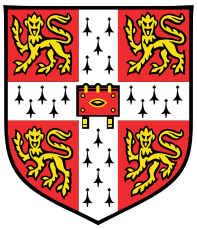
UNIVERSITY OF CAMBRIDGE



CHALK AND THE ARCHITRAVE

MATHEMATICS AND MODERN LITERATURE

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This dissertation is submitted for the degree of Doctor of Philosophy, 2015.

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This dissertation is the result is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

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CHALK AND THE ARCHITRAVE
MATHEMATICS AND MODERN LITERATURE

Alice M. Bamford

Abstract

Mary Poovey remarks that for the literary critic 'numbers constitute something like the last frontier of representation'. Although in recent years there has been a growing critical interest in the intersection of literature and mathematics and in the cultural history of mathematisation, the work is just beginning. This thesis offers an account of what it means for literature to be woven with mathematics and for mathematics to be part of the history of style. I examine the work that mathematics does in a range of literary texts produced in the quantified world of the twentieth century: produced after Ian Hacking's 'avalanche of printed numbers' – in the era, as Alain Badiou puts it, 'of number's despotism'. Through readings of Samuel Beckett, Robert Musil, Gertrude Stein, Wallace Stevens, Wyndham Lewis, Stéphane Mallarmé, Paul Valéry, Jacques Roubaud and others, I trace modern literature's engagement with the symbolic and affective economy of quantification and with the cultural history of mathematics. I place literary treatments of mathematics in dialogue with the versions of mathematics constructed by mathematicians in their prose works (manifestos, historiography, apologias and memoirs).

Jeremy Gray's recent account of modernism in mathematics poses a challenge for the study of literary modernism. Is there really a stylistic homology between modernist mathematics and modernist art and literature? If so, can the history of modernist mathematics shed new light on the phenomenon of literary modernism? Though the history of modernist mathematics offers a useful resource for interpreting some of the invocations of mathematics in modernist literature, I argue that modern literature's engagement with mathematics cannot wholly be explained by reference to modernist mathematics. To describe modern literary mathematics solely in terms of autonomous ontology, formalism and axiomatics – the contours of modernist mathematics' self-conception – would be to elide the commonplace, everyday, demotic mathematics that is woven into the fabric of modern life and modern literature: arithmetic, statistics, accountancy, measurement, the normal curve, probability and half-forgotten schoolroom sums. Modern literature offers resources for a cultural phenomenology of what Jürgen Link calls the 'curve landscapes' (*Kurvenlandschaften*) of our mathematical habitus: of the graphs, algorithms, numbers and models that map social experience.

Moreover, literature has its own mathematical idioms or vernaculars – its own styles of writing about and using mathematics – with their own histories. These vernaculars include geometrical classicism, the non-Euclidean avant-garde, arithmomania, the romantic *mathesis universalis*, chance procedures, pseudomathematical nonsense poetry, combinatorial literature and Oulipean constraint writing. Through the categories I elaborate in the chapters of the thesis – perimathematical writing, the symbolic economy of mathematics, mathematical vernaculars, demotic mathematics and the phenomenology of probability – I hope to contribute to the development of a conceptual vocabulary for the study of literature and mathematics, and to sketch a map of the domain of twentieth-century literary mathematics.

Acknowledgements

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CHALK AND THE ARCHITRAVE
INTRODUCTION

> When your Thomasina was doing maths it had been the same maths for a couple of thousand years. Classical. And for a century after Thomasina. Then maths left the real world behind, just like modern art, really. Nature was classical, maths was suddenly Picassos.
>
> Tom Stoppard, *Arcadia*.[1]

Ludwig Wittgenstein's God struggles with the mathematics of infinite sets. Take the following 'existential proposition': the pattern '777' occurs in the decimal expansion of **π**. Now, Wittgenstein writes:

> Suppose that people go on and on calculating the expansion of **π**. So God, who knows everything, knows whether they will have reached '777' by the end of the world. But can his *omniscience* decide whether they *would* have reached it after the end of the world? It cannot.[2]

It could be the case that no matter how extended the mathematicians make the calculation, they never find the pattern '777' and, as the sequence is infinite, it might be impossible to prove that '777' never occurs in it. 'Even God', Wittgenstein remarks, 'can determine something mathematical only by mathematics'.[3] A statement about the existence of a mathematical entity that does not show how that entity could be constructed is therefore merely: 'a piece of mathematical architecture which hangs in the air and looks as if it were, let us say, an architrave, but not supported by anything and supporting nothing'.[4]

Wittgenstein echoes the reasoning and the rhetoric that Hermann Weyl used in his 1921 manifesto 'On the New Foundational Crisis of Mathematics'.[5] Weyl was defending the intuitionist rejection of the principle of the excluded middle – the principle (invoked routinely, if implicitly, in a large variety of mathematical proofs) that for any proposition, *p*, either *p* is true or not-*p* is true – by describing situations to which it cannot be applied, such as existential statements about number sequences. 'Let us suppose that it is possible to decide for every number *n* whether it has or it does not have the property **E**', he writes. This view presumes that:

> The numbers 1, 2, 3, … may be tested, one by one, for the property **E**. If a number with the property **E** is found, one can terminate; the answer is *yes*. But if such a termination

[1] Tom Stoppard, *Arcadia* (London: Faber and Faber, 1993; repr. 2000), pp. 58-9.
[2] Ludwig Wittgenstein, *Remarks on the Foundations of Mathematics*, ed. by G. H. von Wright, R. Rhees and G. E. M. Anscombe; trans. by G. E. M. Anscombe (Oxford: Blackwell, 1956; 3rd rev. edn 1978; repr. 1989), p. 408.
[3] *Remarks on the Foundations of Mathematics*, p. 408.
[4] *Remarks on the Foundations of Mathematics*, p. 135.
[5] Hermann Weyl, 'Über die neue Grundlagenkrise der Mathematik', *Mathematische Zeitschrift* 10 (1921), trans. by Benito Müller as 'On the New Foundational Crisis of Mathematics', in *From Brouwer to Hilbert: The Debate on the Foundations of Mathematics in the 1920s*, ed. by Paulo Mancosu (Oxford: Oxford University Press, 1998), pp. 86-119.

> does not occur, that is to say, if, after a completed run through the infinite number sequence, no number of kind **E** has been found, then the answer is *no*.[6]

Yet, for Weyl, 'this point of view of a completed run through an infinite sequence is nonsensical':

> Only *after* the finding of a particular number with property **E** has occurred can one have a justification for the answer yes, and – given that not all numbers can be examined – only the insight that it is part of the *essence* of number to have the property $\bar{\mathbf{E}}$ [not-**E**] can provide justification for the answer no. God himself cannot make use of a different reason for deciding. *But these two possibilities no longer oppose each other as assertion and negation*. Neither the negation of the one nor of the other makes any comprehensible sense.[7]

Weyl, like Wittgenstein after him, disliked non-constructive existence proofs. In the 'New Crisis' manifesto, he likened an existential statement such as "'there is an even number'" to 'a piece of paper indicating the presence of a treasure, yet without revealing at which place. Its only value can be to drive me on to look for the treasure. The piece of paper is worthless as long as it is not realized by an underlying actual judgement like "2 is an even number"'.[8] Wittgenstein took up this way of imagining existence proofs. 'A proof that 777 occurs in the expansion of π, without shewing where', he writes, would require rethinking the meaning of the word "'where'": the expansion of π would have to be seen from 'a totally new point of view, so that it shewed e.g. properties of regions of the expansion about which we only know that they lay very far out' – a 'dark zone […] very far on in π, where we can no longer rely on our devices for calculating', and then another zone, accessible to a future mathematics yet to be invented in which 'we can once more see something'.[9]

In the cultural history of early-twentieth century mathematics, Hermann Weyl's writings are significant testimony. 'I have seen our ideas about the foundations of mathematics undergo a profound change in my lifetime', Weyl said in his address at the Princeton Bicentennial Conference in 1946: 'Russell, Brouwer, Hilbert, Gödel. I grew up a stern Cantorian dogmatist. Of Russell I had hardly heard when I broke away from Cantor's paradise'.[10] Weyl is alluding to David Hilbert's famous and firm declaration 'No one shall drive us out of the paradise which Cantor has created for us', made on 4 June 1925 before a congress in honour of Karl Weierstrass.[11] Hilbert sought to defend Cantor and his theory of transfinite numbers against the 'violent' backlash provoked by the discovery of contradictions in set theory. Weyl, too, was part of the

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[6] Weyl, 'On the New Foundational Crisis of Mathematics', p. 97.
[7] Weyl, 'On the New Foundational Crisis of Mathematics', p. 97.
[8] Weyl, 'On the New Foundational Crisis of Mathematics', pp. 97-8.
[9] Wittgenstein, *Remarks on the Foundations of Mathematics*, p. 284.
[10] Hermann Weyl, 'Address at the Princeton Bicentennial Conference' (1946) in Hermann Weyl, *Mind and Nature: Selected Writings on Philosophy, Mathematics, and Physics*, ed. by Peter Pesic (Princeton, NJ: Princeton University Press, 2009), pp. 162-174 (p. 169).
[11] David Hilbert, 'On the Infinite', delivered 4 June 1925, trans. by Erna Putnam and Gerald J. Massey from *Mathematische Annalen* (Berlin) 95 (1926), 161-90, in *Philosophy of Mathematics: Selected Readings*, ed. by Paul Benacerraf and Hilary Putnam (Cambridge: Cambridge University Press, 1983), pp. 183-201 (p. 191).

backlash against set theory and against formalism: 'During a short vacation spent with Brouwer, I fell under the spell of his personality and ideas and became an apostle of his intuitionism'.[12] Indeed, many mathematicians felt uneasy about Cantorian set theory. In a notebook entry from 1924, Paul Valéry recounted a recent conversation he had had with his friend, the mathematician Émile Borel, in which Borel told him that 'he had to abandon his research on set theory because it made him so tired – which made him afraid, gave him the inward premonition of a serious illness if he persisted in that task' as, indeed, 'Cantor and Baire had become gravely ill as a result of their efforts to formulate that same theory'.[13]

Weyl (1885-1955) arrived at the University of Göttingen in 1904, where he took his doctorate under David Hilbert. Weyl left Göttingen in 1913 to take up a post in Zürich. He returned to Göttingen in 1930 to succeed Hilbert but, following the rise of National Socialism in Germany, he emigrated in 1933 to the United States and – like so many others – found a place at the Princeton Institute for Advanced Study, where he remained until his retirement in 1951. In his Princeton address, Weyl described the events and the personal encounters that had defined his career as a mathematician: David Hilbert and his theory of integral equations, L. E. J. Brouwer and his work on topology and intuitionism, Albert Einstein and his theory of general relativity. For Weyl, mathematical activity and philosophical reflection were deeply intertwined. Near the end of his life, he remarked that while mathematical research had been his central purpose, he had also always felt 'the urge to render a reflective account of the meaning and goal of that research'.[14] In these reflective accounts, Weyl bears witness to major upheavals in mathematics and its philosophy and to the intellectual climate, the world wars and the personal conflicts among which those upheavals took place.

