioms they start from'.⁶⁷ Why, Spencer argues, should the methods of reasoning adopted by human beings be any more necessarily valid than the axioms to which these methods are applied? Spencer's solution is not to agree with Whewell that necessary truths are *a priori*; instead, geometrical 'axioms are simply our earliest inductions from experience'.⁶⁸ He invokes his universal postulate: 'A necessary truth is a proposition the negation of

⁶⁴ Ibid, p.350.

⁶⁵ Ibid, p.351.

⁶⁶ [Herbert Spencer] 'The Universal Postulate', *Westminster Review*, 4 n.s. (October, 1853), 513-550 (p.525); Mill, *A system of Logic*, pp.164-5.

⁶⁷ Herbert Spencer, p.525.

⁶⁸ Herbert Spencer, p.522.

which is not only false but inconceivable,’⁶⁹ and he uses this universal postulate to establish the necessity of both the axioms of geometry and the methods of reasoning from them. Evans was clearly impressed by all this philosophical argument; even before the issue of the *Westminster* appeared she told Hennell: ‘If you don’t think the Universal Postulate first rate, I shall disown you as a critic.’⁷⁰ All this gives an indication of what Evans gained professionally from knowing something about theoretical geometry.

Utilitarian Mathematics

George Eliot had little time for a narrow belief in correct methods of teaching geometry. But she had no more time for a narrow approach to the acquisition of utilitarian skills, as I demonstrate in this section. When Eliot came to write *The Mill on the Floss*, she no doubt had Newman’s geometry course, which may well have included his views on the shortcomings of the *Elements* as a text book, in her mind. Newman would have enjoyed the narrator’s description of Mr Stelling’s unbending approach to teaching: a ‘method of education sanctioned by the long practice of our venerable ancestors was not to give way before the exceptional dulness of a boy.’⁷¹ In view of Eliot’s criticism of Mr Stelling’s version of mathematical education, we might ask whether she thought that a more utilitarian mathematics education is what needs to be offered instead?

In June 1860 Eliot wrote to D’Albert-Durade, with whom she had lodged when she was in Geneva, telling him not to send her any more reviews of her books and complaining of the review he had sent: ‘the most ignorant journalist in England would hardly think of calling me a rival of Miss Mulock - a writer who is read only by novel readers, pure and simple, never by people of high culture’.⁷² The journalist had presumably compared Eliot’s first two novels with a novel by Dinah Mulock. In Mulock’s *John Halifax, Gentleman* (1856) John asks the ‘honest, honourable, prosperous tradesman’, Abel Fletcher: ‘Sir, I want work; may I earn a penny?’⁷³ John’s

⁶⁹ Ibid, p.521.

⁷⁰ GEL, 2: p.118.

⁷¹ *The Mill on the Floss*, p.169.

⁷² GEL, 3: p.302.

⁷³ Dinah [Mulock] Craik, *John Halifax, Gentleman* (Stroud: Nonsuch, 2005), pp. 12, 11.

progress from pauper to gentleman is straightforwardly the result of sustained hard work, and concentration on learning precisely what is practically necessary. When asked by Abel: 'Dost thou know anything of tanning?' he replies: 'No, but I can learn.'⁷⁴ He tells Phineas Fletcher: 'I've managed to teach myself to read and add up out of your books' and this means he can earn 'much better wages' by 'collecting money instead of skins'.⁷⁵ Everything John does and everything he learns are focused on achieving worldly success.

Tom's mathematical education does not end when he leaves Mr Stelling; and his ability with horses and ripples and measuring the playground is not the only practical mathematics discussed in *The Mill on the Floss*. After Mr Tulliver's downfall, in a superficially similar way to that of John Halifax, the ever-dutiful Tom goes to Mr Deane to discuss how he can work to rescue his family's finances. The narrator makes it clear that the reader is not expected to picture Tom's uncle Deane as a kindly Abel Fletcher or sympathise too much with him: Tom finds his 'snuff-taking a most provoking habit', and Tom thinks it 'would be very dull, prosy work [...] writing there forever to the loud ticking of a time-piece'.⁷⁶ Unlike Abel Fletcher, Mr Deane chooses to be rigid and discouraging in his manner: 'people don't get much money at anything [...] when they're only sixteen. You've had a good deal of schooling, however: I suppose you're pretty well up in accounts, eh? You understand book-keeping?'⁷⁷ Tom tells Mr Deane: 'We learned Latin [...] and Euclid; and I began Algebra, but I left it off again; and we had one day every week for Arithmetic.' Mr Deane, ever the cautious businessman 'was not going to speak rashly of a raw material in which he had had no experience. But the presumption was that if it had been good for anything, so successful a man as himself would hardly have been ignorant of it.' He believed that 'in case of another war' Latin should be taxed as a luxury, and 'this list of acquirements gave him a sort of repulsion towards poor Tom'.⁷⁸ In other words, Mr Deane sees no immediate value in Tom's skills in terms of profit, and therefore it might be better if Tom had not acquired them; he might have learned something more useful.

⁷⁴ Ibid, p.25.

⁷⁵ Ibid, p.42.

⁷⁶ *The Mill on the Floss*, p.227.

⁷⁷ Ibid, pp.227-8.

⁷⁸ Ibid, p.228.

Mr Deane demonstrates that his business head is allied to rigid patriarchal thinking: ‘Your father had some notion of making you an engineer’, he tells Tom, as if, because Tom’s father had wished it, this opinion might still have some relevance to the present changed situation. Mr Deane impresses on Tom an awareness of the abilities he lacks by giving Tom the reason for his own advancement in the company: ‘I found out how there was a waste of five hundred a year that might be hindered.’⁷⁹ He then further deflates Tom by telling Tom of ‘a young man of two-and-twenty I’ve got my eyes on now[...] he’s made good use of his time - a first-rate calculator – can tell you the cubic contents of anything in no time and put me up the other day to a new market for Swedish bark’.⁸⁰ The tone of Mr Deane’s remarks suggests that Eliot does not intend us to ask what Swedish bark is; all we need to know is that it makes Mr Deane’s company a lot of money. This attitude of Mr Deane contrasts with that of Adam Bede, who has similar calculating powers relating to the contents of beech trees, but who is more interesting and human because he ‘delighted in a fine tree’, rather than delighting only in the profit to be made from it.⁸¹ The contrast between Mr Deane and his young man on the one hand, and Caleb Garth and Fred Vincy in *Middlemarch* on the other is even more marked. Caleb, sympathetically presented by the *Middlemarch* narrator, is interested in everything about business, *except* that it ‘never meant money’, and he takes Fred Vincy on in an optimistic and hopeful way, being ‘sure the lad would turn out well – an open affectionate fellow’.⁸²

So whilst Eliot paints a negative picture of a certain type of education in theoretical geometry, her portrayal of a narrowly focused acquisition of mercenary practical calculating skills is equally damning. The message is the same in both cases: it is not the theoretical geometry or the skill in calculating that is at fault, but the lack of humanity within the context in which the education happens, a context which does not take account of the motivation or aptitude of the learner, nor of the value of mathematics education for the development of rounded human beings. Theoretical geometry, in which Tom ‘feels no interest’, was never the right education for him.⁸³ On the other hand, the strong motivation Tom has for learning book-keeping and accounts

⁷⁹ Ibid, p.227.

⁸⁰ Ibid, p.232.

⁸¹ *Adam Bede*, p.295.

⁸² *Middlemarch*, pp.518, 218.

⁸³ *The Mill on the Floss*, p.309.

in order to make rapid progress is impressive to his aunts and uncles, but less so to the narrator; Tom contracts ‘some rather saturnine sternness, as a young man is likely to do who has a premature call upon him for self-reliance’.⁸⁴ Perhaps partly as a result of this sternness, rather than following a smooth path to fulfilment like John Halifax, Tom meets an early death.

Reasoning about inheritance

It is in her second novel that Eliot begins to address directly the education of girls and women, and she uses logical argument in order to challenge the idea that girls are born with less capability than boys to benefit from a challenging education. The focus of this novel is what happens to a girl in a middle-class provincial society, who happens to have the brains she should not have, and consequently does not receive the education that would be appropriate for her. While the planning for Tom’s education is being narrated, a parallel educational theme is being developed: the conversation between Mr and Mrs Tulliver at the start of the second chapter is not the first intimation that education will be a major theme in this novel. In the first chapter, before we meet the Tulliver couple, the narrator stands on the bridge outside the Tullivers’ house, contemplating the ‘unresting wheel’ of Dorlcote Mill, telling us: ‘that little girl is watching it too [...] rapt in its movement’.⁸⁵ Maggie Tulliver, we soon discover, is an autodidact who is ‘twice as ’cute as Tom’, and who is doubtless as able to learn informal geometry from watching the rotating wheel, as Tom is from the events of his everyday life.⁸⁶

An article by George Lewes that appeared in the *Westminster* in 1856, provides a wealth of botanical and zoological evidence to support his thinking about inheritance; but then suggests that his conclusions may also be reasoned about ‘*à priori*’, which will suit those readers who ‘prefer logical deductions to any massive accumulation of facts’.⁸⁷ The question that Lewes addresses as a climax to his article is this: what is

⁸⁴ Ibid, p.310.

⁸⁵ Ibid, p.8.

⁸⁶ Ibid, p.12.

⁸⁷ [George Henry Lewes], ‘Hereditary influence, animal and human’, *Westminster Review*, 10 n.s. (July, 1856), 135-162 (pp.151-2).

inherited from the male parent, and what from the female?⁸⁸ Lewes concludes that deciding which parent influences what ‘admits of no absolute reduction to a known formula’.⁸⁹ If we argue logically, Lewes suggests, ‘the mind recognises at once the truth of the proposition that sperm-cell and germ-cell are as much to be regarded in the light of reproductions of the parents, as the cells produced by spontaneous divisions are to be regarded in the light of repetitions of the parent-cell.’⁹⁰ He does not believe that each parent exerts equal influence on the offspring; the causes of ‘predominance’ are various – for example, the ‘more potent predominates’ – but it is not the sex of the parent that determines this predominance.⁹¹ Nor is there any suggestion in Lewes’s article that the sex of the child determines which parent predominates: ‘heritage is constant’.⁹² Mr Tulliver is vexed that Tom does not have Maggie’s brains: ‘you never hear him say ‘cute things like the little wench’.⁹³ Having explained to his wife how the superior intelligence is in his family and not in hers, Mr Tulliver tells her ‘That’s the worst on’t wi’ the crossing o’ breeds: you can never justly calkilate what’ll come on’t.’⁹⁴

Mr Tulliver’s remark about crossing breeds can be read as Eliot warning readers to be sceptical about scientists’ theories concerning inheritance. In an article published in 1859, a year before *The Mill on the Floss*, Herbert Spencer advanced theories about human breeding. He was particularly critical of over-educating children to the detriment of their physical health. Whatever the wisdom in his advice about this, Spencer, unlike Lewes, differentiates between the sexes: ‘On women the effects of this forcing system are, if possible, even more injurious than on men.’ Spencer infers that society should educate men more highly than women. And this is quite natural, because men ‘care comparatively little for erudition in women, but very much for physical beauty, and good nature, and sound sense’.⁹⁵ The implication of this statement is that ‘good nature and sound sense’ are more likely to be allied to physical beauty than to intellectual erudition. What is most important for Spencer is ‘the welfare of posterity’. And, since Spencer, like Lewes, believes that acquired characteristics are inherited – the

⁸⁸ Ibid, p.144.

⁸⁹ Ibid, p.151.

⁹⁰ Ibid, p.152.

⁹¹ Ibid, pp.154-5.

⁹² Ibid, p.156.

⁹³ *The Mill on the Floss*, p.20.

⁹⁴ Ibid, p.12.

⁹⁵ [Herbert Spencer], ‘Physical Training’, *British Quarterly Review*, 29 (April, 1859), 362-397 (p.394).

dog Lewes had taught to beg produced a puppy that spontaneously begged – ‘a cultivated intelligence based on a bad *physique* is of little worth, seeing that its descendents will die out in a generation or two’. Conversely, given a good physique, ‘mental endowments may be indefinitely developed’.⁹⁶ While these remarks might be as logically applied to the education of boys as to that of girls, Spencer focuses them clearly on the latter: parents who over-educate their daughters not infrequently ‘doom them to celibacy’.⁹⁷ Mr Tulliver would seem to have conformed to Spencer’s theory when he chose his wife: ‘I picked the mother because she wasn’t o’er ’cute - bein’ a good-looking woman, too, an’ come of a rare family for managing; but I picked her from her sisters o’ purpose, ’cause she was a bit weak, like’. And it turns out that ‘Mrs Tulliver was what is called a good-tempered person [...] the flower of her family for beauty and amiability’.⁹⁸ This is in line with Spencer’s contention that good nature goes with physical beauty. On the other hand, Mrs Stelling is ‘not a loving, tender-hearted woman’, in spite of being a good-looking woman with ‘blond ringlets’, whose ‘skirt sat well’.⁹⁹ So Eliot’s characters provide examples for and against Spencer’s theory about female good nature. And it is the significance of the effect of *both* parents on the characteristics of their offspring that is more significant for the novel, and this Spencer, unlike Lewes, ignores. Mr Tulliver puts the issue roundly for Spencer to hear: ‘when a man’s got brains himself, there’s no knowing where they’ll run to; an’ a pleasant sort o’ soft woman may go on breeding you stupid lads and ’cute wenches, till it’s like as if the world was turned topsy-turvy’.¹⁰⁰ So even in the best biologically regulated families, there can be no plan to ensure that the men will all be intelligent and the women beautiful. Did Spencer read this novel and, if so, did he notice this critique of his theories? He was certainly ‘enthusiastic’ about *Adam Bede* which he read in 1859; he might have noticed some of the narrator’s musings about Hetty that could be seen as critical of his ideas. And Spencer was probably the ‘friend’ who, according to a letter Lewes wrote in 1862, ‘expressed his want of interest’ in *Romola*.¹⁰¹ So it would seem likely, given his prompt reading of both these novels, that Spencer read *The Mill on the Floss* too.

⁹⁶ Ibid, p.395; Lewes, p.141.

⁹⁷ Herbert Spencer, p.396.

⁹⁸ *The Mill on the Floss*, pp.19, 14.

⁹⁹ Ibid, pp.174, 143, 174.

¹⁰⁰ Ibid, pp.19-20.

¹⁰¹ GEL, 3: pp.169-70; 8: p.305.

Mr Tulliver's issue was precisely the problem for provincial middle-class society in 1830 or 1860; whatever society's preferred gender roles, nature may have different ideas, which is where Maggie's problems begin. When society has erroneous theories about human breeding, this affects not only the breeding, but also what happens afterwards to the progeny. Tom makes clear to Maggie what society expects: 'Girls never learn such things' as Euclid and Latin, unlike boys. The irony here is that Tom has only just announced to Maggie and their father that 'there's no sense' in Euclid anyway.¹⁰²

Mrs Tulliver is unconvinced that Maggie *is* particularly clever: 'You talk o' 'cuteness [...] but I'm sure the child's half an idiot i' some things.' Mr Tulliver understands too well that Maggie is a 'small mistake of nature', and does his best to support her. When his wife complains about Maggie's lack of cooperation over her hair, he 'rashly' suggests cutting it off short; just for a moment he appears to contemplate treating her like a boy.¹⁰³ Mr Tulliver worries about Maggie's future: 'it's a pity she isn't made o' commoner stuff – she'll be thrown away, I doubt: there'll be nobody to marry her as is fit for her.'¹⁰⁴ This is a twist on Spencer's clever unmarriageable women, and it is precisely Maggie's problem: she is a woman not made of the common stuff women are supposed to be made of. Much earlier, Mr Tulliver foresees the problem: 'She understands what one's talking about so as never was [...] But it's bad [...] a woman's no business wi' being so clever; it'll turn to trouble'.¹⁰⁵ Maggie apparently comes to think this too: 'She wished she could have been like Bob, with his easily satisfied ignorance'.¹⁰⁶ Jules Law suggests that Mr Tulliver has the need born of sympathy for Maggie to cancel his sister's debt: 'It had come across his mind that if he were hard upon his sister, it might somehow tend to make Tom hard on Maggie at some distant day'.¹⁰⁷ Law suggests that while there is no logic to Mr Tulliver's thinking, no 'sequence of causes and effects', he gains satisfaction from it, sensing that Maggie,

¹⁰² *The Mill on the Floss*, pp.145, 144.

¹⁰³ *Ibid*, p.13.

¹⁰⁴ *Ibid*, p.294.

¹⁰⁵ *Ibid*, p.17.

¹⁰⁶ *Ibid*, p.288.

¹⁰⁷ *Ibid*, p.84.

being as she is, might need similar generous treatment from *her* brother in the future.¹⁰⁸ This exemplifies the parallel patterning Eliot frequently uses in her novels.

Maggie ridicules the kind of education she is expected to suffer: patchwork is ‘foolish work [...] tearing things to pieces to sew ‘em together again’.¹⁰⁹ This echoes a more sardonic assault on feminine accomplishments in ‘Janet’s Repentance’: Miss Linnet ‘can soothe [a husband’s] cares with *crochet* [...] How our fathers managed without *crochet* is the wonder’.¹¹⁰ Even after the family is ruined financially, Maggie feels persecuted by Tom when he rejects her efforts to contribute to the ‘fund in the tin box’, even though this is by means of the feminine activity of sewing: ‘*I’ll* take care that the debts are paid, without your lowering yourself in that way’, Tom tells her.¹¹¹ The word ‘lowering’ says it all.

Logical and mathematical models

Maggie looks up to her brother Tom in spite of her superior intellect and continually feels crushed when he rejects her or is displeased with her. The narrator relates a brief incident concerning fishing as a parable about inheritance. When Tom and Maggie go fishing with Tom’s new rods, ‘Maggie thought it probable that the small fish would come to her hook, and the large ones to Tom’s’.¹¹² In the event, her rod caught a ‘large tench’ which pleased her, mainly because Tom was pleased with her. The fish in the pond represent the inherited brains: ‘there’s no knowing where they’ll run to’. Eliot’s novels abound with extended metaphors and with logical or mathematical images, which, in her last three novels, Eliot sometimes refers to as parables.¹¹³ In Eliot’s novels, Maxwell’s observation, mentioned in the introduction, that different sciences employ the same ‘mathematical processes and trains of reasoning’ is applied to analogical reasoning about society.

¹⁰⁸ Jules Law, ‘Water Rights and the Crossing of Breeds’ in *Rewriting the Victorians: Theory, History and the Politics of Gender*, ed. By Linda Shires (New York and London: Routledge, 1992), pp.52-69 (p.57).

¹⁰⁹ *The Mill on the Floss*, p.14.

¹¹⁰ *Scenes of Clerical Life*, p.185.

¹¹¹ *The Mill on the Floss*, p.293.

¹¹² *Ibid*, p.40.

¹¹³ *Felix Holt*, p.11; *Middlemarch*, pp.248, 320; *Daniel Deronda*, pp.393, 461.

William Whewell, when reviewing Mary Somerville's book, *On the Connexion of the Physical Sciences*, outlines the pitfalls faced by women who engage in science: a characteristic 'of the female intellect is a clearness of perception, as far as it goes: with them, action is the result of feeling; thought, of seeing; [...] their reasoning is undisturbed by the prospect of its practical consequences'.¹¹⁴ In *The Mill on the Floss*, women's ability to reason is similarly deprecated by Mr Stelling: when Maggie asks him if she could learn Euclid, he tells her that girls 'can pick up a little of everything [...] They've a great deal of superficial cleverness [...] They're quick and shallow'.¹¹⁵ Earlier, the narrator tells us that 'Tom became more like a girl' as a result of his wounded pride at not being able to learn Euclid.¹¹⁶

Mr Stelling's judgement about girls is a metaphor: 'quick and shallow' could be a description of a mountain stream. And what does the narrator mean by describing Tom as 'like a girl'? Such analogical use of language enables judgements to be made about girls without their having to be justified either logically or by producing empirical evidence. Eliot explicitly addresses this issue when apostrophising Aristotle in connection with Tom's education: 'would you not have mingled your praise of metaphorical speech [...] with a lamentation that [...] we can so seldom declare what a thing is, except by saying it is something else?' When suggesting that Tom's brain 'was peculiarly in need of being ploughed and harrowed' Mr Stelling employs a metaphor which suggests one view of education. The narrator points out that by 'changing the metaphor', by calling 'the brain an intellectual stomach', for example, we prioritise a different educational approach. Eliot makes her position about mathematical models clear: 'I say nothing against Mr Stelling's theory: if we are to have one regimen for all minds, his seems to me as good as any other.'¹¹⁷ In other words, analogical thinking may be illuminating, and Eliot employs it liberally, but we should not believe that our one analogy presents the whole truth. Universally acceptable empirical evidence is always essential before certainty can be arrived at. Eliot's ironic use in the early chapters of *Middlemarch* of a mathematical model to describe gender relationships is explored in chapter four.

¹¹⁴ Alice Jenkins, *Space and the 'March of Mind'*, p.102.

¹¹⁵ *The Mill on the Floss*, p.150.

¹¹⁶ *Ibid*, p.141.

¹¹⁷ *Ibid*, pp.139-40.

Women and geometry

Mr Stelling's belief in ploughing and harrowing links to notions about the value of Euclid in prestigious male education: Euclid is ideal for teaching boys to reach conclusions through strictly logical reasoning, which leaves them in no doubt that the conclusions are true. This prepares boys to make intellectual and moral decisions that are based on sound logical reasoning rather than on whim, as William Whewell explains:

if [a boy] be left to suppose that mathematical truths depend ultimately on the evidence of the senses, he will look in other subjects for evidence equally palpable; and will not bring away from mathematics that lesson [...] that there exist vast and solid edifices of truth, the foundations of which are not laid in the information which our external senses give us.¹¹⁸

A similar remark could not be made about a girl; women should not wish to aspire to sound logical reasoning. Maggie attempts to rescue herself from the culture of St Ogg's by picking up the discarded books Tom studied with Mr Stelling. She discovers that the Latin, logic and geometry, this 'masculine wisdom', are all 'thick-rinded fruit of the tree of knowledge', an image that suggests that while this wisdom was worthwhile, it was tough to get into. All were subjects that interested Eliot; but Maggie 'had set out towards the Promised Land alone, and found it a thirsty, trackless, uncertain journey'.¹¹⁹ Jenkins tentatively links Maggie's problem to her autodidacticism: and Eliot could be reflecting on her own experience here; she assiduously studied mathematics in 1849 while in Geneva, but it seems she still needed a guide through the desert in the form of a taught geometry course in 1851, to enable her to progress with geometry.¹²⁰ Even men who were gifted mathematicians, wanting to do well in mathematics in the Cambridge Tripos, needed personal coaches.¹²¹ Later, Maggie rejects the 'wrinkled fruit' in favour of devotional texts; the adjective 'wrinkled' suggests that Eliot thinks that Euclid is not only a tough text book, but also one that was no longer useable. But Maggie's dramatic self-renunciation is going to be no solution for her: the 'broad gate that leads to

¹¹⁸ William Whewell, *Thoughts on the Study of Mathematics as Part of a Liberal Education* (Cambridge: Deighton, 1835), p.9; quoted in Jenkins, *Geometry and Gender*, pp.81-2.

¹¹⁹ *The Mill on the Floss*, p.287.

¹²⁰ Jenkins, 'Geometry and Gender', p.87; GEL, 1: p.321.

¹²¹ See, for example, Andrew Warwick, 'Exercising the Student Body', in Christopher Lawrence and Steven Shapin, *Science Incarnate* (Chicago: University of Chicago Press, 1998), pp.288-326 (especially pp. 295-302).

destruction' is suggested by the comment that we all prefer 'the path of martyrdom and endurance, where the palm-branches grow' to the 'steep highway of tolerance, just allowance, and self-blame'.¹²² The 'vain ambition to share the thoughts of the wise' that Maggie renounces was exactly Marian Evans's ambition and was essential for what she did as an editor, and later for what she did as a novelist.¹²³ At the foundation in 1869 of Girton College, a college at last for women in connection with Cambridge University, she told Emily Davies in a letter: 'We strongly object to the proposal that there should be a beginning made "on a small scale".'¹²⁴ Playing at geometry was not enough; women simply needed to get on with it. Davies, who took advice from Eliot, when discussing the curriculum for the new women's Cambridge college, agreed: she wanted women to take exactly the same courses as men: she told Professor Sealey of Cambridge University in 1869 that 'if her girls did anything different from the men it would be construed as inferior and might be held to disqualify them from degrees'.¹²⁵ Like her creator, and like the Girton students, what Maggie needs is what Mr Tulliver says he wants for Tom: 'a good eddication'.¹²⁶

In commenting on the education of Tom and Maggie in an introduction to the novel, Dinah Birch points out that '[n]either are given the right kind of teaching'. Maggie would have benefited from the education Tom receives, while 'Tom needed a practical and perhaps scientific education.' However, her suggestion that they both 'somehow manage to put together a better education than anything either of their parents could manage' is surely to see what transpires too positively: after all, they both come to early watery ends.¹²⁷ Tom may well pay off the family's debts, and impress his aunts and uncles within the economy of values of the Dodsons, but only at the cost of 'contracting some rather saturnine sternness'.¹²⁸ Tom is undermined by taking his vengeful father as a role model: in due course he goes further than his father, anathematising not only lawyers but also his own sister, something his father would never do. Maggie's situation is quite different from Tom's. Maggie's downfall is due less to the

¹²² *The Mill on the Floss*, p.293; Matthew 7. 13-14; Luke 13. 24. The reference to palm branches might suggest Maggie sees herself like Jesus entering Jerusalem on the way to his crucifixion (John 12. 13).

¹²³ *The Mill on the Floss*, p.293.

¹²⁴ GEL, 4; p.401.

¹²⁵ Daphne Bennett, *Emily Davies and the Liberation of Women* (London: André Deutsch, 1990), p.103.

¹²⁶ *The Mill on the Floss*, p.9.

¹²⁷ Dinah Birch, 'Introduction' to *The Mill on the Floss* (Oxford: OUP, 1996), p.xxvii.

¹²⁸ *The Mill on the Floss*, p.310.

idiosyncrasies of her personality than to being in the wrong place at the wrong time; in the first chapter, the narrator describes her as ‘that girl’: in other words, she is a representative for any intelligent spirited girl growing up in provincial middle-class society, and is destroyed by the ‘oppressive narrowness’ of the provincial morality of St Ogg’s.¹²⁹ There would seem to be no education she could have sorted out that would enable her to live in this society.

Emily Davies, who consulted Eliot about the curriculum for the new women’s college, echoed several of the themes in *The Mill on the Floss* in *The Higher Education of Women* (1866). The idiosyncratic theology of St Ogg’s precludes the potentially healthy influence of Anglicanism on the position of women: Davies pointed out that the liturgy used in connection with the rituals of baptism and confirmation, both concerned with goals for living, do not differentiate between boys and girls.¹³⁰ And, Davies avers, the schooling offered to girls is meagre, starting late and finishing early; finishing schools are ‘called upon to “finish” what has never been begun’.¹³¹ Girls listen to adults’ conversation and read books, as Maggie does, and discover that idleness is disapproved of, at least in boys, but that anything they might want to do to cease being idle is not approved of either; consequently girls let themselves ‘go drifting down the stream’.¹³² Eliot, who herself came from the provincial middle class, was ambivalent about everything St Ogg’s stands for: ‘I share with you this sense of oppressive narrowness; but it is necessary that we should feel it, if we care to understand’, her narrator warns us.¹³³ She was similarly ambivalent about other issues addressed in this novel, including the value of different kinds of mathematical education; and, in particular, about the value of Euclid and other versions of theoretical geometry. In this way, geometry is an allegory for the social dilemma explored in the novel. Maggie tries to obtain solace from theoretical geometry, until she finds it arid. Unlike Maggie, her creator did not give up geometry, but instead made significant use of it for presenting her social philosophy in her novels; more will be said about this, particularly in chapters four and six.

¹²⁹ Ibid, p.272.

¹³⁰ Emily Davies, *The Higher Education of Women* (London: Hambledon, 1988), pp.14-17.

¹³¹ Ibid, pp.34-5.

¹³² Ibid, pp.43-50.

¹³³ *The Mill on the Floss*, pp.272.

In *The Mill on the Floss*, Eliot uses mathematics and logic to confront dogma, whether dogma about the correct way to learn geometry, or dogma about the acquisition of utilitarian mathematics, or dogma about inheritance; and in so doing she challenges, through the use of logic, beliefs about women's education and the role of women in society. In the next chapter, which is about *Romola*, the education of women continues to be a theme; Eliot's donation to the new women's college at Cambridge was recorded as 'from the author of *Romola*'.¹³⁴

¹³⁴ GEL, 8: p.414.

Chapter Three

‘Have you robbed somebody else, who is *not* dead?’: mathematics and logic in *Romola*

The Proem to *Romola* hints at a world of uncertainty, of conflicting opinion and of duplicity. This is contrasted with what endures: mathematics and logic on the one hand, human need on the other. Through the novel mathematics and logic are used to develop arguments attacking false assumptions about society and promoting sympathetic understanding.

Eliot makes use of logical patterning in her novels to create links between superficially unconnected incidents. In *Romola*, when Tito visits his alternative wife Tessa and their two children, this is how the narrator describes their younger child Ninna:

Ninna was a blue-eyed thing, at the tottering, tumbling age - a fair solid, which, like a loaded die, found its base with a constancy that warranted prediction.¹

In this sentence there is symbolic mathematics for the reader who wishes to consider it. First, there is the reference to Ninna's age, expressed not in years, but in terms of her size and her physical capabilities; she is short and while not exactly the shape of a cubic die, she is likely to fall onto her bottom without damage. The mathematics involved here is an intriguing combination of geometry, dynamics and probability. Why is it amusing for a small - and unstable - child to fall and then pick herself up, when it would not be amusing for someone bigger? How is a die to be loaded in order to come to rest predominantly on one face, or, in Ninna's case, her bottom? And a loaded die is worth betting on, when you know how it has been loaded, so that you can predict the outcome.

This incident recalls an event much earlier in the novel, where Tito who is newly arrived in Florence and is currently without money to buy food, goes with Nello, whom he has just met and who assumes the role of Tito's sponsor, to beg a breakfast of bread and milk from the pretty Tessa. On this earlier occasion, Tito kisses Tessa twice, first to

¹ *Romola*, p.402.

wake her and then after she has given him his bread and milk. The narrator's reference to Ninna 'tumbling' and regaining her feet echoes the verbal abuse offered by Monna Ghita, Tessa's mother, on this earlier occasion: 'you look for all the world as silly as a tumbler when he's been upside down and has got on his heels again'.² The playful Nello mollifies Monna Ghita by describing to her a reversal of the facts: 'this *bello giovane* has been a little too presumptuous in admiring the charms of Monna Ghita, and has attempted to kiss her while her daughter's back is turned'.³ This reversal is entirely appropriate for Nello, who is the proud possessor of a fine mirror that does reverse the facts. Nello's intervention assists Tito in beginning his relationship with Tessa; the die is loaded in his favour.

With Ninna's tumbling the whole situation is reversed, again like a mirror image: this time, once Tito's mood is sweetened through his admiring Ninna, it is Tessa who successfully begs for a little money from Tito to 'buy some *confetti* for the children'.⁴ The die is now loaded in Tessa's favour but not in Tito's; shortly, Tito, who has become disingenuous, will be defeated by his own deviousness, Tessa will meet Tito's legal wife Romola, and they will be the survivors. And we may notice that it is the girl Ninna that represents the loaded die, rather than her brother, suggesting that women can, in spite of fifteenth-century or nineteenth-century strictures, be adventurous and still fall on their feet.

Romola occupies a position in Eliot's oeuvre between the early, more straightforwardly narrative novels and the sophisticated reasoning and complicated structuring apparent in the multiplot novels *Middlemarch* and *Daniel Deronda*. The act of writing it seemed to bring about a change in Eliot the novelist: 'I began it a young woman,— I finished it an old woman.'⁵ This change is reflected in the way mathematics is used in the novels. In *Romola*, there are few direct references to doing mathematics or to mathematics education, as there were in Eliot's first two novels. But the significance of Eliot's mathematics is apparent in the narrator's use of analogical thinking and logically parallel stories, such as the ones concerning Ninna and Tito that

² Ibid, p.26.

³ Ibid, p.27.

⁴ Ibid, p.402.

⁵ J. W. Cross (ed), *George Eliot's Life as Related in her Letters and Journals*, 3 vols. (Edinburgh and London: Blackwood, 1885), 2: p.352.

have just been described. And it is also apparent in the logical arguments in the novel: as we shall see, Romola reasons like a mathematician or logician about the status of women. And there is as always mathematical imagery: Eliot returns to the optics she introduced in *Adam Bede* and writes symbolically about mirrors and windows. And for Eliot, as has already been explained in the introduction, mathematics is an unchanging certainty in an uncertain and changing world.

Unchanging mathematics and circle imagery

The geometrical properties of the circle, its never-ending continuity, its total symmetry, make it a useful image for both the continuity of life and the power structures in groups of people. The novel begins with circle imagery. Eliot compares the certainty of mathematics with the fragility of other kinds of philosophising in the Proem, which opens with an arithmetical computation by the narrator: ‘More than three centuries and a half ago, in the mid spring-time of 1492’.⁶ This is no accidental use of mathematics, for mathematics continually appears in what follows. As this opening clause might suggest, the theme of the Proem is what has changed in the time between 1492 and 1862, and what has stayed the same. What have stayed the same are, on the one hand mathematics and its applications, and on the other human sympathy and human need. The progress of the ‘angel of the dawn’, travelling ‘with broad slow wing’ and seeing the ‘same great mountain shadows on the same valleys’ evokes the mathematical certainty underpinning the physical geography of Europe: dawn creeps gradually west in 1862 exactly as in 1492; this applied mathematics is then related to a sympathetic understanding of the certainties of human life, as the dawn illuminates ‘the rosy warmth of nestling children [...] sorrow and sickness’.⁷

The narrator has sympathetic understanding too for the struggle of the ‘night-student’ to make meaning out of ‘man’s brief life’, a struggle described using the geometrical image of the circle: this life might be seen by the night-student as ‘an arc in an immeasurable circle of light and glory’.⁸ Prosaically, the image might suggest the perceived circular orbit of the sun round the earth, connecting people in different lands

⁶ *Romola*, p.3.

⁷ Ibid.

⁸ Ibid.

as the sun's light 'pierc[es] into the dwellings of men'; but clearly the image is also to be interpreted more symbolically: 'immeasurable' and 'glory' suggest something beyond physical and human geography, something which, as Felicia Bonaparte puts it, the night-student 'hopes will extend the arc of experience into meaning'.⁹ Like a circle in pure geometry, this circle is 'immeasurable', which might suggest that its significance is unfathomable. This is two-edged. As we shall see in later chapters, mathematics can be used to unify reasoned theories about the world, but it can also be used to give credence to fanciful systems having only apparent meaning.

The metaphorical imagery and the practical mathematics are brought together more straightforwardly when the Proem's narrator suggests that 'we still resemble the men of the past more than we differ from them', and then substantiates this using mathematical physics: 'the great mechanical principles on which those domes and towers were raised must make a likeness in *human building* that will be broader and deeper than all possible change.'¹⁰ 'Human building' can have two meanings: humans building and building humans. First, humans built according to the same laws of mechanics in 1492 and in 1862; but also humans' strengths and weaknesses were built by experiences of kindness or cruelty, encouragement or criticism, sympathy or indifference in the same way in both of those times. At the end of the Proem the narrator returns to the association between the mathematics of human buildings and the building of sympathetic human cultures: the shade, who was living in 1492 and who is returning to view what Florence is now like, is counselled by the narrator to avoid politicians, merchants and scholars, whose beliefs are transient and speculative, but instead to look at 'the sunlight and shadows on the grand walls that were built solidly, and have endured', and at 'the faces of the little children, making another sunlight amid the shadows of age'.¹¹ Mathematics, like human sympathy, does not change; as Adam Bede says, 'The square o' four is sixteen [...] is as true when a man's miserable as when he's happy.'¹²

The image of the circle frequently recurs in the novel. Felicia Bonaparte, for whom every word of *Romola* 'is an image in an intricate symbolic pattern', sees some of this

⁹ Felicia Bonaparte, *The Triptych and the Cross* (Brighton: Harvester, 1979), p.62.

¹⁰ *Romola*, pp.3-4, my emphasis.

¹¹ *Ibid.*, p.9.

¹² *Adam Bede*, p.115.

symbolism as geometric; she relates it to circles in particular.¹³ She may be alluding to the Proem when she mentions the ‘cycle of the day – another circle in the geometric pattern’, which is ‘a recurrent metaphor that outlines the whole progress of the book’.¹⁴ Bonaparte’s symbolic circles range in size from Tito’s ill-fated rings to the alternative cultural circles that characterise Florentine philosophy: the pagan circle centred on Nello; and the Christian circle on Savonarola.¹⁵ Bonaparte here seems to use ‘circle’ of people as a synonym for ‘group’ of people, as Eliot does, particularly in this novel and in *Middlemarch*.

Describing a group of people as a circle might call to mind the Arthurian round table, where each of the knights has equal esteem; the rotational symmetry of the circle expresses this: the circle looks the same from all directions.¹⁶ As somebody new arrives in such a group he can be accommodated in the circle without changing its structure: when Machiavelli is addressing a group at the barber’s shop, he is able to go on uninterrupted ‘as the circle opened to admit Tito’.¹⁷ The men in this group are fearful about the current political upheavals, and a circle is a structure that might make them feel more secure; a circle is a shape with no vulnerable corners. In *Silas Marner* (1862), Eliot’s novel that immediately preceded *Romola*, when Silas arrives at the Rainbow having had his gold stolen, he is placed ‘aloof from every one else in the centre of the circle’; the circular arrangement ensures that all his auditors are of equal prominence, which gives them a sense of protection from this man who is possibly ‘off his head’.¹⁸ In *Romola*, when, on the steps of the Church of San Stefano, Romola is using the bread and wine in her basket to save the life of Baldassarre, whom ironically her husband Tito would have wished dead, a circle of hungry men ‘was pressing rather closely on Romola’. The men crave Romola’s bread, and when the ‘circle had narrowed till the coarse men [...] had left hardly any margin round Romola’, she ‘rose to her feet’ holding out the bread and offering it to the men, while pointing out that if they take it they will be denying it to others in greater need. The crowd round her backs off in response to this combination of compassion and logic. None of them wants to become

¹³ Bonaparte, p.10.

¹⁴ Ibid, p.78.

¹⁵ Ibid, p.89, p.133 et seq.

¹⁶ Bonaparte alludes to the symmetry of the circle (p.62), but does not discuss the power dynamics.

¹⁷ *Romola*, p.371.

¹⁸ *Silas Marner*, pp.54, 53.

conspicuous and vulnerable by snatching the bread. Indeed, it is as the circle breaks up that the individuals become vulnerable: 'The man in the night-cap looked rather silly'.¹⁹

Evidence, logical reasoning and truth

Eliot's mathematical and logical sensitivities frequently induce her to challenge beliefs about society by suggesting that they are not adequately supported by reasoning or evidence. Nancy Paxton documents a strand running through Eliot's novels delineating a tussle between Eliot and Herbert Spencer over the biology of sex. Eliot suggests in a letter to Sara Hennell in 1862, written during the period in which *Romola* was being serialised, that, while it may not be 'kind or right' to 'get a little impatient' with 'an old friend's mind', Spencer has a 'contentment in abstractions'.²⁰ One such 'abstraction' was Spencer's belief that beauty is a sign of goodness: Spencer could not 'reconcile' himself to the 'common opinion that beauty and character are unrelated'.²¹ Was Spencer correct in believing that this was the common opinion in Britain in 1854? Dickens's novels repeatedly question the relationship between goodness and beauty, quintessentially in *David Copperfield*: Dora, David's first wife and his mistake, is 'a Fairy, a Sylph', while Agnes, his second wife, has 'steady, plain, hard-working qualities'.²² But it was not at all uncommon to link beauty to goodness, as Wordsworth does in his poem about a 'Perfect Woman nobly planned / To warn, to comfort, and command', who was also a 'phantom of delight'; and as Coventry Patmore does in his 1853 poem *The Angel in the House*.²³ And according to Davidoff and Hall, by the 1840s, good taste 'confined women within a particular notion of femininity both in their appearance and behaviour. To be large, or loud, or strong, was to be ugly, and carried with it notions of moral collapse as well as physical failure to conform'.²⁴ Eliot's response to Spencer was to develop alternative logical theorising by equivocating. In *Adam Bede*, 'it would be the easiest folly [...] to fall in love with' the 'pretty' Hetty; but Dinah is both attractive *and* good. In *Middlemarch* there is good plain Mary Garth and

¹⁹ *Romola*, pp.354-5.

²⁰ GEL, 4: p.66-7.

²¹ Herbert Spencer, *Essays: Scientific, Political and Speculative*, 3 vols. (London: Longman, Brown, Green and Roberts, 1858), p.417.

²² Charles Dickens, *David Copperfield* (London: Penguin, 2004), pp.397, 613.

²³ William Wordsworth, *The Major Works* (Oxford: OUP, 1984), pp.292-3.

²⁴ Leonore Davidoff and Catherine Hall, *Family Fortunes: Men and Women in the English Middle Class, 1780-1850* (Chicago: University of Chicago Press, 1987), p.191.

selfish beautiful Rosamond Vincy; but then there is also beautiful generous Dorothea. And in *Romola*, Julia Straub sees the eponymous heroine embodying ‘the kind of Neoplatonic ideal of femininity which was based on the fusion of beauty and moral goodness, gentleness and strength’; while the artist Piero di Cosimo questions whether Tito’s beauty is a guarantee of his noble character, when he asks Tito to sit for him to represent the traitor Sinon: ‘a perfect traitor should have a face which vice can write no marks on’.²⁵ *Romola* appeared at much the same time as Mary Braddon’s *Lady Audley’s Secret*, with its beautiful and evil eponymous heroine.

Challenges to cultural norms through the use of logical and philosophical reversals recur in *Romola*. Mark Turner suggests that, while in Britain in the 1860s, it was women’s extramarital affairs that were cited as ‘reasons for the collapse of households’, in *Romola* Eliot ‘reverses cultural norms of gender and sexuality’: it is Tito whose infidelity undermines his relationship with Romola and ultimately destroys him, whereas ‘Tessa the fallen woman survives’.²⁶ When *Romola* was serialised in the *Cornhill*, it was accompanied by illustrations by Fredric Leighton. For Turner, the ‘most conventionally domestic image in the whole *Romola* series’ is of ‘The Other Wife’ which depicts ‘Tessa at Home’.²⁷

Eliot frequently emphasises the need to challenge beliefs that are not based on adequate evidence. When Silas Marner has his gold stolen, the villagers of Raveloe turn for enlightenment to Justice Malam, the magistrate who has a ‘capacious mind, seeing that he could draw much wider conclusions without evidence than could be expected of his neighbours who were not on the Commission of the Peace’.²⁸ Silas has just surmised, on the basis of no evidence, that Jem Rodney has stolen his gold, although he has rapidly withdrawn this accusation after Jem’s alibi is explained to him. This unjust accusation is ironic: Silas himself has only come to be in Raveloe, because he was convicted of stealing money on only circumstantial evidence - unless papprayer and the drawing of lots are considered to be incontrovertible proof. In spite of Justice Malam’s

²⁵ Julia Straub, *A Victorian Muse: The Afterlife of Dante’s Beatrice in Nineteenth-Century Literature* (London: Bloomsbury, 2009), p.78; *Romola*, p.41.