When Weyl arrived at Göttingen in 1904, Hilbert had recently published his 'epoch-making' work on the foundations of geometry, 1899's *Gründlagen der Geometrie*. 'From its pages', Weyl recalls, 'breathed the spirit of the modern axiomatic approach'.[15] As Weyl describes it, Hilbert's Göttingen in the years before 1914 was a perfect synergy of character, place and mathematical aesthetic. Weyl remembers Hilbert's charisma: 'the Pied Piper that Hilbert was, seducing so many rats to follow him into the deep river of mathematics'.[16]Hilbert projected an ethos of mathematical vocation: a contagious belief that mathematics could be both a way of knowing and a way of being. Weyl remembers, too, Hilbert's pupils – his disciples – following their teacher on long walks through the woods surrounding the town of Göttingen. Hilbert's

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[12] 'Address at the Princeton Bicentennial Conference', p. 169.
[13] Paul Valéry, *Cahiers/Notebooks*, *Vol. 4*, ed., by Brian Stimpson and trans. by Norma Rinsler, Brian Stimpson, Rima Joseph and Paul Ryan (Frankfurt am Main: Peter Lang, 2010), p. 195.
[14] Weyl, 'Insight and Reflection' (1955) in *Mind and Nature* pp. 204-221 (p. 204).
[15] 'Insight and Reflection', p. 206.
[16] Hermann Weyl, 'David Hilbert and His Mathematical Work' (1944), in *Levels of Infinity: Selected Writings on Mathematics and Philosophy*, trans. and ed. by Peter Pesic (New York: Dover, 2012), pp. 93-133 (p. 95).

enticing 'brand of mathematical thinking' is, in turn, 'reflected in his literary style which is one of great *lucidity*', forging a clear path for his readers through the landscapes of fin-de-siècle geometry.[17] When reading Hilbert's work:

> It is as if you were on a swift walk through a sunny open landscape; you look freely around, demarcation lines and connecting roads are pointed out to you, before you must brace yourself to climb the hill; then the path goes straight up, no ambling around, no detours.[18]

In his *Gründlagen*, Hilbert aspired to 'choose for geometry a *simple* and *complete* set of *independent* axioms' from which all known geometrical theorems could be deduced.[19] Hilbert's axioms express the relations between three undefined 'systems of things', which he calls '*points*', '*straight lines*' and '*planes*'. 'The complete and exact description of these relations follows as a consequence of the *axioms of geometry*', which are arranged into five groups: the axioms of connection, the axioms of order, the axiom of parallels, the axioms of congruence and the axiom of continuity.[20] Geometry was thus to be rebuilt on logically sound foundations.

Weyl recounts how his youthful faith in Kant – kindled in his parents' attic when he was a schoolboy – was lost at Göttingen as he read the *Gründlagen*, which 'leaves Euclid far behind' as it draws not only on non-Euclidean geometries but also constructs 'a plethora of other strange geometries': 'Kant's bondage to Euclidean geometry now appeared naïve. Under this overwhelming blow, the structure of Kantian philosophy, on which I had hung with faithful heart, crumbled into ruins'.[21]

During the nineteenth century, the authority of Euclidean geometry had collapsed. In his *Essay on the Foundations of Geometry*, Bertrand Russell remarks that the demise of a long established doctrine usually begins with an attack on a single, weak point. That attack then invites yet more criticism, which 'is apt to extend much further than the most daring, at first, would have wished'. Russell marks this pattern in the history of geometry with lines from Robert Browning's 'Bishop Blougram's Apology':

> 'First cut the liquefaction, what comes last,
> But Fichte's clever cut at God himself?'
>
> So it has been with Geometry. The liquefaction of Euclidean orthodoxy is the axiom of parallels, and it was by the refusal to admit this axiom without proof that Metageometry began.[22]

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[17] Weyl, 'David Hilbert and His Mathematical Work', p. 96.
[18] Weyl, 'David Hilbert and His Mathematical Work', pp. 96-7.
[19] David Hilbert, *The Foundations of Geometry*, trans. by E. J. Townsend (Chicago: Open Court, 1921), p. 1.
[20] Hilbert, *The Foundations of Geometry*, pp. 3-4.
[21] Weyl, 'Insight and Reflection', p. 206.
[22] Bertrand Russell, *An Essay on the Foundations of Geometry* (Cambridge: Cambridge University Press, 1897), p. 7.

Euclid's system had a weakness: the 'parallel postulate'. As phrased in the standard English edition of Euclid's *Elements,* the postulate is:

> That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than two right angles.[23]

The parallel postulate is better known as the equivalent assumption that 'through a given point only one parallel can be drawn to a given line'. Direct attempts to deduce the parallel postulate from Euclid's other axioms failed. Mathematicians then attempted to prove the logical deducibility of the parallel postulate indirectly: by negating it, in order to show that its negation leads to contradictions in the geometrical system. The negation of the parallel postulate led, however, to the creation of logically consistent alternative geometries by Bolyai and Lobachevsky in the 1820s and Bernhard Riemann in the 1850s.

Non-Euclidean and *n*-dimensional geometries, as Linda Henderson has documented, were used as inspiration and as metaphors in the visual arts and in literature.[24] For example, Ivan in Dostoevsky's *The Brothers Karamazov* (1880) used the incomprehensibility of non-Euclidean geometry as an analogy for the incomprehensibility of God:

> if God exists and if He really did create the world, then, as we all know, He created it according to the geometry of Euclid and the human mind with the conception of only three dimensions in space. Yet there have been and still are geometricians and philosophers, and even some of the most distinguished, who doubt whether the whole universe, or to speak more widely the whole of being, was only created in Euclid's geometry; they even dare to dream that two parallel lines, which according to Euclid can never meet on earth, may meet somewhere in infinity. I have come to the conclusion that, since I can't understand even that, I can't expect to understand about God. I acknowledge humbly that I have no faculty for settling such questions, I have a Euclidian earthly mind, and how could I solve problems that are not of this world?[25]

Indeed, with the development and acceptance of these non-Euclidean geometries came difficult questions: if geometry no longer intrinsically or straightforwardly referred to actual physical space, what was geometrical knowledge the knowledge of?

Mathematicians and philosophers, Ernst Cassirer argued in *Substanzbegriff und Funktionsbegriff* (1910), were faced with a set of geometries to choose among (including Euclidean, non-Euclidean and higher-dimensional geometries), but they could no longer use experience, intuition or reference to physical space in order to choose among them. In order to win its

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[23] Euclid of Alexandria, *The Thirteen Books of Euclid's Elements*, Vol. I., trans. from the text of Heiberg by T. L. Heath (Cambridge: Cambridge University Press, 1968), p. 155.

[24] Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton, NJ: Princeton University Press, 1983). Literature was also used to resist modern mathematics, as in Charles L. Dodgson's *Euclid and His Modern Rivals* (Mineola, NY: Dover 2004). Dodgson is, of course, better known as Lewis Carroll.

[25] Fyodor Dostoevsky, *The Brothers Karamazov,* trans. by Constance Garnett (Mineola, NY: Dover, 2005), pp. 212-3.

conceptual freedom, geometry had to give up the idea that it was grounded in space. Geometry was increasingly understood, therefore, not as the study of physical space but as the study of particular abstract concepts and relationships: it expressed not empirical but hypothetical knowledge. With the evolution of modern geometry at Göttingen – with Felix Klein's projective geometry and Hilbert's axiomatic method, in particular – the old science of space, founded on intuitive data, measurements and magnitudes, was transformed into and subsumed by a pure theory of relations.[26]

Projective geometry – the study of geometrical properties that are invariant under projective transformations – was revived and developed during the nineteenth century. Felix Klein used projective geometry as a metageometry: a way to find and to represent relationships between the newly diverse set of geometries. Klein's 1872 Erlangen Programme used projective geometry and group theory to unify all existing geometries, including the new non-Euclidean and *n*-dimensional geometries, under a general programme. By comparing the notions of ordinary geometry with the geometrical figures produced by the projective method, Klein constructed principles for a generalised geometry.[27] For Cassirer, Klein's addition of group theory to projective geometry revealed that the 'unchanging geometrical properties are not such in and for themselves, but only in relation to a system of possible transformations'.[28] As such, Cassirer argued, the evolution of projective geometry in the nineteenth century had brought geometry closer to realising the ideal that Leibniz had imagined for it: closer to constructing 'a universal system of possible orders in general'.[29] Modern geometry, Cassirer wrote, 'seeks to free a relation, such as the general relation of "between," which at first seems to possess an irreducible sensuous existence, from this restriction and to raise it to free logical application'.[30] For Cassirer, relations are independent of their *relata* (of the things they might relate). Relations are untied from their original empirical or intuitive content and their meanings are determined by axioms: by abstract rules of connection. For Hilbert, Cassirer writes, geometrical concepts are 'exclusively defined by the conditions to which they are subordinated'.[31] Euclidean definitions 'take the concepts of the point or the straight line as immediate data of intuition, from which fixed content they proceed'. However, in Hilbert's axiomatic treatment of geometry: 'The point and the straight line signify nothing but structures which stand in certain relations with others of their kind, as these relations

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[26] Ernst Cassirer, *Substance and Function and Einstein's Theory of Relativity*, trans. by William Curtis Swabey and Marie Collins Swabey (Chicago: Open Court, 1923), pp. 90-94.
[27] Felix Klein, *Vergleichende Betrachtungen über neuere geometrische Forschungen* (Erlangen: A. Deichert, 1872), trans. by M. W. Haskell as 'A Comparative Review of Recent Researches in Geometry', <http://arxiv.org/abs/0807.3161> [accessed 28 September 2015].
[28] Cassirer, *Substance and Function*, pp. 91-2.
[29] *Substance and Function*, p. 92.
[30] *Substance and Function*, p. 92.
[31] *Substance and Function*, p. 93.

are defined by certain groups of axioms'.[32] For Cassirer, Hilbert's axiomatic procedure is the culmination of 'a tendency of thought, which we can trace in its purely logical aspects from the first beginnings of mathematics': a tendency to make mathematics more general and universal by extending its domain of application beyond any given class of objects.[33]

Hilbert's axiomatisation of geometry and subsequent proposals to formalise the whole of mathematics provoked a variety of mathematical, philosophical and even literary responses. In 'The Foundations of Literature (after David Hilbert)' (1976), Raymond Queneau translated Hilbert's axioms for geometry into literary axioms.[34] Queneau begins by recounting an oft-repeated anecdote about the birth of modern axiomatic mathematics in a Berlin train station:

> After attending a lecture in Halle by Wiener (not Norbert, obviously) on the theorems of Desargues and Pappus, David Hilbert waiting in the Berlin station for the train to Koenigsberg, murmured pensively: 'Instead of points, straight lines, and planes, it would be perfectly possible to use the words tables, chairs, and tankards.' This reflection gave birth to a work that appeared in 1899, *The Fundamentals of Geometry*, in which the author established in definitive (or provisionally definitive) fashion the axiomatic system of Euclidean geometry (and of several others besides).[35]

Queneau takes this anecdote – recounted by Otto Blumenthal, one of Hilbert's students – as a challenge and sets out 'an axiomatic system for literature' in which the primitive terms of Hilbert's axiom system, 'points', 'straight lines', and 'planes', are replaced with 'words', 'sentences' and 'paragraphs'.[36] Indeed, Hilbert himself responded to Gottlob Frege's objection to his axiomatic system by claiming:

> But it is surely obvious that every theory is only a scaffolding or schema of concepts together with their necessary relations to one another, and that the basic elements can be thought of in any way one likes. If in speaking of my points I think of some other system of things, e.g. the system: love, law, chimney-sweep … and then assume all my axioms as relations between these things, then my propositions, e.g. Pythagoras's theorem, are also valid for those things.[37]

Queneau's text is a playful metaphrasis of Hilbert's axiomatic style. Queneau's first axioms are given as follows:

> I, I – *A sentence exists containing two given words.*

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[32] *Substance and Function*, pp. 93-94.
[33] *Substance and Function*, p. 94.
[34] Raymond Queneau, 'The Foundations of Literature (after David Hilbert)', trans. by Harry Mathews, in *Oulipo Laboratory: Texts from the Bibliothèque Oulipienne by Raymond Queneau, Italo Calvino, Paul Fournel, Jacques Jouet, Claude Berge & Harry Mathews* (London: Atlas, 1995), pp. 2-15
[35] Queneau, 'The Foundations of Literature (after David Hilbert)', p. 3.
[36] 'The Foundations of Literature (after David Hilbert)', pp. 3-4.
[37] David Hilbert to Gottlob Frege, December 29 1899, excerpted by Frege, in Gottlob Frege, *Philosophical and Mathematical Correspondence*, ed. by Gottfried Gabriel and others, abridged by Brian McGuinness, trans. by Hans Kaal (Oxford: Blackwell, 1980) Letter IV/4, pp. 38-43 (p. 39).

> COMMENT: Obvious. […]
>
> I, 2 – *No more than one sentence exists containing two given words.*
>
> COMMENT: This, on the other hand, may occasion surprise. Nevertheless, if one considers the words 'years' and 'early', once the following sentence containing them has been written, namely 'For years I went to bed early,' clearly all other sentences such as 'For years I went to bed right after supper' or 'For years I did not go to bed late' are merely pseudo-sentences that should be rejected by virtue of the above axiom.
>
> SCHOLIUM: Naturally, if 'For years I went to bed right after supper' is the sentence written originally, 'For years I went to bed early' becomes the sentence to be excluded by virtue of axiom I, 2. In other words, no one can write *A la recherche du temps perdu* twice.[38]

Queneau's system breaks down almost immediately. Axiom I, 2 is contradicted right from the start: by axioms I, I through I, 3 ('*There are at least two words in a sentence; at least three words exist that do not all belong to the same sentence*') and I, 4a (*A paragraph exists including three words that do not all belong to the same sentence*).[39] All four of these axioms are themselves sentences that contain the words '*words*' and '*sentences*': this repetition contradicts the second axiom, I, 2, which allows only one sentence containing those words to exist. Queneau must create a new 'metaliterary axiom' in order to save the consistency of his system: '*Axioms are not governed by axioms*'.[40] Queneau's text is at once a tribute to Hilbert, a pastiche of Hilbert's axiomatic style and a critique of Hilbert. The first paragraph of *À la recherche du temps perdu*, Flaubert's sentence structure and chapter XCVIII of *Tristram Shandy* are variously sifted, filtered and warped as they are tested against the axioms. Queneau thus stages a confrontation between the axiomatic method and the particularities of literature.

In his June 1925 lecture, Hilbert announced that proof theory 'forms the necessary keystone of the doctrinal arch of axiomatics'.[41] Proof theory would enable the final step in the formalisation of mathematics: using the 'methods of ideal elements', mathematicians would be able to prove the consistency of their basic formal systems. As such, proof theory would lay the final keystone of the mathematical edifice, thereby securing mathematics from threatening forces like the paradoxes of set theory. Architectural metaphors dominate much of the writing about mathematics in the twentieth century.[42] They were deployed, often, in an attempt to describe the changed nature of mathematics and the changed relationship mathematics had with the world after the methodological and ontological upheavals of the late-nineteenth and early-twentieth

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[38] 'The Foundations of Literature (after David Hilbert)', pp. 5-6.
[39] 'The Foundations of Literature (after David Hilbert)', pp. 6-7.
[40] 'The Foundations of Literature (after David Hilbert)', p. 7.
[41] Hilbert, 'On the Infinite', p. 200.
[42] In fact, architectural metaphors have played a crucial role in thinking and writing about mathematics and its philosophy at least as far back as the seventeenth century, as Ferreirós and Gray note in their excellent summary of the topic. See José Ferreirós and Jeremy J. Gray, 'Introduction', *The Architecture of Modern Mathematics: Essays in History and Philosophy*, ed. by José Ferreirós and Jeremy J. Gray (Oxford: Oxford University Press, 2006), pp. 1-45 (pp. 2-3).

centuries (non-Euclidean geometry, Hilbert's formalism, Gödel's incompleteness theorems). The most prominent architectural metaphors were the *foundational crisis* (*Grundlagenkrise*), as formulated by Weyl, and *structure*, epitomised by Bourbaki. Hilbert's foundational programme proposed grounding all existing theories in a finite set of axioms and proving the consistency of those axioms. 'What we have twice experienced, once with the paradoxes of the infinitesimal calculus and once with the paradoxes of set theory, will not be experienced a third time, nor ever again', Hilbert assured his audience.[43] He was, of course, wrong about this.[44] Wittgenstein's image of the architrave supported by nothing and supporting nothing might be read as a response to Hilbert's own architectural metaphor: for Wittgenstein, Hilbert's keystone, and his entire formalist edifice, are standing in mid-air.

For historians Herbert Mehrtens and Jeremy Gray, Hilbert's abstract, axiomatic style exemplifies *modernist* mathematics. Hilbert's work on the foundations of geometry was part of an era of heightened self-reflexivity in mathematics. Clement Greenberg's famous definition of modernism in art – as 'the use of the characteristic methods of a discipline to criticize the discipline itself, not in order to subvert it but in order to entrench it more firmly in its area of competence' – could also be applied to the self-reflexive and formalist aesthetics of twentieth-century metamathematics.[45] Gray reads the developments in mathematics between 1890 and 1930 as a modernist transformation similar to but independent of the modernist transformations in literature, art and music. Gray's argument concerning this 'convergent evolution' of modernisms rests on an understanding of modernism as:

> an autonomous body of ideas, having little or no outward reference, placing considerable emphasis on formal aspects of the work and maintaining a complicated – indeed, anxious – rather than a naïve relationship with the day-to-day world, which is the de facto view of a group of people, such as a professional or discipline-based group that has a high sense of the seriousness and value of what it is trying to achieve.[46]

Alain Badiou, too, describes an epistemic and stylistic homology between literary and artistic modernisms and mathematical modernism:

> There was a desire for pure art, an art in which the only role of semblance would be to indicate the rawness of the real. There was also a call to purify – through axiomatics and formalism – the mathematical real, to purge it of the entire spatial or numerical imaginary of intuitions.[47]

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[43] Hilbert, 'On the Infinite', p. 200.

[44] Kurt Gödel's incompleteness theorems demonstrated that any consistent formal system powerful enough to encompass arithmetic contains a true formula not provable within that system, and, more importantly, that if a formal system is consistent then one cannot prove it to be so within that system.

[45] Clement Greenberg, 'Modernist Painting' (1960), in *The Collected Essays and Criticism, Volume 4: Modernism with a Vengeance, 1957-1969*, ed. by J. O'Brien (Chicago: University Of Chicago Press, 1995) pp. 85-93 (p. 85).

[46] Jeremy Gray, *Plato's Ghost: The Modernist Transformation of Mathematics* (Princeton, NJ: Princeton University Press, 2008), p. 1.

[47] Alain Badiou, *The Century*, trans. by Alberto Toscano (Cambridge: Polity, 2007), p. 53.

Fredric Jameson, meanwhile, uses non-Euclidean geometry as a metaphor for the limit that modernist literature tended towards, but could never reach.[48] Building on Luhmann's conceptual framework, Jameson argues that linguistic differentiation and autonomization projected not only a multiplicity of semi-autonomous sociolinguistic realms (exoteric and esoteric languages, the languages of mass media, of commerce and so on) 'but also, beyond all of those, a kind of empty Utopian domain of language as non-existent and yet as demonstrable and conjectural as non-Euclidean geometry'.[49] This 'realm of non-Euclidean language' defined modernism's aesthetic and its ideology.[50] Yet, Jameson argues that language 'can never be fully autonomous': 'even nonsense rhyme (Lewis Carroll) or the autonomous superlanguage of a Khlebnikov must retain that thin final thread of reference' that connects it to something beyond itself.[51] For Jameson, that thin, final thread is the notion of the 'Absolute': which 'connects even the most non-Euclidean art, from Mallarmé to Jackson Pollock, with all the other differentiated worlds of reference'.[52]

The modernist transformation in mathematics sought to create a self-contained discipline that could account for its own foundations. How, then, could modernism in mathematics relate to the cultural modernisms? Gray admits that although some modernist artists and writers – Robert Musil, for example – picked up on the innovations in mathematics and some modernist mathematicians, like Felix Hausdorff, were open to inspiration from art and literature, there was little direct influence in either direction: 'In view of the high degree of independence of mathematics from the cases of literature and art, and the close agreement of chronology, this looks like a case of what biologists call convergent evolution'.[53] Ann Banfield similarly steps back from making any direct causal links between literary or artistic formalism and mathematical formalism. She argues that 'the formalism of modern art, if not necessarily the result of the influences of formalism in mathematics and logic, was nonetheless a phenomenon in some way possible and explicable only as part of the intellectual history that produced Cantor and Frege, Peano, Whitehead and Russell'.[54] For Herbert Mehrtens, the isolation of mathematics and its historians is crucial to their self-identity. Yet Mehrtens maintains that mathematics' epistemological self-construction is always embedded in social structure: in the cultural production of techniques of meaning and representation. The apparent autonomy of mathematical modernism, for Mehrtens, was enabled by a shifting regime of representation and

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[48] Fredric Jameson, *A Singular Modernity: Essay on the Ontology of the Present* (London: Verso, 2002), pp. 146-160.
[49] Jameson, *A Singular Modernity*, p. 147.
[50] *A Singular Modernity*, p. 147.
[51] *A Singular Modernity*, p. 160.
[52] *A Singular Modernity*, p. 160.
[53] Gray, *Plato's Ghost*, pp. 7-8.
[54] Ann Banfield, *The Phantom Table: Woolf, Fry, Russell and the Epistemology of Modernism* (Cambridge: Cambridge University Press, 2000), p. xii.