²⁶ Mark W. Turner, ‘George Eliot v. Frederic Leighton: Whose Text Is It Anyway?’, in *From Author to Text: Re-reading George Eliot’s Romola* (Aldershot: Ashgate, 1998), pp.17-35 (p.25).

²⁷ Ibid.

²⁸ *Silas Marner*, p.72.

supposed abilities, truth can only be established through logical reasoning, which must be based on sound evidence: Eliot repeatedly pokes fun at those who, like the Landlord of the Rainbow, are 'accustomed to put two and two together'.²⁹ When researching the clothes worn by women in fifteenth-century Florence, in which *Romola* is set, Eliot bemoans the scarcity of evidence: 'Approximate truth is the only truth available, but at least one must strive for that, and not wade off into arbitrary falsehood.'³⁰ The difference between truth, even if sometimes only approximate, and falsehood is a central theme of *Romola*.

Logical reasoning about patriarchal structures

Fathers play an equivocal role in *Romola*. Whilst Tito's wickedness is focused on his betrayal of his adoptive father, the situation is very different for Romola, who has effectively four fathers: her biological father Bardo Bardi; her spiritual father Savonarola, who calls her 'daughter' and whom she calls 'father'; her god-father Bernardo; and her husband Tito. Tito would like to act as her father; Davidoff and Hall describe how in early nineteenth-century marriage, a husband was often seen as 'a father, a brother, and a friend'.³¹ Whilst we are given to understand that Tito's adoptive father has been helpful to Tito in raising him, the situation is much more complicated in Romola's case, and it is only her god-father who gives her advice and support that she can continue to value.

In an essay about *Romola*, Caroline Levine addresses issues of truth and falsehood by offering a persuasive unifying model for structuring our understanding of Romola's role in the novel. Levine suggests that Romola is an empirical scientist establishing the validity of her hypotheses about the men in her life: her father, Tito and Savonarola; and that she comes to realise that these men all 'misrepresent and misread the reality of her experience'.³² Time and experience demonstrate to Romola that her hypotheses, like the men who are their subjects, are inadequate and need to be rejected, so that by the end of the novel, Romola has come to rely on herself for the task of giving meaning to

²⁹ Ibid, p.59.

³⁰ GEL, 4: p.43.

³¹ Davidoff and Hall, p.327.

³² Caroline Levine, 'The Prophetic Fallacy: Realism, Foreshadowing and Narrative Knowledge in *Romola*', in *From Author to Text: Re-reading George Eliot's Romola*, , pp.135-163 (p.137).

her life. Levine questions the assumptions about realism underlying Eliot's scientific approach to rejecting some hypotheses and validating others: the 'particular narrative path' taken in the novel is after all only one of many possible paths.³³ I am suggesting a modification of Levine's model in which, as Bonaparte suggests, *Romola* is seen more as a 'symbolic' than as a 'realistic' novel.³⁴ We might note that Romola is trained in the classics rather than in empirical science by her father, who sees himself as a Platonist, as more than equal to Ficini, who is perceived 'as the very high priest of Platonism'.³⁵ And, since Plato gave pre-eminence to mathematics and dialectic in his philosophy, this would argue for viewing Romola as framing postulates about her existence and then using mathematical logic to draw conclusions from these postulates: if the conclusions prove to be false then the postulates need to be questioned.³⁶ The postulates examined in the novel by Romola are frequently postulates of broad significance: for Turner, when Eliot writes that 'we still resemble the men of the past', she is indicating that the novel 'is as much a story about mid-Victorian England as Renaissance Florence'.³⁷ If we frame Romola's quest to find meaning in terms of logic, some of Levine's problems concerning realist assumptions have less force. The focus is less on describing what the world is like, and more on postulating, and on drawing conclusions about how to act when we find out whether the postulates are or are not valid.

A question which recurs in Eliot's novels is this: to what extent are women the same as men? Throughout the novel, Romola poses this awkward question. In her conversation with her blind father, Bardo, Romola demonstrates to him the understanding she already has of classical culture. Nancy Paxton makes the subtle point that while Romola is reading Politian to Bardo, Bardo interrupts Romola at exactly the point where the passage 'demonstrates the sanctity and redemptive power of the mother'; this draws attention to a cultural misogyny that rejects the suggestion that women's compassionate way of seeing the world is strength rather than weakness.³⁸ Romola clearly believes she has a right to receive a classical education and to be

³³ Ibid, p.160.

³⁴ Bonaparte, p.15.

³⁵ *Romola*, p.51.

³⁶ See, for example, Plato, *The Republic*, trans, by Desmond Lee (London: Penguin, 1987), pp.331-347 (sections 8.2 and 8.3).

³⁷ *Romola*, p.3; Turner, p.21.

³⁸ *Romola*, pp.46-7; Nancy Paxton, *George Eliot and Herbert Spencer: Feminism, Evolutionism and the Reconstruction of Gender* (Princeton: Princeton University Press, 1991), p.125.

regarded as the intellectual equal of her brother. Romola's postulate is that she will find meaning for her life in following her father, Bardo, in his philosophical studies. Bardo appears to read her thoughts when he devalues Romola by mourning the lack of an intellectual collaborator, telling Romola that 'the patience demanded by those who would tread the unbeaten paths of knowledge are still less reconcilable with the wandering, vagrant propensity of the feminine mind than with the feeble powers of the feminine body'. Romola protests that her actions have already provided evidence of her ability to share in his research: 'I read anything you wish me to read.' When Bardo offers contrary evidence, remembering 'thy fainting at the mere search for the references', Romola indicates the speciousness of Bardo's argument: 'father, it was the weight of the books, and Maso can help me,— it was not want of attention and patience'.³⁹ Bardo's remark about the 'vagrant propensity of the feminine mind' is an exact reversal of what Bardo and Romola demonstrate: it is he who has the wandering mind, having no logical basis on which to draw his analogy between physical and intellectual weakness. Taken together with Paxton's earlier point about the interruption, this presents Eliot's view, expressed in a letter to John Morley in 1867, that 'as a mere fact of zoological evolution' women have the worst share of evolutionary advantages, but this does not mean that there should not be 'an equivalence of advantages for two sexes, as to education and the possibilities of free development'.⁴⁰ Paxton points out that, while Spencer, in his 1859 essay 'Physical Training' contended that over-educating girls produced 'physical degeneracy' and loss of beauty,⁴¹ Eliot counters this by insisting that Romola's classical studies have not diminished her 'lovable womanliness'.⁴² And as Bonaparte sees the situation, while Romola cannot be described as a classical scholar, she brings to the classics something that Bardo does not have: 'clear critical intelligence'.⁴³

Romola's conversation with her father follows a similar pattern to Maggie's conversation with Mr Stelling in *The Mill on the Floss*, on the occasion when Maggie suggests she could do Tom's lessons. Mr Stelling, like Bardo, stigmatises the powers of the feminine mind: girls have 'a great deal of superficial cleverness' but are 'quick and

³⁹ *Romola*, pp.49-50.

⁴⁰ GEL, 4: p.364.

⁴¹ [Herbert Spencer], 'Physical Training', *British Quarterly Review*, 29 (April, 1859), 362-397 (p.394).

⁴² Paxton, p.125; *Romola*, p.48.

⁴³ Bonaparte, p.42.

shallow'.⁴⁴ The similarities between the two incidents are striking: just like Bardo, Mr Stelling offers no evidence for his - and society's - misogynistic beliefs. In both cases, a girl is suggesting taking the place of a reluctant brother, and in both cases the father mourns the fact that it is the girl, and not her brother, who manifests the intelligence to succeed, given that such success for a girl is out of the question: Mr Tulliver says of Maggie: 'a woman's no business wi' being so clever; it'll turn to trouble, I doubt.'⁴⁵ Much the same pattern recurs in *Middlemarch* with regard to Dorothea, her uncle and Mr Casaubon.⁴⁶ By ironically eliciting contradictions such as this, Eliot makes the education of girls an issue in *Romola*, as it was in *The Mill on the Floss* and will continue to be in Eliot's later novels. In all cases mentioned, what the girl is proposing to learn is privileged male knowledge: Euclid and the classics. And in all cases, what the girl is wanting to learn is not necessarily of as great value as it is supposed to be, as has already been discussed in connection with *The Mill on the Floss* in chapter two, and will be discussed further in chapters four and six. What is significant is that this knowledge is viewed as prestigious and it is for this reason that it is something to which the girls or women concerned aspire. In 1868 Eliot subscribed fifty pounds to a fund for establishing a women's college in connection with Cambridge University, telling Emily Davies: 'Mr Lewes begs that you will enter that sum on the list as coming from "the author of Adam Bede", or of "Romola" – whichever title you may prefer'. Davies chose *Romola*, suggesting that both Eliot and Davies recognised the relevance of this novel to the issue of women's higher education.⁴⁷

When Romola decides she no longer has love for Tito, she again reasons logically from evidence to conclude that Tito is deceitful. The two main issues that concern Romola are Tito's betrayal of her father by disposing of his library, and his betrayal of his adoptive father. The first is relatively straightforward to establish, and also decisive in convincing Romola that her marriage with Tito is effectively at an end. In a fateful conversation Tito tells Romola that he has appropriated her property, her father's library. Such appropriation was an issue that resonated strongly in mid-Victorian Britain where marriage property laws were being increasingly questioned: in 1856, for example, Marian Evans signed a petition about the position of married women, whose

⁴⁴ *The Mill on the Floss*, p.150.

⁴⁵ *Ibid*, p.17.

⁴⁶ See chapter four.

⁴⁷ GEL, 8: p.414.

property passed to their husbands on marriage; this was sent her by Barbara Leigh Smith and subsequently presented to Parliament with more than three thousand signatures.⁴⁸ This conversation between Tito and Romola is similar to that already described between Bardo and Romola, to the extent that it is only Romola whose approach remains unemotionally rational. One clear difference between Bardo and Tito is that Tito knows that his arguments will not convince Romola; Tito's 'heart was palpitating with anxiety'.⁴⁹ In an attempt to defend himself against Romola's rationality he adopts a patronising tone, insinuating that he understands the world in a way a woman could not: 'That is all a fabric of your own imagination, my sweet one. Your secluded life has made you lay such false stress on a few things.'⁵⁰ Ironically, this insinuation of falsehood is once more the exact reverse of why the ultra-logical and truth-loving Romola poses a problem for Tito. Tito's justifications for selling the library, perhaps reasonable to some extent, are undermined by his assumption, which part of him knows to be unfounded, that he can offer Romola trite explanations and that, being a woman, she will have to accept them. He talks about extending the usefulness of Bardo's 'books and antiquities' by dispersing them; Romola dismisses these arguments as logically irrelevant, in the light of Tito's broken promises and disregard of 'faithfulness, and love, and sweet grateful memories'.⁵¹ In the end, the intellectual weakness of Tito's position is symbolised by his need to lock the door until he has extracted an assurance from Romola not to act in a way disadvantageous to him. 'Do you believe in assurances?' Romola asks Tito contemptuously, in view of Tito's having reneged on his assurances to Bardo.⁵²

The other issue, Tito's betrayal of his adoptive father, provides, of course, much of the plot of the novel, and for Romola involves a gradual accumulation and interpretation of clues. She is unsettled by her interview with her dying brother. She is also aware of the unsubstantiated suspicions both her godfather and Piero di Cosimo have concerning Tito: when she goes to visit Piero she sees the picture he has painted of Tito's fear in his confrontation with Baldassarre outside the Duomo, even though Piero tries to cover the picture up so as to prevent her from seeing it. When the fearful Tito

⁴⁸ GEL, 2: pp.225-7, 229.

⁴⁹ *Romola*, p.267.

⁵⁰ *Ibid*, p.268.

⁵¹ *Ibid*, pp.270-1.

⁵² *Ibid*, p.275.

tells Niccolò that the ‘coat of mail’ he wants to purchase from him is ‘only defensive armour: it can hurt nobody’, Niccolò reasons, correctly as it transpires, but not in the literal way he thinks, that ‘it may make the man who wears it feel himself all the safer if he should want to hurt somebody’.⁵³ Tito has indeed hurt, and continues to hurt, Baldassarre, by stealing his property and disowning him. This coat of mail provides the final and most conclusive evidence for Romola. Immediately after the revelation that Tito has sold her father’s library, she reasons deductively about Tito’s purchase of the body armour. Her premises are that Tito is capable of robbery, because he has robbed her father; and that you do not purchase body armour except to protect yourself from someone who is likely to attack you. She has more facts at her disposal than Niccolò and so can reach the more accurate reasoned conclusion that, just as Tito has ‘robbed’ her dead father by selling his library, he has also ‘robbed somebody else, who is *not* dead’.⁵⁴ Romola reasons in this way, not because she wants to be a cold logician, but in order to defend herself against the prejudices of men who would undermine her reasonable and truthful view of the world. This is a characteristic of the way Eliot employs mathematics and logic in her thinking and writing, not as a way of denying the value of human emotions, but in order to clear away assumptions that prevent these emotions from being valued. Tito and Bardo are alike to the extent that they both seek to diminish Romola by presuming that, as a woman, she has reduced capability to understand.

When Romola goes to visit her dying brother, against her father’s wishes, she meets Savonarola and begins a process of being guided by the authority of yet a third man. Savonarola commands her to ‘Kneel, my daughter’, and the narrator tells us that, ‘in the renunciation of her proud erectness, her mental attitude seemed changed, and she found herself in a new state of passiveness’.⁵⁵ There is, however, little evidence of passiveness in her later confrontation with Tito and her decision to leave him. Having made this decision, Romola intends to go to Venice to find Cassandra Fedeles who may help her become wise enough to ‘rescue her father’s name from oblivion’ by continuing his work: ‘she had invented a lot for herself’, even though it was a lot that was still shaped

⁵³ Ibid, p.228.

⁵⁴ Ibid, p.273.

⁵⁵ Ibid, p.152.

by her father's authority.⁵⁶ Her meeting with Savonarola during her escape changes her mind and she tells him 'I will be guided', when he suggests she should 'Live for Florence'.⁵⁷

At this point in the novel the authority of all three men is significant for Romola: Tito, the husband whose authority she is in the process of rejecting; her father whose work she is considering continuing; and Savonarola who might be able to offer a new worthwhile purpose for her life. As a rational being, Romola is prepared not to dismiss any authority, including Savonarola's, out of hand until she has found it wanting. But subsequent events make it clear that her pride in her reasoned approach to life is as strong as ever. When she goes to see Savonarola to ask him to intervene to prevent her godfather being executed, he is immediately aware of her powerful logical mind; he begins the conversation by remarking that Romola is 'not wont to lay stress on small matters', and while this may seem to indicate Savonarola's willingness to take Romola seriously, even this remark can be read as an attempt to patronise Romola as a defence against her logical argument. When Savonarola defends his refusal to intervene on behalf of Romola's godfather, declaring that his interest is only in setting a philosophical direction for government and that he does not meddle 'with the functions of the State', Romola points out to him his inconsistency: he defended 'Tornabuoni, who has worn two faces, and flattered you with a show of affection, when my godfather has always been honest' and implies that he is not defending her godfather because her godfather has not flattered Savonarola. And Romola exposes Savonarola's suggestion of a plot in which her godfather has been involved as mere hypocrisy: 'What plot?' she asks and then dismisses the evidence Savonarola offers her as propaganda. And she ridicules Savonarola's suggestion that refusing to intervene does not mean that he thinks her godfather should die: 'I have said that I do not desire their death', he tells her unconvincingly. Telling Savonarola: 'I cannot unravel your thoughts, father' is Romola's way of saying that she sees no logic in his arguments; and she demonstrates she is prepared to put her belief in rationality on the line when she reaches a final theological conclusion: 'God's Kingdom is something wider – else, let me stand outside it with the beings that I love.'⁵⁸

⁵⁶ Ibid, p.307.

⁵⁷ Ibid, p.345.

⁵⁸ Ibid, pp. 459, 461, 463, 464.

So eventually Romola rejects all three sources of male authority on rational grounds. By 'drifting away' from patriarchal injunctions Romola discovers herself and recognises her own authority and her own purpose for life: this becomes setting up a household with Tessa and her dead husband's children.⁵⁹ Turner suggests that this is a purpose that disappoints some feminists; albeit the household is unconventional, it is also for Romola 'a return to the domestic sphere'.⁶⁰ But Susan Bernardo suggests that Romola is not 'hopelessly trapped'; instead, she 'creates a household of meaning'.⁶¹ And Paxton distinguishes carefully between a domestic sphere ordained by patriarchal values and a 'woman-centred culture' based on matriarchal values that include valuing family relationships that transcend 'the more restrictive patriarchal model formalised by the laws of marriage and legitimacy'.⁶² Levine cites Romola's 'anti-conventional conclusion', that the 'law was sacred. Yes, but rebellion might be sacred too', as exemplifying a process that 'follows the pattern of empirical science'.⁶³ But it might instead be seen as a rejection of conclusions reached on the basis of patriarchal law when arguments in support of these conclusions are found to be logically flawed.

Mirrors: truth about ourselves and others

Victorian Britain shared with late fifteenth-century Italy an expertise in glass manufacture. In *Romola*, Nello, the barber, is proud of his '*nosce teipsum*' mirror, 'a Venetian mirror from Murano'.⁶⁴ Macfarlane and Martin describe how 'glass-makers on the island of Murano, near Venice, experimented with Roman glass techniques' in the fourteenth century.⁶⁵ Murano became a centre of expertise for glass following an edict of 1291 which banned glass manufacture elsewhere in Venice, because of the danger that the heat from furnaces would burn down houses. In England in the late seventeenth century George Ravenscroft patented the 'remarkable lead glass', and subsequent development in glass manufacture in England culminated in the

⁵⁹ 'Drifting away' is the title of chapter 61.

⁶⁰ Turner, p.29.

⁶¹ Susan M. Bernardo, 'From Romola to *Romola*: The Complex Act of Naming', in *From Author to Text: Re-reading George Eliot's Romola*, pp.89-102 (p.101).

⁶² Paxton, p.140.

⁶³ *Romola*, p.442; Levine, p.137.

⁶⁴ *Romola*, p.35.

⁶⁵ Alan Macfarlane and Gerry Martin, *Glass: A World History* (Chicago: University of Chicago Press, 2002; London: Profile Books, 2002), p.21.

construction of the Crystal Palace for the Great Exhibition in 1851.⁶⁶ In *Romola*, the symbolism of glass, in the form of mirrors and windows, is associated with truth and falsehood. I begin by considering mirrors.

Bonaparte points out that two of the historical figures present at the celebration of Plato's birthday at Rucelli Gardens, Pico della Mirandola and Leon Battista Alberti, were Neoplatonists, or philosophers who studied the philosopher Plotinus. For Plotinus, the sensible world is an inferior image of higher reality, and Plotinus used various metaphors to explain this, including that of the mirror image. Mirrors enable us to see ourselves - but not quite as others see us: left and right are interchanged; the mathematics of mirrors contributes to their metaphorical meaning. Following Plotinus, we might say that the mirror is giving an image of a higher reality: the image is similar to, different from, inferior to and dependent on the ideal.⁶⁷ After Baldassarre arrives in Florence and Tito, his adopted son, denies knowing him, he wants to check that the way he looks has not greatly changed, and that Tito should have recognised him. So just before he is shaved by a barber, he uses the barber's hand-mirror to check that his appearance has not changed radically. His brain has changed and he is no longer able to read, but he recognises 'the same rough, clumsy skin'. The 'shaggy white beard' should not have made him unrecognisable if Tito wanted to recognise him. A bit later he decides to 'contemplate himself slowly' in a pool. He sees no madness in his looks, but concedes to himself that it might have been different at other times. He cannot know how others see him; nevertheless, 'he had felt that Tito knew him' when they met.⁶⁸ Using Neoplatonic ideas we might say that the higher reality of Baldassarre is imperfectly reflected in the image people, including Tito, see of him, and the image he sees of himself.

In Eliot's first novel, *Adam Bede*, the narrator vows to 'give a faithful account of men and things as they have mirrored themselves in my mind'. This provides the narrator with the opportunity to tell us that the mental mirror is 'doubtless defective', and so the image narrated may also be 'faint or confused'; it is far from exactly

⁶⁶ Ibid, p.24.

⁶⁷ John H. Fletcher, 'Chorismos and Emanation in the Philosophy of Plotinus' in R. Baine Harris, *The Significance of Neoplatonism* (Norfolk, Virginia: Old Dominion Research Foundation, 1976), pp.101-120 (pp.101, 104, 106).

⁶⁸ *Romola*, pp.253-4.

congruent to the reality. But the *Adam Bede* narrator has no intention of excusing inaccuracies, whether sensational or flattering, or of touching up anything to make the truth better, or worse, than it is. The narrator first tells us: 'I feel as much bound to tell you [...] what that reflection is, as if I were in a witness-box, narrating my experience on oath', but then indicates the impossibility of reflecting with complete reliability: 'falsehood is so easy; truth so difficult [...] Examine your words well, and you will find that even when you have no motive to be false, it is a very hard thing to say the exact truth, even about your own immediate feelings.'⁶⁹ George Lewes echoes this reference to the witness box in an 1860 essay entitled 'Seeing is believing', written to satirise what happened at séances: 'I am not in the least disposed to doubt what you saw; but only to doubt your *interpretation* of what you saw [...] we cannot accept the evidence that the witness saw the defendant *going* to knock the plaintiff down; that is pure inference'.⁷⁰

Even what we see may not be as objective as Lewes implies. It is difficult for people not to edit what they see of themselves in a mirror, and the use of mirrors is associated with self-deception, even for the truth-seeking Romola. Humans 'do not naturally see the world as it is, but as they expect it to be'.⁷¹ When Romola decides to run away from her marriage to Tito and from Florence, she disguises herself as a *pinzochera*, a nun. As she looks in the mirror to check her attire, she finds that 'she looked strangely like her brother Dino', who had become a monk. She is concerned about the extent to which she is becoming like him in other ways. In a striking anticipation of the pier-glass parable in *Middlemarch*, she 'lifted the candle to the mirror. Surely her disguise would be complete to anyone who had not lived very near to her'.⁷² But, as the narrator indicates a little later, this is egoistic thinking, failing, just as is the case with the *Middlemarch* pier-glass, to take account of the full facts. Romola is oblivious of how her pride gets in the way of her disguise. To others, her similarity to her brother might not be so apparent, because 'something else besides the mere garb would perhaps be necessary to enable her to pass as a Pinzochera [...] her whole air and expression were as little as

⁶⁹ *Adam Bede*, pp.175-7.

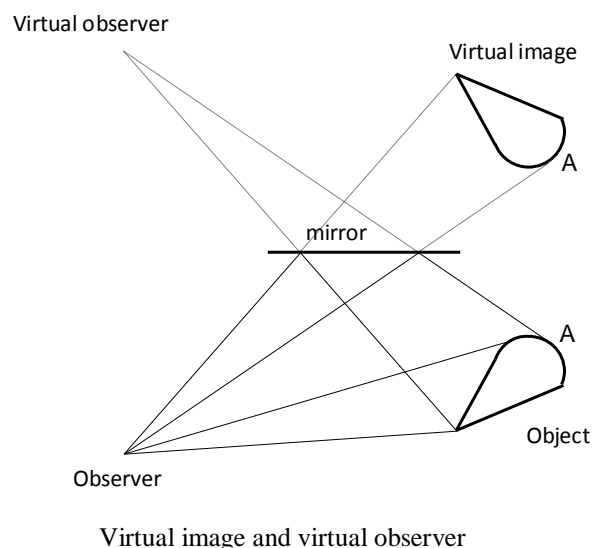
⁷⁰ George Lewes, 'Seeing is Believing', *Blackwood's Edinburgh Magazine*, 88 (October, 1860) 381-95 (p.382).

⁷¹ *Ibid*, p.51.

⁷² *Romola*, p.304.

possible like those of a sister', who would have bent eye-lids and lips moving to repeat prayers.⁷³

Mirror images may help us to see things, literally and metaphorically, from different points of view; the image will change 'according to where the looker is placed'.⁷⁴ This affects not just what we see but also how we see it. Changing our point of view may help to make the conclusions we draw more objective, or the reverse may be true. Baldassarre wants to see himself from Tito's point of view and may be right in believing that Tito did recognise him. Romola wants to see herself from the point of view of those she might meet in the street and fails comprehensively to do this, whatever she herself believes. Isobel Armstrong points out that all mirror images are virtual: 'hosted by matter but not of it'; the light never actually comes from where we perceive the image to be.⁷⁵ The way we perceive mirror images is dependent on our hard-wired assumption that light travels in straight lines. This is why when we look at the world in a mirror, we see a virtual image: we imagine that the light from what we see has reached our eye in a straight line. What we are less aware of is that it is not just the image that it is virtual; it is also the viewer. If I look at an object in a mirror I do not see what I would see if I looked directly at the object: I see what I would see if I was as far behind the plane of the mirror as I am in front. And what I see is not only a



⁷³ Ibid, p.307.

⁷⁴ Isobel Armstrong, *Victorian Glassworlds* (Oxford: OUP, 2008), pp.96.

⁷⁵ Ibid.

different shape; it is also lit in a different way. The diagram shows this. The dotted lines do not represent the path of the light; they are there to indicate where the observer appears to see the image; and also what image the observer sees, which is the image that would be seen by someone in the position of the virtual observer if there was no mirror, except that the image is laterally inverted. In the diagram, the observer looking directly at the object cannot see point A on the object, but can see this point when looking at the mirror image.

The position of the virtual observer might or might not be a physically attainable position. In Lewis Carroll's *Through the Looking Glass, and What Alice Found There* (1871), the idea of the virtual observer in an unattainable position is dramatically illustrated by Alice stepping through the looking glass. The whole of Alice's story centres on the difference in viewpoint, which is amusingly illustrated by what Alice initially sees from her virtual position: the clock, for example, the front of which could not be seen in the mirror, 'had got the face of a little old man, and grinned at her'.⁷⁶ Since we are to some extent aware that, when we observe an object in a mirror, particularly when we look at ourselves, our point of view is somewhere outside of ourselves, we may believe that our point of view is more objective than it is. The significance of point of view in *Middlemarch* and in *Daniel Deronda*, and for Lewes in *Problems of Life and Mind*, is discussed in chapters five and six.

Romola's Proem explicitly suggests that in some significant ways Victorians and fifteenth-century Florentines are the same. The novel might be said to mirror Victorian society from the point of view of fifteenth-century Florence. This is clearly a virtual image, since the image is happening several centuries before the arrival of the object it is reflecting; the novel itself can be seen as the mirror that makes it possible to view this image. When the narrator of *Adam Bede* promises to describe events 'as they have mirrored themselves in my mind',⁷⁷ it seems as if the narrator's mind is not *using* a mirror, but rather *becoming* a mirror. In *The Mill on the Floss*, the narrator is sceptical about Mr Stelling's opinion that in order to teach Tom, Tom's mind needs to be 'ploughed and harrowed' and suggests that different metaphors would indicate different methods of teaching; someone might 'call the mind a sheet of white paper or a

⁷⁶ Lewis Carroll, *The Annotated Alice*, ed. by Martin Gardner (London: Penguin 2001), p.186.

⁷⁷ *Adam Bede*, p.175.

mirror'.⁷⁸ A pupil thought of as a mirror would reflect back to the teacher; and what is reflected back may be not what the teacher expected. The pupil may have misunderstood; alternatively, the pupil's reflection may indicate a misunderstanding on the part of the teacher. Romola, with her 'finely-wrought frame', acts as a mirror for her blind father, Bardo; in this case it is unclear whether the picture in Bardo's mind is the object or the image. Bardo wants Romola to reassure him that a book is in its right place, 'seeking the assurance that the outward fact continued to correspond with the image which lived to the minutest detail in his mind'.⁷⁹ Although Bardo's mental picture is described as the image, for Bardo it seems more like the object, since the library is required to reflect this mental picture. What Bardo wants to see reflected is the world as he imagines it. This is reminiscent of an incident Eliot related to Sara Hennell in a letter written in 1852: 'I went to Kew yesterday on a scientific expedition with Herbert Spencer, who has all sorts of theories about plants – I should have said a *proof*-hunting expedition. Of course, if the flowers didn't correspond to the theories, we said "*tant pis pour les fleurs*".'⁸⁰ Romola is a mirror in which the vain and narcissistic Bardo sees himself:

why is a young man like Poliziano [...] to have a glorious memory [...] why is Ficino, whose Latin is an offence to me [...] to descend to posterity as the very high priest of Platonism, while I, who am more than their equal, have not effected anything but scattered work.⁸¹

Romola is not only Bardo's mirror, but also his student; she learns and challenges Bardo's philosophy by being his mirror. And Romola is also a mirror for Tito. When Tito first meets Bardo and Romola and Bardo tells him of 'the capriciousness of my daughter's memory', Tito 'ventured to turn his eyes towards [Romola], and [...] his face broke into its brightest smile, which was reflected as inevitably as sudden sunbeams in Romola's'. Here Tito and Romola are mirrors for one another: Tito delights Romola by giving her a different point of view, a 'scholar' smiling 'at a deficiency for which she was constantly made to feel herself a culprit'; and Romola's reflection back to Tito is of a woman who is 'not really so cold and proud'.⁸² Later, Romola is a mirror reflecting a very different image for Tito. After the meeting in which Tito tells Romola he has sold

⁷⁸ *The Mill on the Floss*, pp.139-40.

⁷⁹ *Romola*, p.47.

⁸⁰ GEL, 2: p.40.

⁸¹ *Romola*, p.51.

⁸² *Ibid*, p.62.

her father's library, he tells Romola: 'you will forgive me [...] when you have had time to reflect'.⁸³ The two meanings of 'reflect' are both relevant here; Tito looks into the mirror that is Romola's mind and hopes eventually to see reflected forgiveness that will not be there.

Like Romola, Nello functions as a mirror. He insists on doing this, even though he also has his own fine 'Venetian mirror'. When Nello shaves off Tito's beard, he invites Tito to look at the result in his mirror. The name Nello gives his mirror is '*nosce teipsum*', which means 'know thyself'. But Nello impedes the acquisition of such knowledge by metaphorically placing himself between Tito and his mirror, informing Tito that he will discover that he no longer looks like a 'bearded owl or a Barbary ape'. Tito complains that Nello has made him look younger and more like 'a maiden of eighteen', and so he will have more difficulty getting work as a translator. Nello answers him at length, reassuring him that this is not the case and finally telling him he has 'the air of a fallen prince'.⁸⁴ Nello's reflection is hindering Tito from knowing himself; Nello, like the man in Lewes's witness box, is garrulous and interpretative, even though he no doubt sees his dishonesty as motivated by good intentions. Louis-Sébastien Mercier, writing in 1747, conceptually linked a man's image in a mirror with his painted portrait, and suggested that the talent of some painters consisted of 'flattering the subjects he paints with enough skill to persuade them that he is not flattering them'.⁸⁵ Nello is skilful enough here to persuade Tito, even though he does not convince the reader.

The images in a mirror are indeed dependent on where the looker is placed. From where Nello is placed, Tito is a fallen prince, while, as has already been mentioned, Piero sees a potential traitor and mirrors this in his painting. The way Eliot uses mirror symbolism in *Romola* is an indication of the growing sophistication of her novelistic style. In *Adam Bede*, the purpose of the somewhat harshly critical depiction of Hetty's and Arthur's use of mirrors is straightforwardly to suggest their vanity: Hetty lets down her hair to make her look like the 'picture of a lady', and Arthur sees 'his well-looking British

⁸³ Ibid, p.275.

⁸⁴ Ibid, pp.35, 36.

⁸⁵ Sabine Melchior-Bonnet, *The Mirror: A History*, trans. by Katharine H. Jewett (New York and London: Routledge, 2001), p.152.

person reflected in the old-fashioned mirrors'.⁸⁶ The narcissism within *Romola* is more nuanced: in spite of their egoism, we are encouraged to sympathise with Baldassarre, with Bardo, with Tito even, more than we have been encouraged to sympathise with Hetty. And the imposition of egoistic interpretations onto what Nello and others see in Nello's mirror anticipates the much more sophisticated pier-glass image in *Middlemarch*, which will be discussed in the next chapter. Nello as a mirror may be mathematically exact when he reflects the 'gossip of the street-corner', but Bardo suggests that these reflections might not be the truth. The distinction between mathematical exactness and scientific truth becomes particularly significant in connection with non-Euclidean geometries and their implications for *Daniel Deronda*, to be explored in the final chapter.⁸⁷

Windows into conceptual spaces

Defining and differentiating are characteristically mathematical and logical activities. In *Romola*, Eliot uses windows metaphorically to delineate differences between groups of people and to challenge the validity of those differences. One of the reasons why mirrors in public spaces confuse or disconcert us, Armstrong suggests, is that often 'there is no telling outside from in'.⁸⁸ To put it another way, we are all on the same side of the mirror. This is the opposite of what happens when glass is used in windows. Both literally and metaphorically, a window provides limited access from one distinct physical or conceptual space to another.

A comparison of the use of windows in *Adam Bede* and in *Romola* is another indication of Eliot's increasing sophistication as a novelist. In *Adam Bede* we look through the front windows of the Hall Farm, and are somewhat misled by what we see: we need to go inside round at the back to understand what happens there. The different spaces in *Adam Bede* - the farm, Adam's house, the Hall, the rector's house, the countryside - are different physically more than conceptually. By contrast, window symbolism in *Romola* is used to differentiate conceptual as much as physical spaces.

⁸⁶ *Adam Bede*, pp.150, 124.

⁸⁷ *Romola*, p.60.

⁸⁸ Armstrong, p.103.

One pair of contrasting spaces in *Romola* is wealth and poverty, and a related pair is safety and danger. In Italy during the fourteenth century, glass windows were becoming more common, though still more likely to be the preserve of the wealthy.⁸⁹ Eliot refers to this in *Romola*: the shutter in Tessa's room is closed 'not for any penal reasons, but because only the opposite window had the luxury of glass in it'.⁹⁰ Windows are symbols of wealth and power and also of trust and distrust. For richer fourteenth- and fifteenth-century Europeans, 'houses became like camera lenses or peep shows; one sat in muted light and looked out on the richness of colour.'⁹¹ This suggests that those with power can see but not be seen; but this arrangement is far from perfect. Having a window rather than a thick wall makes those inside inevitably more vulnerable, however well the window is designed. Armstrong suggests that windows can be places where 'the boundary is unsafe'.⁹² In *Romola*, intrusion through a window is used to symbolise the vulnerability of those with power when the power balance changes: 'evil youths [...] go prowling about the houses of our citizens carrying sharp tools in their pockets; – no sort of door, or window, or shutter, but they will pierce it [...] Have you by chance detected any small aperture in your door, or window shutter?'⁹³ Windows are a threat to those who are powerful but vulnerable, precisely because they open up a connection between spaces it might be safer to keep separate.

Another pair of conceptual spaces is paganism centred on Nello, and Christianity centred on Savonarola. A group watching the procession for the festival of San Giovanni from the room above Nello's shop are amused by the discomfort averred by the pagan artist Piero di Cosimo over the invasion of aural pollution from the Christian procession outside, 'against which no kind of ear-stuffing was a sufficient barricade'. Tito, on the other hand, another member of this group, is captivated and fascinated by the face of a monk in the procession 'upturned towards him and fixing on him a gaze that seemed to have [...] meaning in it'.⁹⁴ In due course it is Tito and not Piero who, because of the position he places himself in, is vulnerable to the intrusion of the Christian space into his life. The monk, it transpires, is Romola's brother, who is

⁸⁹ Macfarlane and Martin, p.66.

⁹⁰ *Romola*, p.278.

⁹¹ Macfarlane and Martin, p.66.

⁹² Armstrong, p.115.

⁹³ *Romola*, p.164.

⁹⁴ *Ibid*, p.83.

carrying a message for Tito from his adoptive father, and fascination will quickly turn to dread.

Another pair of conceptual spaces is the living and the dead. Tito is threatened by the space of the dead; he is fearful of revelations from Romola's now dead brother and he is terrified of Baldassarre who is quite capable of encompassing the death of both of them. In his novel *Vanity Fair*, Thackeray, who was editor of the *Cornhill*, the journal in which *Romola* was serialised, describes the facility in some houses that consists of 'a little arch in the wall' towards the top of the staircase 'which at once gives light to the stair [...] and serves for another purpose of utility', which is to provide an unobtrusive exit from the building that can be used by undertakers taking out coffins 'so as not to disturb in any unseemly manner the cold tenant slumbering within'.⁹⁵ The arched window serves to keep the space of the hardly living separate from the space of the dead. But the situation is different for Romola, who uses an arched opening for the opposite purpose. What we see when we look through windows is a restricted view of the world, and this may help focus our thoughts on specific ideas. When Romola is discussing with Tito her feelings following the death of her father, Tito is attempting to comfort her with what he suggests are reasoned arguments, but Romola is not responding to him: she 'had her eyes fixed absently on the arched opening, but she had not seen the distant hill; she had all the while been in the chapter-house, looking at the pale images of sorrow and death'.⁹⁶ For Romola, the archway is a window not onto the hill, but into her disconcerted soul, as she recalls the conversation she has had with her brother while he was dying. Metaphorically the archway is a window onto a world of the dead, beyond Tito's easy but unconvincing consolation.

A relative absence of windows produces spaces that are effectively cut off from one another. Bardo's home has 'comparatively small windows', which suits a man who has forsaken 'the vulgar pursuit of wealth in commerce' so that he can collect 'the precious remains of ancient art and wisdom'.⁹⁷ It also means that his daughter can grow up as he wishes, 'aloof from the debasing influence of [her] own sex, with their sparrow-like

⁹⁵ William Makepeace Thackeray, *Vanity Fair* (London: Penguin and BBC, 1999), pp.699-700.

⁹⁶ *Romola*, p.172.

⁹⁷ *Ibid*, pp.45, 51.

frivolity and their enslaving superstition'.⁹⁸ It is a characteristic of Romola's development that, because she refuses to be enslaved, she moves eventually from one extreme to the other, confounding what Armstrong describes as a limitation imposed by the window - 'the body can never follow the eye'.⁹⁹ She removes walls altogether, becoming

accustomed now to be addressed in [a] fraternal way by ordinary citizens, whose faces were familiar to her [...] The idea of home had come to be identified for her less with the house in the Via de' Bardi, where she sat in frequent loneliness, than with the towered circuit of Florence, where there was hardly a turn of the streets at which she was not greeted with looks of appeal or of friendliness.¹⁰⁰

This freedom to move between spaces not limited by walls is consistent with Romola's willingness to accept Tessa and her illegitimate children, eliciting a complaint from her cousin Monna Brigida: 'Fra Girolamo said as good as that widows ought not to marry again. Step in at the door and it's a sin and a shame, it seems; but come down the chimney and you're welcome.'¹⁰¹ The distinction between doors and chimneys has little relevance for someone who has no walls.

Romola abolishes the distinction between inside and outside. But she can still choose not to look through windows into conceptual spaces she would rather not enter. On several occasions she chooses not to look. For example, when mourning her father, hers is one of the 'few fair faces' that chose not to look from windows at the arrival of the French king into Florence.¹⁰² And those around her sometimes make this choosing easier for her; when she is 'at a window' on the occasion of Savonarola's execution, Jacopo Nardi helps her to see only what she wants to see by telling her when to look and when to cover her face.¹⁰³ Choosing what not to notice is one way in which Romola increasingly attains power over her own life.

⁹⁸ Ibid, p.52.

⁹⁹ Armstrong, p.115.

¹⁰⁰ *Romola*, p.357.

¹⁰¹ Ibid, p.531.

¹⁰² Ibid, p.230.

¹⁰³ Ibid, p.543.

Optics and looking through windows

The previous section considered how the imagery of windows challenges the notion that people live in different inviolate spaces. But in *Romola* and in *Middlemarch*, as in *Adam Bede*, Eliot introduces mathematical optics; in these later novels she uses it to make more profound points about the ways in which these conceptual spaces become unstable.

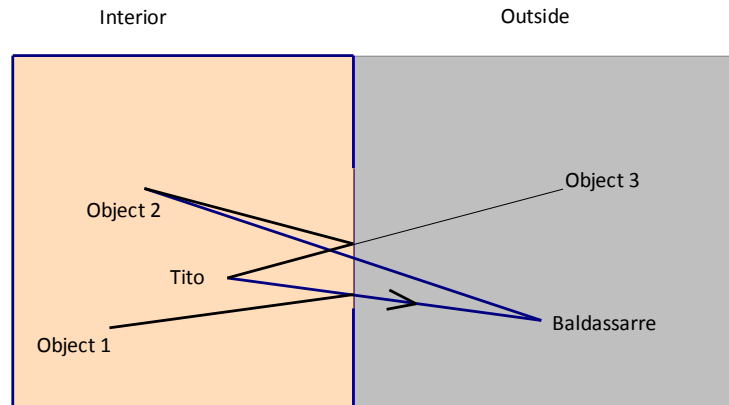
Glass is a medium and a barrier and provides protection of certain kinds for people inside a building: rain beats against it but does not enter. But the presence of glass modifies the nature of the connection between the inside space and the outside. For example, when it rains, windows become misted up and disrupt the connection between the two spaces.¹⁰⁴ But shutters and misted windows are not the only ways of disrupting the visual connection between the spaces opened up by windows. In chapter one I explained through the use of optical principles why, on a sunny day, it is possible to look out of windows but not usually to look in through windows. But this is not always how windows behave. It is the difference between the degree of illumination of the two spaces that determines who sees whom. Seeing out rather than in is only true during daylight; at night, if the interior is illuminated, the situation is reversed.

Baldassarre, bent on revenge, tracks Tito to the celebration of ‘the reputed anniversary of Plato’s death’ at ‘a supper in the Rucellai Gardens’.

He paused among the trees, and looked in at the windows, which made brilliant pictures against the gloom. He could hear the laughter; he could see Tito [...] But the men seated among the branching tapers and the flashing cups could know nothing of the pale fierce face that watched them from without. The light can be a curtain as well as the darkness.¹⁰⁵

¹⁰⁴ Armstrong, pp.114-5.

¹⁰⁵ *Romola*, p.325.



‘The light can be a curtain as well as the darkness’

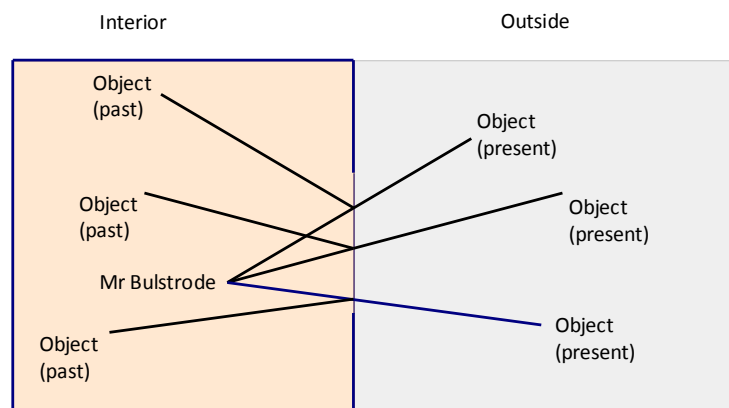
The light is a curtain, because the light inside is much brighter than the light outside. The light reaching the eye of an observer who is inside will be mainly light reflected by the window from interior objects and hardly any light from Baldassarre outside. While light travels from Tito to Baldassarre in the direction of the arrow, the light from Baldassarre to Tito is swamped by the light coming from Object 1 within the room. Similarly, Tito sees Object 2 in the room rather than Object 3 outside. Eliot suggests that there are two cases to consider. First, it might be *completely* dark outside and so no light at all could enter the window. Alternatively, the light inside is much brighter than the light outside, as I have just described. Eliot encapsulates these two alternatives in one short sentence: ‘The light can be a curtain as well as the darkness.’ This situation suits Baldassarre: unlike Tito, he wants access from his space to Tito’s space, but he wants it on his terms; he wants to remain hidden until he is ready. And metaphorically, Tito is dazzled by the flashing lights, so that, although he might otherwise have sensed the presence of Baldassarre, he is oblivious of it.

Perhaps, the most extreme example of the optical phenomenon I have just described is daylight. In *Middlemarch*, when Sir James Chettam hears that Dorothea is going to marry Mr Casaubon, Mrs Cadwallader tells him: ‘Come, come, cheer up! you are well rid of Miss Brooke, a girl who would have been requiring you to see the stars by daylight.’¹⁰⁶ As much light comes to us from the stars during the day as at night, but the sun’s light is emphatically ‘a curtain’ that prevents us from seeing the starlight.

¹⁰⁶ *Middlemarch*, p.54.

There is yet another possibility when considering light through windows. If the outside light is not strong and there is light in the interior, then the intensity of reflected light from objects in the room may match that of the light coming from objects outside, so that inside and outside objects are superimposed. Eliot uses this situation in connection with an image in *Middlemarch*. The apparently puritanically upright Mr Bulstrode has just been rediscovered by a man from his earlier life, who can expose his past immorality. The narrator describes Mr Bulstrode's state of mind like this:

[...] he felt the scenes of his earlier life coming between him and everything else, as obstinately as when we look through the window from a lighted room, the objects we turn our backs on are still before us, instead of the grass and the trees. The successive events inward and outward were there in one view: though each might be dwelt on in turn, the rest still kept their hold in the consciousness.¹⁰⁷



‘The successive events inward and outward were there in one view’

In this case, the reflected interior objects are not pleasing images of revellers, but past events in Mr Bulstrode's life, all too visible to Mr Bulstrode, who would rather look out of his window at what he has previously seen as the pleasing events of the present. He can see both past and present superimposed. Soon all will be dark outside and the whole world will be able to see the events of Mr Bulstrode's past. The critic Isobel Armstrong graphically describes Mr Bustrode's situation like this: ‘the reflection collapses time into space by making simultaneity of succession.’¹⁰⁸

There is another account of double images in *Middlemarch*, involving not windows but mirrors, in an epigraph taken from Eliot's poem ‘A Minor Prophet’:

¹⁰⁷ Ibid, p.578.

¹⁰⁸ Armstrong, p.109.

Full souls are double mirrors, making still
An endless vista of fair things before
Repeating things behind .¹⁰⁹

Double mirrors produce an endless series of receding images, both in front and behind. The message drawn from this is the opposite of that drawn from Bullstrode's lighted room. The image is seen as applying to Dorothea: what she brings with her from her past is seen as informing her present and pointing to the many choices in her future.

Paintings and drawings

Pictures are like mirrors and windows; they offer alternative points of view into conceptual spaces, and can themselves challenge concepts of sameness and difference. In addition to using the mirror, Neoplatonism also uses the portrait as a metaphorical term to describe the emanation of the ideal into the sensible world.¹¹⁰ The portraits of Piero di Cosimo play a significant role in the novel. Mention has been made of Tito, with his 'face that vice can write no marks on' sitting for Piero to represent the traitor Cosimo; and of Piero's depiction of Tito's fear when encountering Baldassarre, which helps Romola to understand what her husband is doing. When Tito goes to see Piero, to ask him to paint a triptych depicting Tito as Bacchus and Romola as a crowned Ariadne, he gets more than he has bargained for. Piero wants to take no detailed instructions from Tito: 'I love not to be choked with other men's thoughts'; nor does he want payment for the triptych, but instead the opportunity to have Romola and Bardo sit for him.¹¹¹ While Tito is at Piero's house he is shown the picture of himself with Baldassarre and Piero comments on the fear on Tito's face, both in the encounter and in the present moment. Piero is clear that his vocation as a painter is to depict ideal reality: he has no time for philosophers who 'spin false reasons'.¹¹²

Frederic Leighton, who contributed twenty-four full-page illustrations to the original serialisation of *Romola* in the *Cornhill*, provided his own windows into the novel, the significance of which is underlined by knowing that 'Eliot welcomed advice from him'

¹⁰⁹ *Middlemarch*, p.691.

¹¹⁰ Fletcher, p.106.

¹¹¹ *Romola*, pp.41, 177-9.

¹¹² *Ibid*, p.180.

about many factual details concerning fifteenth-century Florence.¹¹³ Several of Leighton's illustrations depict iconic incidents discussed in this chapter. Piero paints 'The Blind Scholar and his Daughter', and the serialisation of the novel begins with this, depicted by Leighton. And there are illustrations of the 'recognition' of Tito by Dino at Nello's window, of Baldassarre's first encounter with Tito outside the Duomo, and of his hiding outside in the shadows on the occasion of 'A supper at the Rucellai Gardens'.¹¹⁴



'Suppose you let me look at myself'

One arresting picture from the first issue, entitled 'Suppose you let me look at myself', depicts a startlingly young and cherubic Tito looking in Nello's mirror, after impatiently waiting until allowed to determine his appearance for himself.¹¹⁵ Observing the youthfulness of Tito in this picture gives a chilling poignancy to the closing page of the novel, where Romola is warning Lillo not to follow in his father's footsteps and to let history repeat itself. We are told neither Tito's nor Lillo's ages explicitly, but we can infer that Lillo is not much younger than his shipwrecked father was when he arrived in Florence, because Tito had still to acquire a man's beard, while Lillo's younger sister Ninna is already 'a delicate blue-eyed girl of thirteen'.¹¹⁶ Perhaps Lillo will be saved by having a woman rather than a man as an adoptive parent.

Early in the novel Tito sees a sketch by Piero that hangs in Nello's barber shop. This sketch 'represented three masks', a 'symbolical picture' as Tito describes it. Piero will not say what the picture means: 'everybody has his own interpretation'. Ironically Piero

¹¹³ Turner, pp.21-2.

¹¹⁴ *Cornhill Magazine* (July, 1862), p.1; August 1862; November 1862; February 1863.

¹¹⁵ *Ibid*, July 1862, p.27.

¹¹⁶ *Romola*, p.545.

suggests that those seeking meaning ‘had better inquire of Holy Church’.¹¹⁷ Nineteenth-century readers would recognise this irony: Victorian Britain was largely Protestant, unlike fifteenth-century Catholic Italy, and readers would expect interpretation of scriptures to rest as much on individual as on institutional authority. But the issue of individual or institutional authority in the novel is much wider than that. *Romola* is concerned with the use of individual authority, particularly by women, to challenge cultural norms, norms concerning the nature and role of women. And Eliot uses the underlying truth and ultimate authority of mathematical and logical thinking to develop her philosophical arguments about this in *Romola*. The same applies to *Middlemarch*, which includes two pervasive mathematical images. By the time Eliot wrote *Middlemarch*, Lewes was studying mathematics, and Eliot was studying it with him.¹¹⁸

¹¹⁷ Ibid, pp.33-4.

¹¹⁸ GEL, 5: pp.150, 157.

Chapter Four

Seeing things differently: Boolean algebra, logic and geometry in *Middlemarch*

Issues of sameness and difference which I discussed in *Romola* are even more pressing in *Middlemarch*. Eliot positions scrutiny of what are claimed by some to be objective truths about society in the context of the supposedly objective disciplines of mathematics and logic. *Middlemarch* is a carefully structured novel, which explores problematic issues in Victorian society and structural limitations in Victorian science.

When, in *Middlemarch*, Mr Brooke realises to his amazement that his young niece Dorothea is contemplating marrying the elderly clergyman Edward Casaubon rather than the young and superficially more attractive James Chettam, he presents to her what he sees as the advantages, and especially the disadvantages, of her planned course of action, but makes no dent in her determination to proceed with her plan. Mr Brooke concludes that ‘woman was a problem which, since Mr Brooke’s mind felt blank before it, could be hardly less complicated than the revolutions of an irregular solid.’¹ Selma Brodie suggests that this reference to mathematics is Eliot talking to the reader ‘over the head of Mr Brooke’ and flattering the reader’s mathematical understanding of the Newtonian mechanics that Eliot and Lewes were studying while *Middlemarch* was being written.²

But, concerning the irregular solid, Brodie is almost certainly not correct in suggesting that ‘Lewes was working on just such problems in Newtonian mechanics’; the story is more involved than that.³ In 1869 an exceptionally gifted Russian woman mathematician called Sonja Kovalevskaya invited herself to visit the Leweses.⁴ Kovalevskaya describes this visit and also her later visits to the Leweses for their Sunday afternoon gatherings, at one of which she met Herbert Spencer. Eliot told her: ‘Allow me to present my friend [...] only I have to warn you that he denies the very existence of a woman mathematician’, and then urged her to debate her existence with

¹ *Middlemarch*, p.39.

² Selma Brody, ‘Physics in *Middlemarch*: Gas Molecules and Ethereal Atoms’, *Modern Philology*, 85:1 (August, 1987), 42-53 (p.44); GEL, 5: p.157.

³ Brody, p.44.

⁴ GEL, 5: p.59.

Spencer.⁵ It seems highly probable that mathematics must have been discussed between the two women. Kovalevskaya went on to develop her mathematical career and in 1889 to win the Bordin prize of the French Academy of Science, for extending the solution of a problem concerning ‘the movement of a solid ‘massive’ body [...] with a fixed point’.⁶ This incompletely solved problem was an ‘already classic problem’ worked on by Euler and Lagrange. Given that Kovalevskaya ‘had been interested in this problem almost from the beginning of her mathematical studies’, she is likely to have mentioned it to Eliot, and this might well be the problem referred to in the novel.⁷ If so, it was most certainly not a mathematics problem that Lewes – or even Eliot - would have been able to solve!

The irregular-solid image encapsulates a key theme of the novel: characters find women impossible to understand and then get into serious self-inflicted difficulties. Mr Brooke’s finding ‘woman was a problem’ somehow implies that he expects there to be a single answer to ‘woman’, an answer that continues to elude him completely, even more so, given the unpredictable behaviour of his niece. It took a woman mathematician to solve the problem about irregular solids, but only after Eliot’s death. As far as Eliot was concerned, the mathematical problem, like the problem of ‘woman’ remained insoluble; different women, like different irregular solids, present complex and deep problems. The geometrical image may be contrasted with the one, described in chapter one, which the *Adam Bede* narrator offers of Mr Casson: a shape consisting of two spheres, with little mathematical interest, other than suggesting quintessential perfection.

Some critics have commented on the careful structuring of *Middlemarch*. For Sally Shuttleworth, ‘a wider unity of theme’ is suggested by the book titles and epigraphs.⁸ Several epigraphs have a mathematical flavour and hence the structuring suggests a mathematical mind at work. Avrom Fleishman similarly draws attention to the book titles, believing that the ‘formally most indicative’ of these is ‘The Dead Hand’, which

⁵ Raymond Chapman and Eleanora Gottlieb, ‘A Russian View of George Eliot’, *Nineteenth-Century Fiction*, 33:3 (December, 1978), 348-65 (p.359).

⁶ Michele Audin, *Remembering Sofia Kovalevskaya* (London: Springer-Verlag, 2011), p.90.

⁷ R. Cooke, *The Mathematics of Sonya Kovalevskaya* (New York: Springer-Verlag, 1984), p.13.

⁸ Sally Shuttleworth, *George Eliot and Nineteenth-Century Science: The Make-Believe of a Beginning* (Cambridge: CUP, 1984), p.149.

refers to the ramifications of the Featherstone and Casaubon wills. Featherstone's leads adventitiously to Mr Bulstrode's disgrace.⁹ The pernicious effect of the codicil to Casaubon's will, that stipulates that Dorothea will lose her inheritance from him if she marries Will Ladislaw, is encapsulated in the epigraph for chapter forty-nine:

A task too strong for wizard spells
This squire had brought about;
'Tis easy dropping stones in wells,
But who shall get them out?¹⁰

In this epigraph, Casaubon's action is presented as an example of the second law of thermodynamics, beneath which lies the more primitive mathematical idea of an operation not having an inverse. The unpredictable consequences of Casaubon's codicil comprise much of the action of this novel, which includes discussion of the nature of women, and of Dorothea in particular. It might be judged to bring about the opposite of what was intended, given Dorothea's rebellious nature. The book title 'Three love stories' draws our attention to all three principal young women of the novel, each of whom is involved in some way with more than one man, and all of whom, in very different ways, undermine men, because men do not try hard enough to understand them. Eliot commented on the novel's structure in a letter she wrote to her publisher about the length of the second book of *Middlemarch*; she explains that her manuscript cannot be shortened, because it contains nothing 'irrelevant to my design, which is to show the gradual action of ordinary causes rather than exceptional [...] in some directions which have not been from time immemorial the beaten path', suggesting logical deduction as well as empirical observation.¹¹ The plotting of *Middlemarch* is a logical *tour de force*, benefitting from Eliot's mathematical mind.

Definitions of women

Middlemarch is preoccupied with the issue of putting people into classes. Classification based on gender is where the novel begins, and the notion that there are clear definitions of what women are is problematised. The 'Prelude' to *Middlemarch*,

⁹ Avrom Fleishman, *George Eliot's Intellectual Life* (Cambridge: CUP, 2010), p.174.

¹⁰ *Middlemarch*, p.454.

¹¹ GEL, 5: p.168.

which is not part of Book One, stands apart from the rest of the novel, and might be seen as a manifesto for the structuring of the novel. Eliot's structuring of the novel does not endorse the possibility of an integrated view of the world; Gillian Beer is one of many critics to note how the novel presents and dismisses 'visions of unity', Casaubon's key to all mythologies being just one of these.¹² One powerful structuring theme of *Middlemarch*, a theme that recurs in other of Eliot's novels, is that assumptions about what all women are like make life impossibly difficult, not only for women, such as Maggie Tulliver - 'You could not live among such people' - but also for men: in *Middlemarch*, men's assumptions about women repeatedly result in women thwarting men, frequently without intending to.¹³ The 'Prelude' to *Middlemarch* satirises the regret felt by some people about

the inconvenient indefiniteness with which the Supreme Power has fashioned the natures of women: if there were one level of feminine incompetence as strict as the ability to count to three and no more, the social lot of women might be treated with scientific certitude.¹⁴

Commenting on this passage, Gillian Beer relates the 'limits of variation' in women to the 'analogical or adaptive resemblances' noted by Darwin in his evolutionary account of *The Origin of Species*: superficial similarities that may mislead us into assuming close structural identities that do not exist.¹⁵ I want to draw attention rather to the more basic mathematics and logic underlying this passage, and also emphasised by the reference in the 'Prelude' to the 'cygnet [...] reared uneasily among the ducklings'.¹⁶ The 1843 Andersen fairy story about the ugly duckling is, of course, about definitions: about mathematics rather than biology. If you define the young bird in the story to be a duckling then it is a freak; define it to be a cygnet and things are different. Mathematics and logic are about sameness and difference. In an essay published in the *Leader* (1855), Eliot makes this comment on generalisations about women: 'some of the best things [Margaret Fuller] says are on the folly of absolute definitions of women's nature,

¹² Gillian Beer, 'Myth and the single consciousness: *Middlemarch* and *The Lifted Veil*', in *This Particular Web*, ed. by Ian Adam (Toronto, University of Toronto Press, 1971), pp.91-115 (p.102).

¹³ *The Mill on the Floss*, p.272.

¹⁴ *Middlemarch*, pp.3-4.

¹⁵ Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (London: Ark, 1985), pp.149-50; Charles Darwin, *On the Origin of Species*, ed. by Gillian Beer (Oxford: OUP, 2008), p.314.

¹⁶ *Middlemarch*, p.4.

and absolute demarcations of woman's mission'.¹⁷ Absolute definitions suggest mathematical postulates. This remark, together with the passage from the Prelude, challenges the idea, not only that all women are alike, but also that they are consistently different from all men. This indicates the role of empirical science and also of mathematics. Science helps us discover what women - and men - are like; mathematics underpins science by enabling us to reason about what follows from our discoveries concerning what different women are like, and more particularly about what does *not* follow from our ignorance. The reference to a Supreme Power ironically challenges quasi-mathematical self-evident postulates about women, which it was convenient for some Victorian scientists to assume. For example, Darwin in *The Descent of Man* (1871), postulated 'that if men are capable of a decided pre-eminence over women in many subjects, the average of mental power in man must be above that of woman.'¹⁸ Cynthia Russett points out the logical fallacy in this deduction: even if the hypothesised facts were true, they can as likely be due to a greater standard deviation in men's mental power as to a higher average.¹⁹ Darwin also suggests that such marked differences between men and women are probable, because 'the bull differs in disposition from the cow'!²⁰

In an essay written in 1865 in response to Lecky's *The Influence of Rationalism*, Eliot is disdainful of Lecky's lack of interest in systematic scientific observation, and of his equivocation about quasi-mathematical certainties in order to protect the sensibilities of the 'general reader'. She indicates the appropriate role of science - the 'patient watching of external fact, silencing preconceived notions' - and also of mathematics:

The modern type of the general reader [...] has no hesitation, if you wish it, even to get up at a public meeting and express his conviction that at times, and within certain limits, the radii of a circle have a tendency to be equal; but on the other hand, he would urge that the spirit of geometry may be carried a little too far. His only bigotry is a bigotry against any clearly-defined opinion; not in the least based on scientific scepticism, but belonging to a lack of coherent thought [...]²¹

¹⁷ [George Eliot], 'Margaret Fuller and Mary Wollstonecraft', *Leader*, 6 (13 October, 1855) 988-9 (p.989).

¹⁸ Charles Darwin, *The Descent of Man* (London: Penguin, 2004), p.629.

¹⁹ Cynthia Eagle Russett, *Sexual Science: The Victorian Construction of Womanhood* (Cambridge Mass. and London: Harvard University Press, 1989), p.41.

²⁰ *The Descent of Man*, p.629.

²¹ George Eliot, 'The Influence of Rationalism', *Fortnightly Review*, 1 (15 May, 1865), 43-55 (pp.55, 43).

In *Middlemarch*, Eliot insists that we must wait patiently for evidence before we can, with any authority, either describe particular women or define woman in general; but also, where attributes equally apply to all people, both men and women, we must acknowledge this without equivocation. Mr Brooke, with his ‘miscellaneous opinions, and uncertain vote’ is a perfect example of Eliot’s general reader; he is ‘always objecting to go too far’.²² And not going too far means sooner or later depriving women of the same opportunities as men, often under the pretext of protecting them: Mr Brooke ‘would not have chosen that his nieces should meet the daughter of a Middlemarch manufacturer’.²³

Men’s definitions of women in *Middlemarch*

The early chapters of *Middlemarch* can be read as a series of proofs and refutations of theorems concerning the nature of women. In *The Subjection of Women* (1869), read by Eliot in the year of its publication, John Stuart Mill asserts: ‘Standing on the ground of common sense and the constitution of the human mind, I deny that anyone knows, or can know, the nature of the two sexes, as long as they have only been seen in their present relation to one another [...] What is now called the nature of women is an eminently artificial thing - the result of forced repression in some directions, unnatural stimulation in others.’²⁴ The *Middlemarch* narrator expresses this pressure to conform ironically, when commenting on Dorothea’s aberrant behaviour: ‘Sane people did what their neighbours did, so that if any lunatics were at large, one might know and avoid them.’²⁵ When writing *Middlemarch* Eliot would have been keenly aware of the way in which self-evident *a priori* geometrical postulates were being questioned in a radical way and this is a major focus for chapter six. For George Levine, one characteristic of mid-Victorian realism is that ‘the *a priori* now requires validation’.²⁶

²² *Middlemarch*, pp.8, 83.

²³ *Ibid*, p.83.

²⁴ GEL 8: p.458; John Stuart Mill, *On Liberty and The Subjection of Women* (London: Penguin, 2006), p.155; quoted in Russett, pp.1-2.

²⁵ *Middlemarch*, p.9.

²⁶ George Levine, *The Realistic Imagination* (Chicago and London: University of Chicago Press, 1981), p.18.

Questioning self-evident postulates is a feature of all Eliot's novels, and becomes more explicit in her later novels. 'Fancy what a game of chess would be like if all the chessmen had passions and intellects more or less small and cunning', the *Felix Holt* narrator tells us, 'if your pawns, hating you because they are pawns, could make away from their appointed posts that you might get checkmate on a sudden.'²⁷ This is a fate likely to befall you 'if you depended arrogantly on your mathematical imagination, and regarded your passionate pieces with contempt'.²⁸ Matthew Jermyn's social superiority over Christian Johnson – 'he would not himself dine at Johnson's house'²⁹ – was not behaviour likely to foster Johnson's loyalty, even though Johnson owed his position to Jermyn. 'Deductive reasoners'³⁰ reach unreliable conclusions if they argue from false premises; Eliot warns the reader not to assume that the social world can be explained by reasoning from apparently self-evident starting points.

Self-evident assumptions about women - and men - are a continual preoccupation of the early pages of *Middlemarch*. Book one begins with a postulate about women:

'Since I can do no good because a woman,
Reach constantly at something that is near it.'
– *The Maid's Tragedy*: Beaumont and Fletcher³¹

The first line of this epigraph presents ironically a self-evident *a priori* postulate; the second line states a theorem, because the word 'Since' indicates deduction. From the postulate that women cannot do good, we arrive at the theorem that the best women can do is something close to being good, even though such goodness will never be natural for them.

This encapsulates Mr Brooke's view of women. When Mr Casaubon hints that Dorothea might help Mr Brooke organise his papers, Mr Brooke, to Dorothea's intense annoyance, says something that might suggest to Mr Casaubon that Dorothea is unreliable: 'Young ladies are too flighty'.³² It is not clear whether Mr Brooke is

²⁷ *Felix Holt*, p.236.

²⁸ Ibid.

²⁹ Ibid, p.237.

³⁰ Ibid, p.236.

³¹ *Middlemarch*, p.7.

³² Ibid, p.18.

describing women in general or Dorothea in particular; a distinction which, in any case, Mr Brooke is unlikely to make. Dorothea is keen to learn Latin and Greek, which she sees as ‘provinces of masculine knowledge’, but Mr Brooke castigates Mr Casaubon for starting to teach these languages to Dorothea: ‘classics, mathematics, that kind of thing, are too taxing for a woman - too taxing you know’, using his favourite method of proof by reiteration to establish the truth of his assertion.³³ He assures Casaubon he will not get very far with teaching Dorothea, because of the ‘lightness about the feminine mind’.³⁴ ‘Your sex are not thinkers, you know - *varium et mutabile semper*’, Mr Brooke tells Mrs Cadwallader; ‘You ladies are always against [...] a man’s caring for nothing but truth, and that sort of thing.’³⁵ The last five words make the utterance particularly absurd, even for Mr Brooke. And there is also absurdity in Mr Brooke, with his ‘miscellaneous opinions’, quoting this motto from Virgil describing *woman* as ever fickle and changeable. During his parliamentary campaign, Mr Brooke tells Will Ladislaw: ‘I want to keep myself independent about Reform, you know: I don’t want to go too far [...]’, again echoing the words Eliot used to describe the ‘general reader’ in her 1865 essay.³⁶ The narrator tells us that, for Mr Brooke, ‘women were an inexhaustible subject of study, since even he at his age was not in a perfect state of scientific prediction about them’, with the inference that men ought to be able to predict women.³⁷ In a letter to the *Examiner* in 1873, published under the title ‘Mr Spencer and the women’, Eliot’s friend Sara Hennell complained about how Herbert Spencer thought women should be studied by men and told how to behave by men, and should doubtless not become mathematicians, as Sonja Kovalevskaya had done. Hennell paraphrased John Stuart Mill: ‘all women must speak for themselves’.³⁸

James Chettam can be as mystified as Mr Brooke about women, and particularly about Dorothea; since it is men who guide women about how to behave, James directs his blame exclusively at men for putting Dorothea in a position where she is able to marry Mr Casaubon. He blames Mr Casaubon himself: ‘What business has an old

³³ Ibid, pp. 59, 60.

³⁴ Ibid, p.60.

³⁵ Ibid, p.50.

³⁶ Ibid, p.431.

³⁷ Ibid, p.37.

³⁸ Sara Hennell, ‘Mr Spencer and the Women’, *Examiner* (7 February, 1874), p.135; Mill wrote in *The Subjection of women* (p.159): ‘[T]he knowledge which men can acquire of women [...] is wretchedly imperfect and superficial, and always will be so, until women themselves have told all that they have to tell.’ Eliot thought Hennell’s letter too mild (see chapter six).

bachelor like that to marry?’ and he blames Mr Brooke for allowing Dorothea to marry him.³⁹ James is well-meaning but not very intelligent, unlike Dorothea; but this does not matter, because, as the narrator remarks wryly: ‘A man’s mind – what there is of it – has always the advantage of being masculine [...] even his ignorance is of a sounder quality’.⁴⁰ The satire is again framed in terms of a self-evident axiom: that men are intellectually superior to women, and this is not to be apparently contradicted by individual pieces of evidence. So James should be heeded more than Dorothea simply because he is a man; a woman’s role, whether on horseback or otherwise, is to ‘accompany her husband’.⁴¹ Mr Casaubon soon demonstrates that he too shares the consensus view of the nature of women. He allays Mr Brooke’s anxiety concerning Dorothea’s learning of Greek, telling him, ‘Dorothea is learning to read the characters simply’. And from the ‘answers she got to some timid questions about the value of the Greek accents’ Dorothea suspects ‘that there might be secrets not capable of explanation to a woman’s reason’.⁴²

Generalising about women is not the prerogative only of characters faced with Dorothea’s strange choice of marriage partner. The doctor and scientific researcher Tertius Lydgate, who had a bad experience with one woman, Laure, decides to ‘take a strictly scientific view of woman’. But when, after a particularly harrowing time with his wife Rosamond, Lydgate tells himself, ‘It is the way with all women’, the narrator compares Lydgate unfavourably with all dumb animals - including women, presumably - in his ability to draw hasty and unwarranted conclusions, commenting satirically on ‘this power of generalizing which gives men so much the superiority in mistake over the dumb animals’. But Lydgate’s conclusion ‘was immediately thwarted by’ his remembering ‘the behaviour of another woman’, Dorothea, who on an earlier occasion tells James Chettam: ‘Perhaps we don’t always discriminate between sense and nonsense.’⁴³

³⁹ *Middlemarch*, p.54.

⁴⁰ *Ibid.*, p.20.

⁴¹ *Ibid.*

⁴² *Ibid.*, p.60.

⁴³ *Ibid.*, pp. 144, 556, 29.

The algebraic parable

Gillian Beer suggests that in *Middlemarch*, Eliot ‘seeks out ways beyond the single consciousness’; since each of us is only aware of our own feelings and beliefs and understanding of the world, how can a character, how can a novelist, how can a reader take into account the idea that other people have their own feelings and beliefs and understanding which are equally deserving of respect and attention?⁴⁴ This issue is the focus of the two images in *Middlemarch* which the narrator describes as parables, parables which provide a framework for the logical structuring of the novel. Both parables have mathematics as their basis, something Hillis Miller suggests might be expected: parables are parabolic, like parabolas.⁴⁵ The first parable I shall discuss, the less well-known, has Boolean algebra underlying it and is again about definitions. Algebra appears to have been one of Eliot’s enduring interests. Eliot wrote to her stepson in 1860, suggesting they might work on some algebra together, clearly assuming some substantial previous knowledge: ‘My dear Charles [...] Whereabouts are you in Algebra? It would be very pleasant to study it with you, if I could possibly find time to rub up my knowledge [...] Tell me your latitude and longitude.’⁴⁶ A page of Eliot’s diary in 1879, towards the end of her life, records how she studied Hebrew and Algebra on Friday, went out on Saturday and studied Hebrew and Plato’s *Republic* on Sunday.⁴⁷ The kind of algebra that underlies this first *Middlemarch* parable is what has come to be known as Boolean algebra, the algebra of logical reasoning, the kind of reasoning found in Plato’s *Republic*.

In 1847 George Boole published a book setting forth what he called a calculus for describing logical argument. Boole explained how he was to use algebra to describe logical statements:

Let us employ the symbol 1, or unity, to represent the Universe, and let us understand it as comprehending every conceivable class of objects whether actually existing or not, it being premised that the same individual may be found in more than one class, inasmuch as it may possess more than one quality in common with other individuals. Let us employ the letters X, Y, Z, to represent the

⁴⁴ Beer, ‘Myth and the single consciousness’, p.101.

⁴⁵ J. Hillis Miller, ‘Optic and Semiotic in *Middlemarch*’, in *The Worlds of Victorian Fiction*, ed. by Jerome H. Buckley (Cambridge Mass. and London: Harvard University Press, 1975), pp.125-45 (p.139).

⁴⁶ GEL, 3: p.216.

⁴⁷ GEL, 7: p.209.

individual members of classes, X applying to every member of one class, as members of that particular class, and Y to every member of another class as members of such class, and so on, according to the received language of treatises on Logic.⁴⁸

Having used a letter to stand for any of the members of a particular class, Boole's algebra is then used to make statements about them. As Boole explained:

A logical proposition is, according to the method of this Essay, expressible by an equation the form of which determines the rules of conversion and of transformation, to which the given proposition is subject.⁴⁹

Boole's algebra was familiar to the Leweses. In 1871 George Lewes wrote to Clement Ingleby about Stanley Jevons' logic machine, which was based on Boole's algebra.⁵⁰ And *Middlemarch* abounds with logical arguments that, while not actually using George Boole's algebraic symbolism, nonetheless employ logical structures reflecting his equations. But my first example is from *Felix Holt*, where the narrator is describing how voters for rival candidates at an election could be insulted:

[T]he bodily blemishes of an opponent were a legitimate ground for ridicule; but if the voter frustrated wit by being handsome, he was groaned at and satirised according to a formula, in which the adjective was Tory, Whig or Radical, as the case might be, and the substantive a blank to be filled up after the taste of the speaker.⁵¹

Rather than a Boolean equation, Eliot offers us here a Boolean formula in order to demonstrate the fatuousness of such insults. Converted into the language of Boolean algebra, the insult the narrator suggests takes the form: 'You X Y!', where Y can stand for any offensive word - hypocrite, for example - and X can be 'Tory,' 'Whig' or 'Radical', according to requirement.

I now turn to the humorously satirical parable in *Middlemarch* based on Boolean reasoning.

⁴⁸ George Boole, *The Mathematical Analysis of Logic* (London: Bell, 1847), p.14.

⁴⁹ Ibid, p.7.

⁵⁰ GEL, 9: p.27.

⁵¹ *Felix Holt*, pp.253-4.

[S]ince there never was a true story which could not be told in parables where you might put a monkey for a margrave, and *vice versa* – whatever has been or is to be narrated by me about low people, may be ennobled by being considered a parable; so that if any bad habits and ugly consequences are brought to view, the reader may have the relief of regarding them as not more than figuratively ungentle, and may feel himself virtually in company with persons of some style. Thus while I tell the truth about loobies, my reader's imagination need not be entirely excluded from an occupation with lords; and the petty sums which any bankrupt of high standing would be sorry to retire upon, may be lifted to the level of high commercial transactions by the inexpensive addition of proportional ciphers.⁵²

Putting a monkey for a margrave would have called to mind biological evolution, and especially the ubiquitous cartoons satirising evolution. Leland Monk suggests that the reason for placing the parable of the monkey and the margrave at the end of a chapter in which we have become acquainted with Joshua Rigg, is to forewarn us of the appearance of Rigg's dissolute step-father Raffles 'six chapters later'.⁵³

In the parable, the narrator tells us we can make an algebraic substitution: a monkey for a margrave and *vice versa*. Similarly, we can substitute a lord for a looby. Instead, as the narrator disingenuously suggests, of raising a looby to the status of a lord, this of course has the effect of reducing a lord to a looby. And we can substitute a large sum of money for a small by adding appropriate ciphers or zeros: inexpensive, because, after all, zero is nothing. Monk suggests that Eliot enjoyed using words with multiple meanings and allowing the usage to slip between the meanings, and that this is what is happening here with 'cipher', which is 'not just a zero; it also suggests a puzzle or code, a way of transforming a text in order to conceal its meaning'.⁵⁴ I would add that cipher also means a symbol used to represent something, a symbol such as X and Y in Boole's algebra, and that such usage, instead of concealing meaning might instead reveal it.

Monk suggests that Eliot uses her parables in *Middlemarch* 'in order to expose the egoistic rationalisations of providential thinking'.⁵⁵ My conclusions concerning the purpose of this parable are broadly similar to Monk's, but my method of exploration is different. If we relate this parable to Boole's algebra then our task is to decide how

⁵² *Middlemarch*, p.320.

⁵³ Leland Monk, *Standard Deviations* (Stanford: Stanford University Press, 1993), pp.57-8.

⁵⁴ *Ibid*, p.58.

⁵⁵ *Ibid*, p.63.

Boole's classes of objects – in this case the objects are people – are to be constituted. Statements about the people in these classes then apply to all equally. We can constitute classes however we like. The most immediate application of the parable in the novel is to Raffles and Mr Bulstrode, who can both be considered members of the same class of men to be despised, because of their moral bankruptcy in depriving Will Ladislav's grandmother of her fortune. Mr Casaubon might arguably be included in this class, since he benefited from Will's grandmother's being 'disowned by her family' and, through the codicil to his will, ensures that Will does not receive his just deserts after Casaubon's death.⁵⁶

Boolean classes in *Middlemarch*

Just as in *Adam Bede* the mathematical problems described are an invitation to interested readers to engage with them, so in *Middlemarch* the algebraic parable is an invitation to readers to substitute margraves for monkeys, wherever opportunities may occur in the novel. In Eliot's multiplot novel there is no shortage of such opportunities. What criteria are to be used to decide whether a person is a member of the class to be discussed? From a mathematical point of view classes can be defined at will, and objects, or people, can usefully be placed in the same class if it is possible to say the same things about them, whatever these same things might be. This is exactly what Eliot wants; Hillis Miller describes how a character in a Dickens novel is 'a "symbol" of the whole class', whilst an Eliot character is an 'individual', who is nevertheless subject to 'universal laws of human behaviour'.⁵⁷ So, for Eliot, anyone can be seen as the same as, or different from, anyone else. In this way the parable, like New Testament parables, has universal scope within *Middlemarch* and beyond: it is not just about Raffles and Bulstrode and one or two other similar characters. Sometimes Eliot points overtly to applications of the parable; readers are left to discover other examples for themselves.

'Class' is a slippery word and, in a novel set at the time of the First Reform Act, inevitably evokes the idea of social class. The word 'class' appears on a number of occasions in the novel, sometimes denoting social class, but more often not. Mrs

⁵⁶ *Middlemarch*, p.64.

⁵⁷ Miller, pp.126-7.

Farebrother wonders what Mary Garth's reasons are 'for slighting so respectable a class of men' as clergymen: here it is profession that determines the grouping.⁵⁸ And Mary satirically describes husbands as 'an inferior class of men'.⁵⁹ Where social class *is* referred to, it may be problematised: Will is 'a sort of gypsy, rather enjoying the sense of belonging to no class', while Mrs Cadwallader describes some of those attending Mr Featherstone's funeral as 'monsters – farmers without landlords – one can't tell how to class them'.⁶⁰ Here the use of the word class might suggest an allusion to taxonomy of organisms, an activity which itself can be thought of in terms of problematically organising living things into Boolean classes. Mrs Cadwallader's remark is reminiscent of Mr Casaubon's answer to Mr Brooke's question about how he sorts his documents: 'In pigeon-holes partly', and of Mr Brooke's subsequent protest that this does not work because he never knows 'whether a paper is in A or Z'.⁶¹ This emphasises the arbitrariness of classification.

Boole's mathematical usage of the word 'class' is most clearly echoed in the epigraph to chapter thirteen, which points definitively to the human tendency to place people such as 'unread authors' problematically in classes without knowing much about them:

1st Gent. How class your man? – as better than the most,
 Or, seeming better, worse beneath that cloak?
 As saint or knave, pilgrim or hypocrite?

2nd Gent. Nay tell me how you class your wealth of books,
 The drifted relics of all time. As well
 Sort them at once by size and livery:
 Vellum, tall copies and the common calf
 Will hardly cover more diversity
 Than all your labels cunningly devised
 To class your unread authors.⁶²

What directly follows the epigraph suggests a link with the parable: Mr Bulstrode is placed in different classes by different Middlemarchers, with some seeing him as a

⁵⁸ *Middlemarch*, p.542.

⁵⁹ *Ibid*, p.777.

⁶⁰ *Ibid*, pp.434, 306.

⁶¹ *Ibid*, p.18.

⁶² *Ibid*, p.115.

‘Pharisee’ and others as an ‘Evangelical’, while, most pertinently, still others muse about where he came from; like the authors, he is unread.⁶³ The epigraph points to the arbitrariness of classes, or rather the freedom of the mathematician or logician to define classes in any way at all, provided that the definition is clear, and having defined these classes, to explore the consequences of the definitions. The essence is logical clarity rather than customary or fashionable assumption. When James Chettam insinuates some impropriety in Mr Casaubon by telling Humphrey Cadwallader: ‘I don’t *like* Casaubon’, Humphrey holds him to account for not having a clear definition of his class of disliked people: ‘Why? what do you know against him?’ Since James believes that under all circumstances he ‘only felt what was reasonable’ it seems strange to him that he is expected to have mathematical clarity on this point.⁶⁴ Much later, after Dorothea has decided to marry Will Ladislav, James says he does not want to see her because she has ‘done what is wrong’, whereupon Humphrey again challenges him: the class of women who give up ‘fortune for the sake of a man’ might not be ‘wise’, but theirs is not ‘a wrong action, in the strict sense of the word’.⁶⁵

A word that is used in *Middlemarch* as a synonym for a group of people is the word ‘circle’ and, as discussed in chapter three, a circle of people suggests a group of people with parity of esteem, or sharing attributes, something required for a Boolean class. When Harriet Bulstrode amazes Selina Plymdale by not having heard the gossip about Lydgate and Rosamond, she tells Selina: ‘Your circle is rather different from ours.’⁶⁶ Selina is clearly a member of two classes: one class that gossips about relationships, and one that does not. Her belonging to the intersection of two classes becomes particularly significant after Mr Bulstrode’s disgrace; following her son’s marriage, ‘the late alliance of her family with the Tollers had brought her in connexion with the best circle, which gratified her in every direction except in the inclination to those serious views which she believed to be the best in another sense.’⁶⁷ She belongs, in her heart at least, to both a prestigious but possibly unprincipled social group and also to a class of people with serious religious and moral intentions. Will Ladislav deplores having become a member of several Boolean classes, none of which has Dorothea as a

⁶³ Ibid, pp.115-6.

⁶⁴ Ibid, p.64.

⁶⁵ Ibid, p.766.

⁶⁶ Ibid, p.277.

⁶⁷ Ibid, p.702.

member: 'He felt thrust [...] among the circles of Middlemarchers who made no part of her life.'⁶⁸

Boolean classes are not fixed; they may need to be defined for a particular moment in time. The class of mourners at Peter Featherstone's funeral are compared with 'the animals enter[ing] the Ark in pairs'; all, having 'used their arithmetic', deplore their multitude, with so little 'fodder' to go round.⁶⁹ The narrator's insinuation is that in this Boolean class, as in any other, any one member might be replaced by any other, which proves true, since none of them other than the 'frog-faced' stranger will inherit.⁷⁰ Lydgate is repeatedly undiscerning about the classes he belongs to; he fails, for example, to recognise that he is a member of the same Boolean class as 'the poor', who require Lydgate to be 'adjusting his prescriptions of diet to their small means'; he too has small means, to which his expenditure needs to be adjusted.⁷¹ Lydgate is as the narrator expects men to be: they 'have numerous strands of experience lying side by side and never compare them with each other'.⁷² The task of the narrator and the reader of *Middlemarch* is precisely to make these comparisons. On one occasion, Lydgate's sense of social and intellectual superiority prevents him from seeing his similarity with Ned Plymdale. Lydgate mocks the 'Keepsake', a 'gorgeous watered-silk publication' brought by Ned to Rosamond as a means of paying court to her. 'Do look at this bridegroom coming out of church: did you ever see such a "sugared invention"?' Lydgate says, putting down Ned, much to Rosamond's amusement. The irony is that while Lydgate might ridicule the picture of the 'smirking' bridegroom who thinks himself 'one of the first gentlemen in the land', this is exactly how Lydgate sees himself, and also how Rosamond sees this doctor who 'seemed to have the right clothes on by a certain natural affinity'.⁷³ So Rosamond and Lydgate mock in Ned the traits that they are unable consciously to see in themselves; all three belong to the same Boolean class. In the end, there is one Boolean class that Lydgate is all too aware of

⁶⁸ Ibid, p.408.

⁶⁹ Ibid, pp.310, 311.

⁷⁰ Ibid, p.311.

⁷¹ Ibid, p.552.

⁷² Ibid.

⁷³ Ibid pp.253, 254, 251. Although he does not link it to the parable, this example is suggested by U. C. Knoepfelmacher in 'Fusing Fact and Myth: The New Reality of *Middlemarch*' in *This Particular Web*, pp.43-72 (pp.43-4).

belonging to, the class of men socially rejected by Middlemarch, when he is embroiled with Mr Bulstrode in the scandal involving the death of Raffles.

Sameness and difference

Putting people into Boolean classes is equivalent to asking when and how people are the same and when they are different. *Middlemarch* abounds with echoes, the purpose of which is to draw attention to differences as well as similarities. The reader is often left to decide what conclusions to draw. For example, one echo concerns worldly fashions. Dorothea ‘could not reconcile the anxieties of a spiritual life involving eternal consequences, with a keen interest in [...] drapery’, while Harriet Bulstrode is able to conciliate ‘piety and worldliness, the nothingness of this life and the desirability of cut glass’.⁷⁴ The narrator appears sympathetic to both apparently antithetical positions, but less so to Rosamond, ‘the reverse of Miss Brooke’, whose ‘nymph-like figure and pure blondness’ give her ‘the largest range to choice in the flow and colour of drapery’.⁷⁵ Another echo can be heard in two characters’ first meetings with Dorothea. When Rosamond meets Dorothea for the first time, Dorothea is ‘one of those county divinities not mixing with Middlemarch mortality’.⁷⁶ Rosamond brings to the meeting both the Boolean class of all the ‘county divinities’ and the class of all the Middlemarch ‘mortality’. But when Caleb Garth meets Dorothea for the first time, he does not have any particular expectations: he is impressed by both the content and the style of their communication. He tells his wife: ‘You would like to hear her speak, Susan. She speaks such plain words, and a voice like music.’⁷⁷ When Caleb meets Dorothea, it is just two people who meet; even though there is more difference between their social statuses than between Dorothea and Rosamond, neither is aware of it.