changes in the division of interpretive labour. Mehrtens also argues that the dominant images and narratives of mathematical modernism – the success story of formalist, axiomatic, self-reflexive mathematics – structure and are structured by the teleological historiography of the discipline.[55]

There are, certainly, broad parallels between 'modernist mathematics' and other forms of cultural modernism: a rupture with tradition, a turn toward formalism, and a heightened self-reflexivity. A certain scepticism, however, is in order.[56] Consider, for example, Robert Musil's treatment of the epitome of Gray's mathematical modernism, formalist mathematics, in *The Confusions of Young Törless* (1906). The novel traces the metaphorical nature and epistemological consequences of cracks in the foundations of mathematics. Musil's characters imagine mathematics as, variously, an absent bridge, a web, a crevasse and a justification for systematic torture. After a particularly difficult maths lesson, Young Törless reflects on calculations in which one begins and ends with 'very solid figures', with 'metres or weights or something similarly tangible', but in which these two sets of real numbers are 'connected to one another by something that doesn't exist', i.e., what mathematicians call an imaginary number. 'Isn't that like a bridge', he asks his friend Beineberg:

> consisting only of the first and last pillars, yet you walk over it as securely as though it was all there? For me, there's something dizzying about a calculation like that; as if it goes off God knows where for part of the way. But the really uncanny thing about it is the strength that exists in such a calculation, holding you so firmly that you land safely in the end.[57]

Törless's encounter with the square root of minus one has deep psychological, theological and moral effects. The unreal ground that mathematics is built on – the 'God knows where' of infinity, of non-Euclidean geometry, of irrational, imaginary and complex numbers – opens up inside Törless's head and beneath, before and behind his convictions. The novel centres around the torture of the beautiful schoolboy Basini, who is described as a non-realist mathematical entity. Törless's ambivalent complicity with this torture is both a product of and a way of

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[55] 'Die Möglichkeit der Mathematik, sich selbst zu thematisieren, von Hilbert mit der axiomatischen Methode und der Metamathematik ins Bewußtsein gehoben, erlaubt ihr auch, ihre Geschichte rekurrent zu rekonstruieren und als den einem großen Strom von Problemen und Lösungen darzustellen, der Diskontinuitäten und Sackgassen nicht kennt - als eine große Erfolgsgeschichte der mathematische Vernunft.' Herbert Mehrtens, *Moderne, Sprache, Mathematik: Eine Geschichte des Streits um die Grundlagen der Disziplin und des Subjekts formaler Système* (Frankfurt am Main: Suhrkamp, 1990), p. 140.

[56] Indeed, historians of mathematics have already begun to question whether 'modernism' is a useful category for their field. In a forthcoming essay, Leo Corry argues that it is not enough simply to point out the common features of mathematics and other areas of culture in a given period of time. Modernism is only a useful category for the historian of mathematics if it sheds new light on the common historical processes that produced those shared features. See Leo Corry, 'How Useful is the Term 'Modernism' for Understanding the History of Early Twentieth-Century Mathematics?', *Modernism in the Sciences, ca. 1900-1940*, ed. by Moritz Epple and Falk Mueller (Berlin: Akademie, forthcoming).

[57] Robert Musil, *The Confusions of Young Törless* (*Die Verwirrung des Zöglings Törless*, 1906), trans. by Shaun Whiteside (London: Penguin, 2001), p. 82.

attempting to come to terms with the experience of epistemological uncertainty produced in him by his mathematics lessons. The uncertainty Törless feels about mathematical infinity becomes a metaphor for his vacillation in the matter of Basini's 'punishment':

> The idea of what was about to happen to him [Basini] had utterly torn Törless in two; one moment it was reasonable and ordinary, the next it had assumed that same silence, with images flashing through it, which had gradually seeped into Törless's perception and now, all of a sudden, demanded to be treated as something real and alive, just as the idea of infinity had done before.[58]

Törless's problems with imaginary numbers and mathematical infinity, and the subsequent debates he has about them with Beineberg and with his mathematics teacher (a badly dressed David Hilbert), are refracted versions of positions taken during the fraught early years of twentieth-century philosophy of mathematics. Törless's functionalist position on imaginary numbers – that they are philosophically problematic, an absent bridge, but nevertheless *useful*: 'I've never doubted that that mathematics was right – that's what its success teaches us, after all', he tells Beineberg – is roughly equivalent to Musil's position on the foundational debates in mathematics as expressed in 1913's 'The Mathematical Man': 'after everything has been brought into the most beautiful kind of existence, the mathematicians […] looked all the way to the bottom and found that the whole building was standing in mid-air. But the machines worked!' Musil concludes from this 'that our existence is a pale ghost; we live it, but actually only on the basis of an error without which it would not have arisen'.[59] Törless's coming-of-age encounter with the philosophy of mathematics, the progression he makes towards the views of his author, is threatened by Beineberg's lyrical, intuitionist attacks on mathematical realism, and by the mathematics teacher's shabby formalism. Beineberg criticises the myopia of the 'grown-up' architects of the foundation crisis:

> *They've* drilled a path in a thousand curlicues through their brains, like the inside of a snail shell, and they can only see back as far as the next corner, whether the threat they're spinning behind them still holds or not […] None of them can find his way back […] These grown-ups and clever people have completely spun themselves into a web, one stitch supporting the next, so that the whole miracle looks entirely natural; but no one knows where the first stitch is, the one that hold everything up.[60]

The 'first stitch', for Beineberg, is not a productive error: it is the soul. 'We should really have despaired long ago', he tells Törless, 'because every area of our knowledge is riddled with such crevasses, nothing but fragments drifting in an unfathomable ocean', but instead 'we feel as safe as though we were on dry land […] That feeling is our constant companion, it holds us together,

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[58] Musil, *Young Törless*, p. 70.
[59] Robert Musil, 'The Mathematical Man', 1913, in *Precision and Soul: Essays and Addresses*, ed. and trans. by Burton Pike and David S. Luft (Chicago: University of Chicago Press, 1990), pp. 39-42 (p. 42).
[60] Musil, *Young Törless*, p. 91.

every other moment it protectively takes our intellect in its arms like a little child. Once we have become aware of it, we can no longer deny the soul's existence'.[61] The foundational crisis, then, becomes the site of the soul's expression and justification.

Törless's maths teacher, however, is the acolyte of another God: formalism. The teacher embodies the disappointments of formalism: its inability either to answer Törless's philosophical questions or to relate mathematics to quotidian life. When confronted with Törless's questions about the being of imaginary numbers, the teacher intones the doctrines of his discipline: 'You will have to accept that such mathematical concepts are purely mathematical logical necessities'; 'mathematics is a whole world in itself, and one must have lived within it for a very long time to feel everything that is necessary within it'.[62] Törless's confrontation with his teacher's inaccessible and inarticulate philosophy of mathematics is also a confrontation with the 'chalk' of mathematics: with forms of material embedding and everydayness that Törless finds just as disappointing as he finds Hilbert's logical consistency. Törless faces the 'striking paradox' recently described by two sociologists of mathematics, Michael J. Barany and Donald MacKenzie: 'the conceptual development of mathematics, apparently the most abstract of disciplines, may be influenced profoundly by the technologies of writing, and even by the mundane physicality of blackboards and chalk'.[63] Chalk and the architrave, then, two metaphors embedded in and expressing competing visions of mathematics. If the architrave stands in for Hilbert's baselessness, chalk might be used as an image of mathematics based, if not on the solid ground of a true knowledge of nature, then on and in its materials: blackboards, inscriptions, seminar rooms, scratchings and rubbings-out. In Musil's novel, the mathematician's study is all ink stains and faded, scratchy furniture: Törless 'had had quite a different idea of what a mathematician's study might be like; that it might somehow express the terrible things that were thought there. The ordinariness of it all wounded him; he transferred that hurt to mathematics in general'.[64] The teacher's cheap tobacco smoke settles, a 'thick, dull fog', blunting their theoretical conversation. Pure mathematics is here forced to express itself through and despite the form and materials of the novel: in the meticulous detailing of the everyday.

> The teacher smiled, gave a slight cough, said, "If you will excuse me," and lit a cigarette, smoking it in quick puffs; the cigarette paper – and Törless took this all in, finding it very

[61] Musil, *Young Törless*, p. 132.
[62] Musil, *Young Törless*, p. 86.
[63] Michael J. Barany and Donald MacKenzie, 'A Dusty Discipline', in *The Best Writing on Mathematics 2015*, ed. by Mircea Pitici (Princeton, NJ: Princeton University Press, forthcoming January 2016). For more on chalk, mundane mathematics and the history of the blackboard, see Barany and MacKenzie's longer piece 'Chalk: Materials and Concepts in Mathematics Research', in *Representation in Scientific Practice Revisited*, ed. by Catelijne Coopmans, Janet Vertesi, Michael Lynch, and Steve Woolgar (Cambridge, MA: MIT Press; 2014), pp. 107-129.
[64] Musil, *Young Törless*, p. 84.

> common – was greasy and rustled every time it was rolled; the teacher took his pince-nez from his nose, put it back on again, nodded his head.[65]

The stubborn sensory clashes with the super-sensory, with the transcendent, and drags it back to earth. Metaphor, after all, is only one form of mathematics' materialist baggage: the desire for a universal formal system is always also frustrated by time; by the sequential nature of the working-out, grubbily detailed by Musil in the teacher's slow-motion tics. Barany and MacKenzie trace the way in which 'blackboard mathematics' shapes the discipline: 'Like the proofs it conveys, blackboard writing travels only through rewriting. […] The intrinsic necessity of bit-by-bit unfolding in mathematical exposition is thus built into chalk as its means of writing'.[66] Synchronic knowledge is unpicked by the resistant, bit-by-bit nature of its diachronic means of inscription. And so it is, I would suggest, with modern literature's multiple, dusty, smelly encounters with mathematics. The homology of mathematical and cultural modernism suggested by Gray and Mehrtens is but part of the story.

For the literary critic, Mary Poovey remarks, 'numbers constitute something like the last frontier of representation'.[67] Although in recent years there has been a growing critical interest in the intersection of literature and mathematics and in the cultural history of mathematisation, the work is just beginning.[68] This thesis presents a series of studies in the genres of modern mathematics, literature's mathematical vernaculars and the literary phenomenology of the quantified world. I explore what it means for literature to be woven with mathematics and for mathematics to be part of the history of style. I examine the work that mathematics does in a range of literary texts produced in the quantified world of the twentieth century: produced after Ian Hacking's 'avalanche of printed numbers' – in the era, as Alain Badiou puts it, 'of number's despotism'.[69] Through readings of Samuel Beckett, Robert Musil, Gertrude Stein, Wallace Stevens, Wyndham Lewis, Stéphane Mallarmé, Paul Valéry, Jacques Roubaud and others, I trace modern literature's engagement with the symbolic and affective economy of quantification and with the cultural history of mathematics. I place literary treatments of mathematics in dialogue with the versions of mathematics constructed by mathematicians in their prose works

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[65] Musil, *Young Törless*, p. 85.
[66] Barany and MacKenzie, 'Chalk: Materials and Concepts in Mathematics Research', p. 115.
[67] Mary Poovey, *A History of the Modern Fact* (Chicago: University of Chicago Press, 1998), p. xi.
[68] Recent interventions include *Circles Disturbed: The Interplay of Mathematics and Narrative*, ed. by Apostolos Doxiadis and Barry Mazur (Princeton, NJ: Princeton University Press, 2012), Alice Jenkins, 'Genre and Geometry: Victorian Mathematics and the Study of Literature and Science', in *Uncommon Contexts: Encounters Between Science and Literature, 1800-1914*, ed. by Ben Marsden, Hazel Hutchinson and Ralph O'Connor (London: Pickering and Chatto, 2013), pp. 111-124, and Moritz Epple, 'Links and Their Traces: Cultural Strategies, Resources, and Conjunctures of Experimental and Mathematical Practices' in *Science as Cultural Practice Vol. I*, ed. by Moritz Epple and Claus Zittel (Berlin: Akademie Verlag, 2010), pp. 217-240.
[69] Ian Hacking, *The Taming of Chance* (Cambridge: Cambridge University Press, 1990), p. 5; Alain Badiou, *Number and Numbers*, trans. Robin Mackay (Cambridge: Polity, 2008), p. 1.

(manifestos, historiography, apologias and memoirs) and other 'perimathematical' writing.[70]

Gray's account of modernism in mathematics poses a challenge for the study of literary modernism. Is there really a stylistic homology between modernist mathematics and modernist art and literature? If so, can the history of modernist mathematics shed new light on the phenomenon of literary modernism? Though the history of modernist mathematics offers a useful resource for interpreting some of the invocations of mathematics in modernist literature, this thesis argues that modern literature's engagement with mathematics cannot wholly be explained by reference to modernist mathematics. To describe modern literary mathematics solely in terms of autonomous ontology, formalism and axiomatics – the contours of the self-conception of modernist mathematics – would be to elide the commonplace, everyday, demotic mathematics that is woven into the fabric of modern life and modern literature: arithmetic, statistics, accountancy, measurement, the normal curve, probability and half-forgotten schoolroom sums.[71] Hogben's best-selling *Mathematics for the Million* (1936) listed the ways in which everyday life had been quantified and his excessive, overflowing enumeration mirrored the modern experience of a world become numerical:

> We live in a welter of figures: cookery recipes, railway time-tables, unemployment aggregates, fines, taxes, war debts, over-time schedules, speed limits, bowling averages, betting odds, billiard scores, calories, babies' weights, clinical temperatures, rainfall, hours of sunshine, motoring records, power indices, gas-meter readings, bank rates, freight rates, death rates, discount, interest, lotteries, wavelengths, and tire pressures. […] Ratios, limits, acceleration, are no longer remote abstractions, dimly apprehended by the solitary genius. They are photographed upon every page of our existence.[72]

Modern literature offers resources for a cultural phenomenology of what Jürgen Link calls the 'curve landscapes' (*Kurvenlandschaften*) of our mathematical habitus: of the graphs, algorithms, numbers and models that map social experience.[73]

Moreover, literature has its own mathematical idioms or vernaculars – its own styles of writing about and using mathematics – with their own histories.[74] These vernaculars include geometrical classicism, the non-Euclidean avant-garde, arithmomania, the romantic *mathesis universalis*, chance procedures, pseudomathematical nonsense poetry, combinatorial literature and Oulipean constraint writing. Indeed, literature's engagement with mathematics is not always an

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[70] The term 'perimathematical' comes from Raymond Queneau's manifesto for the Oulipo, 'Potential Literature', in *Oulipo: A Primer of Potential Literature*, ed. and trans. by Warren Motte (London: Dalkey Archive Press, 2014), pp. 51-65 (p. 51).

[71] I have borrowed the phrase 'demotic mathematics' from Stanley Corngold who remarks on 'math in the demotic register' in his essay on 'Bookkeeping in the Modernist Novel' in *Modernism* 1, ed. by Astradur Eysteinsson and Vivian Liska (Amsterdam: John Benjamins, 2007), pp. 367-382 (p. 368).

[72] Lancelot T. Hogben, *Mathematics for the Million* (New York: WW Norton, 1940), p. 20.

[73] Jürgen Link, *Versuch über den Normalismus* (Oplanden: Westdeutscher Verlag, 1996).

[74] See also Steven Connor's formulation of 'vernacular mathematics' in 'Quantum Writing: Literature and the World of Numbers', lecture given on 13 June 2013 <http://stevenconnor.com/quantumwriting/> [accessed 27 September 2015].

engagement with the mathematics of its day: 'Not all people exist in the same Now', as Ernst Bloch put it in 'Nonsynchronism and the Obligation to Its Dialectics'.[75] The Oulipo movement, perhaps the most direct and extensive attempt to model literature on modern, axiomatic mathematics, began in 1960 and as such cannot be straightforwardly understood as the product of a modernist zeitgeist. In the work of many authors, the cultural history of mathematics – of the ways in which mathematics has been imagined – is itself used as a cultural resource: as a repertoire of images, metaphors and ideas.

Throughout the thesis, there are three layers of mathematical context doing different but interconnected explanatory work: the history of so-called 'modernist' mathematics from Hilbert to Bourbaki, the literary history of mathematics (modelled as diachronic resonance) and the social history of quantification – of how the world became numerical. From the knotted fabric of literary mathematics, I will attempt to untangle an epistemology of theft: a story of bricolage and borrowing, of disciplinary parables, epistemic virtues and moments of consolation. Through the categories I elaborate in the chapters of the thesis – perimathematical writing, the symbolic economy of mathematics, the mathematical vernacular, demotic mathematics and the phenomenology of probability – I hope to contribute to the development of a conceptual vocabulary for the study of literature and mathematics and to sketch a map of the domain of twentieth-century literary mathematics.

In the first part of the thesis I explore the genres of modern mathematics. I begin with a mathematical *Bildungsroman*: Imre Lakatos's *Proofs and Refutations*. I analyse various threshold or liminal genres of modern mathematics: manifestos, prefaces, parables, essays and even poetry. My focus, however, is on the mathematical manifesto. Mathematical manifestos are works of polemic and performative disciplinary criticism that announce a new foundational programme in mathematics, break with the previous order and promote a certain image of mathematics and its history. Embedded in these images of mathematics are traces of the cultural history of mathematics: of the making of mathematical values like rigour and exactness. Drawing on Lorraine Daston and Peter Galison's *Objectivity*, I consider exactness and rigour as 'epistemic virtues' constructed and reinforced by moral values, disciplinary norms, rhetorical strategies and techniques of self-discipline.[76] I analyse three examples of the genre of the mathematical manifesto: Augustin-Louis Cauchy's 1821 introduction to his *Cours d'analyse*, Hermann Weyl's 1921 'On the New Foundational Crisis of Mathematics' and Bourbaki's 1948 'The Architecture of Mathematics'. By reading these texts as manifestos and alongside other examples of the genre – literary and artistic manifestos such as F. T. Marinetti's 'Technical Manifesto of Futurist

[75] Ernst Bloch, 'Nonsynchronism and the Obligation to Its Dialectics' (1932), trans. by Mark Ritter, *New German Critique* 11 (1977), 22-38 (p. 22).
[76] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010).

Literature' (1912), Ezra Pound's essay on 'Vorticism' (1914), Velimir Khlebnikov's 'Artists of the World! (a written language for Planet Earth: a common system of hieroglyphs for the people of our planet)' (1919) and the Oulipo manifestos of François Le Lionnais, Raymond Queneau and Jacques Roubaud – I will explore how both mathematics and literature trade in the symbolic, moral and affective economies of mathematics. The manifestos of the European avant-gardes have been read as attempts to re-negotiate and give legitimacy to the role of the artist and the writer at a time when the social value of their expertise was felt to be under threat. References to mathematics pervaded the manifestos of the European avant-gardes. The deployment of mathematics as an organising metaphor and appeals to the epistemic virtues of mathematics are, indeed, common strategies in the construction of literary and artistic movements: Novalis's definition of Romanticism, T. E. Hulme's geometrical classicism, or the mathematical analogies of Pound's vorticist manifestos, for example. Just as the history of mathematics bears witness not to a 'royal road' to modern precision, exactness and foundational rigour, but rather to the cyclical, strategic deployment of calls to foundational retrenchment, rigour and formalism, so, too, does literary history reflect the cyclical and strategic deployment of mathematics as a cultural and symbolic resource at moments of disciplinary re-negotiation.

Samuel Beckett's work is the thread that runs through the second part of the thesis: 'Literature's Mathematical Vernaculars'. I trace lines of connection between Beckett's literary mathematics and the overlapping, criss-crossing mathematical vernaculars of twentieth-century literature: following their entanglements and sketching their genealogies. I analyse the ways in which the cultural history of ancient Greek mathematics becomes an archive of resources – metaphors, images, techniques and concepts – for literature. Beckett's prose plays with the relationship mathematics has to history and to rhetoric. Demotic mathematics – or 'low mathematics' as Beckett himself once referred to it –[77] is a broken tool in Beckett's world and it is broken in interesting ways. Demotic mathematics ought to be about rules: ought to be a series of basic instructions for the processing of information. Yet these rules, in Beckett's world, have a jarring unreadinesstohand. His numbers lurch uneasily into objects, his objects into numbers, revealing, as they do so, traces of the cultural history of mathematical ideas, entities and practices. Demotic mathematics is made strange and the way in which it is made strange is what I'm calling Beckett's mathematical vernacular. Beckett's mathematical vernacular grows out of a series of puns in *Dream of Fair to Middling Women* and *Murphy*: out of the characters' faulty cultural memory of an ancient Greek way of thinking about the world as made of mathematics. Beckett's mathematical vernacular has many regional variants and modalities: puns, nonsense, elegy and geometrical worldmaking, for example. It develops in reference to other literary uses of mathematics – by, for example, Gertrude Stein and James Joyce – and to ways of thinking and

[77] Samuel Beckett, *Proust and Three Dialogues with George Duthuit* (London: John Calder Publishers, 1999), p. 124.

writing about mathematics that Beckett refashions from philosophy: from Kant, Pascal, Leibniz, Descartes and Poincaré. I examine the life of a persistent refrain in Beckett's work: the idea of arithmetic as refuge or consolation. I draw on Ludwig Wittgenstein's idea of mathematical alchemy and Reviel Netz's theory of the rhetoric of mathematics to examine Beckett's use of the grammar of mathematical supposition and fiat. Finally, I suggest that Beckett's depiction of mathematical consolation might help us to read Poincaré's use of mathematics as a language for reading ruins: as a way of perceiving a continuity, expressed in mathematical equations, that runs through the history of our errors.