One of Humphrey Cadwallader’s roles in the novel is to draw attention to assumptions about sameness and difference. When debating Dorothea’s proposed marriage to Will Ladislav that will make her poorer, he points out, much to his wife’s annoyance, the similarity with his own situation; Mrs Cadwallader ‘vexed her friends by marrying me’, because, like Dorothea, she became poorer through her choice of

⁷⁴ *Middlemarch*, pp.8, 252.

⁷⁵ *Ibid*, p.89.

⁷⁶ *Ibid*, p.406.

⁷⁷ *Ibid*, p.518.

marriage partner.⁷⁸ *Middlemarch* offers many examples of sameness, and some of these provide the most explicit examples of Eliot's application of the parable. When the narrator describes the doctors in Middlemarch, their similarities and differences are simultaneously mentioned. Paradoxically they may all be said to belong to the same Boolean class by being in a class of their own: 'everybody's family doctor was remarkably clever [...] [t]he evidence of his cleverness [...] lying in his lady-patients' immovable conviction, and was unassailable by any objection except that their intuitions were opposed by others equally strong'.⁷⁹ Eliot clearly enjoys the absurdity here. Eliot makes a more serious point about sameness through the events involving Flavell and Dagley's boy. Dagley is a poor tenant farmer, Flavell a Methodist preacher, and Mr Brooke a magistrate. After Dagley's boy is caught poaching, stealing a hare, and Mr Brooke has had him locked in a barn, Mr Brooke goes to see Dagley with the clear idea that Dagley should beat his son. He takes advantage of a lift with his niece Dorothea. On the way he tells her about Flavell, who *also* stole a hare and came up before Mr Brooke when he was on the bench. Mr Brooke let him off because he gave a witty speech in his defence. Mr Brooke does not notice the connection between the two poaching incidents; he has just finished telling this story to Dorothea when he says, apparently without any irony: 'But here we are at Dagley's'.⁸⁰

Choosing a spouse

James Chettam is looking for a wife and Mrs Cadwallader suggests Dorothea Brooke to him. When James discovers that Dorothea is engaged to Mr Casaubon he courts Celia Brooke. Clearly Dorothea and Celia are in a class of eligible Miss Brookes and apparently interchangeable. When Dorothea is deleted from this class as a result of her engagement, Mrs Cadwallader offers suitably mathematical advice to James: 'if I were a man I should prefer Celia, especially when Dorothea was gone.'⁸¹ This is Eliot's mathematical joke: mathematically, selecting a member from a class of one is logically no different from selecting a member from a class of two, or of a hundred for that matter. Several of the characters in the novel fall into the same Boolean class as a consequence of their naivety in choosing a marriage partner and in using faulty

⁷⁸ Ibid, p.768.

⁷⁹ Ibid, p.133.

⁸⁰ Ibid, p.369.

⁸¹ Ibid, p.54.

reasoning to help them do so. Lydgate discriminates between Dorothea and Rosamond by seeing Dorothea as an intellectually demanding woman who would make him feel tired - it would be like 'going from your work to teach the second form' - while with Rosamond he would come home to 'sweet laughs for bird-notes, and blue eyes for a heaven'.⁸² Rosamond is equally misguided, 'thinking of her evening dresses for the visit to Sir Godwin Lydgate's' and generally exaggerating the significance of Lydgate's family connections.⁸³ As for Dorothea, she worships 'a man whose learning almost amounted to a proof of what he believed!'; the narrator cautions that, even though 'Dorothea's inferences may seem large', it must be remembered that 'wrong reasoning sometimes lands poor mortals in right conclusions [...] Because Miss Brooke was hasty in her trust, it is not therefore clear that Mr Casaubon was unworthy of it.'⁸⁴ George Lewes makes a similar point in his 1871 letter about Jevons' logic machine, insisting that 'the truth or falsity of a conclusion never resides in the form but in the matter.'⁸⁵ Lewes goes on to deny that 'a true conclusion could be *deduced* from false premises'.⁸⁶ What the narrator argues concerning Dorothea's trust in Mr Casaubon is that, while a true conclusion cannot be deduced from false premises, the conclusion might nevertheless be true, even if the premises are false. What is the same about all the examples of Boolean classes is that Eliot bundles people together in a way that mocks serious attempts social scientists may make to classify people – and particularly to classify women differently from men.

The pier-glass

The purpose of the algebraic parable just discussed is to problematise the concepts of sameness and difference, which are not only about position in society, or gender, or occupation, but also more profoundly about the kind of people we are. Raffles does not look like Mr Bulstrode or like Mr Casaubon, but they are all alike in being driven by the power of money; and Caleb Garth, who has little interest in acquiring money is in this respect not like them. The other parable in *Middlemarch* has a somewhat similar

⁸² Ibid, p.88.

⁸³ Ibid, p.330.

⁸⁴ Ibid, pp.21, 23-4.

⁸⁵ GEL, 9: p.28.

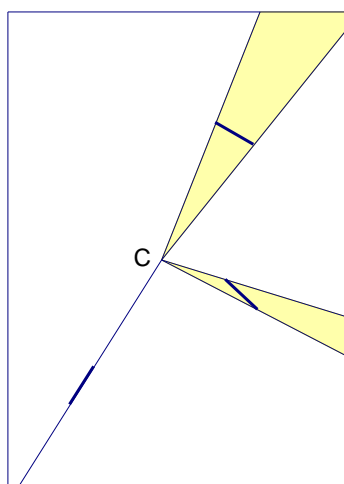
⁸⁶ Ibid, my emphasis.

purpose, suggesting that we are all the same and yet we are all different and can never really know about one another. This parable has geometry underlying it.

An eminent philosopher among my friends, who can dignify even your ugly furniture by lifting it into the serene light of science, has shown me this pregnant little fact. Your pier-glass or extensive surface of polished steel made to be rubbed by a housemaid, will be minutely and multitudinously scratched in all directions; but place now against it a lighted candle as a centre of illumination, and lo! the scratches will seem to arrange themselves in a fine series of concentric circles round that little sun. It is demonstrable that the scratches are going everywhere impartially, and it is only your candle which produces the flattering illusion of a concentric arrangement, its light falling with an exclusive optical selection. These things are a parable. The scratches are events and the candle is the egoism of any person now absent – of Miss Vincy, for example.⁸⁷

At the centre of this image is an optical illusion; in order to understand the implications of this parable, it is helpful to have a clear idea of the mathematics behind this illusion.

Why is it that we see circles, even though the scratches go ‘everywhere’ and ‘in all directions’?

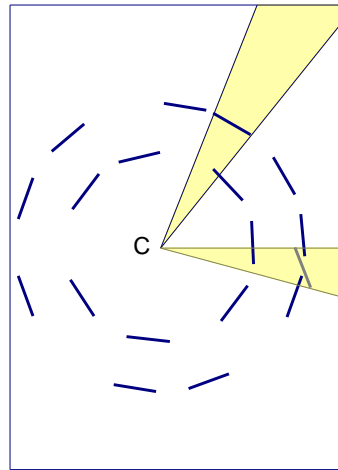


‘scratched in all directions’

In this first diagram, the candle is at point C. For the sake of this explanation, all three scratches drawn are the same length, are straight and are roughly the same distance from the candle. Scratches that are more or less perpendicular to the ray coming from the candle, like the one at the top, receive more light, as the diagram shows, and so they

⁸⁷ *Middlemarch*, p.248.

will show up much more strongly. Although the diagram does not show this, it should also be clear that scratches close to the candle will receive more light and show up more strongly than more distant scratches.



‘flattering illusion of concentric arrangement’

The second diagram shows how these perpendicular scratches form the illusion of concentric circles, circles which will become fainter when farther from the centre. The circles are rough and ready, because other scratches, like the grey scratch in this diagram, show up to a lesser extent and blur the circles. There will, of course, be numerous scratches like the grey scratch; so, although it is possible to observe the circles, they do not present a geometrically elegant picture.

Untypically, Eliot offers the reader an interpretation of this image. ‘The scratches are events’ and when ‘Miss Vincy, for example,’ views herself and the world in the pier-glass, her ego, represented by her candle, arranges the scratches in a pattern which flatters it. Her ego is a ‘little sun’, and is at the centre of her universe, in accordance with Ptolemaic theory. Although the circles are blurred, and although a fine drawing would normally mean an accurate drawing, we are told ironically that the circles form a ‘fine series’. Eliot puns the word ‘fine’: from the point of view of Rosamond’s ego, the picture they present of the world is just fine. The narrator of *Felix Holt* describes how the garrulous coachman Samson would speak ironically of ‘fine stories’ about the ‘Transome business’ but he would not tell the stories: ‘Samson was right in saying that there had been fine stories – meaning, ironically, stories not altogether creditable to the

parties concerned'.⁸⁸ The word 'fine' is used in much the same way in the pier-glass parable; egoistic characters in *Middlemarch* tell fine inaccurate stories about other people in Middlemarch society.

Spencer's image

The narrator tells us that the idea for the pier-glass image came from 'an eminent philosopher'. Critics have long debated the identity of the philosopher. Selma Brody, for example, writing in 1984, conjectures that the philosopher was John Tyndall, a scientist and populariser with a 'gift of making things easier'; she reiterates this conjecture in another essay in 1987.⁸⁹ But in 1991 Nancy Paxton provided a convincing argument that the 'eminent philosopher' is Herbert Spencer. She points out that in his second edition of *The Principles of Psychology*, published almost simultaneously with *Middlemarch*, Spencer uses the same optical illusion and interprets it in much the same way that Eliot interprets her image. Spencer uses his image to explain what he calls errors in 'class reasoning'.

On a cold winter's night, a gas-light seen through the window of a cab, or a light in a shop looked at through a pane that has been rubbed, is surrounded by a halo. Whoever examines will see that the halo is made of scratches on the glass; the curves of which are arcs of circles having the light for their centre.⁹⁰

Are the circles real? Yes, the scratches that form them are really there. It is just that they are not telling the whole truth. Or the truth at all. Spencer continues:

This example is typical of a wide range of complex propositions, in which, along with certain conspicuous facts affirmed, there is a tacit denial of facts of an opposite kind, which are by the necessities of the case inconspicuous. The popular generalisation that 'murder will out' is one in point.⁹¹

⁸⁸ Felix Holt, p.10.

⁸⁹ Selma Brody, 'Origins of George Eliot's "Pier-Glass" Image', *English Language Notes*, 22:2 (1984) 55-8 (p.57); Brody, 'Physics in *Middlemarch*', p.46.

⁹⁰ Nancy Paxton, *George Eliot and Herbert Spencer* (Princeton: Princeton University Press, 1991), p.174; Herbert Spencer, *The Principles of Psychology*, 2 vols. (London: Williams and Norgate, 1899), 2: p.397.

⁹¹ Ibid, pp.397-8.

Spencer then points out that the belief that ‘murder will out’ arises from focusing on those murders initially concealed that are ultimately uncovered; and ignoring the many other murders that remain concealed. This error is particularly difficult to avoid with the murder example: how long do you wait before you know that a murder will not be solved? Spencer explains that class reasoning is prone to error because, when we ‘predicate’ a class, in this case murders that are solved, we implicitly draw attention to those examples which confirm our hypothesis and ignore those which do not. Spencer’s example about unsolved murders is just one example. There are many situations which exhibit failures in class reasoning in a similar way. This class reasoning can also be seen as having connections with Eliot’s other algebraic parable.

Clearly the use Spencer makes of the optical illusion has much in common with the use Eliot makes of it. In both cases the scratches are events, and the circles represent the false conclusions we draw from these events by ignoring or failing to notice other events. Are the circles produced by the scratches real in both images? In a sense they are; they are visibly composed of actual scratches. There are many murders that indeed are solved. Rosamond can point to many events which might support her way of seeing the world. But the full truth is not told, because in both cases there has been an ‘optical selection’.

Similarities between Spencer’s image and Eliot’s image

Let us summarise Spencer’s and Eliot’s use of these images. To explain his theory of failure of class reasoning in connection with ‘propositions qualitatively distinguished’, Spencer uses an image, a metaphor, based on an optical illusion.⁹² Spencer begins with this metaphor and then uses it to help him expound his theory. This is a scientific theory, which is part of his *Principles of Psychology*. His theory helps us to ‘compare conclusions with scientific rigour’.⁹³ Eliot’s uses a metaphor, based on the same optical illusion, to expound her scientific theory.

The domain for Spencer’s theory is the set of people who, through carelessness or lack of insight, fail to think with sufficient precision about the propositions they are

⁹² Ibid, p.393.

⁹³ Ibid, p.399.

asserting. This will be some, not all people. Or it may be most people on some occasions. What is the domain for Eliot's theory? Unlike Spencer, Eliot is ostensibly writing a novel rather than a scientific treatise, albeit that the novel's subtitle is suggestively 'A study of provincial life'. So Eliot does not need to be as straightforward as Spencer in her explanation of the theory; in fact, she is deliberately disingenuous. According to the neat interpretation Eliot provides, the parable apparently concerns Rosamond. When we first read the parable, Eliot deftly disguises any other interpretation from us. One way in which she does this is by making the remainder of the chapter with which the pier-glass parable begins, which is about Rosamond and her assumptions about Lydgate, follow on without even a paragraph break. But, as Elizabeth Ermarth points out, the 'candle is the egoism of [...] Rosamond Vincy, *for example*.'⁹⁴ Clearly, if Rosamond is just an example, the domain of the theory is bigger than just Rosamond. For example, when Dorothea and Celia meet Mr Casaubon, Dorothea sees a 'distinguished-looking' man with a 'great soul' who reminds her of Locke and Celia sees an 'ugly' man with a 'sallow' complexion and 'two white moles'.⁹⁵ Both make, quite literally, an 'optical selection'. Evidence from the rest of the novel makes it clear that the domain of application of the theory is all of us. The reader has been cunningly drawn into the domain by Eliot: any reader who, at first reading, skips over the 'for example' and sees the image applying only to Rosamond is as guilty as Rosamond of an 'optical selection'. Such readers - probably most if not all of us - see the circles.

Eliot's psychological theory is far more complicated and more devastating than Spencer's. Spencer's theory is about how easy it is for some people to make a mistake. Eliot's theory is about how all people continually make mistakes, by structuring their beliefs about the world according to their egos, and such structuring inevitably distorts their perception of truths about the world. Spencer provides evidence for his scientific theory by drawing attention to those people who assert that 'murder will out'; and he offers one other example. Eliot offers similar but far more extensive anecdotal evidence for her theory: the thoughts, actions and beliefs of the characters in her novel, and also implicitly the thoughts, actions and beliefs of the readers of her novel.

⁹⁴ Elizabeth Deeds Ermarth, 'George Eliot and the World as Language', in *George Eliot and Europe*, ed. by John Rignall (Aldershot: Scolar Press, 1997), pp.33-43 (p.36), my emphasis.

⁹⁵ *Middlemarch*, p.19. This is David Carroll's observation: see David Carroll, 'Middlemarch and the Externality of Fact', in *This Particular Web*, pp.73-90 (p.77).

How Eliot adapted Spencer's image

A clearer understanding of Eliot's theory can be obtained by considering the differences between Eliot's and Spencer's images. One difference concerns the physical locations in which the images are placed. In Spencer's image, the viewer is in the street: in a cab or looking in a shop window. This carries the implication that the theory is an impersonal one, relevant to the public space. Perhaps we do make mistakes in our class reasoning when our meeting with others includes discussion of current affairs, but we need not take too much account of Spencer's concerns about this, unless we are philosophers or scientists or journalists or others who make public pronouncements. By contrast, Eliot places her image in the home, making it more personal and its implications less avoidable: it is '*your* pier-glass'. The theory, this location suggests, will have an inescapable relevance to us all. Spencer's image concerns a light from a street lamp or in a shop window. It is not our light and so we are not responsible for it, even though we can make mistakes when we look at it. Eliot converts windows into a mirror and a light into a candle that we ourselves hold. This immediately turns us into agents; we produce the distorted view, and the mirror suggests that this is our distorted view both of the world and of ourselves. We see the circles not out of our ignorance, but as a result of our egos.

What is more, Eliot's image insists that our distorted view of ourselves and of the world is unavoidable. We cannot see anything in the mirror without light, and to get light we must use our candles – our egos. We are bound to reach false conclusions and these will have serious consequences. Hillis Miller draws attention to this, although not in connection with the pier-glass: 'As the narrator says, in what might be taken as a diagnosis of mental illness from which all of the characters in *Middlemarch* suffer, "we all of us, grave or light, get our thoughts entangled in metaphors, and act fatally on the strength of them"'.⁹⁶

There are differences between the ways in which Spencer and Eliot explain the optical illusion. Both agree that some scratches are illuminated and others are not

⁹⁶ J. Hillis Miller, 'Narrative and History', *ELH*, 41:3 (Autumn, 1974) 455-473 (pp.464-5).

illuminated, or are illuminated less. Spencer tells us that the scratches illuminated are ‘arcs of circles having the light for their centre’. Such a condition on the scratches is far too stringent. Straight scratches will be illuminated as much, or almost as much, as curved scratches, provided they are in the appropriate direction. Eliot’s explanation is more sophisticated. What is important is not whether the scratches are arcs of circles; what is important is their position and direction, as has already been explained. Eliot is carefully not specific in suggesting that only those scratches that produce the concentric circle are selected. As well as being mathematically more accurate, this gives the image more room for manoeuvre.

Spencer explains what the observer can do in order to appreciate that what is being seen is an optical illusion.

[...] he will find that, on moving his head about, that through whatever part of the glass he looks, there is around the light a similar halo of illuminated concentric scratches. This discovery makes it clear that the proposition he originally affirmed to himself (that the glass was scratched in curves concentric with the light) was entirely misleading.⁹⁷

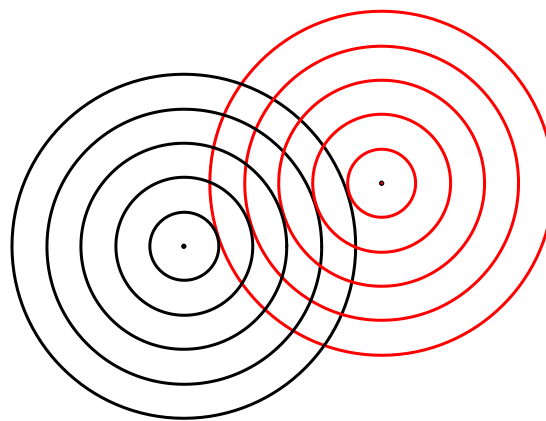
Moving the head about highlights another difference between Spencer’s model and Eliot’s. In interpreting Spencer’s model, after moving we still see effectively the same pattern; what we learn is not that the pattern is different; simply that it is illusory. With Eliot’s image, a different point of view produces a different pattern. A person places her candle against the pier-glass and sees a pattern, which she believes to be the truth; a different person places his candle at a different point and so sees a different pattern, which is a conflicting truth. Neither person moves their candle. If and when the candle is moved the deluded thinking is at least partially demolished; the person realises, not only that his or her pattern is illusory, but also that there is more than one version of the apparent truth. In an epigraph introducing a chapter about Mr Bulstrode’s fragile ego, Eliot quotes Rasselas: ‘Inconsistencies [...] cannot both be right, but imputed to man they may both be true.’⁹⁸

With Spencer’s theory, those of us who are insufficiently wise all come to the same false conclusion: murder will out. With Eliot’s theory we all come to different

⁹⁷ Spencer, p.397.

⁹⁸ *Middlemarch*, p.574.

conclusions. Are they false conclusions? Who is there who can judge this? Spencer's image is about differences between people, only to the extent that some people are fooled into misinterpreting the halos, while others are wise enough not to be fooled. And when people correctly interpret the halos, they all come to the same conclusion: they realise that some murders are solved and others are not. Eliot's theory is about both sameness and difference. The theory does not apply only to Rosamond, but to everybody. The message is that all people are egocentric and consequently deluded: 'We are all of us born in moral stupidity, taking the world as an udder to feed our supreme selves'.⁹⁹ The way we see the world is different from the way others see the world, which produces political, social and emotional problems.



'our supreme selves'

Here are two people's event patterns. Their candles are in different positions. Some events (scratches) are seen by both people. They both see events where circles touch, but not necessarily where circles cross, because the angle may be wrong. Even where both people see an event they interpret it completely differently, because it is in two completely different circles of events. However, although we see different events and interpret them differently, the *patterns* made by our events are geometrically identical, geometrically congruent. So in this sense we are all the same.

This, of course, includes eminent philosophers. When introducing the pier-glass parable, the narrator tells of an 'eminent philosopher [...] who can dignify even your ugly furniture by lifting it into the serene light of science'. The extravagant words 'eminent', 'dignify', 'ugly' and 'serene' are mischievously ironic. As Michael

⁹⁹ Ibid, p.198.

Rectenwald has pointed out, the serene light of science must be just another *candle*.¹⁰⁰ All scientists, eminent philosophers and social scientists, like Herbert Spencer, and George Lewes - like George Eliot herself - have their vision distorted by their egos: the parable of the pier-glass tells us such misperception is universal. This is true, however worthy our intentions are. The narrator tells us that 'the egoism which enters into our theories does not affect their sincerity; rather, the more our egoism is satisfied, the more robust is our belief.'¹⁰¹ An eminence has a higher mind than the rest of us. Spencer's image, taken together with his 'murder will out' example, implies that all we need in order to correct our naive misapprehensions is an eminent philosopher - like Spencer. Eliot's image, on the other hand, tells us that there is no eminence from which we can view the truth without our egos getting in the way. Theories are needed for science, but theories are produced using more than facts. And however carefully the theories are produced they will be tarnished by seeing the circles. Gillian Beer suggests that, for all his bumbling, we 'should always pay attention to Mr Brooke'.¹⁰² What does Mr Brooke say? 'I went into science a great deal myself at one time; but I saw it would not do. It leads to everything'.¹⁰³ One way of reading this is that scientists make science demonstrate what they want it to demonstrate.

Upright James Chettam is someone who is clear about what the facts demonstrate, being 'convinced that his own satisfaction was righteous' when he thought of the 'mountainous distance between Ladislav and Dorothea' as a result of the revelation that Will is 'the grandson of a thieving Jew pawnbroker'. Since, to James's annoyance, Mr Brooke has previously sponsored Will, James consequently takes 'some pleasure in pointing Mr Brooke's attention to this ugly bit of Ladislav's genealogy, as a fresh candle for him to see his own folly by'.¹⁰⁴ The candle reminds the reader of the pier-glass; James's satisfaction is, of course, not quite righteous, because he still feels jealous possessiveness towards Dorothea.

¹⁰⁰ Michael Rectenwald, 'The Construction and Deconstruction of Science in *Middlemarch*', *Victorian Web* (last modified 19 December 2008)

<http://www.victorianweb.org/authors/eliot/middlemarch/rectenwald2.html>.

¹⁰¹ *Middlemarch*, p.489.

¹⁰² Beer, 'Myth and the single consciousness', p.94.

¹⁰³ *Middlemarch*, p.16.

¹⁰⁴ *Ibid*, p.727.

Earlier, the narrator addresses the variety of views expressed by Dorothea's circle about Mr Casaubon.

I protest against any absolute conclusion, any prejudice derived from Mrs Cadwallader's contempt for a neighbouring clergyman's alleged greatness of soul, or Sir James Chettam's poor opinion of his rival's legs, - from Mr Brooke's failure to elicit a companion's ideas, or from Celia's criticism of a middle-aged scholar's personal appearance. I am not sure that the greatest man of his age, if ever that solitary superlative existed, could escape these unfavourable reflections of himself in various small mirrors; and even Milton, looking for his portrait in a spoon, must submit to have the facial angle of a bumpkin.¹⁰⁵

There is more than an echo of the pier-glass parable here; each member of Dorothea's circle provides his or her own possibly sincere but certainly partial impression of Mr Casaubon, and what is omitted has the effect of distorting the representation of Mr Casaubon. The pier-glass is a plane mirror, but for egoists it might just as well be a convex mirror like a spoon, given their distorted interpretation of what they see.

The pier-glass image is pure geometry, and there is no distance measure in pure geometry, no closeness; there is no suggestion that some candles are closer together than others. The narrator uses the word 'close' quite frequently in *Middlemarch*, but never to suggest that two people are psychologically close. On the contrary, the narrator is forever suggesting that people are never close enough to understand one another. This, for example, is the narrator describing the married couple Lydgate and Rosamond: 'Between him and her indeed there was that total missing of each other's mental track, which is too evidently possible even between persons who are continually thinking of each other.'¹⁰⁶ Mental tracks are reminiscent of pier-glass circles. If we consider the diagram with the two sets of concentric circles, one belonging to Rosamond, say, and one to Lydgate, we can see that a certain event, where two circles touch, is shared by both of them, and yet such an event is interpreted in completely different ways, because each sees it as belonging to a completely different circle of events, or 'mental track'. So having your partner constantly in your thoughts would appear to be no guarantee of closeness. Even in the sympathetic Garth family, when her mother suggests that anyone might love teaching, Mary tells her 'curtly': 'I suppose we never quite understand why

¹⁰⁵ Ibid, pp.77-8.

¹⁰⁶ Ibid, pp.550-1.

another dislikes what we like, mother.’¹⁰⁷ The narrator illustrates the same point using Peter Featherstone and Joshua Rigg. Featherstone leaves his Stone Court estate to Rigg, expecting him to enjoy living there. ‘But how little we know what would make a paradise for our neighbours!’¹⁰⁸ These two characters are hardly to be valued for their empathy and insight into the feelings of others, and so it is not surprising that they do not understand what would please one another. But the narrator phrases this remark in a way that suggests that none of us has any more real understanding of our neighbours than these two self-absorbed men.

Listening

What we see when we look depends on our point of view. Listening is a means of exploring the misconceptions arising from what we mistakenly think we see; but listening itself depends on the acuity of the listener’s ear. And Eliot suggests that there are limitations on how acutely we can listen. For Eliot, perfect understanding is always unattainable.

In seeking out ways ‘beyond the single consciousness’, Eliot turns from looking to listening, something that Eliot herself highly valued. Levine pictures her ‘listening [...] with selfless and disciplined attention to her admiring visitors’.¹⁰⁹ The value of characters listening to each other in order to overcome the inadequacies of simply looking is repeatedly alluded to in the novel. When the narrator laments ‘how little we know what would make a paradise for our neighbours’, the reason for this is provided: ‘We judge from our own desires, and our neighbours themselves are not always open enough even to throw out a hint of theirs.’¹¹⁰ Were we to say what we want and others were to listen, then they would know. Lamenting his fading eyesight to Mr Brooke, Mr Casaubon tells him: ‘I want a reader for my evenings; but I am fastidious in voices, and I cannot endure listening to an imperfect reader.’¹¹¹ Dorothea’s voice is presumably acceptable to Mr Casaubon; it is certainly admired by other people. Caleb’s admiration of Dorothea’s voice, which is ‘like music’ and reminds him of The Messiah, is an echo

¹⁰⁷ Ibid, p.375.

¹⁰⁸ Ibid, p.488.

¹⁰⁹ George Levine, ‘George Eliot’s Hypothesis of Reality’, *Nineteenth-Century Fiction*, 35:1 (June, 1980), 1-28 (p.1).

¹¹⁰ *Middlemarch*, p.488.

¹¹¹ Ibid, p.16.

of Will's adoration of the same quality in Dorothea: 'But what a voice! It was like the voice of a soul that had once lived in an Aeolian harp'.¹¹² Will is unhappy about Naumann's desire to paint Dorothea and challenges Naumann: 'how would you paint her voice, pray? But her voice is much diviner than anything you have seen of her.'¹¹³ For Will, looking alone is not enough, and he protests about Naumann treating Dorothea as an object for visual gratification: 'As if a woman were a mere coloured superficies!' His painting enterprise involves Naumann in deceit: he has to pretend that his main purpose is to paint Mr Casaubon. Not seeing beyond the surface is precisely what the pier-glass parable warns against; our limited egoistic perceptions of others are a result of our failure to attend to them. As Will tells Naumann, women 'change from moment to moment'.¹¹⁴

Where Caleb differs from Will is in being interested not only in Dorothea's voice, but also in what that voice is saying, in unequivocally admiring her intellect. For Will there is 'too much cleverness' in what Dorothea says: 'A man is seldom ashamed of feeling that he cannot love a woman so well when he sees a certain greatness in her: nature having intended greatness for men.'¹¹⁵ In the novel Caleb is in a class on his own, as the only *man* who consistently admires women's intellects: especially those of Dorothea, his daughter Mary and his wife Susan.

Listening can compensate for the imperfections of visual perception. Dorothea marries Mr Casaubon, believing she knows far more about him than she does know, as she rapidly comes to realise. This is how the narrator describes the situation for Dorothea after her disillusionment.

[I]t had been easier to her to imagine how she would devote herself to Mr Casaubon, and become wise and strong in his strength and wisdom, than to conceive [...] that he had an equivalent centre of self, whence the lights and shadows must always fall with a certain difference.¹¹⁶

There are clear echoes here of the pier-glass image, the 'equivalent centre of self' evoking the double set of concentric circles, representative of different points of view;

¹¹² Ibid, pp.518, 74.

¹¹³ Ibid, p.179.

¹¹⁴ Ibid.

¹¹⁵ Ibid, pp.74, 365.

¹¹⁶ Ibid, p.198.

candles at different points cast light and shadows on the scratches with a certain difference. The pier-glass message is that we cannot *know* anything about how other people construct their sense of reality. All that we can learn to know - as Dorothea is learning - is that their reality *is* different from ours. She learns about Mr Casaubon by attending to what he is saying to her. Dorothea has to learn to listen: the younger Dorothea clearly does not listen well enough to understand or sympathise with her sister. When Celia tells her it is 'exactly six months' since Dorothea received their mother's jewels, she replies sarcastically: 'What a wonderful little almanac you are, Celia!'¹¹⁷

We are told that few characters in *Middlemarch* pay attention to what others say, and none - including the reader - pay sufficient attention really to understand; when Dorothea 'is discovered in a fit of weeping six weeks after her marriage', the narrator suggests that this is not particularly unusual and that 'we do not expect people to be deeply moved by what is not unusual', because people have limited ability to sympathise:

If we had a keen vision and feeling of all ordinary human life, it would be like hearing the grass grow and the squirrel's heart beat, and we should die of that roar which lies on the other side of silence.¹¹⁸

This sentence suggests the importance of listening carefully. Keen vision is presented as the ability to hear. But Eliot also suggests that if human beings were to have too great a sympathy for others, they would be overwhelmed, harmed by it. This idea appears to rehearse Eliot's description in her 1859 novella, *The Lifted Veil*, of the 'abnormal sensitivity' of Latimer, who was aware of 'the mental process' of others: 'It was like a preternaturally heightened sense of hearing, making audible to one a roar of sound where others find perfect stillness.'¹¹⁹ All this reinforces the message, constantly reiterated in *Middlemarch*, that there are limits to what we can know, indeed to what it is healthy to know, about others and therefore about society.

¹¹⁷ Ibid, p.11.

¹¹⁸ Ibid, p.182.

¹¹⁹ *The Lifted Veil*, pp.13, 18.

The pier-glass image too suggests that our knowledge of the world must always be necessarily limited. The narrator tells us what happens when action is taken to improve the sharpness of the reflection in the mirror:

Your pier-glass or extensive surface of polished steel made to be rubbed by a housemaid, will be minutely and multitudinously scratched in all directions.

Make the mirror smoother and it will reflect better, except that there will be more scratches and more interference from the concentric circles. The mathematician William Kingdon Clifford suggested the possibility that there are necessary limits on our knowledge about cosmological space in a lecture given probably in 1873, in which he questioned whether Euclid's axioms are self-evident. He considered whether the space in which we live necessarily has the property of 'elementary flatness', a property required if Euclid's postulates are to be applicable to the space we live in. While this needs to be a property of three-dimensional space, Clifford offered a two-dimensional analogy. Consider the surface of what we suppose to be a perfect sphere. It is curved, but the curvature can be reduced if we take a small enough piece of the surface and enlarge it. We can continually enlarge it and imagine it will simply get flatter and flatter. However, this assumption may not be true: eventually what we may find is fatal imperfections on the surface, unevenness that cannot be done away with. His explanation included this remark about the possibility that there is no elementary flatness: 'we have merely to point to the example of polished surfaces. The smoothest surface that can be made is the one most completely covered with the minutest ruts and furrows.'¹²⁰ The 'minutest ruts and furrows' on polished surfaces echoes Eliot's polished pier-glass 'minutely and multitudinously scratched in all directions'. So Eliot's pier-glass and her remark about dying of the roar may both have suggested to Clifford his explanation, especially in view of the fact that he began a friendship with Eliot in 1873, about which more will be said in chapter six.

Eliot described Kovalevskaya's Russia as one of 'those ultra-civilised regions' because it promoted the education of women.¹²¹ Eliot's encouragement of Kovalevskaya to debate with Spencer about female mathematicians, and Eliot's

¹²⁰ William Kingdon Clifford, *Lectures and essays*, ed. by Leslie Stephen and Frederick Pollock, 2 vols. (London: Macmillan, 1901), 1: p.385.

¹²¹ GEL, 5: p.59.

inclusion of Kovalevskaya's mathematics in her novel are small indications of Eliot's intention to use pure mathematics to frame her comments on the 'woman' question in particular, and her arguments about society more generally. Eliot's mathematics gave her the insight that many beliefs, classifications and rules of behaviour were, like mathematical objects, the result of arbitrary definition. Using this insight, in *Middlemarch* she goes about challenging arbitrary conventions and unfounded assumptions with a will. This chapter has described how Eliot uses her two mathematically-based parables to help her do this. Chapter five will consider the way Eliot explores, in her last two novels, *how* such arbitrary beliefs and practices develop and are communicated, and the way she uses what some Victorians called 'mixed mathematics' (applied mathematics) to do this.

Chapter Five

Binding the great with the small in *Middlemarch* and *Daniel Deronda*

In Eliot's novels, and particularly in her last two novels, Eliot makes allusions to a number of different concepts in applied mathematics and mathematical physics, including the calculus, statistics, astronomy, kinetic theory of gases and resonance. The calculus is not strictly applied mathematics, but it was and is indispensable in the development of theoretical systems that model the world. Measurement, particularly of size, is crucially important in mathematical physics and often involves ratio and proportion, or relating the great to the small.

Writing about the scientific culture in Eliot's novels, Peter Alan Dale quotes the narrator of *The Mill on the Floss*: 'Does not science tell us that its highest striving is after the ascertainment of a unity which shall bind the smallest things with the greatest?'¹ For Levine, mid-Victorian realism involved 'a shift of focus from the large to the small, from the general to the particular'; and the 'primary conventions of [such] realism are its deflation of ambition and passion, its antiheroism, its tendency to see all people and things within large containing social organisations'.² In other words, realist novelists write about ordinary people having ordinary lives, not about outstanding people having spectacularly successful lives. This sets the theme for the present chapter, which discusses how Eliot uses applied mathematics to address ideas of size – size of people and of their philosophies - in *Middlemarch* and in *Daniel Deronda*.

Book eight of *Daniel Deronda* begins with an astronomical image:

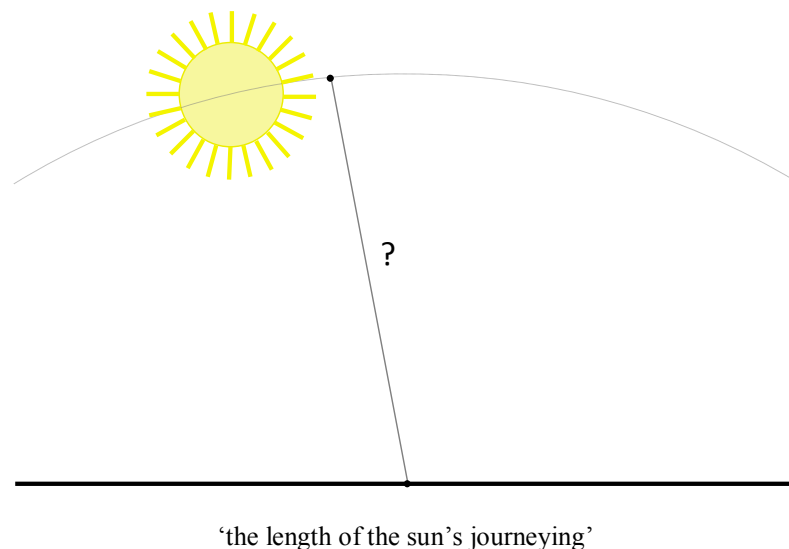
Extension, we know, is a very imperfect measure of things; and the length of the sun's journeying can no more tell us how far life has advanced than the acreage of a field can tell us what growths may be active within it. A man may go south, and, stumbling over a bone, may meditate upon it till he has found a new starting-point for anatomy; or eastward, and discover a new key to language telling a new story of races [...] and at the end of a few months he may come back to find his neighbours grumbling at the same parish grievance as before, or to see the same elderly gentleman treading the

¹ Peter Alan Dale, *In Pursuit of a Scientific Culture: Science, Art, and Society in the Victorian Age* (Wisconsin: University of Wisconsin Press, 1989), p.86; *The Mill on the Floss*, p.273.

² George Levine, *The Realistic Imagination* (Chicago and London: University of Chicago Press, 1981), pp.13, 15.

pavement in discourse with himself [...] pausing at the same shop-window to look at the same prints. If the swiftest thinking has about the pace of a greyhound, the slowest must be supposed to move, like the limpet.³

This paragraph is about proportion and scale: some characters (and some animals) make much more rapid changes as part of a much bigger universe than others. Gwendolen's rector uncle and his family in Penicote are like the 'neighbours at the parish pump'. They maintain their parochial attitudes and beliefs; for example, they are still seeing the Jews as alien: 'Bertha could not imagine what Jews believed now'.⁴ But while nothing has been happening in Penicote, Gwendolen herself has been married, her husband has been killed and her friend Daniel, who has become aware that he is a Jew, has challenged her whole belief system. Daniel, Mirah, Catherine and Klesmer are among those experiencing rapid change. While Eliot's sympathies appear to be predominantly with those who change, she seems characteristically reluctant to come down totally on one side of this debate: there is something touchingly affecting about the behaviour of the 'elderly gentleman'.



It is perhaps because Eliot wants to complicate things, that the image of the sun we are being offered assumes that the earth is at the centre cosmologically; we are invited to contemplate, not only the sun's apparent movement across the sky, but more precisely the length of its journeying, which has to be answered poetically. There is no interpretation that would enable us to answer it scientifically, because any answer

³ *Daniel Deronda*, p.603.

⁴ *Ibid*, p.606.

depends on how far away we might imagine the sun to be. There is a tendency in the novel, that will be explored later, to see those who do not change as metaphorically taking a geocentric position and those who do a heliocentric one: as Anna Henschman puts it, ‘Eliot often uses the perception that the earth is at the centre of the universe as an analogy for the misguided egoism of such characters as Gwendolen Harleth, Rosamond Vincy and even Edward Casaubon’.⁵ In 1871 Eliot read John Herschel’s *Outline of Astronomy* (1849), which describes not only the solar system, but also distant nebulae that put our tiny planet into perspective.⁶ Henschman suggests that Eliot’s view is complex: the geocentric image of the sun reminds us that we all have an everyday view of the cosmos that sits alongside our scientific view, and helps makes sense of it: the reader is to feel ‘the expansion and contraction of his or her mental space’.⁷

Calculus and speed

One branch of pure mathematics with wide applications in applied mathematics and physics, both now and in Victorian times, is the differential calculus: ‘the mathematician who came to give [Eliot] lessons found she was already in’ it.⁸ Eliot demonstrated her continuing interest in calculus by copying this passage from Comte into a *Daniel Deronda* notebook:

By the infinitesimal calculus it becomes possible in geometry to treat curved lines as composed of an infinity of rectilinear elements [...] & in mechanics, varied motions as an infinite series of uniform motions, succeeding each other at infinitely small intervals of time.⁹

Calculus suggests that infinitesimally small changes are significant because an infinite number of them accumulate to produce palpable outcomes. Eliot had a long-standing fascination with infinities and infinitesimals; for example, in a letter written in 1841 she apologised to Maria Lewis for sending her a diatribe describing her inadequacy: ‘I shall weary you out of your last infinitesimal of patience’.¹⁰ The young Marian Evans had an extravagant way of expressing herself! In Eliot’s last novel, Gwendolen expresses her

⁵ Anna Henschman, *The Starry Sky Within: Astronomy and the Reach of the Mind in Victorian Literature* (Oxford: OUP, 2014), p.162.

⁶ GEL 5: p.150.

⁷ Henschman, p.164.

⁸ Acton, ‘George Eliot’s “Life.”1’, *Nineteenth Century*, 17 (March, 1885), 464-85 (p.471).

⁹ Jane Irwin, ed., *George Eliot’s Daniel Deronda Notebooks* (Cambridge: CUP, 1996), p.23.

¹⁰ GEL, 1: p.108.

intentions for her marriage in a similar extravagant way: she sees Grandcourt 'as a man over whom she was going to have indefinite power'.¹¹

When describing Dorothea's mistaken belief in the capaciousness of Mr Casaubon's mind, the *Middlemarch* narrator warns: 'Signs are small measurable things, but interpretations are illimitable'.¹² Ironically, while Mr Casaubon's academic ambitions may be unbounded, the everyday reality is different; his residence in Lowick is described as 'small-windowed and melancholy-looking', and the reader is to draw a similar conclusion about its owner.¹³ For Eliot, small-mindedness was not just ineffectual; it could be morally stultifying.

Differential calculus, as described in the passage Eliot quoted from Comte, is itself used to 'bind the smallest things with the greatest'.¹⁴ It is a set of procedures for dealing with processes of gradual and continuous change through the use of infinitesimally small steps. Eliot believed that small wrong actions could accumulate and become insidious. Debating with Emily Davies the importance of always telling the truth, she spoke of 'the wide far-reaching consequences of every action'.¹⁵ The *Middlemarch* narrator talks of 'the creeping paralysis' resulting from Lydgate's relationship with a less than 'ideal wife', and this is her description of the fate of men like Lydgate, who lose their idealistic energy: 'Nothing in the world more subtle than the process of their gradual change!'¹⁶ The *Middlemarch* character who most starkly demonstrates the insidious effects of slow change through the accumulation of immorality and hypocrisy is Mr Bulstrode, who pretends to be unable to discover his step-daughter, who is the rightful heir of his widow's ill-gotten fortune. He uses this fortune to acquire and maintain power in Middlemarch; Gwendolen's delusion about having indefinite power seems to be shared by Mr Bulstrode, but with more apparent reason. The narrator uses a mathematical model, when describing his charitable giving, which is 'both minute and abundant'. The same total donation given to charity can be achieved by giving a small number of large amounts or a large number of small amounts; Mr Bulstrode prefers the latter method, because it enables him to keep control over a large number of events, and

¹¹ *Daniel Deronda*, p.265.

¹² *Middlemarch*, p.23.

¹³ *Ibid*, p.67.

¹⁴ *The Mill on the Floss*, p.273.

¹⁵ GEL, 6: p.286.