The third part of the thesis, 'Demotic Mathematics and the Quantified World', explores the texture of applied mathematics in modern literature and the cultural history of mathematisation. In particular, I examine literary modernism as it confronts a world made out of probabilities. The architecture of that world was shaped by historical mutations in the concept of probability. These mutations were also shifts in the style of probability. Ian Hacking and Lorraine Daston have traced the history of probability's style from its emergence in the 1660s, through its 'classical period', to 1900. I consider what happened next: modernist probability. In my analysis, modernist probability refers both to literary modernism understood as embedded in probabilities – embedded in the applied mathematics of statistics, insurance and physics – and to probability's own modernism: its conversion to pure mathematics between 1900 and 1933. The chapter unravels the referential texture of probability with particular attention to three mathematical tools – the normal curve, the law of large number and the sample space – and how they work as analogies, metaphors and allegories in the writing of applied mathematicians – Adolphe Quetelet, Gustav Fechner, C. S. Peirce, Karl Pearson and Max Planck – and literary modernists: Robert Musil and Wallace Stevens. I consider how Musil and Stevens use the form of the hypothesis as a structural response to probability. I argue that modernist literature offers a phenomenology of probability – an archive of ways of living with and through mathematical models and curves – and that the literary treatment of probability in the 1930s and 1940s is distinctive: it resists the terms of probability's own modernism and it draws on the accrued literary and rhetorical history of probability to investigate what it means for the world of probabilities to become coterminous with the world as such.

The structure of the thesis might, therefore, be described as radiation from a centre: from formal mathematics to the mathematics of everyday experience. The first part of the thesis analyses the construction of images of mathematics and the genres of modern mathematics. In the second part of the thesis, literary uses of mathematics are considered in relation not primarily to formal mathematics but to other literary uses of mathematics. The final part of the thesis explores literary responses to the quantified world.

GENRES OF MODERN MATHEMATICS

THE MATHEMATICAL MANIFESTO

A Mathematical *Bildungsroman*

Gamma, a student in Imre Lakatos's drama, *Proofs and Refutations*, suggests: 'Why not have mathematical critics just as you have literary critics, to develop mathematical taste by public criticism?'[1] Lakatos's drama is set in a mathematics classroom. The students are debating the proof of the Euler characteristic for polyhedra.[2] *Proofs and Refutations* follows the journey of Euler's Theorem from its birth as naïve conjecture through the mistakes and the revolutions of nineteenth-century mathematics, to adulthood. As they speed through a century of mathematical history, the students live Lakatos's lesson: rigour and proof are historically variable values and practices.

Proofs and Refutations offers, too, an education in the value of error: mathematical knowledge develops by dialectical criticism. Lakatos summarised this process in his appendix to *Proofs and Refutations*. First, there is a primitive conjecture (the thesis) and a 'proof' is formed ('*a rough thought-experiment or argument, decomposing the primitive conjecture into subconjectures or lemmas*'). Then comes the antithesis: 'global' counterexamples are found that appear to undermine the primitive conjecture. The proof is re-examined in order to find the '*guilty lemma*': the subconjecture that can account for the global counterexamples. The guilty lemma, which may have been hidden or misstated in the original proof, is now made into an explicit condition of the primitive conjecture. This is the synthesis: the improved conjecture, produced by proof analysis, supersedes the primitive conjecture.[3]

Lakatos's stated enemy was the formalist philosophy of mathematics. In particular, Lakatos objected to the formalist *image* of mathematics, which equated mathematics with 'its formal axiomatic abstraction' and the philosophy of mathematics with metamathematics.[4] Mathematics' self-reflexivity was 'canonized', Leo Corry writes, by the establishment of the discipline of metamathematics. Metamathematics, in turn, 'shaped many of the dominant images of twentieth century mathematics': such as the view that the philosophical problems in mathematics – its meta-issues – are best approached not by means of philosophy but by 'creating

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[1] Imre Lakatos, *Proofs and Refutations: The Logic of Mathematical Discovery*, ed. by John Worrall and Elie Zahar (Cambridge: Cambridge University Press, 1976), p. 98.
[2] The conjecture that for all polyhedra the number of their vertices, V, minus the number of their edges, E, plus the number of their faces, F, is 2 ($V-E+F=2$).
[3] *Proofs and Refutations*, p. 127.
[4] *Proofs and Refutations*, p. 1.

"reflexive" mathematical theories aimed at providing clear-cut answers'.[5] Corry points out that certain trends in twentieth-century philosophy – analytical approaches and logical positivism – 'can be seen as parallel to the dominance of this image of mathematics'.[6]

Images of mathematics are, to borrow Barry Barnes's view of representations, 'actively manufactured renderings of their referents, produced from available cultural resources'.[7] They are also social mechanisms that construct the boundaries of knowledge and credibility. In *Modern Algebra and the Rise of Mathematical Structures*, Corry argues that there is a distinction between the 'body of knowledge' and the 'images of knowledge', but that 'borderline' is 'blurred and historically conditioned'. [8] Images of mathematics shape the conception and practice of mathematics. They shape, too, the way the history of mathematics is written. Corry charts the construction of the image of mathematics as the science of structures: one of the dominant images of mathematical modernity. He traces the transformation of a local image of knowledge (the structural image of algebra, presented in Bartel L. van der Waerden's 1930 textbook *Moderne Algebra*, in which the idea of an algebraic structure defines the discipline's self-conception) into an image of the whole discipline. Corry writes that: 'the whole Bourbaki project in its mature form may be defined as an attempt to extend to the whole of mathematics the disciplinary image put forward in *Moderne Algebra*': all the branches of mathematics were to be seen as manifestations 'one and the same underlying, general idea, i.e., the idea of a mathematical structure'.[9] 'Nicolas Bourbaki' was the pseudonym adopted in the 1930s by a group of predominantly French mathematicians who began collectively writing a new treatise on analysis. The projected modern analysis textbook evolved into a multi-volume treatise, *Éléments de mathématique*. The *Éléments* was designed to express a unified, modern conception of mathematics: it was to be a self-contained reconstruction of the core elements of modern mathematics in largely formalised language.

In Lakatos's opinion, formalism was disconnecting mathematics not just from its philosophy but also from its history: 'according to the formalist concept of mathematics, there is no history of mathematics proper. Any formalist would basically agree with Russell's "romantically" put but seriously meant remark, according to which Boole's *Laws of Thought* (1854) was "the first book ever written on mathematics"'.[10] Mathematics further exempts itself from history, in Lakatos's view, by forced adherence to a particular style of writing. This 'Euclidean' or 'deductivist' style imposes a fixed structure on the presentation of mathematics: the text begins with a list of axioms, lemmas and/or definitions, this list is followed by the theorem and the

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[5] Leo Corry, *Modern Algebra and the Rise of Mathematical Structures*, (Basel: Birkhäuser, 2nd edn, 2004), pp. 5-6.
[6] Corry, *Modern Algebra and the Rise of Mathematical Structures*, pp. 5-6.
[7] Barry Barnes, *Interests and the Growth of Knowledge* (London: Routledge and Kegan Paul, 1977), p. 6.
[8] Corry, *Modern Algebra and the Rise of Mathematical Structures*, pp. 4-5.
[9] Leo Corry, 'Mathematical Structures from Hilbert to Bourbaki: The Evolution of an Image of Mathematics' in *Changing Images of Mathematics in History: From the French Revolution to the New Millenium*, ed. by Umberto Bottazzini and Amy Dahan Dalmedico (London: Routledge, 2001), pp. 167-186 (p. 181).
[10] *Proofs and Refutations*, p. 142.

theorem is followed by the proof. Readers of mathematics are watching a 'conjuring act': the deductivist style enforces the dogma that 'all propositions are true and all inferences valid' and presents mathematics 'as an ever-increasing set of eternal, immutable truths'.[11] By tearing the results from their heuristic context and hiding the mathematician's initial conjectures, the counterexamples and the work of proof-analysis, deductivist style enforces a sense of finality and steels itself against criticism. 'Deductivist style', Lakatos writes, 'hides the struggle, hides the adventure. The whole story vanishes, the successive tentative formulations of the theorem in the course of the proof-procedure are doomed to oblivion while the end result is exalted into sacred infallibility'.[12]

Lakatos advocates, instead, the adoption of a heuristic style, in which the text would tell the story of its own emergence: the adventure and struggle of conjecture, counterexamples, criticism and proof-analysis. Indeed, John Kadvany astutely identifies the genre in which Lakatos's own book should be located: in its narrative trajectory, *Proofs and Refutations* is 'a mathematical and historical *Bildungsroman*'.[13]

In this chapter, I analyse threshold or liminal genres of modern mathematics: the manifestos, prefaces, parables and essays that mediate and frame the discipline's entanglement with that which it understands to be other than itself. The analysis of the mathematical manifesto, in particular, sheds light on the ways in which the discipline of mathematics has imagined itself and the social, historical and textual conditions of that imaginative labour. Gamma's suggested new genre – 'mathematical criticism' – can already be found in mathematical manifestos: these works of prescriptive and performative disciplinary criticism seek to shape mathematical 'taste' by 'public criticism'. Mathematical manifestos reinforce and reconfigure the links between the disciplinary self-construction of mathematics, the repertoire of cultural images of mathematics and the social structure in which mathematical knowledge is embedded. The metaphors and rhetorical strategies deployed in 'perimathematical' or threshold texts are mediators: translating mathematics out of the formal language of proof and into a network of historical and rhetorical entanglements.

This is not, of course, to suggest that the mathematical proof is exempt from social, cultural and historical entanglements, nor that its style cannot productively be analysed. Claude Chevalley – a founding member of Bourbaki – wrote in a 1935 essay that:

> Mathematical style, just like literary style, does not pass from one epoch to another without undergoing significant fluctuations. Without doubt, each author possesses an individual style; but one can also see a general trend in every historical epoch that is fairly recognisable. On occasion, under the influence of powerful mathematical figures, this

[11] *Proofs and Refutations*, p. 142.
[12] *Proofs and Refutations*, p. 142.
[13] John Kadvany, 'A Mathematical Bildungsroman', *History and Theory* 28.1 (1989), 25-42.