¹⁶ *Middlemarch*, pp.551, 135.

thus use the power he retains 'for the glory of God'. Middlemarchers are unimpressed by such nice behaviour: their scales 'could only weigh things in the lump'.¹⁷

Bulstrode's need to control is strongest in connection with his own conscience, where his religion is in conflict with the manner in which he has acquired his wealth; an epigraph tells of 'the living myriad of hidden suckers whereby the belief and the conduct are wrought into mutual sustainment'.¹⁸ The words myriad and suckers suggests multitudinousness and smallness, and Bulstrode's method of self-justification is to contrast the greatness of God with the smallness and unworthiness of himself and, especially, of other Middlemarchers. Eliot uses an image that suggests differential calculus, to describe how Bulstrode justifies the morally dubious journey he has travelled, which began when he corruptly obtained his money and has apparently ended in his having become a respectable and Christian banker: he breaks it 'into little sequences, each justified as it came by reasonings which seemed to prove it righteous': an infinite series of infinitesimal steps, each of which, because of its smallness, does not manifest the shape of the corrupt whole.¹⁹ This is an unsuccessful challenge to the mathematics; an infinite number of infinitesimal changes can produce a large change. For Eliot, how Mr Bulstrode 'gradually explained the gratification of his desires into satisfactory agreement with [his] beliefs' provided an example of how truth about the world is so readily distorted by being filtered through our egos, which can underestimate the cumulative significance of the small untruths we are embracing.²⁰

Colossal Lydgate

Dale suggests that in Eliot's novels, heroes and heroines are undermined by living in a 'degraded' society, made up of people with small ideas: 'You could not live among such people.'²¹ Small-mindedness certainly helps undermine people aspiring to greatness, but such people sometimes behave in ways which contribute to their own downfall. Eliot develops this theme in *Middlemarch*, using the mathematics of proportion and scale. The mathematical concept of proportion had been of interest to

¹⁷ Ibid, pp.145-6.

¹⁸ Ibid, p.487.

¹⁹ Ibid, p.580.

²⁰ Ibid, p.581.

²¹ Dale, pp.85-6; *The Mill on the Floss*, p.272.

Marian Evans ever since she was thirteen, when she started at the Miss Franklins' School, where she seemed to enjoy arithmetic, given that she produced twenty pages in her school notebook about the 'single Rule of Three'. The first problem she considered was this: 'If a gallon of beer cost 10d what is that per [36 gallon] barrel?'²² In order to make sensible use of numerical data, comparisons have to be made, and consequently proportion is a tool of practical importance for understanding the application of arithmetic to the world. This is reflected in Eliot's repeated and sharply focused use of proportion.

The need for a sense of proportion is a key theme of chapter fifteen of *Middlemarch*, which is centred on Tertius Lydgate. The chapter begins in a similar way to the chapter about the pier-glass, discussed in chapter four. In place of 'An eminent philosopher' here we have 'A great historian'.²³ Eliot had never been particularly impressed by eminences: in 1852, not long after Marian Evans first arrived, relatively unknown, in London, she told John Chapman her opinion of potential contributors to the *Westminster Review*, all of whom were considerably more eminent than she was: 'Martineau writes much that we can agree with and admire [...] Froude a little less so [...] Defective as [Lewes's] articles are, they are the best we can get *of the kind*.'²⁴ The great historian, we are soon told by the *Middlemarch* narrator, is a colossus 'whose huge legs our living pettiness is observed to walk under'.²⁵ So we are led to think that Lemuel Gulliver is being offered to us as a synecdoche for Jonathan Swift; a new edition of *Gulliver's Travels* appeared in 1864. But no: the 'great historian, as he insisted on calling himself' turns out to be not Swift, but Henry Fielding. Apparently Fielding has become a colossus because he has 'the happiness to be dead a hundred and twenty years ago'.²⁶ But whatever the narrator claims, the mention of colossi is surely intended to evoke Swift's Gulliver. If evidence for this is needed, a few paragraphs later the narrator mentions that when he was a boy Lydgate would be 'deep in [...] Rasselas or Gulliver'; and when Lydgate is the victim of 'hampering threadlike pressure of small social conditions' in Middlemarch society, Elizabeth Ermarth sees this as a 'quiet

²² Gordon S. Haight, *George Eliot: A Biography* (Oxford: OUP, 1968), p.12.

²³ *Middlemarch*, p.132.

²⁴ GEL, 2: p.49.

²⁵ *Middlemarch*, p.132.

²⁶ *Ibid.*

literary joke linking Middlemarchers with Lilliputians'.²⁷ Middlemarch, like Lilliput, is figured in terms of changes of scale, small-mindedness and cutting people down to size.

Lydgate is susceptible to being a victim in this way, because of what the narrator calls his 'commonness': his 'conceit' which is 'of the arrogant sort', manifesting itself, not only in his unwillingness to take small people seriously, but also in his weakness for women and in his lack of rational judgement about them: as a doctor, Lydgate 'cared not only for "cases", but for John and Elizabeth, especially Elizabeth'.²⁸ Evidently Lydgate as a boy wanted to read 'any sort of book he could lay his hands on: if it were *Rasselas* or *Gulliver*, so much the better'.²⁹ We are also told that a 'liberal education had of course left him free to read the indecent passages in the school classics', from which he acquired 'a general sense of secrecy and obscenity'.³⁰ For Gowan Dawson, this suggests that Lydgate's interest in an anatomical text 'on the highest shelf' may have been to use it as a stimulus for masturbation, before it performed the role of exciting his interest in a future career.³¹ Swift's *Gulliver* tells us that the king of the Lilliputians 'desired I should stand like a colossus, with my legs as far asunder as I conveniently could'.³² We can deduce a somewhat indelicate allusion if we link this statement to Eliot's previously mentioned reference to 'colossi whose huge legs our living pettiness is observed to walk under', given that *Gulliver* relates how the king of the Lilliputians commanded his army to march between his legs: 'And to confess the truth, my Breeches were at that Time in so ill a Condition, that they afforded some Opportunities for Laughter and Admiration.'³³ This lewd reference to *Gulliver*'s proportionately colossal genitalia intimates one of the roots of Lydgate's tragedy: his judgement of women. Lydgate is motivated exclusively by a woman's physical appeal and is unable to make scientific judgements about her suitability as a wife. 'There was no help for this in science' when Rosamond's and Lydgate's eyes meet.³⁴

²⁷ Ibid, pp.134, 169; Elizabeth Deeds Ermarth, 'George Eliot and the World as Language', in *George Eliot and Europe*, ed. by John Rignall (Aldershot: Scolar Press, 1997), pp.33-43 (p.34).

²⁸ *Middlemarch*, pp.140, 136.

²⁹ Ibid, p.134.

³⁰ Ibid, p.135.

³¹ Gowan Dawson, *Darwin, Literature and Victorian Respectability* (Cambridge: CUP, 2007), p.135.

³² Jonathan Swift, *Gulliver's Travels* (Oxford: OUP, 1998), p.29.

³³ Ibid.

³⁴ *Middlemarch*, p.250.

Like Gulliver in Lilliput, Lydgate sees himself towering ethically over the other Middlemarch doctors. He has the grand moral ambition to practise as a scrupulously ethical doctor: he would not be one of the people who hypocritically ‘make a profit out of poisonous pickles’ while ‘exposing adulteration’ through their public campaigning.³⁵ Poisonous pickles, or drugs, become the first target for Lydgate’s reforming zeal. The narrator expresses this by means of inverse proportion: ‘large cubic measures of physic [were] prescribed by unscrupulous ignorance’: the less knowledge the more drugs.³⁶ As will be described shortly, Lydgate manifests his own ignorance by failing to appreciate the value of drugs for Mr Mawmsey and his family as a placebo, and it is this lack of sympathy with ordinary people that contributes to Lydgate’s failure to make his case. And alongside his intention to practise as a reforming doctor, Lydgate has ambitions to pursue a career as an experimental scientist: ‘intellectual conquest’ alongside ‘the social good’.³⁷ Lydgate’s downfall is partly due to his failure to connect his twin ambitions: ‘to do good small work for Middlemarch, and great work for the world’.³⁸ He fails to attend sufficiently to the small, to apply his rational researcher’s mind adequately to his professional and personal life. At the Vincys’ party, Camden Farebrother reminds Lydgate of what he used to say must be done by the scientist: ‘a man’s mind must be continually expanding and shrinking between the whole human horizon and the horizon of an object-glass’.³⁹ Lydgate conspicuously fails to do this, and consequently achieves neither of his ambitions. ‘One must hire servants who will not break things’, Lydgate remarks to Mrs Vincy, when she wonders at the extravagance of his spending on dinner plate, and the narrator opines: ‘Certainly, this was reasoning with an imperfect vision of sequences. But at that period there was no sort of reasoning which was not more or less sanctioned by men of science.’⁴⁰ This echoes Eliot’s essay ‘The Progress of the Intellect’ (1851): ‘It is this invariability of sequence which can alone give value to experience’.⁴¹ Lydgate’s reasoning takes no account of the logic underlying practical physics and sociology. The reference to ‘that period’ is, of course, satirical; Eliot is

³⁵ Ibid, p.138.

³⁶ Ibid, p.137.

³⁷ Ibid, p.136.

³⁸ Ibid, p.139.

³⁹ Ibid, p.602.

⁴⁰ Ibid, p.331.

⁴¹ [George Eliot], ‘The Progress of the Intellect’, *Westminster Review*, 54 (January, 1851), 353-368 (p.355).

making a comment on science in the 1870s as well as in the 1830s, and protesting against wild conclusions that do not pay due regard to logical reasoning.

Statistical quantities and statistical generalisations

Statistics is concerned with drawing meaningful conclusions from data, often numerical data. In order to do this it is important to guard against drawing large conclusions from small samples, and against failing to take account of the assumptions that might lie behind the collection and interpretation of data. The community in *Middlemarch*, Eliot's 'study of provincial life' is, in the judgement of some critics, appropriately depicted by the image of the web, an image that offers a particular way of interpreting social data. The most quoted reference to web imagery in the novel occurs in the same first paragraph of chapter fifteen in which reference is made to colossi. After telling us that Henry Fielding in his novels 'seems to bring his arm-chair to the proscenium and chat with us in all the lusty ease of his fine English', which is exactly what the *Middlemarch* narrator is doing, the same narrator continues:

But Fielding lived when the days were longer (for time, like money, is measured by our needs) [...] all the light I can command must be concentrated on this particular web, and not dispersed over that tempting range of relevancies called the universe.⁴²

We are told that 'time, like money, is measured by our needs'. In other words, there is no absolute measure of what constitutes a large amount of money or a small amount of time: we need to know how much time or money is required and for what. Before we can interpret statistics we need to understand the context and also the function of the data. The narrator makes this point more explicitly later in the novel:

Lydgate had not been long in town before there were particulars enough reported of him to breed much more specific expectations and to intensify differences in partisanship; some of the particulars being of that impressive order of which the significance is entirely hidden, like a statistical amount without a standard of comparison, but with a note of exclamation at the end. The cubic feet of oxygen yearly swallowed by a full-grown man – what a shudder they might have created in some

⁴² *Middlemarch*, p.132.

Middlemarch circles! ‘Oxygen! nobody knows what that may be – is it any wonder the cholera has got to Dantzic? And yet there are people who say quarantine is no good!’⁴³

Do not simply quote a large number followed by an exclamation mark and expect it to mean anything! Eliot seems to be quite mischievous here. She demands a standard of comparison, but even assuming that cholera had anything to do with the amount of oxygen breathed, what standard of comparison would help make sense? I calculated that the volume of oxygen I breathe in a year is very approximately the volume of my house. I do not know where to go with that, which I think is Eliot’s intention; what she does is underline the fact that the wow factor of statistics often has little or nothing to do with mathematical reasoning or anything sensible at all.

Back in 1856, Marian Evans, in ‘The Natural History of German Life’, lampooned ‘the tendency created by the splendid conquests of modern generalisation, to believe that all social questions are merged in economical science, and that the relations of men to their neighbours may be settled by algebraic equations’.⁴⁴ Because she knew what mathematics did, and didn’t, tell us, she was in a good position to attack the naivety of commentators who produced easy and misleading answers based on inadequate data or an inadequate understanding of statistics. And in 1861 Eliot read Henry Buckle’s book, *History of Civilisation in England*. She wrote this to her publisher:

I am very far behind Mr Buckle’s millennial prospect, which is, that men will be more and more congregated in cities and occupied with human affairs, and so less and less under the influence of Nature [...] whereby superstition will vanish and statistics will reign for ever and ever.⁴⁵

Buckle’s book made use of the ideas of Quetelet, who had in 1835 published a book about ‘l’homme moyen’, the average man, a concept that led on to distinguishing the characteristics of different groups of people by means of differing statistical averages.⁴⁶ Buckle’s 1857 book, much in vogue in many quarters, espoused a historical determinism, with society developing according to fixed statistical laws, leading to the kind of fatalism that Eliot strongly opposed.⁴⁷ Eliot and Lewes in 1871 read a book by

⁴³ Ibid, p.416.

⁴⁴ [George Eliot], ‘The Natural History of German Life’, *Westminster Review*, 10 n.s. (July, 1856), 51-79 (p.55).

⁴⁵ GEL, 3: p.417.

⁴⁶ Ian Hacking, *The Taming of Chance* (Cambridge: CUP, 1990), pp.107-9.

⁴⁷ Ibid, pp.125-6.

W. Wundt rebutting the notion of statistical laws that could constrain individual freedom.⁴⁸ Eliot's use of the phrase 'very far behind' suggests that she not only disagreed with Buckle's philosophy but also found his statistical arguments flawed.

The familiar web image: 'all the light I can command must be concentrated on this particular web and not dispersed over that tempting range of relevancies called the universe', can itself be interpreted as having a statistical undertow. The narrator is 'unravelling certain', meaning specific, 'human lots'.⁴⁹ To help argue that the unravelling produced will not be generalisable to the whole 'universe', the narrator uses the geometry of light as a basis for the image. If a candle is held close to a wall, it illuminates one part of the wall clearly and more distant parts hardly at all; if it is held further away, it illuminates more of the wall, but not so brightly. In the image Eliot offers there is only a limited amount of light available for understanding Middlemarch society, and there is also the difficulty of seeing clearly; so the image echoes some of what is learnt from the pier-glass, providing a warning against a belief that conclusions about the world can be objective or certain. The inhabitants of Middlemarch are multiply connected and entangled, but there are not readily discernible patterns that enable social behaviour to be explained with ease. Instead, all we can do is cautiously extrapolate from observations and work at understanding this particular web as well as we can.

Another instance of the woven web in *Middlemarch* occurs in the Finale:

the fragment of a life, however typical, is not the sample of an even web: promises may not be kept, and an ardent outset may be followed by declension; latent powers may find their long-awaited opportunity; a past error may urge a grand retrieval.⁵⁰

In this instance the web metaphor is used to describe not the network of relationships between people, but the network of events and behaviours over time within a single life. Here again there is reference to a statistical concept: sampling. The narrator is again warning against generalising from a sample; against assuming that there is a regular geometrical pattern in the web. This is an injunction not to judge people too hastily:

⁴⁸ Ibid, p.128; GEL 5: p.150.

⁴⁹ *Middlemarch*, p.132.

⁵⁰ *Middlemarch*, p.779.

people will change and they will sometimes behave out of character, if indeed there is such a thing as character. Some people will disappoint; others will exceed expectations. Even James Chettam, for all he has said against Will Ladislaw, learns to be 'on a footing of reciprocal tolerance' with him for the sake of Celia and Dorothea.⁵¹

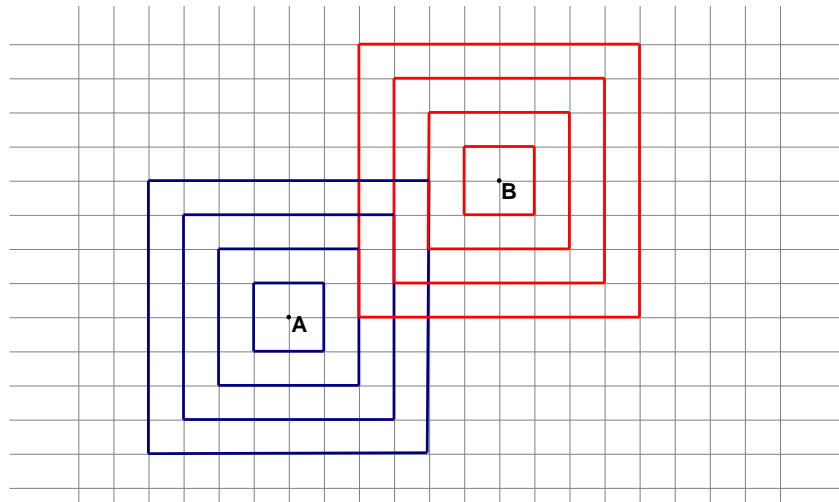
In his seminal 1975 essay on *Middlemarch* Hillis Miller includes the woven web among 'a family of related metaphors' which imply that 'society is in some way like a material field' open to 'scientific investigation'. For Miller, 'that the texture of Middlemarch society as a whole may be accurately represented in a metaphor of woven cloth is taken for granted throughout the novel.'⁵² While the two woven-web quotations I have discussed are suggestive of the possibility of exploring a sample in order to make broader conjectures about society, both images are framed so as to suggest that caution needs to be applied, and I am reluctant to endorse Miller's use of the word 'accurately'. In fact, Miller goes further, inferring from the web imagery that, for Eliot, 'investigation of a sample *will* lead to valid conclusions about the whole', in spite of the *Middlemarch* narrator asserting the direct opposite: 'the fragment [...] is not the sample of an even web'.⁵³ Later in Miller's essay, when he lays the web metaphor alongside the pier-glass parable, he expresses more caution about drawing conclusions concerning the evenness of society: 'Middlemarch society appears to be a web only because a certain kind of subjective light is concentrated on it.' Selma Brody suggests a mathematical interpretation connecting the web with the pier-glass. A web seen as a piece of woven cloth is a 'two-dimensional' lattice. Such a lattice has no centre. Imagine choosing any lattice point, as on a piece of squared paper, from which to view the lattice. Just as the concentric circles on the pier-glass superficially appear the same wherever the candle is placed, as explained in chapter four, the lattice superficially appears the same from any one such point as from any other.⁵⁴ I picture it as shown on the next page. When events are imagined on the strands of the web, the events seen by an

⁵¹ Ibid, p.784.

⁵² J. Hillis Miller, 'Optic and Semiotic in *Middlemarch*', in *The Worlds of Victorian Fiction*, ed. by Jerome H. Buckley (Cambridge Mass. and London: Harvard University Press, 1975), 124-148 (p.130).

⁵³ Miller, p.129; my emphasis; *Middlemarch*, p.779.

⁵⁴ Selma Brody, 'Physics in *Middlemarch*: Gas Molecules and Ethereal Atoms', *Modern Philology*, 85:1 (1987) 42-53 (p.45).



The same from any one such point as from any other

observer at A would be configured differently from the events (some of which are the same) seen by an observer at B. Eliot is using mathematics – in this case the geometry of the web – to insist not on the precision of science’s view of the world, but on its lack of precision. In *Daniel Deronda* Eliot quotes La Rochefoucauld: ‘Il est plus aisé de connaître l’homme en général que de connaître un homme en particulier.’⁵⁵ Making generalisations about all people is easy, and often fails to take sufficient account of individual differences.

Repeatedly in her novels, Eliot satirises statistical averages. In her first novel, Eliot appears to be using the concept of being above the average straightforwardly with reference to Adam: the narrator tells us that Adam was ‘by no means a marvellous man’ and yet he ‘was not an average man’.⁵⁶ But in the same novel, Eliot satirises the scope claimed for statistics: ‘if there were such a thing as taking averages of feeling,’ the narrator mocks, when describing Arthur’s state of mind.⁵⁷ And in an essay published in the *Westminster* in 1854, Marian Evans is sceptical about the idea of a typical man: ‘Throughout the animal world, the higher the organization, the more frequent is the departure from the normal form. We do not often see imperfectly-developed or ill-made insects, but we rarely see a perfectly-developed, well-made man.’⁵⁸

⁵⁵ *Daniel Deronda*, p.260.

⁵⁶ *Adam Bede*, p.212.

⁵⁷ *Ibid*, p.310.

⁵⁸ [George Eliot], ‘Woman in France: Madame de Sablé’, *Westminster Review*, 62 (October, 1854), 448-473 (p.451).

Eliot's scepticism about statistical models is apparent from the narrator's description of Lydgate arriving in Middlemarch with noble aspirations to reform medicine and change the world. The narrator satirises the previously mentioned mid-Victorian mania for statistical models, by telling us, *not* simply that Lydgate aimed to be a good reforming doctor, but by alluding to his ambitions thus, incidentally referring to the statistical measure of 'mean':

Considering that statistics had not yet embraced a calculation as to the number of ignorant or canting doctors which absolutely must exist in the teeth of all changes, it seemed to Lydgate that a change in the units was the most direct mode of changing the numbers. He meant to be a unit who would make a certain amount of difference towards that spreading change which would one day tell appreciably on the average, and in the mean time [...] ⁵⁹

The narrator ironically laments that there are no statistics for the number of 'canting' doctors and implies that, if available, such statistics would help change to take place. In one of her *Middlemarch* notebooks Eliot collected information concerning the qualifications and rules for licensing of doctors in England and Scotland: the data does not include the number of 'canting' doctors, of course, and Eliot's joke is that such subjective statistics could not ever be obtained. ⁶⁰ Eliot puns on the word 'unit'. A change of units does, spuriously, change the numbers and could provide a way of making the statistics look more impressive than they are. Lydgate, intended to be a 'unit' in a different sense, a doctor standing out from others, who would, through his reforms perhaps, significantly change the average – the mean.

The narrator again lampoons statistical averages when ironically depicting the extravagant and insufficiently considered ambitions of many young men: 'He was but seven-and-twenty, an age at which many men are not quite common'. ⁶¹ The word 'common' here could mean average; Eliot deliberately chooses this word, because the narrator later describes Lydgate as 'common' in a different sense, meaning he was arrogant and lacking in emotional and social refinement. What happens to these over-ambitious men of twenty-seven is that they eventually prove insufficiently strong to

⁵⁹ *Middlemarch*, p.137.

⁶⁰ John Clark Pratt and Victor A. Neufeldt, *George Eliot's Middlemarch Notebooks* (Berkeley, Los Angeles and London: University of California Press, 1979), pp.60-1.

⁶¹ *Middlemarch*, p.133.

withstand the pressures of life and become ‘shapen after the average and fit to be packed by the gross’, a reference here to the statistical mode, in other words the most common value, rather than the mean.⁶² Eliot is mocking statistical models which would want to suggest that, once it is established that some men lose their noble youthful idealism, then it must happen to all men.

The kinetic theory of gases

As Gillian Beer points out, Eliot’s contemporary, R. H. Hutton complained that Eliot’s use of the word ‘dynamic’ at the beginning of *Daniel Deronda*: was ‘pedantically over-scientific’.⁶³ Hutton is focusing on a characteristic of both *Middlemarch* and *Daniel Deronda*, which is that Eliot uses the imagery associated with mechanical forces to describe interactions between characters. For Selma Brody, some of such imagery in *Middlemarch* is inspired by the kinetic theory of gases that was being formulated by physicists such as John Tyndall, who wrote about it in his 1863 book *Heat as a Mode of Motion*.⁶⁴

In kinetic theory, small randomly-moving particles, taken together, have large-scale non-random effects. As Brody suggests, the gas theory image works as a counter-balance to the web image; while the essence of the web image is apparent order and pattern and also connectedness, the gas theory image is about randomness, with individual molecules having no connection with other molecules except that they exist within the same gas container and collide with one another.⁶⁵ As an indication of Eliot’s intentional use of this image, Brody mentions the epigraph for chapter sixty-four:

All force is twain in one: cause is not cause
Unless effect be there; and action’s self
Must needs contain a passive.⁶⁶

⁶² Ibid, p.135.

⁶³ Gillian Beer, *Darwin’s Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (London: Ark, 1985), p.149; R. H. Hutton, *Spectator*, 49 (1876), 1131-3.

⁶⁴ John Tyndall, *Heat as a Mode of Motion* (London: Longmans Green, 1863); Brody, pp.46-7.

⁶⁵ Brody, p.48.

⁶⁶ *Middlemarch*, p.608.

This encapsulates Newton's Third Law of Motion: 'To every action there is an equal and opposite reaction,' a law that explains the behaviour of gas particles when they collide.⁶⁷ Brody also points to the final paragraph of chapter nineteen: 'There are characters which are continually creating collisions and nodes for themselves in dramas which nobody is prepared to act with them.'⁶⁸ Brody applies gas theory to the interactions between Mr Brooke, Will Ladislaw and Mr Casaubon and between Lydgate and Rosamond.⁶⁹

While Brody discusses the interactions of major characters to exemplify her theory, exploring the behaviour of minor characters such as Mr Mawmsey and his associates might be even more effective in this connection. Lydgate is thoughtlessly drawn to sharing with Mr Mawmsey the grocer his hostile views on the habit doctors have of overdosing their patients. The narrator cautions: 'let the wise be warned against too great readiness at explanation: it multiplies the sources of mistake'.⁷⁰ In this chance meeting with Mr Mawmsey Lydgate is not wise: he behaves 'thoughtlessly'. And in their collision, the momentum created by Mr Mawmsey's 'friendly jocoseness' causes Lydgate to make his unwise remarks. As a result of this collision Mr Mawmsey is pushed into a different track: 'in truth his views were perturbed'.⁷¹ So he recites Lydgate's opinions to Mrs Mawmsey who is taking strengthening medicine for her asthma; she puts her own spin on them in talking to 'an intimate female friend'; Mrs Mawmsey also tells Mr Gambit, and eventually '[o]ther medical men' hear about it.⁷² Eliot is not here describing a conspiracy against Lydgate; the interactions are too random for such an interpretation. Instead, what Lydgate has done is set forth a chain reaction of collisions, in each of which characters act as what Brody calls 'inertial egoists'.⁷³ For example, while Mr Mawmsey might seem to have the best interests of his asthmatic wife and family in mind when he rejects Lydgate's philosophy about drugs, he is actually thinking of his own view of himself. He has been comforted by the thought that he has been carrying out 'his responsibilities as a husband and father' to his

⁶⁷ Brody, p.49.

⁶⁸ Brody, p.48; *Middlemarch*, pp.179-80.

⁶⁹ Brody, pp.49-51.

⁷⁰ *Middlemarch*, p.417.

⁷¹ Ibid.

⁷² Ibid, pp.418-9.

⁷³ Brody, p.48.

asthmatic family by paying for regular medication to improve their health.⁷⁴ Similarly, Mrs Mawmsey is keen to justify to her friend, and thus to herself, her taking of expensive medicine: 'I should like him to tell me how I could bear up at Fair time, if I didn't take strengthening medicine for a month beforehand.'⁷⁵ Characters can in this way be seen as random billiard balls careering in a new direction following collisions which provide new anxieties which they need egoistically to justify. So when we are told that 'Middlemarch, in fact, counted on swallowing Lydgate and assimilating him very comfortably', there is no Machiavellian plot involved: only the normal random interactions of egoistic Middlemarchers. Understanding *Middlemarch* entails paying attention to the small people.⁷⁶

Resonance

I now turn to another phenomenon of mathematical physics in which small forces can move large bodies. Will Ladislaw, while ruminating about the forthcoming parliamentary election, in which Mr Brooke is a candidate and he is Mr Brooke's agent, and while dreaming that Mr Brooke might win and then eventually get promoted to the Cabinet, with Will as his 'Under-Secretary', observes to himself: 'This is the common order of things: the little waves make the large ones and are of the same pattern.'⁷⁷ What sounds like a theorem in mathematical physics suggests that small changes can result in large changes. Will's remark suggests resonance, where a vibration, or wave, in a small object can make a larger object vibrate, but only when the frequency of the little wave is compatible with the natural frequency of vibration of the large object: waves indeed need to be 'of the same pattern'. The impetus given by the small waves impinging on the large object will then have a cumulative effect. Resonance, both literally and metaphorically, is a common occurrence that can sometimes be helpful, pleasant, rewarding, productive, but can sometimes be irritating, unpleasant and even dangerous. In *Middlemarch*, resonance is first mentioned in the Prelude, where it is refers to small people having a great influence: 'far-resonant action' is denied to many aspiring Saint Theresas, who will fail to have the 'opportunity' to emulate their

⁷⁴ *Middlemarch*, p.418.

⁷⁵ Ibid.

⁷⁶ Ibid, p.144.

⁷⁷ Ibid, p.433.

namesake and perform anything as influential as ‘the reform of a religious order’.⁷⁸ The physical phenomenon of resonance is described in detail in one of the epigraphs in *Middlemarch*:

How will you know the pitch of that great bell
Too large for you to stir? Let but a flute
Play ‘neath the fine-mixed metal: listen close
Till the right note flows forth, a silvery rill:
Then shall the huge bell tremble – then the mass
With myriad waves concurrent shall respond
In low soft unison.⁷⁹

Here the phenomenon of resonance is the basis of an experiment carried out, in order to draw conclusions about the pitch of a bell. In his course of eight lectures on ‘Sound’, given in 1867, John Tyndall describes how ‘I have here a fine, sonorous bell [...] which I throw into intense vibration by passing a resined bow across its edge’.⁸⁰ Tyndall goes on to describe the use of a tube,

capable of being lengthened and shortened by a telescopic slider [...] I bring it near the vibrating bell, but the resonance is feeble. I lengthen the tube by drawing out the slider, and, at a certain point, the tone swells out.⁸¹

Drawing out the slider changes the natural frequency of vibration of the tube, and at some point this coincides with the frequency of the bell’s vibrations.

In the chapter introduced by Eliot’s epigraph, resonance is used to describe the moment at which Lydgate’s relationship with Rosamond becomes an engagement. Lydgate thinks he is safe from Rosamond: ‘He did admire Rosamond exceedingly; but that madness which had once beset him about Laure was *not*, he thought, *likely* to recur in relation to any other woman.’⁸² The phrase ‘not likely’ used in this way is not rational thinking in this context. Lydgate is vulnerable to Rosamond’s charms: their natural frequencies coincide. When he visits her house to pass on a message, Rosamond

⁷⁸ Ibid, p.3.

⁷⁹ Ibid, p.274.

⁸⁰ John Tyndall, *Sound: A Course of Eight Lectures Delivered at the Royal Institution of Great Britain* (London: Longmans Green, 1867), p175.

⁸¹ Ibid, p.176.

⁸² *Middlemarch*, p.153, my emphasis.

drops her chain and Lydgate picks it up. In so doing he is close to Rosamond and notices ‘a certain helpless quivering which touched him quite newly’. As the epigraph has it: ‘Then shall the huge bell tremble’. This moment ‘was the crystallising feathertouch: it shook flirtation into love’.⁸³

Resonance is used by Eliot to depict Lydgate as a man whose passions can be excited in ways that thwart his scientific reasoning. Rosamond is the ‘flute’ played ‘neath the fine-mixed metal’ repeatedly for Lydgate. When the relationship between Lydgate and Rosamond turns acrimonious, resonance between them becomes dangerous. After one of their arguments about how to deal with their debts, Lydgate feels ‘dread’ about further difficult discussions with his wife. ‘It was as if a fracture in delicate crystal had begun, and he was afraid of any movement that might make it fatal.’⁸⁴ The image here is of the resonating vibration reaching a critical amplitude and shattering the crystal: in other words, marital arguments might reach such an intensity that he thinks ‘I shall love her no more.’⁸⁵

On another occasion there is a specific reference to the resonance epigraph in connection with the relationship between Rosamond and Will Ladislaw; and in this case the critical amplitude is reached, with potentially destructive consequences. Dorothea has just discovered Will comforting Rosamond and therefore in an apparently compromising position with her. Will is furious and blames Rosamond. Instead of going away, Will ‘had a horrible inclination to stay and shatter Rosamond with his anger’.⁸⁶ That this is an intimation of destructive resonance is demonstrated by the explicit reference to the resonance epigraph: Will ‘was dangerously poised, and Rosamond’s voice now brought the decisive vibration’, by speaking in ‘flute-like tones of sarcasm’.⁸⁷ Rosamond’s ‘flute’ makes Will’s ‘huge bell’ more than ‘tremble’, and he vents his rage on Rosamond.

Resonance is strongly associated with music, and Delia da Sousa Correa points to an incident in *Daniel Deronda* in which the ‘musical magus’ Julius Klesmer, who has

⁸³ Ibid, p.282.

⁸⁴ Ibid, p.613.

⁸⁵ Ibid.

⁸⁶ Ibid, pp.731-2.

⁸⁷ Ibid, p.732.

offered to play incidental music on the piano for the domestic tableau in which Gwendolen Harleth is starring, strikes, at an appropriate dramatic moment, a ‘thunderous chord’, as a result of which a ‘moveable panel’ flies open, revealing a picture of ‘the dead face and the fleeing figure’ and terrifying Gwendolen.⁸⁸ For Correa, this suggests that Klesmer has uncanny powers, capable of ‘disturbing Gwendolen in the very heart of home’. However, Correa also points to Eliot’s ‘gentle mockery of spiritualism’ in relation to this incident:

‘It is very mysterious. It must be the spirits.’

‘But there is no medium present.’

‘How do you know that? We must conclude that there is, when such things happen.’⁸⁹

Rather than relying on supernatural explanations of phenomena, Eliot prefers science; in this case it is resonance that dislodges the panel, Gwendolen’s sister having forgotten to lock it.⁹⁰ Klesmer’s uncanny powers are certainly not in evidence in the narrator’s description of his relationship with Catherine, in which both participants take a nervous while to confess their attraction to one another. Neither could do this using words or plain actions, but they resonate with one another, without either being able fully to interpret what is happening. Klesmer sends a ‘storm through the piano’, reminiscent of the ‘thunderous chord’ and hence of the concept of resonance, the narrator having alluded to ‘the systole and diastole of a blissful companionship’, intimating rhythmic sympathy. Klesmer and Catherine have a ‘sympathy in taste’ – the word sympathy means ‘feeling with’ – and their situation as male teacher and female pupil resonates in the narrator’s and the reader’s mind with the ‘days of Abelard’ and Heloise.⁹¹ As happens repeatedly in Eliot’s novels, resonance is used to describe couples falling in love: in *Adam Bede* we are told, in connection with Hetty’s love for Arthur, that ‘instruments called human souls have only a very limited range of music, and will not vibrate in the least under a touch that fills others with tremulous rapture or quivering agony’.⁹²

⁸⁸ *Daniel Deronda*, pp.42, 49.

⁸⁹ Delia da Sousa Correa, ‘George Eliot and the Germanic “Musical Magus”’ in *George Eliot and Europe*, ed. by John Rignall (Aldershot: Scolar, 1997), pp.98-112 (pp.109-10).

⁹⁰ *Daniel Deronda*, p.50.

⁹¹ *Ibid.*, pp.203-209.

⁹² *Adam Bede*, p.96.

When Daniel's acquaintances remark to him that his 'appearance was of a kind to draw attention', this intended compliment 'found an angry resonance' in Daniel, the reason for which 'a clue has already been given': Daniel is ignorant of, and sensitive about his parentage.⁹³ Resonance is a phenomenon whereby particular things and people respond in sympathy with one another, even in spite sometimes of differences in size, which might be difference in social class, or in strengths of egos. And as we have seen, such sympathetic response is sometimes, but far from always, beneficial.

Gravitational attraction and the conservation of energy

Alice Jenkins sees *Middlemarch* as a novel in which the 'web' metaphor may depict 'the society of Middlemarch as a field made up of [Faraday's] lines of force.'⁹⁴ The same might be said about society in *Daniel Deronda*. '[C]lassic field theory' in *Middlemarch* might describe characters connected through wealth, sexual desirability, kinship or patronage; in *Daniel Deronda* the focus is sexual, social or ideological attraction.⁹⁵ Electromagnetic and gravitational field theory aptly depicts such attraction, because electrical, magnetic and gravitational forces can all function at a distance. While Eliot was writing *Daniel Deronda*, Lewes was working on the first two volumes of his *Problems of Life and Mind*, volumes that make substantial use of mathematics and mathematical physics. Lewes writes about the employment of 'Ideal constructions' by mathematicians; they are 'fictions' that differ from 'the brute simplicity of Sensation' because they are simplified versions of reality, true under 'ideal' conditions.⁹⁶ For example, Newton showed that, if the inverse-square law of gravitational attraction is assumed, the orbit of a planet around the sun is an ellipse, in accordance with Kepler's first law. But the orbits of planets are not ellipses, Lewes explains, because there is more than one planet in the solar system. 'Are then Kepler's laws illusions? By no means: they are abstractions.'⁹⁷ To sum up, the path of a planet is approximately an ellipse: if there was only one planet it would traverse an ellipse exactly. Eliot manifested a specific interest in conic sections, of which ellipses are one

⁹³ *Daniel Deronda*, p.158.

⁹⁴ Alice Jenkins, *Space and the 'March of Mind': Literature and the Physical Sciences in Britain, 1815-1850* (Oxford: OUP, 2007), p.204

⁹⁵ Ibid.

⁹⁶ George Henry Lewes, *Problems of Life and Mind: The Foundations of a Creed*, 2 vols. (London: Trübner, 1874-5), 1: pp.266, 272.

⁹⁷ Ibid, p.269.

example, in her preparation for *Daniel Deronda*. She quoted from Harriet Martineau's translation of Comte in one of her notebooks: 'The study of the properties of the same figure is so extensive, that the labours of geometers for twenty centuries have not exhausted the study of conic sections.' This topic was of enduring interest to Eliot; Eliot told Sarah Marks in 1880 that she was studying conic sections every morning because 'she didn't want to lose the power of learning'.⁹⁸

In 1865 Eliot read an article by John Tyndall on 'The Constitution of the Universe', published in Lewes's *Fortnightly*, describing it in a letter as 'a splendid piece of writing on the higher Physics'.⁹⁹ This article is primarily about the conservation of energy: energy is converted into different forms but the totality of energy never diminishes. Tyndall describes how 'energy is possible to bodies not in motion, but which, in virtue of attraction or repulsion, possess a power of motion which would realise itself if hindrances were removed'.¹⁰⁰ When this happens, this power of motion, which Tyndall calls 'potential energy', is converted into '*vis viva*': the energy of motion. If subsequently this motion is blocked the energy is converted into heat and light. In volume four of *Problems of Life and Mind*, edited for publication by Eliot after Lewes's death, Lewes writes about how each organism is 'a system of forces [...] over and above the particular motives [...] we are conscious of a Will, a Personality, which determines these [forces] to be what they are'.¹⁰¹

Alan Dale picks up on the chemistry mentioned in Tyndall's article and suggests that Daniel and Gwendolen are energised by a 'chemical reaction' between them.¹⁰² I shall choose to focus instead on the physics of gravitational and electromagnetic force fields, Lewes's systems of forces; I begin with the episode in *Daniel Deronda* in which Julius Klesmer and Catherine Arrowpoint declare their love for one another. Now, 'always supposing no disturbance', the potential energy pent up within Klesmer's and Catherine's passion for one another would have been 'secure from overflow'.¹⁰³ This is a recurring theme of Eliot's: society does not permit women to use their energy freely.

⁹⁸ GEL, 9: p.293.

⁹⁹ John Tyndall, 'The Constitution of the Universe', *Fortnightly Review*, 3 (1 December, 1865), 129-144; GEL, 4: p.210.

¹⁰⁰ Tyndall, 'The Constitution of the Universe', p.142.

¹⁰¹ Rosemary Ashton, *G. H. Lewes: A Life* (Oxford: Clarendon, 1991), p.279; Dale, p.153.

¹⁰² *Ibid.*, p.152.

¹⁰³ *Daniel Deronda*, p.205.

But the sudden declaration of this passion releases Catherine's energy in the form of Tyndall's *vis viva*. Now free to move in her force field, Catherine is 'determined to take the straightest possible' way to tell her parents; 'determined' can suggest inevitability in accordance with the laws of physics.¹⁰⁴ When Catherine encounters her parents' resistance to her plans, her *vis viva* is converted into heat in her argument with her parents. Klesmer's *vis viva* causes him to leave the Arrowpoints' house, Quetcham, in a hurry, because Quetcham 'had in fact become too hot for him'.¹⁰⁵

Hardy's astronomy and Eliot's conic sections

Thomas Hardy and George Eliot both make metaphorical use of astronomy in their novel writing. But whereas Hardy is interested in the technology of astronomy, Eliot's focus is more on the mathematical and philosophical theory behind it.

Hardy's novel *Two on a Tower* is centrally about astronomy and astronomers. For Pamela Gossin, 'there is not another novel in the whole of English literature that has so much of its content and form focused on astronomy'.¹⁰⁶ In *Two on a Tower*, Swithin and Viviette exhibit two contrasting cosmologies: 'his scientific, hers religious', while in *Daniel Deronda* cosmological and religious themes run parallel, as will become clearer in chapter six.¹⁰⁷ In *Daniel Deronda*, the contrasting cosmologies are geocentrism, metaphorically the cosmology of the inhabitants of Diplo, who are at the centre of their own unchanging world, and heliocentrism, the cosmology of Daniel, Mordecai, Mirah and, eventually, Gwendolen, who accomplish movement and change. Another significant difference between Eliot's and Hardy's novels is in the way astronomy is used. While both make effective metaphorical use of this subject, Hardy incorporated into *Two on a Tower* the latest astronomical research; and, as Gossin tells us, he also consulted an astronomical engineer 'for information on lens grinding and telescope construction', which he made use of in the novel: 'The astronomer stretched out his arm, and the whole dome turned horizontally round, running on balls with a rumble of thunder [...] Swithin then manipulated the equatorial and put it through its

¹⁰⁴ Ibid, p.209.

¹⁰⁵ Ibid, p.202.

¹⁰⁶ Pamela Gossin, *Thomas Hardy's Novel Universe: Astronomy, Cosmology and Gender in the Post-Darwinian World* (Aldershot: Ashgate, 2007), pp.155-6.

¹⁰⁷ Ibid, p.157.

capabilities in like manner.’¹⁰⁸ By contrast, when writing *Daniel Deronda*, Eliot was primarily interested in making metaphorical use of planetary motion within the solar system, and in the mathematics that lies behind it; she appears to have had little interest either in the latest astronomical information, or in telescope engineering or any other technicalities. The main character is a dreamy mathematician rather than an experimental astronomer.

Eliot’s interest in the mathematics of planetary motion is manifested in a number of ways. Henchman suggests that Eliot is distinguished from Hardy by being interested in multiple bodies: she cites the ‘unceasing’ journey of stars and the ‘visible arc in the wanderer’s orbit’ which imply the ‘invisible pathways the astronomer must deduce’.¹⁰⁹ I see these as evidence for an interest not just in multiple bodies, but also in the mathematics underlying astronomy. Her ongoing involvement with conic sections has already been mentioned; and in *Middlemarch*, the narrator demonstrates Eliot’s interest in the theory of planetary motion by asking the reader to consider this: ‘Has the theory of the solar system been advanced by graceful manners and conversational tact?’¹¹⁰ Physical laws are physical laws, not dependent on the high moral standing of those who formulate or espouse them. Eliot’s remark is almost certainly a reference to Isaac Newton, and reads like an echo of Augustus De Morgan’s *Essays on the Life and Work of Isaac Newton*: ‘That unvarying dignity of mind is the necessary concomitant of great power of thought is a pleasant creed, but hardly attainable except by those whose love of their faith is insured by their capacity for believing what they like.’¹¹¹ In these essays De Morgan began to question the veracity of Newton’s high moral reputation, while continuing to extol his mathematics and physics. As admirers of both De Morgan and Newton, Eliot and Lewes are likely to have been familiar with this work.¹¹² Eliot’s interest in Newton’s inverse-square law of gravitation is intimated in *Middlemarch* by the *Trumpet* newspaper’s ironic reversal of the proportion in this law, in its satire on Mr Brooke’s selective altruism: ‘But we all know the wag’s definition of a philanthropist: a man whose charity increases directly as the square of the distance.’¹¹³

¹⁰⁸ Ibid, pp.157-8.