> style undergoes revolutions that inflect the writing, and thus the thought, of the following periods.[14]

Chevalley goes on to identify and to analyse several such revolutions in the style of mathematical proof: the Weierstrassian 'style des ε' (epsilon style) and the Hilbertian axiomatic style. As David Bloor writes, variations in mathematical thought, style and meaning – in what counts as mathematics, as rigorous and so on – are often 'rendered invisible' by 'the knife-edge insistence that a style of thinking only deserves to be called mathematics in as far as it approximates to our own'.[15]

Style is intimately involved in the construction of mathematical knowledge. Gilles Gaston Granger's *Essai d'une philosophie du style* (1968) understood mathematical style as way of structuring both the relationship between concepts and the relationship we have to those concepts. Through analysis of Euclidean, Cartesian and vectorial styles, Granger argues that 'style plays a role that might be thought essential both to the dialectic of the internal development of mathematics and to its relation to the world of more concrete objects'.[16] Philosophers and historians of mathematics have only recently begun to realise the possibilities of this line of enquiry. Paolo Mancosu's 2009 essay, 'Mathematical Style', is the first survey of the topic of style in the philosophy of mathematics and concludes that 'the work is only just beginning. One needs many more case studies of mathematical styles and a clearer articulation of the epistemological and ontological consequences yielded by different conceptualizations of style'.[17] Although a particular style of mathematical presentation, the deductive proof, is widely held to be representative of ancient Greek mathematics, Liba Taub has recently shown that, in fact, Greek mathematics deployed a wide variety of genres including poetry, dialogue, commentary, biography, narrative and letters. The *Cattle Problem* is perhaps the most famous example of a mathematical problem composed as a poem, but as Taub points out there are many extant examples of mathematical problems presented as epistles.[18] Reviel Netz's *Ludic Proof* traces the stylistic features of Hellenistic mathematics and the 'homology' of this style with the literary style of the period. Hellenistic mathematical treatises were 'mosaic compositions': juxtaposing personal and impersonal authorial voice to striking effect, embracing hybridity and delighting in 'the carnival of calculation'.[19] Netz begins *Ludic Proof* by reading a canonical work of Hellenistic mathematics, Archimedes' *Spiral Lines*, twice: first ('very quickly') for its 'content' (to extract the 'mathematical

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[14] Claude Chevalley, 'Variations du style mathématique', *Revue de Métaphysique et de Morale* 42.3 (1935), 375-384 (p. 375).
[15] David Bloor, *Knowledge and Social Imagery* (London: Routledge, 1976), p. 129.
[16] Gilles Gaston Granger, *Essai d'une philosophie du style* (Paris: Armand Colin, 1968).
[17] Paolo Mancosu, 'Mathematical Style', in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (spring 2010 edition).
[18] Liba Taub, 'On The Variety of "Genres" of Greek Mathematical Writing: Thinking about Mathematical Texts and Modes of Mathematical Discourse', *Writing Science: Medical and Mathematical Authorship in Ancient Greece*, ed. by Markus Asper (Berlin: De Gruyter, 2013), pp. 333-366.
[19] *Ludic Proof*, p. 117.

substance'), and then ('at a more leisurely pace'), so that we may experience the unfolding of the exposition (the style). Netz's 'ludic proof' is an aesthetic: a collection of stylistic properties that can be identified in many works of Hellenistic mathematics and Hellenistic poetry.[20] The principle of mosaic composition included 'genre-breaking' and led, indeed, to the breaking of boundaries between geometry and poetry.[21] *Ludic Proof* is an investigation into the conditions of possibility for certain rhetorical forms and therefore for certain thoughts: practical criticism, it turns out, can help us to understand 'what is involved in mathematics being of this or that age'.[22]

Mathematical manifestos mobilise the political conditions and cultural assumptions of the historical moments in which they were written. Traces of the discipline's social and cultural history – of the making of mathematical values like rigour and exactness – are inscribed in the manifesto's mathematical criticism. I will focus here on three mathematical manifestos that mark crucial moments in the nineteenth and twentieth-century history of mathematics. The first is the introduction to Augustin-Louis Cauchy's 1821 textbook, the *Cours d'analyse*, seen by historians of mathematics as marking a disjuncture between the hugely productive but informal development of the calculus over the previous 150 years and the start of its formalisation. The second is Hermann Weyl's 1921 'Über die neue Grundlagenkrise der Mathematik', the single most trenchant response to the late nineteenth and early twentieth century 'foundations crisis', a crisis that was in a sense the consequence of a series of mathematical results that showed contradictions in, or inherent limits of, efforts at formalisation. The third is Nicolas Bourbaki's 'L'Architecture des Mathématiques' (1948), which articulated the project of Bourbaki's *Éléments de mathématique*, an enormously influential mid twentieth century effort to re-found mathematics. I intersperse my treatment of these manifestos with analysis of literary manifestos from various avant-garde movements, including the vorticist, futurist and Oulipo movements, in order to consider how the images, practices and epistemic virtues of mathematical culture were reinterpreted as they were woven into the fabric of literary culture.

The genre of the manifesto dominated literary culture in the years before the First World War. Luca Somigli attributes the surge in literary and artistic manifestos in the early-twentieth century to a legitimation crisis: the manifestos of the European avant-gardes were attempts to variously 're-negotiate' and 're-legitimate' the role of the artist and the writer at a time when the social value of their expertise was felt to be under threat and the category of the work of art was called into question.[23] The genre of manifesto is particularly suited to what Tom Gieryn calls

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[20] In Netz's aesthetics, categories are 'observer concepts': 'the aesthetic of X' refers to the stylistic properties of Hellenistic texts which can be identified 'regardless of whether or not such stylistic properties were articulated by the Hellenistic actors themselves' in their own writings on aesthetics. See *Ludic Proof*, p. xii.

[21] Netz, *Ludic Proof*, p. 117.

[22] Netz, *Ludic Proof*, p. 241.

[23] Luca Somigli, *Legitimizing the Artist: Manifesto Writing and European Modernism, 1885-1915* (Toronto: University of Toronto Press, 2003).

'boundary-work': to crossing, dissolving, redrawing and reinforcing boundaries.[24] As Somigli writes, the manifesto can be used to define 'the relationship between the field of cultural production and other competing fields such as that of political power, and can simultaneously articulate a series of positions within the field itself'.[25] The literary manifestos of the early twentieth century overflowed with invocations of mathematics. The manifesto's layer of mathematical reference was a site of symbolic struggle. Competing visions of literature were articulated through competing deployments of mathematics: competing worlds of number and clashing geometrical rhetorics.

Indeed, the use of mathematics as a cultural resource is a recurrent tactic in the construction and legitimation of literary movements. In 1798, for example, Friedrich von Hardenberg (Novalis) defined Romanticism as the exponentiation of the everyday and the logarithmizing of the mystical:

> The world must be made Romantic. In that way one can find the original meaning again. To make Romantic is nothing but a qualitative raising to a higher power. In this operation the lower self will become one with a better self. Just as we ourselves are such a qualitative exponential series. This operation is as yet quite unknown. By endowing the commonplace with a higher meaning, the ordinary with mysterious respect, the known with the dignity of the unknown, the finite with the appearance of the infinite, I am making it Romantic. The operation for the higher, unknown, mystical and infinite is the converse – this undergoes a logarithmic change through this connection – it takes on an ordinary form of expression. Romantic philosophy. *Lingua romana*. Raising and lowering by turns.[26]

Novalis proposed both a '*Poetics* of mathematics' and a 'Mathematics of *poesy*'.[27] Hans Niels Jahnke argues that Novalis both assimilated elementary aspects of a particular, contemporaneous mathematical school – the binomial formula used by the combinatorial school – and, in his fragment 'Arytmetika Universalis', sought a general or universal conception of the meaning of mathematics.[28] The romantic *mathesis universalis* was carried over into twentieth-century literary mathematics: it persisted as a utopian mathematical vernacular in the universal language projects of, for example, Velimir Khlebnikov, who considered Novalis and Leibniz his kindred spirits. For Jeffrey T. Schnapp, Friedrich Schlegel's romantic, idealist appropriation of mathematical notation in *Fragmente zur Litteratur und Poesie* (1797) 'summons up the dream, anticipated in the universal language schemes of the prior century but exceeded in ways that point forward to

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[24] Thomas F. Gieryn, 'Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists', *American Sociological Review* 48.6 (1983), 781-795.
[25] Somigli, *Legitimizing the Artist*, p. 53.
[26] Novalis, *Novalis: Philosophical Writings*, trans. and ed. by Margaret Mahony Stoljar (Albany, NY: State University of New York Press, 1997), p. 60.
[27] Novalis, *Notes for a Romantic Encylcopaedia: Das Allgemeine Brouillon*, ed. and trans. by David W. Wood (Albany, NY: State University of New York Press, 2007), p. 195.
[28] Hans Niels Jahnke, 'Mathematics and Culture: The Case of Novalis', Science in Context 4.2 (1991), 279 – 295 (p. 288).

Futurism, of a language that transcends or subtends time and space'.[29] Indeed, this 'romantic precedent' informs Schnapp's mapping of global futurist mathematics: it suggests 'the purely quantitative is but the visible horizon of a deeper set of *qualitative* aspirations' – a 'statistical sublime', which Schnapp identifies as one of futurism's 'rhetorics of number'.[30]

'Mathematics repairs the ruin of rules', Jacques Roubaud wrote of his own movement, the Oulipo. The Oulipo – 'Ouvroir de Littérature Potentielle', or 'Workshop of potential literature' – had its first official meeting on 24 November 1960. Many Oulipean texts are manifestos. Indeed, as the manifesto is a genre of potentiality (positioned between what has been done and what is to be done), it is a particularly suitable vehicle for the group's 'Potential Literature'. The analogy between literature and mathematics was essential to the Oulipo. The group's members have included professional mathematicians like Roubaud himself, Claude Berge and Paul Braffort. Roubaud argues that for the members of Oulipo, the 'exhaustion' of traditional literary forms and rules 'is the starting point in the search for a *second foundation*, that of mathematics'.[31] Oulipo wanted to replace rules with axiomatic constraints and forms with Bourbakian structures. Where earlier literary and artistic avant-gardes – such as vorticism and futurism – developed and deployed diverse, often largely informal mathematical vernaculars, Oulipo sought to explicate and to codify their literary mathematics. Oulipo did not use mathematics simply as a legitimating discourse, as a code for their modernity, autonomy or aesthetic stance, nor merely as a source of metaphors; rather, for Roubaud, Queneau and their comrades, literature's affiliation with mathematics was and is an end in itself.

Yet, here we might pause and recall Adorno's criticism of such aesthetic affiliations with mathematics. For Adorno, although mathematics shares certain characteristics with art ('on the basis of its formalism, mathematics is itself aconceptual; its signs are not signs of something, and it no more formulates existential judgments than does art; its aesthetic quality has often been noted') attempts to directly equate aesthetic forms and mathematical forms are acts of self-deception and self-renunciation.[32] Like Roubaud, Adorno saw the recourse to mathematics as motivated by the ruin of rules. Roubaud was content to look to mathematics for inspiration: for the axioms and structures through which to generate his 'potential literature'. Adorno, on the other hand, argued that mathematics could not repair the ruin of rules:

> Mathematization as a method for the immanent objectification of form is chimerical. Its insufficiency can perhaps be clarified by the fact that artists resort to it during historical

[29] Jeffrey T. Schnapp, 'The Statistical Sublime', in The History of Futurism: The Precursors, Protagonists, and Legacies, ed. by Geert Buelens, Harald Hendrix and Monica Jansen (Lanham, MD Lexington Books, 2012), pp. 107-128 (p. 107).
[30] Schnapp, 'The Statistical Sublime', p. 110.
[31] Jacques Roubaud, 'Mathematics in the Method of Raymond Queneau' in *Oulipo: A Primer of Potential Literature*, pp. 51-65 (p. 93).
[32] Theodor W. Adorno, *Aesthetic Theory*, trans. and ed. by Robert Hullot-Kentor (London: Continuum, 2009), p. 181.