¹⁰⁹ Henchman, p.168; *Daniel Deronda*, pp.3, 135.

¹¹⁰ *Middlemarch*, p.78.

¹¹¹ Augustus De Morgan, *Essays on the Life and Work of Isaac Newton* (Chicago and London: Open Court, 1914), p.122.

¹¹² See, for example, GEL, 5: p.283.

¹¹³ *Middlemarch*, p.360.

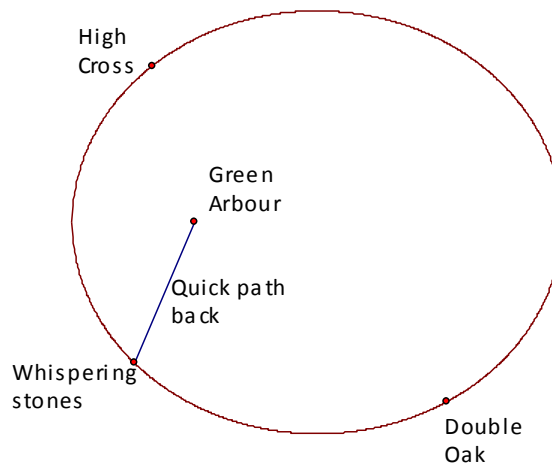
Eliot demonstrates her interest in conic sections in *Daniel Deronda* through the archery in the novel. Eliot will of course have known that the path of a projectile is a conic section, a parabola.



Arrows and parabolas

Arrows fired in the archery competitions would not travel in parabolas, because arrows used in archery are flighted so as to take advantage of air resistance, and thus have a flatter trajectory. However, the path of an arrow *is* a parabola under Lewes's 'ideal' conditions. And there is also an ellipse in connection with the archery. In giving an account of Lord Brackenshaw's roving archery event, the narrator describes the route to be taken by the archers as a 'curve that might be drawn through certain well-known points, such as the Double Oak, the Whispering Stones, and the High Cross'; the word 'curve' and the description of its manner of drawing through 'points' are suggestive of a mathematical figure.¹¹⁴ This figure might be readily imagined as an ellipse, with the archers as planets. At the focus of this ellipse is Green Arbour, the base for the expedition. The number of points the curve is described as passing through is three, and it can be shown mathematically that, given the position of one of its foci, the path of an ellipse is uniquely determined by giving three points on it, as shown in the diagram on the following page.

¹¹⁴ *Daniel Deronda*, p.123.



‘curve that might be drawn through certain well-known points’

Some time after the start, the orbiting archers speed up, ‘hurrying obliquely forward under the guidance of Mr Lush’, perhaps as a result of Kepler’s second law, which is that a planet sweeps out equal areas in equal intervals of time and so speeds up when closer to the focus.¹¹⁵ At this moment of acceleration, close to the Whispering Stones, Gwendolen is acted on by the gravitational force emanating from Lydia Glasher, who detains her to listen to her story. Consequently, Gwendolen loses her kinetic energy, and so, as a result of the gravitational force field she is in, she ‘determined to take this [short] way back to the Green Arbour, which she reached quickly’.¹¹⁶ As with Catherine Arrowpoint, ‘determined’ can suggest physical inevitability; like Catherine, Gwendolen returns to this focus in a straight line under the attraction of its gravity. John Tyndall’s 1865 article explained how, ‘were it stopped in its orbit to-morrow, under the operation of this force [gravitation] the earth would rush towards the sun’.¹¹⁷ Throwing Gwendolen out of her orbit is exactly what Lydia does. Cosmic forces then begin to shape Gwendolen’s life.

Gwendolen’s attractive and repulsive forces

It is because Gwendolen’s astronomical ‘position’ in the novel is equivocal - is she a sun or a planet? - that most of the allusions in the novel to cosmic forces are centred on Gwendolen. Gwendolen has seen herself as sexually attractive rather than sexually

¹¹⁵ Ibid, p.127.

¹¹⁶ Ibid, p.128.

¹¹⁷ Tyndall, ‘The Constitution of the Universe’, p.131.

attracted, as is appropriate for a sun: her attraction is to horse riding rather than to men. Gwendolen's cousin Rex is one of those who are sexually attracted to her, and at the start of a particular fox hunt in which they are both intending to participate, his attraction to his cousin acts like electricity for him. First we are told about Gwendolen's acquaintances of which Rex is jealous, whose horses 'swept the surrounding space as effectually as a revolving lever'. As Rex is approaching Gwendolen on his horse and the hunt begins, suddenly 'the whole field was in motion as if the whirl of the earth were carrying it; Gwendolen along with everything else'.¹¹⁸ Although the 'field' ostensibly refers to those taking part in the hunt, the imagery, which includes Gwendolen with her 'core of confidence', suggests an electric motor suddenly starting, imparting to Rex an 'impetus to utter his love' and to Gwendolen the thrill of hunting on horseback.¹¹⁹ Later in the novel, when Grandcourt brings Gwendolen her horses, the horses, and not Grandcourt, give her a 'thrill of exultation'.¹²⁰

Gwendolen's non-sexual courtship with Grandcourt is described with copious electromagnetic and gravitational imagery. When Grandcourt is first coming to Wanchester, a rumour of it 'touched all classes within a certain circuit': Grandcourt is an electric battery. The current of electricity magnetises the Arrowpoints and the Gascoignes 'in the same direction.'¹²¹ Gwendolen seems in no doubt about the attraction her magnetic field will have for Grandcourt: 'my arrow will pierce him'.¹²² However, the local maidens may not be the only forces acting on Grandcourt; when he does not appear at the expected time Lord Brackenshaw suggests '[h]e may have been pulled in another direction'.¹²³ After Grandcourt meets Gwendolen, Gwendolen's suggestion that they meet in the ballroom is answered with 'perfect gravity'.¹²⁴ Later their fields align themselves: 'Grandcourt's own thought was looking in the same direction'.¹²⁵ Flirting is one thing, but Gwendolen's fear of sex makes the contemplation of marriage with Grandcourt quite another. But the combined forces of

¹¹⁸ *Daniel Deronda*, p.58.

¹¹⁹ *Ibid*, pp.59, 58.

¹²⁰ *Ibid*, p.258.

¹²¹ *Ibid*, p.75, 77.

¹²² *Ibid*, p.79.

¹²³ *Ibid*, p.88.

¹²⁴ *Ibid*, p.95.

¹²⁵ *Ibid*, p.110.

magnetism and electricity are more powerful than the force of magnetism alone: after the circumstances of Gwendolen's family change, matters develop a critical 'mass and momentum' and the impending move to Sawyer's cottage causes 'a new current of fear' to pass through Gwendolen.¹²⁶ Electromagnetism later has more powerfully alarming effects on Gwendolen: as the time approaches when she must make a decision about marrying Grandcourt, the 'activity within her made a warm current through her terror'.¹²⁷ When Grandcourt is about to arrive on the occasion when Gwendolen agrees to marry him, but is at the stage when she is sure she will not agree to marry him, there is a 'new current in her frame' that will enable her to 'concentrate all her energy in [...] self-control'. When love making begins, the lovers are 'seated at an agreeable distance', agreeable to Gwendolen because the forces at this distance are not too great.¹²⁸

Ceasing to be a sun and becoming a planet reduces Gwendolen's size in her own estimation. Her relationship with Daniel puts her in touch, for the first time, we are implicitly told, with her sexuality; and she 'had about as accurate a conception of marriage [...] as she had of magnetic currents.'¹²⁹ *Daniel Deronda* opens in the casino at Leubronn, the place where Gwendolen first becomes reluctantly aware of her sexuality. In the first sentence of the novel, we are told that when Daniel is watching Gwendolen, her glance has a 'dynamic quality', with 'those beams' producing 'the wish to look again felt as coercion', forcing Daniel to address the question: 'Was she beautiful or not beautiful?'¹³⁰ At this point, Gwendolen is still the attractor rather than the attracted. In the preface to his *Treatise*, Maxwell referred to the 'electromagnetic speculation [...] originated by Gauss', that electromagnetic forces were acting at a distance in a vacuum, speculation being 'entirely alien from the way of looking at things' Maxwell adopted.¹³¹ Lewes made use of Maxwell's *Treatise* in 'Appendix C' of his second volume of *Foundations of a Creed*, where he argued vociferously against the possibility of 'action

¹²⁶ Ibid, pp.195, 197.

¹²⁷ Ibid, p.253-4.

¹²⁸ Ibid, p.254.

¹²⁹ Ibid, p.252.

¹³⁰ Ibid, p.3.

¹³¹ James Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 2 vols. (Oxford: Clarendon, 1873), 1: pp.ix-x.

at a distance' with respect to gravitation or electromagnetism.¹³² Lewes cites three passages from Maxwell's *Treatise* in support of his thesis, and this is the third:

The observed action at a considerable distance is therefore explained [by me] by means of a great number of forces acting between bodies at very small distances, for which we are as little able to account as for the action at a distance however great [preferred by others]. Nevertheless, the consideration of the phenomena, as explained in this way, leads us to [...] form a theory which we should have overlooked if we had been satisfied with the explanation of action at a distance.¹³³

Lewes divides the scientists he mentions into two groups: those who, according to Lewes mistakenly, adopt the idea of electromagnetic action at a distance, including Gauss, Weber, Riemann and Neumann (these are all mentioned by Maxwell); and those who, like Faraday, Thomson, Tait and Clerk Maxwell 'correctly' assume a material medium by which the forces are transmitted.¹³⁴ For Lewes, as for John Tyndall, an ether was needed to transmit electromagnetic and gravitational forces. Eliot will have been familiar with Lewes's views, of course, but will surely have noted the difference of opinion between scientists on the existence of an ether; so her allusion to the casino providing a 'well-brewed [...] visible haze' for transmitting the electromagnetic energy between Gwendolen and Daniel could be read as a gentle satire.¹³⁵ Soon Gwendolen becomes uncomfortably conscious of the mutual attraction between her and Daniel, experiencing Daniel's 'evil eye' focused on her.¹³⁶ Daniel and Gwendolen are both increasingly aware of their own sexuality and of the forces acting between them.

Sunlight and starlight

When writing about astronomy in her last two novels Eliot uses the mathematics of light. She also plays with ideas of predictability: with how much certainty did current science describe the cosmological universe?

Gwendolen's meeting with Lydia Glasher and subsequently with Daniel mark the beginning of a transformation in which she increasingly experiences herself as a planet,

¹³² Lewes, 2: pp.481-7.

¹³³ Maxwell, p.123 (paragraph 104).

¹³⁴ Lewes, 2: p.485.

¹³⁵ *Daniel Deronda*, p.3.

¹³⁶ *Ibid*, p.6.

rather than as the centre of her own universe. Hitherto, Gwendolen's 'potent charm [...] may seem so full a reason for Gwendolen's domestic empire, that to look for any other would be to ask the reason of daylight when the sun is shining'.¹³⁷ The daylight of Gwendolen's empire persists even through the family's financial troubles; clouds are rarely thick enough to screen the sun's light completely. It is only when the night comes, following her marriage to Grandcourt, that Gwendolen has to learn to see by moonlight and starlight; in this she is assisted by Daniel, who, during the party at the Abbey, takes her to see 'the finest possible moonlight'.¹³⁸ This is literally what happens, but it also expresses metaphorically what subsequently occurs that evening when Daniel and Gwendolen discuss Gwendolen's beliefs.¹³⁹

Optics is a recurring theme in Eliot's novels. In chapter three I explained how Mrs Cadwallader's advice to James Chettam – 'Come, come, cheer up! you are well rid of Miss Brooke, a girl who would have been requiring you to see the stars by daylight.' – alludes to the same phenomenon that occurs in *Romola* when Baldassarre cannot be seen in the Russelai gardens, because the 'light can be a curtain as well as the darkness'.¹⁴⁰ We cannot see the stars during the day, because, while the stars continue to emit as much light as in the night, the sun's light is a 'curtain'. Richard Proctor's 1868 article in the *Cornhill* on solar eclipses provides a popular account of the evidence for this: 'In the total eclipse of 1706, which was observed in Montpelier, bright stars Aldebaran and Capella and planets Venus, Mercury and Saturn were visible to the naked eye.'¹⁴¹ Mrs Cadwallader's apparent message to James is that Dorothea would be a wife with unconventional behaviour and wild ideas, who would be impossible for a man like James to cope with. But part of the author's implied message is that Dorothea, like Eliot, may be interested in mathematical astronomy, and that through a study of astronomy it *is* possible to know where the stars and planets are during the day, and even how they would appear to an observer if the light from the sun did not blot them out. Anna Henchman points out that in *Confessions of an English Opium-Eater* (1821), a book owned by Eliot and Lewes, Thomas De Quincey also wrote about seeing stars by daylight, and like Eliot, used this as 'a metaphor for the mind': 'the stars seem to

¹³⁷ *Daniel Deronda*, p.32.

¹³⁸ *Ibid*, p.381.

¹³⁹ *Ibid*, p.382-3.

¹⁴⁰ *Middlemarch*, p.54; *Romola*, p.325.

¹⁴¹ [Richard Anthony Proctor], 'Great solar eclipses', *Cornhill Magazine*, 18 (August, 1868), 155-169 (p. 159).

withdraw before the common light of day, whereas, in fact, we all know that it is the light which is drawn over them as a veil; and that they are waiting to be revealed when the obscuring daylight shall have withdrawn.¹⁴² In astronomy, ‘apparent phenomena’ are repeatedly in conflict with ‘real phenomena’.¹⁴³

On the other hand, in a later 1846 essay De Quincey humorously questions the idea of ‘real phenomena’. Can we know what a planet or other heavenly body is doing when it is out of our sight? De Quincey describes the astronomer’s knowledge of heavenly bodies as ‘something like a Lloyd’s list’ of ships on the high seas:

Comets: due 3; arrived 1.

Mercury: when last seen, appeared to be distressed, but made no signals.

Pallas and Vesta: not heard of for some time, supposed to have foundered.¹⁴⁴

De Quincey is suggesting, as Henschman puts it, that astronomers ‘should not be so sure that the universe will continue to run like clockwork’.¹⁴⁵ In an epigraph in *Daniel Deronda* Eliot also asks what a planet - or a person - might be doing when out of sight:

Men, like planets, have both a visible and an invisible history. The astronomer threads the darkness with strict deduction, accounting so for every visible arc in the wanderer’s orbit; and the narrator of human actions, if he did his work with the same completeness, would have to thread the hidden pathways of feeling and thought which lead up to every moment of action [...]¹⁴⁶

Like De Quincey, Eliot uses sometimes invisible planets as a metaphor for challenging human certainty. Her language is less burlesque and her conclusions are less nihilistic, but she nevertheless implies that many of the pronouncements by social scientists have failed to take sufficient account of the hidden intricacies and complicated connections within human society. Eliot’s use of the planetary metaphor implies the value of the deductive mathematical capacity of the human mind for making sense – and, more particularly, for warning against premature conclusions. This epigraph is placed at the

¹⁴² William Baker, *The George Eliot - George Henry Lewes library* (New York and London: Garland, 1977), p.52; Thomas De Quincy, *Confessions of an Opium-Eater and Other Writings*, ed. Barry Milligan (London: Penguin, 2003), p.77; Henschman, p.66.

¹⁴³ Ibid.

¹⁴⁴ Ibid, p.59.

¹⁴⁵ Ibid, p.60.

¹⁴⁶ *Daniel Deronda*, p.139.

start of the chapter in which we share Daniel's hidden childhood, and in which we learn how he makes up for his lack of information about his parentage by incorrect guessing.

For Anna Henschman, one message of *Middlemarch* and particularly of *Daniel Deronda* is that, while having a scientific view of the universe is essential in the long run, Eliot advocates 'a scientifically inaccurate view of the universe as the best precursor to learning what the universe is actually like'.¹⁴⁷ Eliot explores how 'human beings build up a sense of the larger universe': the *Daniel Deronda* narrator suggests that 'a human life should be well-rooted in some spot of a native land' and that '[t]he best introduction to astronomy is to think of the stars as belonging to one's own homestead'.¹⁴⁸ Such a homely common-sense view can then be integrated with a grand scientific view and in this way we can keep our feet on the ground. Henschman points out that 'the Great Bear seen from the back windows' provides a domestic astronomical image for the Meyricks: it does appear to rotate, but it does not change its position in the sky, because it is at the astronomical North Pole.¹⁴⁹ Making the Great Bear the view through the Meyricks' window is a clever device, enabling a conception of a fixed earth to coexist with a conception of the earth as only a small speck in a constantly changing universe. In order to make sense of our human experience, we need to see ourselves as simultaneously great and small.

This chapter has explored some of Eliot's frequent reference to applied mathematics, particularly in her last two novels. Sometimes such reference consists of a straightforward comment about the appropriate and inappropriate way the mathematics is used: this is particularly true of statistics. Much of the time the mathematics is imagistic, providing a model to be exploited as an extended metaphor for some aspect of society. One reason Eliot uses the imagery of the mathematical sciences is to ground her ideas about human psychology and sociology in reasoned argument; mathematics and physics have replaced Christianity in providing a sure basis for her thought. Eliot is seeking to show that much of what happens to people in society is not to be attributed to

¹⁴⁷ Henschman, p.161.

¹⁴⁸ Henschman, pp.158, 160; *Daniel Deronda*, pp.15, 16.

¹⁴⁹ Henschman, pp.170-1.

luck or being special or different in some way; it is the ‘gradual action of ordinary causes’.¹⁵⁰

In *Daniel Deronda*, the great and the small are epithets that could also be applied respectively to the Victorian aristocratic culture, presented by Eliot as somewhat decadent, and the European Jewish culture. The relative positioning of these two cultures is one of the themes of my final chapter. The need to settle for an inaccurate view of the physical and the social universe was an important idea for Eliot; our theoretically exact mathematics teaches us that science is never exact. And some people in the 1870s were beginning to accept that even mathematics does not always produce unequivocal truths. This sets the stage for the final chapter, which will explore probability, the mathematical science of uncertainty, together with non-Euclidean geometry which, at the time Eliot wrote *Daniel Deronda*, was challenging the long-held belief that the geometry of the universe we live in can be known with exact certainty.

¹⁵⁰ GEL, 5: p.168.

Chapter Six

Conceiving the inconceivable: probability and geometry in *Daniel Deronda*

Gillian Beer describes Eliot's last novel, *Daniel Deronda* (1876) as a 'novel haunted by the future'.¹ The mathematics in the novel reflects this: chance and probability and non-Euclidean geometry are two themes in evidence in the novel.

Daniel Deronda opens in a casino, and this sets the scene for a novel concerned with certainties, probabilities and possibilities, with what must happen, what is likely to happen and what might happen. Gwendolen Harleth is gambling at a casino table and winning spectacularly, and consequently drawing attention to herself: 'She had begun to believe in her luck, others had begun to believe in it'.² In due course she becomes aware of being watched by Daniel, and when this happens, her luck changes and she begins to lose, apparently believing that this is the result of Daniel's 'evil eye'.³ This may not only refer to an irrational belief that the roll of the roulette ball can be influenced by the malevolence of an onlooker; the alert reader may also see an early intimation of Daniel's Jewish background, since it was believed by some that Jews were 'possessed of the evil eye, which they were fully capable of using for nefarious purposes'.⁴

In one of her *Daniel Deronda* notebooks, Eliot made notes on 'Gambling Superstitions', an article by Richard Proctor, known principally as a popularising astronomer. One thing she noted concerned the gambler 'Garcia with his run of luck followed by a crowd who copy his play', just as gamblers copy Gwendolen in the novel.⁵ Eliot noted just five items from Proctor's long article, and perhaps the most surprising of these describes an activity frequently called Count Buffon's needle:

¹ Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (London: Ark, 1985), p.181.

² *Daniel Deronda*, p.6.

³ Ibid.

⁴ Frank Feisenstein, *Anti-Semitic stereotypes: A Paradigm of Otherness in English Popular Culture, 1660-1830* (Baltimore and London: John Hopkins University Press, 1998), p.58.

⁵ Jane Irwin, ed., *George Eliot's Daniel Deronda Notebooks* (Cambridge: CUP, 1996), p.283.

If a rod be tossed over a grating of parallel bars, the number of times it will fall through will depend on the length & thickness of the rod, the distance between the bars, & the proportion in which the circumference of a circle exceeds the diameter.⁶

In an essay about *Daniel Deronda*, Jesse Rosenthal tells us that if the length of the rod is equal to the distance between the parallel bars of the grating, the probability that the rod crosses a bar is two divided by pi, the ratio of the circumference to the diameter of a circle. It also needs to be said that for this result to hold the thickness of the rod and of the bars needs to be negligible. Rosenthal remarks that this ‘mathematical oddity’, paraphrased by Eliot in her notebook, clearly ‘made an impression on Eliot’.⁷ One reason for this might be that Count Buffon’s needle links probability with geometry; and geometry is used to calculate the probabilities in this instance. What this chapter will demonstrate is that probability and geometry are both significant in *Daniel Deronda* and are linked mathematical themes.

Gambling superstitions and the law of large numbers

The roulette wheel is an example of situations where theoretical probabilities can be easily established. The European roulette wheel has thirty-seven pockets into which the ball can fall after the wheel has been spun. By law, there must be an equal probability that the ball will fall into any of the pockets, and so the probability that the ball will fall into the pocket marked ‘28’, for example, is one in thirty-seven. Of course, the fact that the pockets on a roulette wheel are not labelled in numerical order makes absolutely no difference to the randomness of the situation. Other situations involving equiprobable outcomes include the tossing of dice, the flipping of coins and the dealing of cards. When a die is tossed, because it has six faces, the probability of obtaining a five, say, is one in six. What exactly does this mean? This means that if the die is tossed a large number of times, fives will be obtained on approximately one sixth of the tosses. The two important ideas in this statement are ‘large number’ and ‘approximately’. The proportion of events in which a particular outcome occurs is called the relative frequency of that outcome. Mathematically the situation can be expressed thus: the relative frequency of a particular outcome tends towards a limit value as the number of

⁶ Ibid.

⁷ Jesse Rosenthal, ‘The Large Novel and the Law of Large Numbers; or, Why George Eliot Hates Gambling’, *ELH*, 77:3 (Fall, 2010), 777-811 (pp.810-1).

repeated events increases indefinitely; and this limit is the probability of the outcome occurring. This is known as the law of large numbers, first described by S. D. Poisson in the 1830s.⁸

Eliot effectively includes this law in her *Daniel Deronda* notebook: ‘True that results will right themselves but not over any given number of localized chances.’⁹ This formulation includes an important caveat for gamblers. While in the long run the proportion of fives thrown on a die will be approximately one in six, the fact that hitherto more fives than expected have been thrown tells us nothing about what will happen on the next throw. Even if the three previous throws have each resulted in a five, a five is neither more nor less likely on the next throw. Eliot opines that the ‘axioms of a professional gambler’ might be expected to ‘savour of a certain sort of wisdom’, but ‘are all utterly untrustworthy’. She cites the superstition that ‘the oftener the same number has occurred in succession, the nearer we are to the certainty that it will not recur in the next turn up’.¹⁰

Count Buffon’s needle, mentioned previously, is an example of a situation where, unusually, a theoretical probability can be calculated, but through a geometrical argument rather than by the occurrence of equiprobable outcomes, and this may partly explain Eliot’s interest. What is true of many or most real-life situations, however, is that there is no theoretical way of obtaining probabilities. The *Daniel Deronda* narrator tells us ironically that Nature, oblivious to patriarchal norms, ‘accommodates herself ill to our favourite practices by making “only children” daughters’, lamenting that nature cannot alter the chance of having a boy baby, even if that baby is to be an only child.¹¹ The chance will be one in two, approximately. Only approximately, because we cannot infer the chance that a baby being born is a boy simply on the grounds that there are two possibilities, any more than we can infer that the chance a particular team will win a football match is one in three, because there are three possible outcomes: win, lose and draw. Charles Darwin reported in *The Descent of Man*, that ‘the male births in England are as 104.5 [...] to 100 female births’.¹² Now, provided that the number of cases used to

⁸ Ian Hacking, *The Taming of Chance* (Cambridge: CUP, 1990), p.95.

⁹ Irwin, p.283.

¹⁰ Ibid.

¹¹ *Daniel Deronda*, p.202.

¹² Charles Darwin, *The Descent of Man* (London: Penguin, 2004), p.250.

produce this result is large enough, this ratio can be treated as a probability; it might be said that the probability of a child born in Britain in 1870 being a boy is 1045 out of 2045. This is turning the use of the law of large numbers on its head. Instead of stating that over a large number of trials the proportion of outcomes of a particular type approximates more closely to the theoretical probability, we derive the probability from the proportion, because there is no other way to derive it.

This process needs to be treated with caution, and there are two considerations. Is the number of trials large enough? And, more seriously, is the situation sufficiently well-defined to obtain a meaningful result at all? Darwin reported not only the proportions of babies who were boys in England, but in other countries too, and they were significantly different: for example, in Russia there were 108.9 male births to 100 female births. Biological laws are not obedient to national boundaries presumably; and so what is problematic about such probabilities is how the classes are drawn up, how the data are grouped together. Would the ratio of boys in the South of England be different from that in the North, or the ratio among middle-class families be different from that among poor families? Darwin's data might have been sufficient to answer these questions, had the questions been posed. Perhaps they were.

Ian Hacking describes how, in the 1830s, Adolphe Quetelet calculated averages, such as the mean height of a population, and then imbued these averages with enduring significance. Quetelet looked at data for crime rates and found the rates to be constant, up to a point: averages became a 'real feature' of a population, opening the way for national stereotypes, a way of obtaining apparently enduring probabilities, using relative frequency. Quetelet explained variability in the data during some years by ascribing them to perturbations in society, like perturbations caused to planets by other bodies passing close to them.¹³ This led Quetelet to a kind of emotionless 'statistical fatalism', which Eliot grimly satirises in 'Janet's Repentance':

The emotions, I have observed, are but slightly influenced by arithmetical considerations: the mother, when her sweet lisping little ones have all been taken from her one after another [...] finds small consolation in the fact that the tiny dimpled corpse is but one of a necessary average, and that a thousand other babies brought into the world at the same time are doing well [...] if you stood beside

¹³ Hacking, p.113.

the mother [...] it is probable you would be equally unable to see a ground of complacency in statistics.¹⁴

For Eliot, the probability of a baby dying is clearly a matter not of inexorable statistical law but, partly at least, the result of social policy that should be guided by human sympathy. The mathematician Eliot is questioning what she thought was the facile use of arithmetic – and statistics – to draw extravagant conclusions concerning social morality. The way the population is grouped will change the statistics. In the extreme case the population is not grouped at all: Eliot alludes to such Biblical arithmetic when she mentions ‘more joy in heaven over the one sinner that repenteth’.¹⁵ In the long quotation above Eliot implicitly uses probability in two contrasting ways: the probability of a baby dying is apparently firmly based on objective ‘arithmetic calculations’, whereas the probability that you would not be complacent about the death is merely a subjective opinion, albeit one likely to weigh more heavily on the reader. Poisson in the 1830s, distinguished between ‘probability’ and ‘chance’: probability is the subjective ‘reason we have for thinking that the event did or will take place’; chance denotes ‘an objective property of an event, the “facility” with which it can occur’.¹⁶ Chance is what might nowadays be described as mathematical probability, while Poisson’s ‘probability’ concerns the unquantified opinions we have about events. An epigraph in *Daniel Deronda*, commenting implicitly on Gwendolen’s self-image, tells us that the ‘most obstinate beliefs that mortals entertain about themselves are such as they have no evidence for beyond a constant, spontaneous pulsing of their self-satisfaction’.¹⁷ And the same goes for the most obstinate beliefs mortals entertain about others: in her essay ‘Silly Novels by Lady Novelists’ Eliot indicates her alarm that a lady novelist who ‘mistakes vagueness for depth, bombast for eloquence, and affectation for originality’, will open the way for ‘superficial’ men to say with regard to female intellect that the ‘average nature of women is too shallow and feeble a soil to bear much tillage’, or for Mr Stelling to tell Maggie Tulliver, when she asks him about Euclid, that girls ‘couldn’t go far into anything. They’re quick and shallow.’¹⁸

¹⁴ Ibid, p.114; *Scenes of Clerical Life*, p.270.

¹⁵ Ibid; Luke 15. 7.

¹⁶ Hacking, p.96.

¹⁷ *Daniel Deronda*, p.213.

¹⁸ [George Eliot], ‘Silly Novels by Lady Novelists’, *Westminster Review*, 66 (October, 1856), 442-461 (p. 455); *The Mill on the Floss*, p.150.

Optimistic futures in *Middlemarch*

Eliot's interest in probabilistic thinking is infused in her novels, particularly *Middlemarch* and *Daniel Deronda*. In everyday language, the law of large numbers says that previous experience is useful, and the more previous experience you have the more useful it will be. An obvious group of people for whom probability is of significance is the gamblers. The narrator of *Daniel Deronda* describes the common belief that we never get what we wish for. But '[t]his desponding view of probability the hopeful entirely reject, taking their wishes as good and sufficient security for all kinds of fulfilment'.¹⁹ While this is written with reference to Daniel, it is more evidently applicable in *Middlemarch* than in *Daniel Deronda*. The 'irrepressible hopefulness' with which Fred Vincy practises the flute, is echoed in his 'hopeful disposition' telling him that that when he 'got into debt, it always seemed to him highly probable that something or other – he did not necessarily conceive what – would come to pass enabling him to pay'.²⁰ In this case, his hopes are dashed when the monetary present Peter Featherstone is about to give him turns out to be too small to meet his present needs. Fred's optimism never prompts him to learn from previous experience; instead, he buys and sells horses with the fond belief that he will make money, even though previous experience should tell him otherwise.

Fred borrows money from Caleb Garth to fund his dealing in horses and his 'losses at billiards'.²¹ Caleb might appear to be a gambler too in his own way. He has 'failed in the building business'; and he lends money to Fred, because Fred is an 'open affectionate fellow', even though, judging by previous experience, Fred is unlikely to repay what he borrows.²² Later, even though Caleb is too busy, he accedes to Mr Bulstrode's request that he undertakes to put Stone Court in order, apparently gambling on the fact that, with Bulstrode's acquiescence, Stone Court may one day be Fred's and Mary's. In thinking about Mary's 'probable happiness', as in other actions he takes, he does not evaluate the odds, not because he is absurdly optimistic like Fred, but because doing good work and bringing happiness to others is more important than having

¹⁹ *Daniel Deronda*, p.322.

²⁰ *Middlemarch*, pp.96, 125.

²¹ *Ibid*, p.215.

²² *Ibid*, pp.217, 218.

money.²³ In one sense, he shares Fred's 'hopeful disposition'; he is a gambler, not with irrational expectations of winning, but with the belief that if he works hard things will come right in the end. His wife Susan, who sometimes despairs of his indifference to ever having enough money for his family's needs, sums up Caleb neatly, when commenting on his dreams about Stone Court: "'But suppose the whole scheme should turn out to be a castle in the air?'" said Mrs Garth. "Well, well," replied Caleb, "the castle will tumble about nobody's head".²⁴ Susan might reluctantly agree that in this case Caleb is right.

Like her mother, Caleb's daughter Mary is certainly no gambler: she 'was accustomed to think rather rigorously of what was probable, and if a belief flattered her vanity she felt warned to dismiss it as ridiculous'; so she habitually underestimates the odds of her winning anything she wants.²⁵ She loves Fred, but is unprepared even to entertain him as a suitor, until he sorts out how he is going to earn his living: 'I think it would be wicked in me to marry you even if I did love you.'²⁶ Camden Farebrother, Mary's other suitor, is apparently a gambler: he plays cards in order to make ends meet for his family. But his gambling is of a very different kind; his play is 'masterly' and while he plays, his face is 'a striking mixture of the shrewd and the mild'.²⁷ Whether this behaviour in a vicar is or is not morally reprehensible, it is certainly rational and informed by previous experience: he has mainly won in the past and so he will mainly win in the future. If the 'axioms of a professional gambler' do not usually 'savour of a certain sort of wisdom', Farebrother, if he is to be called a professional gambler, is clearly an exception.²⁸

Lydgate is not in the habit of gaming, but on one occasion Fred finds him in the Green Dragon playing billiards for money, as a consequence of his desperation over the family finances. Fred eventually goes up to him and, while he cannot bring himself to say to him: 'You are losing confoundedly, and are making everybody stare at you; you had better come away', he uses a pretext to shake Lydgate from his behaviour.²⁹ While

²³ Ibid, p.651.

²⁴ Ibid.

²⁵ Ibid, p.543.

²⁶ Ibid, p.130.

²⁷ Ibid, p.153.

²⁸ Irwin, p.283.

²⁹ *Middlemarch*, p.633.

Lydgate only rarely indulges in gaming for money, he is a gambler with regard to his hasty marriage to Rosamond, in spite of warnings that neither of them will have much money. His work as a scientist involves ‘combining and constructing with the clearest eye for probabilities’, but he is unable to evaluate probabilities in other situations.³⁰ He fails to learn from experience concerning his disastrous relationship with the French woman Laure, and irrationally believes that now he has ‘more reason than ever for trusting his judgement’, and ‘that madness which had once beset him about Laure was not, he thought, likely to recur in relation to any other woman’; so he marries Rosamond while knowing little about her.³¹ The narrator suggests that, at the beginning of Lydgate’s life in Middlemarch, his career would be ‘a fine subject for betting’, provided that anyone ‘could appreciate the complicated probabilities of an arduous purpose, with all the possible thwartings and furtherings of circumstance, all the niceties of inward balance, by which a man swims and makes his point or else is carried headlong’.³² Eliot uses the language of probability to describe how Lydgate’s optimistic carelessness leads to financial and marital disaster. Lydgate’s previous experience is not of course restricted to Laure: ‘He cared not only for “cases” but for John and Elizabeth, especially Elizabeth’.³³ Talk of cases suggests Quetelet’s normative statistics, which Lydgate dismisses, but the criteria he uses instead are neither rational nor sympathetic. He meets Dorothea and is dismissive of her attractions, because she does not ‘look at things from the proper feminine angle’. The narrator remarks: ‘Destiny stands by sarcastic with our *dramatis personae* folded in her hand.’³⁴ Destiny can be interpreted as the belief that previous experience predicts future events, but only probably. With her paper folded unseen in her hand destiny might here be interpreted as the Law of Large Numbers.

Controlling the future in *Daniel Deronda*

Gillian Beer points to the opening epigraph in *Daniel Deronda* and suggests that the novel is preoccupied with dread, and in particular dread of what is to come: ‘Let thy

³⁰ Ibid, p.154.

³¹ Ibid, pp.144, 153.

³² Ibid, p.140.

³³ Ibid, p.136

³⁴ Ibid, p.88.

chief terror be of thine own soul: There [...] Lurks vengeance'.³⁵ As a consequence of this dread, characters try to control the future, either through predicting the future, or by trying to control other people, or both. Beer suggests that the reader is caught up with this, trying to predict the plot, and this helps make probability a key idea in the novel.³⁶

Gamblers are concerned with predicting the immediate future. When, in the casino, Gwendolen becomes aware that Daniel is watching her, she irrationally interprets his interest as an 'evil eye' that will change her luck, which has already appeared to change. She wants to retain control over her immediate future and not cede it to Daniel and so 'her enraged resistance [...] includes luck among its objects of defiance'.³⁷ In other words, she no longer wants to depend any further on luck and so decides to 'lose strikingly'.³⁸ The immediate future that she is *not* in control of, and does *not* predict, is her receipt of a letter from her mother telling her that her family has lost all its money as a result of shares suddenly losing all their value, something which might be viewed as gambling on a large scale. 'I cannot conceive that all your property is gone at once, mamma', she protests, an ironic echo on a larger scale of what Gwendolen brought about in the casino.³⁹ Although this conversation happens a short while after her loss of napoleons in the casino, the events are separated by twenty chapters in the novel, suggesting Gwendolen's inability to connect her own behaviour to that of other people.

Mirah Lapidoth's father gambles addictively; he appears to have taken up gambling as a substitute for controlling his family, after his son Ezra (Mordecai) has departed and Mirah has run away in order to escape being married off to a wealthy husband. When he meets up with Mirah in London he still tries to control her through his use of childish dependency. Mr Gascoigne is also someone who likes to be in control of his family. After attempting to discover Grandcourt's suitability as a husband for Gwendolen by checking up on his past, Mr Gascoigne bets on Grandcourt not being a betting man, who will squander all his fortune: 'Whatever Grandcourt had done, he had not ruined himself'.⁴⁰ While he may bet correctly about this, Mr Gascoigne bets wrongly overall, because he is the unworldly worldly clergyman who is able to envisage and dismiss

³⁵ *Daniel Deronda*, facing p.1; Beer, p.216.

³⁶ Ibid.

³⁷ *Daniel Deronda*, p.6.

³⁸ Ibid.

³⁹ Ibid, p.198.

⁴⁰ Ibid, p.77.

every possible self-indulgent past for Grandcourt that did not happen, but not that Grandcourt has a mistress and children, who will inherit his fortune.

Gwendolen, while not a habitual gamer, has a gambling mentality when working out what she will do with her life, apparently prepared sometimes to leave what happens to her to fate, to what is effectively the toss of a coin. Would she decide to marry Grandcourt or not: 'that result was one of two likelihoods that presented themselves alternately'.⁴¹ Its inability to be 'predicted' causes her 'astonishment and terror'.⁴² She is even more astonished when other people do not endorse what she wants. The narrator uses a similar metaphor, this time involving a balance rather than the toss of a coin, when Gwendolen is seeking advice from Klesmer about whether or not she might have a career as a singer: 'Gwendolen felt that she was being weighed. The delay was unpleasant. But she did not yet conceive that the scale could dip on the wrong side.'⁴³ In both cases there is dread about not knowing how to control the future.

Gwendolen talks about probabilities in a conversation with Rex concerning whether she intends to go hunting. Rex's sister Anna has told Rex that Gwendolen will intend to hunt and Gwendolen describes Anna as a 'little clairvoyante', before telling Rex: 'Clairvoyantes are often wrong: they foresee what is likely. I am not fond of what is likely; it is always dull. I do what is unlikely.'⁴⁴ Rex points out the logical flaw in what Gwendolen has said: 'When once I knew what people in general would be likely to do, I should know you would do the opposite.' So Gwendolen says she would sometimes 'do what was likely for people in general', whereupon Rex tells her intriguingly that being perverse makes anyone predictable: 'You see you can't escape some kind of likelihood. And contradictoriness makes the strongest likelihood of all.' This points to how hard it is for people deliberately to act randomly and unpredictably. Gwendolen's dread of the future is making her want to maintain a greater control over knowing what is going to happen to her than other people have: people do what is normal, but she does 'as she likes'.⁴⁵

⁴¹ Ibid, p.114.

⁴² Ibid.

⁴³ Ibid, p.216.

⁴⁴ Ibid, p.56.

⁴⁵ Ibid, pp.56, 57.

Gwendolen is a keen observer of others, but a fallible observer of herself. She insightfully predicts the love between Catherine Arrowpoint and Julius Klesmer: she tells her mother that Grandcourt ‘will find Miss Arrowpoint just married to a needy musician, Mrs Arrowpoint tearing her cap off, and Mr Arrowpoint standing by’. ‘Was ever any young witch like this?’ the narrator asks.⁴⁶ On the other hand, ‘Gwendolen conceived that after marriage she would most probably be able to manage [Grandcourt] thoroughly. How was it that he caused her unusual constraint now?’⁴⁷ She fails to interpret her experience correctly, and so her prediction proves disastrously wrong. Grandcourt’s prediction that he can control Gwendolen ultimately proves fatally wrong. Gwendolen’s eventual salvation is to face her dread and stop predicting safe things for herself, despite the degree of pain this causes. At the end of the novel she tells Daniel in a letter: ‘It is better – it shall be better with me because I have known you.’⁴⁸ Attempted prediction of her own future has been replaced by an act of faith.

Aristotle’s probable plots

The epigraph for chapter forty-one of *Daniel Deronda* is a quotation from the part of Aristotle’s *Poetics* that deals with poetic plots: ‘This, too, is probable, according to that saying of Agathon: “It is a part of probability that many improbable things will happen.”’⁴⁹



‘many improbable things will happen’

This is a familiar paradox in probability theory: when one of the whist players in *Middlemarch* is dealt a hand, the odds against his being dealt that particular hand are

⁴⁶ Ibid, p.79.

⁴⁷ Ibid, p.115.

⁴⁸ Ibid, p.695.

⁴⁹ Ibid, p.434.

more than six hundred billion to one, and yet this particular hand has just been dealt! This epigraph introduces a chapter in which Daniel is evaluating probabilities concerning Mordecai: is he a crank or is he worth listening to?

In his *Poetics*, which Eliot reread in June 1865 ‘with fresh admiration’, Aristotle is writing about the plots of tragedies.⁵⁰ Fleishman suggests that ‘George Eliot, it is not too much to claim, was the first tragic novelist’, and that the ‘tragic sense of life’ applies particularly to the ‘female protagonists’.⁵¹ Aristotle declares the poet’s function to be ‘to describe, not what *has* happened, but the kind of thing that might happen, i.e. what is possible as being probable or necessary’.⁵² This suggests that plotting has to do with probability: does what is depicted have the ring of likelihood for the reader? For Aristotle this comes into sharpest focus where the plot involves a discovery, and Aristotle enumerates six species of discovery. I shall describe some of these species as I consider how discoveries in the plots in Eliot’s novels relate to them; all but one of my discoveries relate to female protagonists and draw attention to the tragedy in Eliot’s novels.

The most dramatic discovery in *Adam Bede* occurs when Adam sees Hetty and Arthur kissing each other goodbye. Adam’s day prior to this discovery is spelt out in great detail by the narrator, as I described in chapter one, and it is only because certain chance things have happened that Adam makes his discovery in the Grove, ‘where he had never been for years’.⁵³ And yet there is no fatalistic suggestion by the narrator that the discovery was ‘meant’ to happen. Arthur and Hetty were not particularly discreet about their relationship, and so it is probable that they would be discovered sooner or later. And dramatically, it is ‘necessary’, to use Aristotle’s term, that the discovery is made by Adam and not anyone else. Happenings always seem improbable after the event. The roulette wheel has got to land on one number; once it has landed on twenty-five, for example, we may marvel that it did, since the probability of its doing so was so

⁵⁰ GEL 4:195.

⁵¹ Avrom Fleishman, *George Eliot’s Intellectual Life* (Cambridge: CUP, 2010), p.9.

⁵² John Warrington, trans., *Aristotle’s Poetics, Demetrius on Style, Longinus on the Sublime* (London: Everyman, 1963), p.17; Humphrey House, *Aristotle’s Poetics: A Course of Eight Lectures* (London: Hart-Davis, 1956), p.59.

⁵³ *Adam Bede*, pp.294-5.

small. Aristotle calls this species of discovery the ‘best of all discoveries [...] when the great surprise occurs as the result of a probable incident’.⁵⁴

In *The Mill on the Floss*, Mr Tulliver discovers not suddenly but gradually, that Maggie has a more powerful intellect than Tom, to his surprise and also to that of the Victorian reader possibly, but afterwards he reasons that it was likely to happen: ‘when a man’s got brains himself, there’s no knowing where they’ll run to’.⁵⁵ This was discussed more fully in chapter two. In *Romola* the eponymous heroine uses logic, as described in chapter three, to discover that Tito has stolen from someone who is not yet dead, thus making her rift from her husband irreparable. Both these are examples of discovery by ‘deductive reasoning’, the ‘next best’ species, according to Aristotle.⁵⁶

In *Middlemarch*, the most tragic discovery does not involve a ‘female protagonist’, but a male banker. Raffles discovers his old business colleague Nicholas Bulstrode, through adventitiously picking up one of Bulstrode’s letters, which he uses initially to wedge his flask firmly in its case. The narrator is at pains to point out the likelihood of such events occurring sooner or later:

As the stone which has been kicked by generations of clowns may come by curious little links of effect under the eyes of a scholar, through whose labours it may at last fix the date of invasions and unlock religions, so a bit of ink and paper which has long been an innocent wrapping or stop-gap may at last be laid open under the one pair of eyes which have knowledge enough to turn it into the opening of a catastrophe. To Uriel [...] the one result would be just as much of a coincidence as the other.⁵⁷

While the probability of a particular loose stone being the means of a significant discovery is small, if a discovery is made using such a stone then, retrospectively, that unremarked and roughly treated stone will have been found to be remarkable. In the same way, Bulstrode’s discarded letter – ‘a bit of ink and paper’ – can be the means of a significant discovery by Raffles, even though many other discarded pieces of paper by many other people would not have had any such significance. Uriel takes the role of probability theory: the one set of events can be treated by the same mathematics as the

⁵⁴ Warrington, p.30.

⁵⁵ *The Mill on the Floss*, pp.19-20.

⁵⁶ Warrington, pp.29, 30.

⁵⁷ *Middlemarch*, p.386.

other. This recalls Agathon's saying: 'It is a part of probability that many improbable things will happen.'⁵⁸ Retrospectively, the discovery becomes one of Aristotle's species of 'probable incidents', even though it is bad luck for Mr Bulstrode. It is also an example of Aristotle's species of 'discovery through memory, from a man's consciousness being reawakened'.⁵⁹ Raffles no longer needs to importune his step-son Joshua Rigg for money, when his memory of what he and Bulstrode did in the past provides an apparently much more fruitful source of support.

When choosing a tragic discovery in *Daniel Deronda* I am steered by the narrator towards selecting the Arrowpoints' discovery that their daughter Catherine is intending to marry, not a man with rank in society – they have already suggested several such men and could continue to suggest others – but a Jewish musician of no wealth or status. We are steered towards this discovery, because in connection with it the narrator provides a detailed exposition of Aristotle, whose 'best' species of discovery is 'that which arises from the incidents themselves, when the great surprise occurs as the result of a probable incident'.⁶⁰ The *Daniel Deronda* narrator tells us:

As to the possibility of [Catherine's] being in love with Klesmer [her parents] were not at all uneasy – a very common sort of blindness. For in general mortals have a great power of being astonished at the presence of an effect towards which they have done everything, and at the absence of an effect towards which they have done nothing but desire it [...] The truth is something different from the habitual lazy combinations begotten by our wishes. The Arrowpoints' hour of astonishment was come.⁶¹

Here is Eliot's mathematical mind at work in constructing her arguments. Previous experience of human behaviour tells us one thing; societal myth-making another. The probability that Catherine would prefer a lord with status is apparently inestimably greater than the probability of her responding to mutual sexual attraction, mutual admiration and mutual respect between a dedicated music teacher and a willing and talented pupil.

⁵⁸ *Daniel Deronda*, p.434.

⁵⁹ Warrington, p.29.

⁶⁰ Warrington, p.30.

⁶¹ *Daniel Deronda*, pp.202-3.

Daniel, Mordecai and non-Euclidean geometry

So far the focus of this chapter has been on probability. This section moves from probability towards the other mathematical theme, non-Euclidean geometry, which is, in an obvious sense, related to probability. Mid-Victorian mathematicians and philosophers debated whether it was possible that the universe was non-Euclidean, and whether it was probable. Non-Euclidean geometry might herald a revolution in thinking about what was known for certain, or it might be a flight of fancy espoused by cranks and fanatics.

The most significant of Daniel's discoveries are of Mirah and of Mordecai. It is purely by chance that Daniel is at hand to prevent Mirah from drowning herself. The probability of Daniel being there just at the right moment is very small; for Aristotle 'a convincing impossibility is always preferable to an unconvincing possibility'.⁶² This particular impossibility becomes convincing as a result of the dramatic and didactic use made of it within the novel. Discovering Mordecai is somewhat different, because Daniel is deliberately looking for him, and looking in a Jewish quarter of London where he might expect to find him. Paradoxically, Mordecai claims more foresight concerning the discovery than Daniel, even though he does not know whom he is looking for. When they meet on Blackfriars Bridge, in spite of his not knowing how Daniel will be travelling, he tells Daniel 'I expected you to come down the river. I have been waiting for you these five years.'⁶³ Daniel is more prosaic about the way they have met. The chance event was discovering Mirah; after that, 'the way seems made up of plainly discernible links'.⁶⁴ Discovering Mirah led on to becoming interested in the Jews and then to discovering Mordecai.

Having encountered Mordecai, an excited visionary, Daniel has to decide whether to believe in him, to decide whether he is a crank or whether he has a view of the world that is worth taking seriously. *Daniel Deronda* was written in the middle of the 1870s, a decade in which debate raged about the foundations of mathematics. These foundations were being shaken by mathematical research casting doubt on the certainty of

⁶² Warrington, p.52.

⁶³ *Daniel Deronda*, p.423.

⁶⁴ *Ibid*, p.439.

geometrical assumptions about the space we live in. In chapter two, I described how geometry can be developed deductively from Euclid's postulates, and also how mathematicians in Eastern Europe early in the nineteenth century had demonstrated that Euclid's postulates may not be self-evidently true. By 1870 this thinking had spread to Britain and had begun to create waves. Melanie Bayley sees a parallel between Mordecai's radical ideas and those associated with non-Euclidean geometry: 'Eliot's most overtly philosophical novel [...] derives important intellectual support for Mordecai's visionary politics from movements in mathematics away from determinism and experiential certainty'.⁶⁵ Non-Euclidean geometry and its contribution to *Daniel Deronda* will provide the focus for the remainder of this chapter. Was it possible that the revolutionary ideas about geometry arriving in Britain within the ten years before *Daniel Deronda* was published, could mean that the geometrical space we live in is non-Euclidean? In 1870 many philosophers and mathematicians believed it was not possible. I shall examine the context in which Eliot was writing *Daniel Deronda* and the ways in which she responded to the non-Euclidean issue in her novel.

Before beginning a detailed discussion of the views of non-Euclidean geometry taken by different mathematicians and philosophers, I shall mention some evidence for positing a parallelism between non-Euclidean geometry and Mordecai's vision. There is one specific mention of Euclid in the novel and it occurs when Daniel discovers the bookshop in which Mordecai is working. Before entering the bookshop Daniel looks at the books on display outside, and muses about the lack of enthusiasm a seller of second-hand books typically shows about the books he is selling: 'even a Jew will not urge Simson's Euclid on you with an affectionate assurance that you will have pleasure in reading it'.⁶⁶ Alice Jenkins suggests that this allusion to 'Simson's Euclid', which was 'perhaps the best-selling [...] geometry textbook of the nineteenth century', is Eliot's comment on the continuing centrality of Euclid's *Elements* as a text book for teaching geometry in English schools and universities.⁶⁷ By inference, it is also a comment on conservative beliefs about the nature of cosmological space, as well as about the nature of the Jews. Bayley suggests that from 'the moment we first meet' Mordecai, he is 'set

⁶⁵ Melanie Bayley, 'Mathematics and Literature in Victorian England' (unpublished doctoral thesis, University of Oxford, 2010), p.213.

⁶⁶ *Daniel Deronda*, p.325.

⁶⁷ Alice Jenkins, 'Geometry', *Journal of Victorian Culture* 12:2 (2007), 267-272 (especially p.268).

against references to mathematics, or more precisely to geometry': symbolically, Mordecai, with his unbelievable visions, is juxtaposed with non-Euclidean geometry, which also involves apparently unbelievable visions.⁶⁸ It is in chapter forty-one that the narrator describes Daniel's debate about whether he can take Mordecai seriously, and the narrator does this by using direct references to both probability and geometry, as we shall see. An implicit question is whether non-Euclidean geometry can be taken seriously.

Some Victorians, whose thinking was familiar to George Eliot, were responding to this and related issues. In particular, I shall consider the views of Herbert Spencer and George Lewes, who worked at establishing criteria whereby truths could be ascertained; and William Kingdon Clifford who was more interested in ensuring that so-called truths came under scrutiny and could be doubted. I shall also consider the stance of Eliot herself, as reflected in her letters and in her novel.

Herbert Spencer's inconceivables

In *Daniel Deronda* Eliot makes fun of the belief that perfectly plausible alternative ways of seeing the world are inconceivable. In 1870 most mathematicians in Britain continued to believe that Euclid's postulates provide the indisputably true description of space and that any other explanation was inconceivable. William Whewell's *a priori* certainty about this was described in chapter two; for Whewell our intuition told us that the space we live in must be Euclidean. The philosopher Herbert Spencer did not believe in *a priori* truths but had other arguments for establishing certainty. In his 1853 article about his 'Universal Postulate' Spencer argued that something was certain if its negation was inconceivable. This produced 'necessary truths', which were not *a priori* truths, Spencer insisted. Spencer tacitly implied that his Universal Postulate could produce mathematical truth. He acknowledged that what had been inconceivable to people in the past might now be conceivable, but insisted that our best hope of knowing truth is to use, presumably provisionally, our present understanding of what is inconceivable.⁶⁹ As time went by Spencer appears to have fudged this provisionality

⁶⁸ Bayley, p.234.

⁶⁹ [Herbert Spencer], 'The Universal Postulate', *Westminster Review*, 60 (October 1853), 513-50 (pp.521-2).

reservation, and he sought to establish irrefutable truths. The problem with applying his criterion is to find agreement on what is or is not conceivable. In 1873 and 1874, a critical interchange between Spencer and a mathematician and physicist called John Moulton indicates some of the ways in which Spencer's thinking about *a priori* truths had changed. In an article in the *British Quarterly Review*, Moulton reviewed three of Spencer's works: the second edition of *First Principles*; *Principles of Biology*; and *The Principles of Psychology*. Moulton appeared to express admiration for the breadth of Spencer's acquaintance with science and philosophy.⁷⁰ However, Moulton was particularly critical of what he saw as Spencer's tendency to claim that alternatives to 'his most cherished ideas' are 'inconceivable':

And if philosophers like Mr. Spencer derive pleasurable sensations from pronouncing with a kind of papal infallibility what propositions are conceivable and what are not, then let them do so [...] So soon as we have experimental grounds for accepting a proposition, we shall accept it; and [...] we shall manage to conceive it as well as we can conceive anything else.⁷¹

In his reply to Moulton in the *Fortnightly Review*, Spencer claimed that Newton's laws of motion provide evidence that Newton believed *a priori* truths exist, since Newton's laws could not be established by experiment.⁷² Calling some laws of physics *a priori* truths would seem to put Spencer in much the same position as Whewell, even though Spencer would claim to have arrived at his position in a completely different way. In his subsequent response to Spencer's *Fortnightly Review* article, Moulton pointed out the 'fallacies' in Spencer's arguments concerning Newton's laws and insisted that the key difference between himself and Spencer was that what Spencer calls an *a priori* physical truth, based on its negation being inconceivable, he calls a 'scientific hypothesis', which may or may not be true, but which explains the currently observed facts.⁷³

Eliot, a long-time friend of Spencer with an interest in Spencer's ideas, described Spencer's 'Universal Postulate' article as 'first-rate' when he first presented it in

⁷⁰ John Fletcher Moulton, 'Herbert Spencer', *British Quarterly Review*, 58 (October, 1873), 472-504 (p.472).

⁷¹ Ibid, pp.474, 475.

⁷² Herbert Spencer, 'Replies to Criticisms', *Fortnightly Review*, 14 n.s. (December, 1873), 715-739 (pp.738-9).

⁷³ John Fletcher Moulton, 'Note to the article on Herbert Spencer', *British Quarterly Review*, 59 (January, 1874), 215-218 (p.216).

1853.⁷⁴ However, she also frequently disagreed with Spencer and did not share what she saw as his tidy preconceptions about the universe. In a much quoted letter, written in 1852, she told Sara Hennell: ‘I went to Kew yesterday on a scientific expedition with Herbert Spencer, who has all sorts of theories about plants - I should have said a *proof*-hunting expedition. Of course, if the flowers didn’t correspond to the theories, we said “*tant pis pour les fleurs*”.’⁷⁵ She made essentially the same point in a much later letter to Hennell in 1877, describing how Spencer’s ‘mind both “spontanément and systématiquement” rejects everything that cannot be wrought into the web of his own production.’⁷⁶ Eliot did not accept Spencer’s ‘inconceivables’ concerning women’s intellects, women’s education and women’s role in society. In his *Principles of Biology*, published in 1864, Spencer attributes the reproductive sterility of some ‘girls’ to ‘the overtaxing of their brains’; and proposed that ‘[m]ost of the flat-chested girls who survive their high-pressure education, are incompetent’ to breast-feed their infants.⁷⁷ Spencer is suggesting that women should not be over-educated and that their main role in society is the propagation of the race.

Spencer’s anti-feminist views were attacked in a letter by Hennell, published in the *Examiner* in 1874, commenting on Spencer’s *Study of Sociology*. Hennell’s focus was to insist that women should be identified as women when they speak and write, and not have men speaking for them.⁷⁸ Eliot found Hennell’s attack surprisingly mild: she told Hennell that Hennell’s published letter ‘hardly makes apparent the severe objections you mentioned to me. But I am not sorry there should be a little boiling of peas shot at poor Mr. Spencer just now, for he is running the gauntlet in rather a fatiguing way between Cambridge men who are criticising his physics and psychology.’⁷⁹ John Moulton was the Cambridge man criticising Spencer’s physics, and ‘carrying on a venomous as well as harassing attack in the *British Quarterly*’.⁸⁰ This suggests that Eliot disapproved of the hostile tone of Moulton’s attack; however, the word ‘venomous’ suggests that she believed the attack was potent and is likely to have agreed with its substance. Eliot does not ‘boil the peas’ in *Daniel Deronda*, when describing Catherine

⁷⁴ GEL, 2: p.118.

⁷⁵ Ibid, p.40.

⁷⁶ GEL, 6: p.426.

⁷⁷ Herbert Spencer, *Principles of Biology*, 2 vols. (New York: Appleton, 1886), 2: p.486.

⁷⁸ Sara Hennell, ‘Mr Spencer and the Women’, *Examiner* (7 February, 1874), p.135.

⁷⁹ GEL, 6: p.15.

⁸⁰ Ibid.

Arrowpoint's mother's outrage when Catherine and her Jewish piano teacher Julius Klesmer declare their love for one another. Critics appear not to have noticed that the narrator's description echoes Moulton's satire on Spencer: 'Where marriage is inconceivable, a girl's sentiments are safe [...] Catherine's limit of the conceivable did not exactly correspond with her mother's'.⁸¹ And Eliot may have been satirising Spencer's claims about Newton's laws when she included among the fanatics in chapter forty-one a man 'convinced that he had the mathematical key to the universe which would supersede Newton'.⁸²

Clifford's agnosticism about geometry

William Kingdon's Clifford's views on the philosophy of science and on non-Euclidean geometry, in particular, influenced Lewes and Eliot and this section clarifies what exactly he thought about the geometry of space.

Spencer's ideas were widely influential on positivist thinkers, and his 'evolution-hypothesis' impressed William Kingdon Clifford, a mathematician and populariser of science, who shared Spencer's earlier belief 'that the whole of our knowledge comes from experience; [...] not the experience of you and me, but of all our ancestors'.⁸³ This being so, new experience will change what we know. More than Spencer, Clifford always leant towards opening up doubt, rather than closing it down. It is permission to doubt that Clifford expressed in a lecture, using this striking aphorism: 'it is not right to be proper'.⁸⁴ As a philosopher of science, Clifford did not believe in either Whewell's intuitive truths or the later Spencer's *a priori* truths. He stated his position about all laws of science emphatically: 'a law would be theoretically universal if it were true of all cases whatever; and this is what we do not know of any law at all'.⁸⁵ This statement was linked to a discussion of our ignorance about whether space is Euclidean; *a fortiori* it would apply to laws describing empirical results, such as Newton's laws of motion. For Clifford, there were, in other words, no universal truths.

⁸¹ *Daniel Deronda*, p.203.

⁸² *Ibid.*, p.435.

⁸³ William Kingdon Clifford, *Lectures and essays*, ed. by Leslie Stephen and Frederick Pollock, 2 vols. (London: Macmillan, 1901), 1, pp.89, 118, 332. All subsequent references to Clifford, which do not cite a source, refer to this source (volume 1).

⁸⁴ *Ibid.*, p.117.

⁸⁵ *Ibid.*, p.157.

Clifford popularised non-Euclidean geometry through his lectures. In his 1872 lecture on ‘The Aims and Instruments of Scientific Thought’ his central theme was questioning ‘the uniformity of nature’, and he incorporated non-Euclidean geometry into his argument.⁸⁶ While Clifford, of course, had no more evidence that the universe was non-Euclidean than anyone else, he pointed out in his lecture that it was impossible to prove the universe exactly Euclidean. In 1870 many English mathematicians were unprepared to speculate about geometrical uncertainties in this way: when J. J. Sylvester alluded to such speculation in his 1869 British Association lecture, several English geometers protested that anything other than Euclidean geometry was ‘inconceivable’.⁸⁷ By contrast, Clifford made *his* position clear when he said: ‘But, then, we cannot be sure that the facts will not make us learn to conceive them; in which case they will cease to be inconceivable.’⁸⁸

To make matters clear, I shall describe exactly what mathematicians like Clifford were saying about geometry, and I shall refer to Clifford’s 1872 ‘Aims and Instruments of Scientific Thought’ lecture, of which the Leweses had an off-print, presumably given to them by Clifford in 1873 or 1874, since by then he was a frequent visitor. This off-print is now in Dr Williams’s Library, London. George Lewes annotated it liberally. Almost certainly, Eliot will also have read it and discussed it with Lewes, and quite possibly with Clifford too.

Euclid’s postulates describe a theoretical geometrical space. It had been assumed that there were no logically possible alternatives to Euclid’s postulates for describing geometrical space (despite the doubts about the parallels axiom described in chapter two) and therefore that his postulates must describe the space we live in. William Whewell wrote that our thinking about lines ‘resides in *the idea of space* [...] we cannot contemplate [objects] geometrically, without conceiving them in space which is subjected to geometrical conditions’: these geometrical conditions were Euclid’s

⁸⁶ Ibid, pp.149, 154-5.

⁸⁷ J. J. Sylvester, ‘A Plea for the Mathematician’, *Nature*, 1 (1869), 237-9 (p.238); Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (San Diego and London: Academic Press, 1988), pp. 56-7, et al.

⁸⁸ Clifford, p.178.

postulates.⁸⁹ Thus geometry gave us irrefutable truths about space. Reasoning from the postulates we could be certain that space was infinite, and that the sum of the angles of a triangle was two right angles, and many other things beside. But Clifford was aware of the work done early in the nineteenth century by Lobachevski and Gauss and others, and also of Riemann's later authoritative work on the non-Euclidean geometries, which Clifford translated into English in 1873.⁹⁰ What these mathematicians did was produce alternative postulates for a theoretical geometrical space, postulates which they proved were logically consistent. They did this by postulating alternatives to the parallels axiom.

So mathematicians had defined several possible theoretical geometries. In some of these geometries space was still infinite, in others it was of finite extent; in all of them, the sum of the angles of a triangle was either greater than or less than, rather than equal to, two right angles. It is true that while these alternative geometrical spaces were relatively easy to conceive in two dimensions, they were difficult to conceive in three dimensions; however, the difficulty of doing this in no way detracted from their viability. In order to discover which theoretical geometry correctly described the space we actually live in, measurement, rather than abstract logical reasoning, was required. Clifford insisted in his lecture that 'the question, "Does space contain a finite number of cubic miles, or an infinite number?" is a perfectly intelligible and reasonable question which remains to be answered *by experiment*'.⁹¹ What can be said about non-Euclidean geometries is that the properties of small geometrical configurations approximate to those that would obtain in Euclidean geometry.

In chapter two I explained Legendre's apparent vindication of the parallels axiom, quoted by Newman: in alternative geometries, the larger the triangle, the more the sum of its angles differed from two right angles. It was found by experiment that, even for large terrestrial triangles, deviation from Euclidean geometry could not be detected, and so Euclid's geometry could be used for practical purposes, even if our space is non-Euclidean. But Clifford pointed out that the geometry of the very big was unknown

⁸⁹ William Whewell, *The Mechanical Euclid*, 3rd edn (Cambridge: CUP, 1838), pp.159-60.

⁹⁰ Bernhard Riemann, 'On the Hypotheses which Lie at the Bases of Geometry', trans. by W. K. Clifford, *Nature* 8 (1873), 14-17, 36-7.

⁹¹ Clifford, pp.175-6, my emphasis.

(and, incidentally, he was prescient in suggesting that the geometry of the very small was also unknown): ‘the truth [...] for very much larger things, or very much smaller things, or parts of space which are at present beyond our reach, is a matter to be decided by experiment’.⁹² Clifford suggested that if ‘three points are taken in space, distant from one another as far as the sun is from α Centauri, and [if] the shortest distances between these points are drawn so as to form a triangle’ the sum of the angles of such a triangle might not be exactly two right angles.⁹³ Clifford went on to emphasise the need to be clear about what ‘exact’ means. It may not be possible to detect that the sum of the angles of a triangle whose sides are a mile long differs from two right angles, because the error might be far too small. ‘But between this inconceivably small error and no error at all, there is fixed an enormous gulf; the gulf between practical and theoretical exactness’.⁹⁴ In order to know that our space is Euclidean we require theoretical exactness, and experiment will never produce theoretical exactness; practical exactness means simply that our space is close enough to being Euclidean for us to assume Euclid’s theorems can be applied in terrestrial situations; but it does not produce incontrovertible truth.

Non-Euclidean geometry, Lewes and *The Foundations of a Creed*

This section considers George Lewes’s view of non-Euclidean geometry, as a prelude to asking whether or not Eliot agreed with Lewes.

In 1873 the Leweses came to know Clifford, that ‘great, great mathematician’, as Eliot described him in a letter to her publisher.⁹⁵ When Clifford announced his engagement in 1874, Lewes wrote to congratulate him and to hope that this would: ‘leave your *rare* intellect free to work out its glorious destiny[...] Nature doesn’t often send forth such gifted sons, and when she does, Society usually cripples them.’⁹⁶ Evidently Clifford was having a significant influence on the Leweses’ thinking. But in spite of his endorsement of Clifford’s giftedness, the scientific agnosticism in Clifford’s paper unsettled Lewes. One example concerns Clifford’s remarks on scientific

⁹² Ibid, p.155.

⁹³ Ibid.

⁹⁴ Ibid, p.156.

⁹⁵ GEL 5: p.403.

⁹⁶ GEL 6: p.102.

explanation. For Clifford, explaining a phenomenon simply meant describing ‘the unknown and unfamiliar as being made up of the known and the familiar’.⁹⁷ Lewes marked this sentence on his copy with a marginal line. In a footnote, Clifford explains how he disagrees with J. S. Mill and Spencer about this. ‘Both those writers regard subsumption under a general law as a species of explanation.’ Lewes marks this sentence with a tick, indicating he either agrees with Clifford’s argument or, more likely, given his annotations elsewhere on the article concerning general laws, with Mill and Spencer.⁹⁸ But Clifford refuses to give primacy to the notion of laws of nature: saying that a body falls because of gravitation is, for Clifford, no explanation, because we are familiar with bodies falling long before we know the law of gravitation.⁹⁹ Implicitly, Clifford is again here rejecting the possibility of *a priori* universal truths, such as Newton’s laws: all we can do is explain phenomena in terms of more familiar phenomena, explanations from which human beings derive ‘pleasure’.¹⁰⁰

By the 1870s, Lewes, like Spencer, was seeking criteria for deciding what philosophically should count as truth, and in 1873 and 1874 *The Foundations of a Creed* was published in two volumes.¹⁰¹ Partly because of its controversial topicality, no doubt, Lewes decided it was necessary to address the issue of non-Euclidean space, which he did in both volumes: in ‘Appendix A’ to the second volume, he summarises his position on the status of Euclidean axioms for the ‘*real* space’ we inhabit.¹⁰² Bayley sees ‘Appendix A’ as evidence that Lewes changed his mind after writing most of *Foundations of a Creed*, and became more sympathetic towards the possibility that our universe is non-Euclidean. I shall explain why I do not share this view. Bayley doubts ‘whether Lewes would have understood [Riemann] fully’; I would go farther and suggest that Lewes was unclear about the meaning of non-Euclidean geometry.¹⁰³

Lewes begins by disagreeing with Whewell’s position. The ‘confidence of the *à priori* school’, Lewes suggests, must have surely been shaken by Hermann Helmholtz

⁹⁷ Clifford, p.167.

⁹⁸ See the Leweses’ copy of ‘Aims and Instruments of Scientific Thought’, p.508, in Dr Williams’s Library, London, reference C.2.21 (front).

⁹⁹ Clifford, pp.169-70.

¹⁰⁰ Ibid, p.169.

¹⁰¹ George Henry Lewes, *Problems of Life and Mind: The Foundations of a Creed*, 2 vols. (London: Trübner, 1874-5).

¹⁰² Lewes, 2; p.455.

¹⁰³ Bayley, p.225.

arguing that the axioms of geometry are not universally true.¹⁰⁴ In his copy of Whewell's *The Mechanical Euclid* Lewes had marked with a marginal line the paragraph in which Whewell asserts that Euclid's 'axioms may be said to be known by intuition'.¹⁰⁵ Jonathan Smith contrasts 'the idealists' necessary truths' concerning Euclidean geometry with the 'popularizations of non-Euclidean geometry' by Helmholtz and Clifford who 'championed geometry as an empirical science', and concludes from 'Appendix A' that Lewes believed in 'the necessary truth of Euclid's axioms'.¹⁰⁶ This is surely contradicted by the scorn Lewes shows for the '*à priori* school'. While Lewes disagreed with Gauss and Helmholtz about the status of Euclid's axioms, he made it clear that he was *not* aligning himself with idealists. He quoted Lobachevski's translator Houël: geometrical speculations about non-Euclidean geometry 'throw into the region of chimeras the hope [...] that it is possible to demonstrate the axiom of Euclid respecting parallels otherwise than through Experience'.¹⁰⁷ Lewes added that being obliged to use experience is 'a result devoutly to be wished'.¹⁰⁸

By contrast with Smith, Bayley suggests that Lewes's approval of Helmholtz's shaking of Whewell's *a priori* uncertainties provides evidence that Lewes changed his mind after writing most of *Foundations of a Creed*, and 'adopted a more tolerant view of Lobachevski's challenge to Euclid's parallel postulate'.¹⁰⁹ I do not share Bayley's view: Lewes tells us he cannot admit 'the suggestion of Gauss and Helmholtz that, because we can conceive a Space in which its axioms would not be truths, the Euclidean Geometry is not rigorous, not necessarily true'.¹¹⁰ Lewes has a habit of wrapping up his assertions in negatives, which makes it hard to be clear what exactly he is asserting. He would appear here to be claiming the 'necessary truth' of Euclidean geometry but presumably not in the way the idealists understood it.

¹⁰⁴ Lewes, 2: p.455.

¹⁰⁵ P.182 of the 5th edn, of *The Mechanical Euclid* in Dr Williams's Library, reference A.5.19 (back).

¹⁰⁶ Jonathan Smith, *Fact and Feeling: Baconian Science and the Nineteenth-Century Literary Imagination* (Madison and London: University of Wisconsin Press, 1994), pp.184, 187.

¹⁰⁷ But note Clifford, p.159: 'Accordingly, many maintained that we know these exact laws by intuition. These said always one true thing, that we did not know them from experience.'

¹⁰⁸ Lewes, p.455.

¹⁰⁹ Bayley, p.221.

¹¹⁰ Lewes, 2: p.462.

So what was Lewes's belief about the necessary truth of Euclid? As an empiricist he was wary of theoretical truths. 'Real Truths' have to accord with our 'Feeling', a word Lewes uses to mean what we feel through using all our senses. Feeling tells us, so far as Lewes is concerned, that space is Euclidean; so it is Euclidean. Lewes understands that mathematicians have produced alternative geometries that are logically consistent and that therefore define geometrical spaces, but they do not describe *our* space. He tells us that even Helmholtz '*admits* that our [Euclidean] geometry is true for all beings living in a Space of three dimensions', a misunderstanding of Helmholtz's position.¹¹¹ Lewes points out at some length that Euclidean axioms can be seen as true, because, even though straight lines drawn in the real world are not actually exactly straight and planes are not exactly flat, we can work in our thinking with ideal lines and planes, a view which not one of the debating and disagreeing mathematicians is likely to have had any issue with.¹¹² While Lewes seems to suggest that inexactness emanates from imperfections in 'drawing' the lines, proponents of non-Euclidean geometry, like Clifford, were talking about something quite different: the conventional 'assumption of *theoretical* exactness in the laws of geometry' as they apply to the world around us.¹¹³

This statement of Clifford's clearly provoked Lewes. On his copy of Clifford's 'Aims and Instruments' paper, Lewes penned this comment: 'Laws have boundaries. Space is a theoretical abstraction which eliminates the human centre.'¹¹⁴ Lewes appeared to misunderstand Clifford's use of the word 'theoretical' and to assume that Clifford is muddling practical results obtained from imperfectly drawn or measured geometrical configurations with theoretical results applying to theoretically exact triangles, a somewhat presumptuous assumption, given Clifford's mathematical status. Clifford meant that our space might be such that the sum of the angles of a *theoretically* exact triangle is not exactly two right angles. In an otherwise very favourable review of Lewes's first volume of *Foundations of a Creed*, Clifford disagreed with Lewes about 'necessarily true' statements: 'The actual empirical position is a very simple one: no

¹¹¹ Ibid, p.456, my emphasis. Lewes is deriving Helmholtz's views from his article in *Academy* 5 (12 February, 1870), 128-9 (p.128).

¹¹² Lewes may here be quoting Clifford quoting Mill, perhaps, but Mill is making a slightly different point about the truth of axioms; see Clifford, pp.327-30.

¹¹³ Clifford, p.176, my emphasis

¹¹⁴ See Lewes's copy in Dr Williams's library, p.511.

general statement is known to be true'.¹¹⁵ To sum up, it is clear from Lewes's reference to 'the fictions of Laputa' at the beginning of 'Appendix A' and to 'the imaginary creations of poets' at the end, that non-Euclidean geometry is not 'a reality' in our universe.¹¹⁶ Lewes values literary imagination, but the results it might prompt are always to be interpreted in the light of empirical observation.

Clifford, Eliot and *Daniel Deronda*

Eliot discussed Lewes's writing with him, and would have read what Lewes read, particularly if it was mathematics. She would, however, not necessarily have agreed with Lewes. In 1872, when reading the manuscript of the first volume of *The Foundations of a Creed*, she told Mrs Mark Pattison that 'it is a holiday to sit with one's feet at the fire reading one's husband's writing - at least, when like mine, he allows me to differ from him'.¹¹⁷ Differences were particularly likely to have arisen over geometry: Eliot had been a geometer for much longer than Lewes: 'Did I tell you that in the last two years he has been mastering the principles of mathematics? This is an interesting fact, impersonally, at his age', she wrote to Hennell in 1872.¹¹⁸ Eliot would not have readily rejected a continental approach to geometry: *Daniel Deronda* is not a novel that endorses a self-consciously English position. Daniel, the mathematician, says to himself: 'I want to be an Englishman, but I want to understand other points of view. And I want to get rid of a merely English attitude in studies'.¹¹⁹

Clifford's espousal of non-Euclidean geometry was consistent with his belief that all propositions about the world and about experience must be continually questioned, a belief symbolically summarised by his startling aphorism: 'It is not right to be proper', a position necessary to ensure that ideas evolve. Otherwise, 'conventional habits of thought' may 'get such power that progress is impossible'.¹²⁰ Chapter forty-one of *Daniel Deronda* takes this theme. Daniel muses about Copernicus, Galileo and Socrates, all men who were not 'proper' in Clifford's sense: Copernicus took the earth

¹¹⁵ William Kingdon Clifford, 'Problems of Life and Mind: The Foundations of a Creed, Vol. 1 (review)', *Academy* (7 February, 1874), 148-50 (p.150).

¹¹⁶ Lewes, pp. 455, 465.

¹¹⁷ GEL, 5: p.344.

¹¹⁸ GEL, 5: p.330.

¹¹⁹ *Daniel Deronda*, p.155.

¹²⁰ Clifford, p.117.

away from the centre of the universe, Galileo scandalised the Italian church through his ridicule of its Ptolemaic beliefs, and Socrates ‘consistently maintains that he knows nothing’ and was executed for ‘perverting the minds of the young’.¹²¹ And it is not proper to listen to a ‘consumptive Jew, possessed by a fanaticism’, like Mordecai.¹²²

Clifford’s aphorism ends a lecture he gave in 1868. The concluding section of this lecture is a powerful advocacy of creativity and flexibility in connection with the process of learning. Clifford suggests that the attitude of the learning mind should be ‘one of creation rather than acquisition’. This is from a lecture given by Clifford in 1868:

A new branch of mathematics [...] was denounced by the Astronomer-Royal [...] as doomed to be forgotten, on account of its uselessness. Now [...] the reason why we cannot go further in our investigations of molecular action is that we do not know enough of this branch of mathematics. If the mind is artistic, it must not sit down in hopeless awe before the monuments of the great masters [...] Still less must it tremble before the conventionalism of one age, when its mission may be to form the whole life of the age succeeding.¹²³

Daniel echoes Clifford’s last sentence during his musing about Mordecai: ‘Shall we say, “Let the ages try the spirits, and see what they are worth?” Why, we are the beginning of the ages.’¹²⁴ And the narrator tells us that, with his mathematical studies at Cambridge, Daniel ‘found the inward bent towards comprehension and thoroughness diverging more and more from the track marked out by the standards of examination’.¹²⁵ For Clifford, ‘[n]o amount of erudition or technical skill or critical power can absolve the mind from the necessity of creating, if it would grow’;¹²⁶ and Eliot’s narrator tells us, when calling Euclid’s apparently self-evidently deductive Euclidean geometry into question, that ‘[n]o formulas for thinking will save us mortals

¹²¹ *Daniel Deronda*, p.436; see e.g. Bertrand Russell, *History of Western Philosophy* (London: Allen & Unwin, 1961), pp.103, 109. ‘Socrates is an evil-doer and a curious person, searching into things [...] and making the worse appear the better cause, and teaching all this to others’; reminiscent of Clifford, perhaps.

¹²² *Daniel Deronda*, p.435. It is interesting to compare Eliot’s descriptions of Mordecai in Chapter 41 with descriptions of Clifford. See, for example, Gowan Dawson, *Darwin, Literature and Victorian Respectability* (Cambridge: CUP, 2007), p.164: Clifford ‘had gained a certain notoriety as a libertarian, republican and even an anarchist’. By the time Eliot wrote this chapter, she was probably aware of Clifford’s consumptive illness.

¹²³ Clifford, p.115.

¹²⁴ *Daniel Deronda*, p.436.

¹²⁵ *Daniel Deronda*, p.152.

¹²⁶ Clifford, pp.116.

from mistake in our imperfect apprehension of the matter to be thought about.’¹²⁷ Our creative minds need to be able to imagine possible alternatives.

‘Aims and Instruments of Scientific Thought’ in *Daniel Deronda*

For another significant influence on the novel I return to Clifford’s 1872 lecture, the theme of which was stated by Clifford thus: ‘I want to find out what we mean when we say that the uniformity of Nature is exact’, or in other words, that our universe is exactly Euclidean. This provides an interpretation for the epigraph for the opening chapter.

Men can do nothing without the make-believe of a beginning. Even Science, the strict measurer, is obliged to start with a make-believe unit, and must fix on a point in the stars’ unceasing journey when his sidereal clock shall pretend that time is at Nought. His less accurate grandmother Poetry has always been understood to start in the middle; but on reflection it appears that her proceeding is not very different from his; since Science, too, reckons backwards as well as forwards, divides his unit into billions, and with his clock-finger at Nought really sets off *in media res*. No retrospect will take us to the true beginning; and whether our prologue be in heaven or on earth, it is but a fraction of that all-presupposing fact with which our story sets out.¹²⁸

Gillian Beer suggests that this epigraph may have been inspired by an 1874 article by R. A. Proctor in the *Contemporary Review*. Proctor suggests that ‘there can be no conceivable limits to space and time’, and for Eliot, this would mean the scientist must start *in media res*.¹²⁹ Proctor asserts that ‘we cannot hope to determine the real beginning of this earth’s history’, and for Eliot, ‘[n]o retrospect will take us to the true beginning’.¹³⁰ While the notion of unbounded time and starting in the middle links the epigraph to Proctor’s article, the article would not seem to suggest the *need* for the ‘make-believe of a beginning’, or the ‘all-presupposing fact’, or the emphasis on accuracy.

¹²⁷ *Daniel Deronda*, p.438.

¹²⁸ *Ibid*, p.3.

¹²⁹ Beer, p189; Richard Anthony Proctor, ‘The Past and Future of our Earth’, *Contemporary Review*, 25 (December, 1874), 74-92 (p.74).

¹³⁰ *Ibid*, p.77.

While Beer and Shuttleworth relate the epigraph metaphorically to the structure and genre of *Daniel Deronda*, I suggest interpreting it additionally in terms of agnosticism about axiomatic geometry: as a consequence of non-Euclidean geometries, there were no longer irrefutable postulates, but since postulates were needed they must be ‘make-believe’.¹³¹ For Proctor, ‘inconceivable’ infinities were unquestionable. Clifford saw things differently: in his lecture, Clifford asserted that, since space may be non-Euclidean, we do not know whether it is finite or not.¹³² Eliot’s image of the ‘stars’ unceasing journey’ might be suggested by Clifford’s ‘parts of space which are at present beyond our reach’, about which we know little: are they Euclidean or not?¹³³ Consequently, we can only start from ‘such portions of space as we can reach’, in other words, ‘*in media res*’, and we observe that our part of the universe is Euclidean - possibly.¹³⁴ Only possibly, because science, even though dividing ‘his unit into billions’ unlike his ‘less accurate grandmother Poetry’, still cannot provide ‘theoretical exactness’.¹³⁵ And while Whewell and Spencer may claim severally to provide an *a priori* prologue ‘in heaven’, Clifford’s prologue must be ‘on earth’. Clifford rejected *a priori* truths, and so ‘[n]o retrospect will take us to the true beginning’. And even though science is more ‘accurate’ than poetry, lack of ‘theoretical exactness’ means that we cannot know the true beginning of anything.

Is space Euclidean or not Euclidean?

Daniel Deronda is a novel bursting with binary questions, the answers to which purport to provide certainty about what is sometimes far from certain. Eliot continually challenges assumptions of this kind. Non-Euclidean geometry provides a topical binary question about the geometry of space, which some mid-Victorians like Clifford thought currently unanswerable. It therefore provided an appropriate metaphor for Eliot’s reasoned uncertainty.

Ironically and surprisingly, the ‘all-presupposing fact with which our story sets out’ is, it transpires, not a postulate, but a question: ‘Was she beautiful or not beautiful?’¹³⁶ The uncertain genre of *Daniel Deronda* is encapsulated in this question. Sarah Gates

¹³¹ Beer, pp.191-2. Shuttleworth, p.175 et al.

¹³² Clifford, pp.175-6.

¹³³ Ibid, p.155.

¹³⁴ Ibid.

¹³⁵ Ibid, p.156.

¹³⁶ *Daniel Deronda*, p.3.

focuses on this opening paragraph to suggest that Gwendolen is not a romantic heroine, and so she cannot marry Daniel: she ‘eludes the traditional standards of heroine description, to which passive beauty and virtue are essential’.¹³⁷ This opening question haunts Daniel throughout the novel and remains unanswered at the end: Gwendolen tells Daniel: ‘It is better – it shall be better’.¹³⁸ ‘Is she beautiful?’ the Princess asks Daniel ‘abruptly’. When he asks who, she puts him on the spot: ‘The woman you love.’¹³⁹ Equally abruptly, Daniel is confronted with the possibility that he might be the illegitimate son of Sir Hugo. Daniel and other characters face similar stark questions they cannot answer or cannot immediately answer throughout the novel. Is Daniel a Jew? Is Mordecai worth listening to? Will Gwendolen marry Grandcourt? Can Grandcourt’s past be safely ignored? Will Daniel and Gwendolen be lovers? Is Catherine safe with Klesmer? Where characters in the novel answer these questions prematurely they are usually wrong. Mr Gascoigne is confident that Grandcourt’s past has no relevance to whether Gwendolen should marry him, and Lush ‘will take odds that the marriage will never happen’.¹⁴⁰ Hans, Sir Hugo and Lady Mallinger are convinced that Daniel will marry Gwendolen; the Arrowpoints know that Catherine is safe with Klesmer.¹⁴¹ Clifford asks: ‘Is the universe finite or infinite?’ and knows that there is as yet no answer.

Is the universe Euclidean? Eliot’s most explicit reference to the foundations of geometry in the novel is a prose poem in chapter forty-one.

Suppose [Mordecai] had introduced himself as one of the strictest reasoners: do they form a body of men free from false conclusions and illusory speculations? The driest argument has its hallucinations, too hastily concluding that its net will now at last be large enough to hold the universe. Men may dream in demonstrations, and cut out an illusory world in the shape of axioms, definitions, and propositions, with a final exclusion of fact signed Q.E.D. No formulas for thinking will save us mortals from mistake in our imperfect apprehension of the matter to be thought about. And since the unemotional intellect may carry us into a mathematical dreamland where nothing is but what is not,

¹³⁷ Sarah Gates, “‘A Difference of Native Language’: Gender, Genre, and Realism in *Daniel Deronda*”, *ELH*, 68:3 (Fall 2001) 699-724 (p.705).

¹³⁸ *Daniel Deronda*, p.695.

¹³⁹ *Ibid*, p.569.

¹⁴⁰ *Ibid*, pp.77-8, 121.

¹⁴¹ *Ibid*, pp.622, 653, 203.

perhaps an emotional intellect may have absorbed into its passionate vision of possibilities some truth of what will be.¹⁴²

Bayley suggests that here ‘Mordecai is contrasted with a traditional mathematician’, whose geometry has become illusory in the sense that the self-evident postulates or axioms can no longer be considered self-evident.¹⁴³ And those who reject the possibility of non-Euclidean geometry are *excluding the facts* that might tell against Euclidean geometry. The word *matter* has a double meaning: both ‘subject’, but also ‘the tangible physical world’ that will tell us what sort of space to believe in. Mordecai says: ‘I measure the world as it is, which the vision will create anew.’¹⁴⁴ Daniel’s response to Mordecai is open-mindedness: Daniel’s ‘nature was too large, too ready to conceive regions beyond his own experience, to rest at once in the explanation, “madness”’.¹⁴⁵ As Clifford said, ‘It is not right to be proper’.

Like Clifford, Eliot did not believe in philosophical certainties. For example, several characters in *Middlemarch* fail to find their ‘Key to all Mythologies’.¹⁴⁶ The end of *Daniel Deronda* provides no sense of completion: Daniel is off on a quest to the East, and Gwendolen is beginning a new journey to who knows where. Clifford once told a lecture audience: ‘you have really done nothing else from morning to night but *change your mind*’.¹⁴⁷ In *Daniel Deronda*, Eliot’s mathematical joke, which juxtaposes the insane ‘contriver of perpetual motion’ with Copernicus and Galileo, who themselves contrived perpetual motion for the earth, is emblematic of a novel which takes issue both with those characters and with those philosophers who do not have ‘the courage to think that true which appears to be unlikely’.¹⁴⁸

This chapter has focused on two mathematical themes in *Daniel Deronda*, both concerned with uncertainty. One theme, probability, arises from our inability to predict the future accurately, and several of the novel’s characters have their predictions falsified. The departure of *Daniel Deronda* from generic conventions concerning the

¹⁴² *Daniel Deronda*, p.438.

¹⁴³ Bayley, p.242.

¹⁴⁴ *Daniel Deronda*, p.426.

¹⁴⁵ *Ibid*, p.423.

¹⁴⁶ This is the title of Mr Casaubon’s ‘great work’; see *Middlemarch*, p.58.

¹⁴⁷ Clifford, p.79.

¹⁴⁸ *Daniel Deronda*, p.436; Clifford, p.43.

romantic novel means that the reader is unable to predict the novel's ending: for example there is no marriage or other resolution for the heroine, Gwendolen. The other mathematical theme, axiomatic geometry, was, in the 1870s, the subject of new uncertainty, and this is reflected in the novel by including events that are regarded by some characters as being just as inconceivable as alternatives to Euclid's axioms.

One way to illustrate the connection between the two themes is to use the law of large numbers to characterise the different positions of Eliot and Lewes with regard to non-Euclidean geometry. A roulette wheel is so manufactured that each number has an equal probability of being chosen. Pure mathematicians might talk about a fair roulette wheel, one for which the probabilities are exactly equal. The law of large numbers tells us that if such a wheel is spun a large number of times, the proportions of each number coming up will be approximately equal, and will become increasingly equal the more times the wheel is spun. Of course, real roulette wheels, however carefully engineered, will have imperfections, and so the probabilities will not be exactly equal. But it might take an inordinately large number of spins of the wheel to determine which number is very slightly most likely. Lewes's position on Euclid is as if space obeys Euclid's laws in the same way that theoretically fair roulette wheels have equally probable outcomes; experiments only yield approximate results, but the theoretical exactness is what underpins those results. For Clifford and Eliot, space is like real-world roulette wheels. The only way we can evaluate it is either through countless experiments or through devising some alternative ingenious method. For Eliot, as for Clifford, discrepancies between Euclidean theory and practical results may well be due to the inevitable approximations, but there remains the possibility that space is the equivalent of imperfections in the roulette wheels themselves. Consequently there are no unquestionable truths, either about geometrical space or about the future. Eliot wrote in a letter in 1874: 'Difficulties of thought and acceptance of what is without full comprehension belong to every system of thinking. The question is to find the least incomplete'.¹⁴⁹ This sense of incompleteness, and Eliot's struggle to be as complete as possible have significant implications for how Eliot understood and communicated social issues.

¹⁴⁹ GEL, 6: p.100.

Conclusion

In the only substantive reference to mathematics in his survey of *George Eliot's Intellectual Life*, Avrom Fleishman addresses Eliot's 'make-believe of a beginning', which opens the first chapter of *Daniel Deronda*. Fleishman endorses the view, discussed in chapter six, that this opening epigraph is concerned with our need to start from arbitrary though plausible postulates, if we are going to prove anything in geometry: 'Eliot's dictum presupposes that science, by constructing hypothetical schemas and employing conventional systems, for example mathematics, can reach solid though modifiable truths.'¹ Both of the words 'solid' and 'modifiable' are applicable to the way geometry is used to describe the world, then as now: mathematics is a system of ideas and theorems which are logically consistent, and which can sometimes be used to describe aspects of the world. Fleishman goes on to suggest a link with Gödel's theorem, published in 1931: 'Eliot's position on arbitrary starting points [...] may be restated in terms of Gödel's theorem: no formal system can, from within itself, logically determine its starting points. [...] Eliot did not, of course, have the benefit of Gödel's proof'.² While Eliot knew nothing of Gödel, she did know about non-Euclidean geometry, which Fleishman does not mention. Fleishman's suggestion is not only problematically ahistorical; it does not fit Eliot's 'make-believe of a beginning' in the way non-Euclidean geometry does. Gödel's theorem is entirely about formal logical systems – the theory of arithmetic, for example – and states that whatever axioms we choose, there will always be statements that can be made *within the system* that are undecidable; they can be proved neither true nor false. Non-Euclidean geometry, on the other hand, relates formal systems to the *real world*: it demonstrates that we can never logically deduce self-evident postulates to define the geometry of the space we live in. *This* is what is analogous to Eliot's challenge to the *a priori* social assumptions about the Victorian world.

But Eliot's primary purpose as a mathematical novelist was not to champion a particular mathematical development; her interests in mathematics were much broader than that. She was, like Adam Bede, concerned with 'math'ematics and the natur o'

¹ Avrom Fleishman, *George Eliot's Intellectual Life* (Cambridge: CUP, 2010), p.166.

² *Ibid.*, pp.166-7.

things',³ with using mathematics and mathematical ways of thinking to help make sense of the world, the social world in particular. This thesis has demonstrated how she does this in many of her novels. Eliot's final publication *The Impressions of Theophrastus Such* (1878) is in essay form, and this provides her with the opportunity to be explicit about the mathematical basis of some of her thinking and of the arguments she uses in her novels. In *Adam Bede*, for example, Eliot uses inverse proportion to explain how the donkey defies the urging of boys and how Wiry Ben defies the urging of Adam, as described in chapter one. In *Impressions*, proportion is used in a similar way to explain the growing strength of Merman's attacks on the scholarship of Grampus: 'His certainty that he was right naturally got stronger in proportion as the spirit of resistance was stimulated.'⁴ The more the donkey and Merman are told what to do, the less they are prepared to do it.

Eliot's interest in the learning of arithmetic, most notably in evidence in *Adam Bede*, reappears in *Impressions* when Aquila miscalculates nine times thirteen, giving the answer as one hundred and two, as described in chapter one. What is ironically important here is not the inaccuracy of the result but the dazzlingly spurious statistical use that is made of it by the charismatic Aquila.⁵ Eliot is lamenting not only ignorance about elementary arithmetic, but also the misuse of statistics resulting from the use of incorrect data, as discussed in chapter five.

Eliot takes an even-handed view of historical progress. On the one hand, she repeatedly satirises, particularly but not exclusively in *Middlemarch*, the notion that the present age has largely eradicated the moral imperfections of the past. She sometimes does this through ludicrous use of statistics. In *Adam Bede* Eliot achieves her irony through spuriously quantifying a length of time: 'Sixty years ago [...] all Clergymen were not zealous'; and an even more philosophically absurd use of a time period occurs when the *Middlemarch* narrator tells the reader: 'In those days the world in general was more ignorant of good and evil by forty years than it is at present.'⁶ But on the other hand, Theophrastus Such uses mathematical language and mathematical logic to *defend* the present age in comparison with ages past:

³ *Adam Bede*, p.180.

⁴ *Impressions*, p.34.

⁵ *Ibid.*, pp.88-9.

⁶ *Adam Bede*, p.175; *Middlemarch*, p.176.

I see no rational footing for scorning the whole present population of the globe, unless I scorn every previous generation [...] and so on – scorning to infinity. This may represent some actual states of mind, for it is a narrow prejudice of mathematicians to suppose that ways of thinking are to be driven out of the field by being reduced to an absurdity. The Absurd is taken as an excellent juicy thistle by many constitutions.⁷

Eliot uses the concept of an infinite sequence to suggest that, since each generation inherits ‘diseases of mind and body’ from the generation before, scorning the present generation implies, as the result of an iterative process, scorning all past generations.⁸ Theophrastus intimates his method of mathematical proof: that of *reductio ad absurdum*, before lamenting that logically absurd beliefs frequently have considerable currency in society: they are juicy thistles, attractive to the animals that eat them, and yet liable to cause harm. So Eliot employs mathematics to maintain an even balance of opinion about whether the world is getting better or worse; using mathematics to indicate when things are far from certain is a characteristic of Eliot’s novels.

Eliot’s novels abound with characters believing in absurdities. In *Adam Bede*, Eliot conflates the sensible with the absurd: Bartle Massey, for example, while expressing views on the learning of arithmetic which Adam and indeed Eliot clearly applaud, goes on to rail against women and absurdly uses his relationship with his bitch Vixen - he ‘always called Vixen a woman’ - to demonstrate that women have no sense.⁹ Romola’s father Bardi absurdly confounds Romola’s inability to cope physically with ‘the weight of the books’ with her assumed inability to comprehend weighty arguments.¹⁰ In Eliot’s last novel, *Daniel Deronda*, the Arrowpoints’ assumptions concerning Catherine’s willingness to do their bidding provide just one example of the absurd decisions made by those whose behaviour is in opposition to their goals: ‘Parents are astonished at the ignorance of their sons, though they have used the most time-honoured and expensive means of securing it’.¹¹ Paying money for education is no substitute for thinking about what your children need to learn,

⁷ *Impressions*, p.16.

⁸ *Ibid.*

⁹ *Adam Bede*, p.238.

¹⁰ *Romola*, p.50.

¹¹ *Daniel Deronda*, pp.202-3.

It is not a coincidence that these three examples all concern societal assumptions about women. Eliot frequently based her attack on such assumptions on mathematical or logical reasoning. So Theophrastus links Merman's love of logically problematic questions with his patronising attitude towards 'woman':

What chiefly attracted him in all subjects were the vexed questions which have the advantage of not admitting the decisive proof or disproof that renders many ingenious arguments superannuated. Not that Merman had a wrangling disposition[...] Such flexibility was naturally much helped by his amiable feeling towards woman, whose nervous system, he was convinced, would not bear the continuous strain of difficult topics.¹²

This is an echo of Mr Brooke's unsubstantiated belief, plucked apparently out of the air, that 'classics, mathematics, that kind of thing, are too taxing for a woman – too taxing, you know'.¹³ In a similar way Mr Stelling seeks to stifle Maggie's interest in Euclid by suggesting that girls 'can pick up a little of everything', but while they have 'a great deal of superficial cleverness [...] [t]hey're quick and shallow'.¹⁴ There is clearly no scholarship supporting these pronouncements, which are uttered opportunely, with the prejudice of those who fail, unlike Euclid, to think logically. In this way Eliot cuts men like Mr Brooke and Mr Stelling down to size, a theme discussed in chapter five, particularly with reference to Lydgate.

In *Daniel Deronda* Eliot more generally cuts British culture down to size, as described in chapter six. Theophrastus provides the reader with an ambivalent view of smallness, of pettiness, as it manifests itself in Britain:

Hence our midland plains have never lost their familiar expression and conservative spirit for me; yet at every other mile, since I first looked on them, some sign of world-wide change, some new direction of human labour has wrought itself into what one may call the speech of the landscape – in contrast with those grander and vaster regions of the earth which keep an indifferent aspect in the presence of men's toil and devices. What does it signify that a lilliputian train passes over a viaduct amidst the abysses of the Apennines?¹⁵

¹² *Impressions*, pp.26-7.

¹³ *Middlemarch*, p.60.

¹⁴ *The Mill on the Floss*, p.150.

¹⁵ *Impressions*, pp.22-3.

The English countryside is apparently praised for its smallness, which creates a cosy familiarity; and yet this very smallness makes it hard for the countryside to accommodate technological developments without its being swamped by them, in contrast to parts of Europe which can absorb growth and development without their character being changed. This echoes issues in *Daniel Deronda*, where European geometry and European Judaism are valued when set against decadent British culture. Theophrastus suggests a remedy for our individual pettiness: ‘But there is a loving laughter in which the only recognised superiority is that of the ideal self, the God within, holding the mirror and the scourge for our own pettiness as well as our neighbours.’¹⁶ Theophrastus’ reference to a mirror recalls the pier-glass parable in *Middlemarch*. The loving laughter remedy is not adopted by Sir James who gives Mr Brooke ‘a fresh candle for him to see his own folly by’; but this ideal self is manifested by Camden Farebrother: ‘by dint of admitting to himself that he was too much as other men were, he had become remarkably unlike them in this – that he could excuse others for thinking slightly of him’.¹⁷

In her *Middlemarch* Folger notebook, Eliot mentioned ‘Personal Equations, Memoir on, by Prof. Mitchell’, but commented no farther.¹⁸ She provided one interpretation for the term ‘personal equation’ in *Theophrastus Such*:

In certain branches of science we can ascertain our personal equation, the measure of the difference between our own judgements and an average standard: may there not be some corresponding correction of our personal partialities in moral theorising? [...] is there no remedy or corrective for that inward squint which consists in a dissatisfied egoism or other want of mental balance?¹⁹

This might be read as a summary of what the parables in *Middlemarch* are about: learning not to draw rash conclusions from limited evidence, particularly when there is no wide corroboration. Camden Farebrother corrects his inward squint by allowing others to think little of him. The mathematical basis of the scientist’s ‘personal equation’ is clear: different observers, astronomers, for example, are likely to make slightly different measurements of phenomena, and the personal equation is a measure

¹⁶ Ibid, p.12.

¹⁷ *Middlemarch*, pp.727, 175. The remark about Farebrother is a logical inversion of the parable of the Pharisee and the publican (see Luke 18. 11).

¹⁸ John Clark Pratt and Victor A. Neufeldt, *George Eliot’s Middlemarch Notebooks* (Berkeley, Los Angeles and London: University of California Press, 1979), p.41.

¹⁹ *Impressions*, p.8.

of the systematic bias a particular observer might have. This measure can be used to improve the veracity of the observer's results. The quotation from *Theophrastus Such* is suggesting that a similar mathematical basis might be available to inform psychological, sociological and moral theorising.

There are several passages in *Impressions* that reiterate the messages from both the *Middlemarch* parables and make explicit the mathematical logic on which they are based. Theophrastus boasts that the 'circumstance of my rearing has at least delivered me from certain mistakes of classification',²⁰ meaning that he avoids making invidious distinctions between groups of human beings. This boast recalls the algebra parable about the monkey and the margrave, one of the two *Middlemarch* parables. But it also suggests the other parable about the pier-glass, since, ironically, there is something pharisaical in Theophrastus's superiority. Believing that he is the only person exempt from error as manifested by others in his class is the

infirm logic of the coachman [...] demanding a difficult belief in him as the sole exception from the frailties of his calling; but it is rather astonishing that the wholesale decriers of mankind and its performances should be even more unwary in their reasoning than the coachman, since each of them not merely confides in your regarding himself as an exception, but overlooks the almost certain fact that you are wondering whether he inwardly excepts *you*.²¹

The last chapter of *Impressions* is entirely built on an echoing of both the *Middlemarch* parables. Eliot begins with an allusion to fineness of classification in biology and then moves on to mathematically based ideas of sameness and difference:

To discern likeness among diversity, it is well known, does not require so fine a mental edge as the discerning of diversity amidst general sameness [...] Yet even at this stage of European culture one's attention is continually drawn to the prevalence of that grosser mental sloth which makes people dull to the most ordinary prompting of comparison – the bringing things together because of their likeness. The same motives, the same ideas, the same practices are alternatively admired and abhorred [...] according to their association with superficial differences, historical or actually social: even learned writers [...] show an attitude of mind not greatly superior in its logic to that of the frivolous fine lady who is indignant at the frivolity of her maid.²²

²⁰ Ibid, p.19

²¹ Ibid, p.40.

²² Ibid, p.135.

Eliot applies this argument to the spitefulness with which a sense of history, of solidarity, of enterprise is glorified in the British, the Greeks, the Italians, while being despised in the Jews. She does this using the logic implicit in substituting a monkey for a margrave; but those who exhibit this spitefulness are unaware of the illogic of their position, because, like the frivolous fine lady, they bring their own candles to the pier-glass.

The Victorian man of letters Leslie Stephen did not care for Eliot's analytical approach as a novelist. Stephen admired Eliot's earlier novels, but her 'too analytic' later novels provide 'abstract analyses of character, instead of showing us the concrete person in action'.²³ The mathematical physicist James Clerk Maxwell would not seem to have agreed with him. In a letter to his friend Lewis Campbell in 1873 he described *Middlemarch* as 'not a mere unconscious myth [...] but an elaborately conscious one, in which all characters are intended to be astronomical or mythical/meteorological'.²⁴ While this description is clearly tongue in cheek, it suggests that Maxwell admired not only Eliot's novel, but also the analytical nature of her thinking. In his autobiography, Charles Darwin tells us that 'in after years I have deeply regretted that I did not proceed far enough to understand something of the great leading principles of mathematics, for men thus endowed seem to have an extra sense'.²⁵ Some women clearly had it too! Through the repeated use of logical argument, which often parodies those who make unwarranted assumptions, especially about women, Eliot demonstrates her agreement with this observation by Augustus De Morgan:

mathematical demonstration has acquired the name of certain, on account of the simplicity and perfect admissibility of the principles assumed, and the strict logical nature of the steps by which conclusions are deduced from these principles. The results are also, in many cases, matters of common experience [...] The same species of logic is used in all inquiries after truth; but the broad distinction between mathematics and the rest is, that the data or assumptions are few, understandable and known to the student from the beginning [...] they require no induction from facts which can be disputed.²⁶

²³ Leslie Stephen, 'George Eliot', *Cornhill Magazine*, 43 (February, 1881), 152-168 (p.161).

²⁴ James Clerk Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell, Vol. 2, 1862-1873*, ed. by P. M. Harman (Cambridge: CUP, 1995), pp.840-1.

²⁵ Charles Darwin, *Autobiography*, ed. by George Gaylord Simpson (New York: Collier, 1950), p.34

²⁶ [Augustus De Morgan], 'On Mathematical Instruction', *Quarterly Journal of Education*, 1 (April, 1831), 264-269 (p.265).

De Morgan concludes that, through the use of mathematical demonstration, the student can distinguish between reasoning and hypothesis. Eliot's use of mathematics frequently has this purpose.

The mathematics in her novels is never abstruse, and always accurately judged. Indeed, Eliot's use of mathematics is so seamless, that it can be appreciated by those who wish to notice it, but can be glossed over by other readers, in the same way as her use of classical mythology or church history, for example. This is perhaps because she was highly competent as a mathematician: experts can make their subject readily understood by novices, an outcome that lesser practitioners struggle to achieve. Eliot could certainly do hard mathematics; she told John Cross that she 'thought she might have attained to some excellence in [geometry] if she had been able to pursue it'.²⁷ Instead, she was a novelist, who used geometry and other mathematics to help her say what she wanted to say in her novels.

In her novels Eliot demonstrates a continuing interest in the Bible, the Gospels in particular, and her references often have a link to mathematics, as I have demonstrated. Eliot gave up her Christian faith, but she kept her mathematics, which perhaps became her new faith, her new certainty. In making more or less this point, George Levine quotes an early Eliot essay: 'The divine yea and nay [...] are effectually impressed on human deeds and aspirations, not by means of Greek or Hebrew, but by [the] inexorable law of consequences'.²⁸ In *Middlemarch*, when Dorothea is learning to understand Mr Casaubon, the narrator tells us that Dorothea needs 'an idea wrought back to the directness of sense, like the solidity of objects', in order to learn that Mr Casaubon 'had an equivalent centre of self'.²⁹ Mathematics provided this solidity for Eliot.

In the introduction I compared Eliot with Lewis Carroll. Whatever their similarities, the stark difference between them concerning their use of absurd mathematical images is in the feelings these images arouse in the reader. There is a lack of empathy, of sensuality, of love in the Alice books. We are amused, but do not mind what happens to

²⁷ J. W. Cross, *George Eliot's Life as Related in her Letters and Journals*, 3 vols. (Edinburgh and London: Blackwood, 1885), 3: p.423.

²⁸ George Levine, *The Realistic Imagination: English Fiction from Frankenstein to Lady Chatterley* (Chicago: University of Chicago Press, 1981); [George Eliot], 'Mackay's Progress of the Intellect', *Westminster Review*, 54 (January, 1851), 353-368 (p.355).

²⁹ *Middlemarch*, p.198.

the duchess or the white rabbit, or even to Alice: we do not feel with her even when she sheds a 'pool of tears'. But we do feel for the absurd characters in Eliot's novels, even in the midst of their mathematically demonstrable absurdity. We feel for the comical Mr Casson, unable to 'reconcile his dignity with the satisfaction of his curiosity [about Dinah's preaching] by walking towards the Green'; and when the arrogant Lydgate tells Mrs Vincy that 'One must hire servants who will not break things' and the narrator comments that 'this was reasoning with an imperfect vision of sequences' we may laugh at Lydgate, but we are also apprehensive about his future.³⁰ And we weep tears for the no longer absurd Gwendolen when she loses Daniel and shrinks into a 'mere speck'.³¹ Eliot uses mathematics in her novels to make us think, but also to make us laugh and to make us care.

³⁰ *Adam Bede*, p.15; *Middlemarch*, p.331.

³¹ *Daniel Deronda*, p.689.

Bibliography

George Eliot's Fiction and Letters

Adam Bede (Oxford: OUP, 1998)

Daniel Deronda (Oxford: OUP, 1998)

Felix Holt, The Radical (Oxford: OUP, 1998)

The Impressions of Theophrastus Such (London: J. M. Dent, 1995)

The Lifted Veil and Brother Jacob (Oxford: OUP, 2009)

Middlemarch (Oxford: OUP, 1998)

The Mill on the Floss (Oxford: OUP, 1998)

Romola (Oxford: OUP, 1998)

Scenes of Clerical Life (Oxford: OUP, 2000)

Silas Marner (Oxford: OUP, 1998)

Haight, Gordon S., ed., *The George Eliot Letters*, 9 vols. (London: OUP, 1954-1978)

Other Sources

Acton, 'George Eliot's "Life."1', *Nineteenth Century*, 17 (March, 1885), 464-85

Armstrong, Isobel, *Victorian Glassworlds* (Oxford: OUP, 2008)

Ashton, Rosemary, *G. H. Lewes: A Life* (Oxford: Clarendon, 1991)

Audin, Michele, *Remembering Sofia Kovalevskaya* (London: Springer-Verlag, 2011)

[Aytoun, William], 'Greenwich Time', *Blackwood's Edinburgh Magazine*, 63 (March, 1848), 354-61

Baker, William, *The George Eliot - George Henry Lewes library: An Annotated Catalogue* (New York and London: Garland, 1977)

Bayley, Melanie, 'Mathematics and Literature in Victorian England'(unpublished doctoral thesis, University of Oxford, 2010)

Beer, Gillian, 'Alice in Time', *Modern Language Review* 106: 4 (October 2011), xxvii-xxxviii

_____*Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (London: Ark, 1985)

_____'Myth and the single consciousness: *Middlemarch* and *The Lifted Veil*', in *This Particular Web*, ed. by Ian Adam (Toronto, University of Toronto Press, 1971), pp.91-115

Bennett, Daphne, *Emily Davies and the Liberation of Women* (London: André Deutsch, 1990)

Bernardo, Susan M., 'From Romola to *Romola*: The Complex Act of Naming', in *From Author to Text: Re-reading George Eliot's Romola*, ed. by Caroline Levine and Mark W. Turner (Aldershot: Ashgate, 1998), pp.89-102

Birch, Dinah, 'Introduction' to *The Mill on the Floss* by George Eliot (Oxford: OUP, 1996)

Bonaparte, Felicia, 'Introduction' to *Middlemarch* by George Eliot (Oxford: OUP, 1996)

_____*The Triptych and the Cross* (Brighton: Harvester, 1979)

Boole, George, *The Mathematical Analysis of Logic* (London: Bell, 1847)

Brody, Selma, 'Origins of George Eliot's "Pier-Glass" Image', *English Language Notes*, 22:2 (1984) 55-8

_____'Physics in *Middlemarch*: Gas Molecules and Ethereal Atoms', *Modern Philology*, 85:1 (August, 1987), 42-53

Brontë, Charlotte, *Jane Eyre* (Oxford: OUP, 2000)

[Brougham, Henry], 'Mr Fellenberg's establishments at Hofwyl', *Edinburgh Review*, 31 (December, 1818), 150-165

Brown, Daniel, *The Poetry of Victorian Scientists: Style, Science and Nonsense* (Cambridge: CUP, 2013)

Cooke, R., *The Mathematics of Sonya Kovalevskaya* (New York: Springer-Verlag, 1984)

Craik, Dinah [Mulock], *John Halifax, Gentleman* (Stroud: Nonsuch, 2005)

Cross, J. W., *George Eliot's Life as Related in her Letters and Journals*, 3 vols. (Edinburgh and London: Blackwood, 1885)

Carroll, Lewis, *The Annotated Alice*, ed. by Martin Gardner (Harmondsworth: Penguin, 1970)

_____ *Euclid and his Modern Rivals* (London: Constable, 1973)

Chapman, Raymond, and Eleanora Gottlieb, 'A Russian View of George Eliot', *Nineteenth-Century Fiction*, 33:3 (December, 1978), 348-65

Clifford, William Kingdon, 'Aims and Instruments of Scientific Thought', in Dr Williams's Library, London, reference C.2.21 (front), offprint of a lecture owned by Eliot and Lewes

_____ *Lectures and essays*, ed. by Leslie Stephen and Frederick Pollock, 2 vols. (London: Macmillan, 1901)

_____ 'Problems of Life and Mind: The Foundations of a Creed, Vol. 1 (review)', *Academy* (7 February, 1874), 148-50

Dale, Peter Alan, *In Pursuit of a Scientific Culture: Science, Art, and Society in the Victorian Age* (Wisconsin: University of Wisconsin Press, 1989)

Darwin, Charles, *Autobiography*, ed. by George Gaylord Simpson (New York: Collier, 1950)

_____ *The Descent of Man* (London: Penguin, 2004)

_____ *On the Origin of Species*, ed. by Gillian Beer (Oxford: OUP, 2008)

da Sousa Correa, Delia, 'George Eliot and the Germanic "Musical Magus"' in *George Eliot and Europe*, ed. by John Rignall (Aldershot: Scolar Press, 1997), pp.98-112

Davidoff, Leonore, and Catherine Hall, *Family Fortunes: Men and Women in the English Middle Class, 1780-1850* (Chicago: University of Chicago Press, 1987)

Davies, Emily, *The Higher Education of Women* (London: Hambledon, 1988)

Dawson, Gowan, *Darwin, Literature and Victorian Respectability* (Cambridge: CUP, 2007)

De Morgan, Augustus, *Essays on the Life and Work of Isaac Newton* (Chicago and London: Open Court, 1914)

[De Morgan, Augustus], 'The Elements of Euclid', *Dublin Review*, 11 (November, 1841), 330-355

_____ 'Galileo Galilei', in Society for the Diffusion of Useful Knowledge, *The Penny Cyclopaedia*, 30 vols. (London: Charles Knight, 1833-1843), 11: pp.44-47

_____ 'Mathematics', in *The Penny Cyclopaedia*, 30 vols. (London: Charles Knight, 1833-1843), 15: pp.11-14

_____ 'On Mathematical Instruction', *Quarterly Journal of Education* 1 (April, 1831), 264-269

De Quincy, Thomas, *Confessions of an Opium-Eater and Other Writings*, ed. by Barry Milligan (London: Penguin, 2003)

Dickens, Charles, *David Copperfield* (London: Penguin, 2004)

_____ *Dombey and Son* (Oxford: OUP, 2001)

_____ *Great Expectations* (Oxford: OUP, 1994)

_____ *Hard Times* (London: Penguin, 2003)

Drinkwater, John, *The Life of Galileo Galilei* (London: 1830)

Eliot, George, 'The Influence of Rationalism', *Fortnightly Review*, 1 (15 May, 1865), 43-55

_____ 'Romola', *Cornhill Magazine*, 6 (July, 1862) to 8 (August, 1863)

[Eliot, George], 'Life and Opinions of Milton', *Leader*, 6 (4 August 1855), p.750

_____ 'Mackay's *Progress of the Intellect*', *Westminster Review*, 54 (January, 1851), 353-368

_____ 'Margaret Fuller and Mary Wollstonecraft', *Leader*, 6 (13 October, 1855) 988-9

_____ 'The Natural History of German Life', *Westminster Review*, 10 n.s. (July, 1856), 51-79

_____ 'Silly Novels by Lady Novelists', *Westminster Review*, 10 n.s. (October, 1856), 442-461

Ermarth, Elizabeth Deeds, 'George Eliot and the World as Language', in *George Eliot and Europe*, ed. by John Rignall (Aldershot: Scolar Press, 1997), pp.33-43

Feisenstein, Frank, *Anti-Semitic stereotypes: A Paradigm of Otherness in English Popular Culture, 1660-1830* (Baltimore and London: John Hopkins University Press, 1998)

Fleishman, Avrom, *George Eliot's Intellectual Life* (Cambridge: CUP, 2010)

Fletcher, John H., 'Chorismos and Emanation in the Philosophy of Plotinus' in R. Baine Harris, *The Significance of Neoplatonism* (Norfolk, Virginia: Old Dominion Research Foundation, 1976), pp.101-120

- Gardner, Martin, 'Introduction' to *The Annotated Alice* by Lewis Carroll (Harmondsworth: Penguin, 1970)
- Gaskell, Elizabeth, *Cranford and Cousin Phillis* (Harmondsworth: Penguin, 1976)
- Gates, Sarah, "'A Difference of Native Language': Gender, Genre, and Realism in *Daniel Deronda*", *ELH*, 68:3 (Fall 2001) 699-724
- I. Grattan-Guinness, 'Victorian Logic: From Whately to Russell', in *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011), pp.359-376
- Gray, Jeremy, 'Overstating their Case? Reflections on British Pure Mathematics in the 19th Century', in *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011) pp.397-414
- Gossin, Pamela, *Thomas Hardy's Novel Universe: Astronomy, Cosmology and Gender in the Post-Darwinian World* (Aldershot: Ashgate, 2007)
- Hacking, Ian, *The Taming of Chance* (Cambridge: CUP, 1990)
- Haight, Gordon S., *George Eliot: A Biography* (Oxford: OUP, 1968)
- Hardy, Thomas, *The Return of the Native* (London: Macmillan, 1974)
- Helmholtz, Hermann, 'The Axioms of Geometry', *Academy* 5 (12 February, 1870), 128-9
- Hemming, George, 'The Ordnance Survey', *Bentley's Quarterly Review*, 2 (January, 1860), 335-68
- Henchman, Anna, *The Starry Sky Within: Astronomy and the Reach of the Mind in Victorian Literature* (Oxford: OUP, 2014)
- Henderson, Andrea, 'Symbolic Logic and the Logic of Symbolism', *Critical Inquiry* (Autumn 2014) 78-101
- Hennell, Sara, 'Mr Spencer and the Women', *Examiner* (7 February, 1874), 135
- Henry, Nancy, *The Life of George Eliot: A Critical Biography* (Chichester: Wiley-Blackwell, 2012)
- House, Humphrey, *Aristotle's Poetics: A Course of Eight Lectures* (London: Hart-Davis, 1956)
- Howson, Geoffrey, *A History of Mathematics Education in England* (Cambridge: CUP, 1982)
- Irwin, Jane, ed., *George Eliot's Daniel Deronda Notebooks* (Cambridge: CUP, 1996)

Jenkins, Alice, 'Geometry', *Journal of Victorian Culture* 12:2 (2007), 267-272

_____'George Eliot, Geometry and Gender', in *Literature and Science*, ed. by Sharon Ruston (Cambridge: Brewer; The English Association, 2008), pp.72-90

_____'Mathematics and Mental Health in Early Nineteenth-Century England', *BSHM Bulletin*, 25 (2010), 92-103

_____*Space and the 'March of Mind': Literature and the Physical Sciences in Britain, 1815-1880* (Oxford: OUP, 2007)

Knoepfelmacher, U. C., 'Fusing Fact and Myth: The New Reality of *Middlemarch*' in *This Particular Web*, ed. by Ian Adam (Toronto, University of Toronto Press, 1971), pp.43-72

Law, Jules, 'Water Rights and the Crossing of Breeds' in *Rewriting the Victorians: Theory, History and the Politics of Gender*, ed. By Linda Shires (New York and London: Routledge, 1992), pp.52-69

Levine, Caroline, 'The Prophetic Fallacy: Realism, Foreshadowing and Narrative Knowledge in *Romola*', in *From Author to Text: Re-reading George Eliot's Romola*, ed. by Caroline Levine and Mark W. Turner (Aldershot: Ashgate, 1998), pp.135-163

Levine, George, 'Determinism and Responsibility in the Works of George Eliot', *PMLA*, 77:3 (June. 1962), 268-279

_____'George Eliot's Hypothesis of Reality', *Nineteenth-Century Fiction*, 35:1 (June, 1980), 1-28

_____*The Realistic Imagination: English Fiction from Frankenstein to Lady Chatterley* (Chicago and London: University of Chicago Press, 1981)

Lewes, George Henry, *Problems of Life and Mind: The Foundations of a Creed*, 2 vols. (London: Trübner, 1874-5)

[Lewes, George Henry], 'Hereditary influence, animal and human', *Westminster Review*, 10 n.s. (July, 1856), 135-162

_____'Seeing is Believing', *Blackwood's Edinburgh Magazine*, 88 (October, 1860) 381-95

Macfarlane, Alan, and Gerry Martin, *Glass: A World History* (Chicago: University of Chicago Press, 2002; London: Profile Books, 2002)

Magnello, M. Eileen, 'Vital Statistics: The Measurement of Public Health', in *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011), pp.261-282

Mann, A. J. S., and A. D. D. Craik, 'Scotland: Land of Opportunity but Few Rewards', in *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011), pp.77-102

Maxwell, James Clerk, *The Scientific Letters and Papers of James Clerk Maxwell, Vol. 2, 1862-1873*, ed. by P. M. Harman (Cambridge: CUP, 1995)

_____ 'Sectional Proceedings: Section A, Mathematics and Physical Science, BAAS', *Nature*, 2 (1870), 419-422

_____ *A Treatise on Electricity and Magnetism*, 2 vols. (Oxford: Clarendon, 1873)

Melchior-Bonnet, Sabine, *The Mirror: A History*, trans. by Katharine H. Jewett (New York and London: Routledge, 2001)

Mill, John Stuart, *On Liberty and On the Subjection of Women* (London: Penguin, 2006)

_____ *A System of Logic, Ratiocinative and Inductive* (Longmans, Green: London, 1925)

[Mill, J. S.], 'Whewell's moral philosophy', *Westminster Review*, 2 n.s. (October, 1852), 349-385

Miller, J. Hillis, 'Narrative and History', *ELH*, 41:3 (Autumn, 1974) 455-473

_____ 'Optic and Semiotic in Middlemarch', in *The Worlds of Victorian Fiction*, ed. by Jerome H. Buckley (Cambridge Mass. and London: Harvard University Press, 1975), pp.125-45

Milton, John, *Paradise Lost*, (London: Penguin 2000)

Monk, Leland, *Standard Deviations* (Stanford: Stanford University Press, 1993)

More, Hannah, *Strictures on the Modern System of Female Education*, 2 vols. (London: Cadell and Davies, 1799)

Moulton, John Fletcher, 'Herbert Spencer', *British Quarterly Review*, 58 (October, 1873), 472-504

_____ 'Note to the article on Herbert Spencer', *British Quarterly Review*, 59 (January, 1874), 215-218

[Mozley, Anne], 'Adam Bede and recent novels', *Bentley's Quarterly Review*, 1 (July, 1859), 433-472

Newman, Francis William, *The Difficulties of Elementary Geometry: Especially Those which Concern the Straight Line, the Plane, and the Theory of Parallels* (London: Ball, 1841)

- Noakes, Vivien, 'Lear, Edward (1812–1888)', *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, Oct 2006
[<http://www.oxforddnb.com/view/article/16247>, accessed 14 Feb 2016]
- Paxton, Nancy, *George Eliot and Herbert Spencer: Feminism, Evolutionism and the Reconstruction of Gender* (Princeton: Princeton University Press, 1991)
- Plato, *The Republic*, trans, by Desmond Lee (London: Penguin, 1987)
- Poovey, Mary, Writing about Finance in Victorian England: Disclosure and Secrecy in the Culture of Investment, *Victorian Studies* 45:1 (2002) 17-41
- Pratt, John Clark, and Victor A. Neufeldt, *George Eliot's Middlemarch Notebooks* (Berkeley and London: University of California Press, 1979)
- Price, Michael H., *Mathematics for the Multitude?* (Leicester: The Mathematical Association, 1994)
- _____, 'Spencer, (William) George (bap. 1790, d. 1866)', *Oxford Dictionary of National Biography*, Oxford University Press, online edn (2004)
<doi:10.1093/ref:odnb/26139>
- [Proctor, Richard Anthony], 'Gambling Superstitions', *Cornhill Magazine*, 25 (June, 1872), 704-717
- _____, 'Great solar eclipses', *Cornhill Magazine*, 18 (August, 1868), 155-169
- _____, 'The Past and Future of our Earth', *Contemporary Review*, 25 (December, 1874), 74-92
- Rectenwald, Michael, 'The Construction and Deconstruction of Science in *Middlemarch*', *Victorian Web* (last modified 19 December 2008)
<http://www.victorianweb.org/authors/eliot/middlemarch/rectenwald2.html>
- Rice, Adrian, 'Introduction' to *Mathematics in Victorian Britain*, ed. by Raymond Flood, Adrian Rice and Robin Wilson (Oxford: OUP, 2011)
- Richards, Joan L., *Mathematical Visions: The Pursuit of Geometry in Victorian England* (San Diego and London: Academic Press, 1988)
- Riemann, Bernhard, 'On the Hypotheses which Lie at the Bases of Geometry', trans. by W. K. Clifford, *Nature* 8 (1873), 14-17, 36-7
- Russell, Bertrand, *History of Western Philosophy* (London: Allen & Unwin, 1961)
- Rosenthal, Jesse, 'The Large Novel and the Law of Large Numbers; or, Why George Eliot Hates Gambling', *ELH*, 77:3 (Fall, 2010), 777-811
- Russett, Cynthia Eagle, *Sexual Science: The Victorian Construction of Womanhood* (Cambridge Mass. and London: Harvard University Press, 1989)

Shuttleworth, Sally, *George Eliot and Nineteenth-Century Science: The Make-Believe of a Beginning* (Cambridge: CUP, 1984)

Smith, Jonathan, *Fact and Feeling: Baconian Science and the Nineteenth-Century Literary Imagination* (Madison and London: University of Wisconsin Press, 1994)

Spencer, Herbert, *Essays: Scientific, Political and Speculative*, 3 vols. (London: Longman, Brown, Green and Roberts, 1858)

_____ *Principles of Biology*, 2 vols. (New York: Appleton, 1886)

_____ *The Principles of Psychology*, 2 vols. (London: Williams and Norgate, 1899)

_____ 'Replies to Criticisms', *Fortnightly Review*, 14 n.s. (December, 1873), 715-739

[Spencer, Herbert], 'Physical Training', *British Quarterly Review*, 29 (April, 1859), 362-397

_____ 'Progress: Its Law and Cause', *Westminster Review*, 11 n.s. (April, 1857), 445-485

_____ 'The Universal Postulate', *Westminster Review*, 4 n.s. (October, 1853), 513-550

Spencer, W. G., *Inventional Geometry: A Series of Questions, Problems and Explanations* (London: Mozley, 1860)

Stendhal, *The Red and the Black*, trans. by Catherine Slater (Oxford: OUP, 1991)

Stephen, Leslie, 'George Eliot', *Cornhill Magazine*, 43 (February, 1881), 152-168

Straub, Julia, *A Victorian Muse: The Afterlife of Dante's Beatrice in Nineteenth-Century Literature* (London: Bloomsbury, 2009)

'Survey Act 1841', <http://www.legislation.gov.uk/ukpga/Vict/4-5/30/section/2> (Accessed: 3-2-14)

Swift, Jonathan, *Gulliver's Travels* (Oxford: OUP, 1998)

Sylvester, J. J., 'A Plea for the Mathematician', *Nature*, 1 (1869), 237-9

Thackeray, William Makepeace, *Vanity Fair* (London: Penguin and BBC, 1999)

Thompson, E. P., 'Time, Work-Discipline, and Industrial Capitalism', *Past and Present*, 38 (December, 1967), 56-97

Toole, Betty Alexandra, 'Byron, (Augusta) Ada [*married name* (Augusta) Ada King, countess of Lovelace] (1815–1852)', *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, Oct 2009
[<http://www.oxforddnb.com/view/article/37253>, accessed 6 Sept 2016]

Trudeau, Richard J., *The Non-Euclidean Revolution* (Boston: Birkhäuser, 1987)

Turner, Mark W., 'George Eliot v. Frederic Leighton: Whose Text Is It Anyway?', in *From Author to Text: Re-reading George Eliot's Romola*, ed. by Caroline Levine and Mark W. Turner (Aldershot: Ashgate, 1998), pp.17-35

Tyndall, John, 'The Constitution of the Universe', *Fortnightly Review*, 3 (1 December, 1865), 129-144

_____ *Heat as a Mode of Motion* (London: Longmans Green, 1863)

_____ *Sound: A Course of Eight Lectures Delivered at the Royal Institution of Great Britain* (London: Longmans Green, 1867)

Warrington, John, trans., *Aristotle's Poetics, Demetrius on Style, Longinus on the Sublime* (London: Everyman, 1963)

Warwick, Andrew, 'Exercising the Student Body', in Christopher Lawrence and Steven Shapin, *Science Incarnate* (Chicago: University of Chicago Press, 1998), pp.288-326

Whewell, William, *Astronomy and General Physics with Reference to Natural Theology* (London: Bohn, 1852)

_____ *The Mechanical Euclid*, 3rd edn (Cambridge: CUP, 1838)

_____ *The Mechanical Euclid*, 5th edn, in Dr Williams's Library, London, reference A.5.19 (back), owned by Eliot and Lewes

_____ 'On the Influence of the History of Science upon Intellectual Education', in *Lectures on Education* (London: Parker, 1855), pp.3-36

_____ *Thoughts on the Study of Mathematics as Part of a Liberal Education* (Cambridge: Deighton, 1835)

Wolmar, Christian, *Blood, Iron and Gold: How the Railways Transformed the World* (London: Atlantic, 2009)

[Wilkinson, Thomas Turner], 'English mathematical literature [mainly on T. S. Davies]', *Westminster Review*, 55 (April 1851), 70-83

Wordsworth, William, *The Major Works* (Oxford: OUP, 1984)

_____ *The Thirteen-Book Prelude*, ed. by Mark L. Reed (Cornell: Ithaca and London: 1991)

Wright, Daniel, 'George Eliot's Vagueness', *Victorian Studies*, 56:4 (Summer 2014), 625-648