> periods when the traditional self-evidence of forms dissolves and no objective canon is available. At these moments the artist has recourse to mathematics; it unifies the level of subjective reason attained by the artist with the semblance of an objectivity founded on categories such as universality and necessity.[33]

For the artist to reach outside of the domain of the aesthetic for a source of legitimacy is, however, only to further undermine art's claim to legitimacy. 'Rather than embodying the abiding lawfulness of being, its own claim to legitimacy', Adorno writes, 'the mathematical aspect of art despairingly strives to guarantee its possibility in a historical situation in which the objectivity of the conception of form is as requisite as it is inhibited by the level of consciousness'.[34] Structures imported from mathematics might offer the 'semblance' of objectivity. Yet, Adorno argues, those structures and that objectivity crumble in the act of translation: 'the organization, the relation of elements to each other that constitutes form, does not originate in the specific structure and fails when confronted with the particular'.[35] For the Oulipean Raymond Queneau, that crumbling, that failure, that patchy translation, was something to be embraced and represented. In 'The Foundations of Literature (after David Hilbert)', as I discussed in the introduction, Queneau formulates an axiomatic system for literature. He lifts his axioms from David Hilbert's *Foundations of Geometry*, applies them to literature, and creates a manifesto that enacts, via its own internal logic, the impossibility of complete formalisation.

Exactness and Epistemic Grace

'All epistemology begins in fear', Daston and Galison write in their history of objectivity.[36] Many poets, critics, mathematicians and linguists in the first half of the twentieth century shared a fear about language: an anxiety about the ways in which words, as in Eliot's 'Burnt Norton', 'Decay with imprecision'.[37] That anxiety overwhelmed Paul Valéry. In 1925, Valéry described how his younger self – afflicted with 'the acute malady of precision'[38] – had renounced poetry on the grounds that imprecision and vagueness could too easily creep in. His malady also inspired Paul Valéry to imagine a man of perfect precision, a character he called 'Monsieur Teste'. This character is a man incapable of saying anything vague, in whose mind 'language is always on trial': a man of pure rigour 'who thinks (from long training, from habit become nature) continually and on every occasion according to data and studied definitions'; a man for whom 'Everything is referred to himself, and, in himself, to strict rules'.[39] Teste's first public appearance was in 1896

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[33] Adorno, *Aesthetic Theory*, pp. 188-9.
[34] *Aesthetic Theory*, p. 189.
[35] *Aesthetic Theory*, p. 189.
[36] Daston and Galison, *Objectivity*, p. 372.
[37] T. S. Eliot, *Four Quartets* (London: Faber and Faber, 1944), p. 12.
[38] Paul Valéry, *Monsieur Teste*, trans. by Jackson Mathews (New York: Alfred A Knopf, 1948), p. 3.
[39] Valéry, *Monsieur Teste*, p. 82.

(in *La Soirée avec Monsieur Teste*) and Valéry continued to amass notes on this man of precision – narratives, letters and other fragments – until his death in 1945. Valéry poured his speculations about the mathematical imagination (the speculations of his *Cahiers*, his daily notebooks) into Monsieur Teste, who inhabits and surveys the mathematical domain of his own mind – a domain where the possible is the real – and all possibilities can be surveyed and sorted by 'definite operations'.[40]

In 1927, Valéry wrote to the mathematician Jacques Hadamard, and told him how envious he was of mathematicians. 'I often invoke your skilled gods when I struggle in a mess of impressions and relations', he told Hadamard:

> I have wished a thousand times that a mathematical demon – not that of Maxwell, but that of Riemann – would appear and help me to construct a schema of my simultaneous ideas. The geometer has the fortune of realizing, thanks to the simplicity of the initial conditions and the clear and perfect separation of operations, what the literary artist glimpses and misses at each instant because of the complexity of his objects, the impure and statistical character of ordinary language and of its forms…[41]

Valéry's letter tails off – he does not want, he writes, to fall prey to the temptations of analogy. After all, as he wrote in his notebook, '[i]t is the strict – "rigorous" – limitation of its language that is the virtue of mathematics. Its limits – The constraints of precision'.[42]

Valéry's character, Monsieur Teste, and his understanding of mathematical language are built on an understanding of mathematics as what Lorraine Daston calls a 'moral economy': a habitus in which precision, exactness, rigour and other epistemic virtues are intertwined with codes of personal behaviour, with ways of seeing and with techniques of representation.[43] The moral economies of science and mathematics have, for Daston, an ambiguous relationship with 'the culture in which they are embedded'. Though there is evidence that science's epistemic virtues 'derive both their forms and their emotional force' from that wider culture, there is also evidence that when cultural forms are 'uprooted and combined within a moral economy of science', they 'become naturalized to that milieu'.[44] In what follows, I consider the valences of the cultural configuration 'mathematics': the ways in which mathematical practices are embedded in culture and how images of mathematics are constructed. I explore, too, the circulation of mathematical symbols, names and emblems across different epistemic cultures, esoteric and exoteric, local and global: the operations of the moral and symbolic economies of mathematics.

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[40] Valéry, *Monsieur Teste*, p. 7.
[41] Paul Valéry to Jacques Hadamard, 1 May 1927, Letter LXXXVI in Valéry, *Lettres à Quelques-Uns* (Paris: Gallimard, 1952), pp. 171-2 (pp. 171-2).
[42] Paul Valéry, *Cahiers/Notebooks*, Vol 4, p. 225.
[43] Lorraine Daston, 'The Moral Economy of Science', *Osiris* 10 (1995), 2-24.
[44] Daston, 'The Moral Economy of Science', p. 24.

Parables of Rigour

> Thus, written in accordance with the axiomatic method and keeping always in view, as it were on the horizon, the possibility of a complete formalization, our series lays claim to perfect rigour.
>
> N. Bourbaki, *Elements of Mathematics.* [45]

> ALPHA: 'Today absolute rigour is attained.'
> [*Giggling in the classroom.*]
>
> Imre Lakatos, *Proofs and Refutations.* [46]

'Every discipline tells a story', Simon Schaffer writes: 'where it comes from, what it is and where it is going. Disciples learn such parables as part of their induction'.[47] The tales that disciplines tell about themselves are at once descriptive and normative, Schaffer points out, both 'mnemonic' and 'monitory'. Disciplinary histories (stories of discovery with 'exemplary protagonists', for example) 'help make what they purport merely to announce': as parables, they establish and reinforce the epistemic and behavioural norms of a disciplinary community.[48] Parables form a tacit curriculum; they socialise the apprentice into a disciplinary community: its ways of feeling, modes of recognition and techniques of credibility. Parables, too, bear historical traces of Daston's moral economies: of the relational webs of 'affect-saturated values' that are 'integral to science: to its sources of inspiration, its choice of subject matter and procedures, its sifting of evidence, and its standards of explanation'.[49]

According to one such mathematical parable, modern mathematical rigour began in 1821 with Augustin-Louis Cauchy and his new textbook of analysis (the *Cours d'Analyse*). In the parable, Cauchy initiated the Weierstrassian revolution in analysis: banishing infinitesimals (numbers that were infinitely small yet handled mathematically as if they existed and could be subjected to ordinary arithmetical operations) from the calculus in the name of rigour by replacing them with the apparatus of formal proof universally known to mathematicians (because of the pervasive role in those proofs of these Greek letters) as the 'epsilon-delta' method.[50] The parable is routinely told in history books and textbooks, with some (such as historian of mathematics Judith Grabiner) viewing Cauchy's methods as the most important innovation in the

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[45] Nicolas Bourbaki, *Elements of Mathematics: Theory of Sets*, English trans. of *Éléments de Mathématique, Théorie des Ensembles*, (Berlin: Springer, 1968, repr. 2004), p. 12.
[46] Lakatos, *Proofs and Refutations*, p. 52.
[47] Simon Schaffer, 'How Disciplines Look', in *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences*, ed. by Andrew Barry and Georgina Born (New York: Routledge, 2013), pp. 57-82 (p. 57).
[48] Schaffer, 'How Disciplines Look', p. 57.
[49] Lorraine Daston, 'The Moral Economy of Science', p. 4.
[50] See e.g. Judith V. Grabiner, 'Who Gave You the Epsilon? Cauchy and the Origins of Rigorous Calculus', *American Mathematical Monthly* 90. 3 (1983), 185-194. Epsilon-delta proof sounds as if it is a mathematical technicality, but it is more than that. One former mathematics student told me that in 1968 (at the high watermark of Bourbaki's influence on mathematics teaching), learning how to do epsilon-delta proofs marked the student's transition from informal high-school calculus to university education in formal, pure mathematics.

techniques of rigorous proof since Euclid.[51] The 'Translator's Preface' to the 2009 English translation of the *Cours d'analyse* opens: 'Modern mathematics strives to be rigorous. Ancient Greek geometers had similar goals, to prove absolute truths by using perfect deductive logic starting from incontrovertible premises'.[52] Cauchy's textbook is described as:

> one of the most influential mathematics books ever written. Not only did Cauchy provide a workable definition of limits and a means to make them the basis of a rigorous theory of calculus, but also he revitalized the idea that all mathematics could be set on such rigorous foundations. Today, the quality of a work of mathematics is judged in part on the quality of its rigor; this standard is largely due to the transformation brought about by Cauchy and the *Cours d'analyse*.[53]

In their *Elements of the History of Mathematics*, Bourbaki write: 'the mathematicians of the beginning of the XIXth century, tired of this formalism without restraint and without bases, brought Analysis back into the paths of rigour'.[54] Bourbaki refer, in particular, to Gauss and to Cauchy. Bourbaki quote Gauss's 1812 memoir, in which he expresses his desire to conduct his work '*in all rigour, and done to satisfy those whose preferences go to the rigorous methods of the ancient geometers*'. Yet, Bourbaki write, it was Cauchy in his *Cours d'analyse* who established the first principles of calculus using 'correct methods'.[55]

The story of Cauchy and the invention of modern rigour is, indeed, moral history or parable rather than factual history. In 'Ten Misconceptions from the History of Analysis and Their Debunking', Błaszcyzk, Katz and Sherry marshal the evidence to refute claims that 'Cauchy took first steps toward replacing infinitesimals by rigor' and gave a 'modern' – i.e. an 'epsilontic' – definition of continuity'.[56] Indeed, Błaszcyzk et al argue not only that the received interpretation of Cauchy's contribution to analysis is anachronistic, but that the history of mathematics has been systematically distorted by a dominant 'ideology of ontological minimalism': in accordance with this ideology, the history of analysis has been reimagined 'as a pre-ordained march toward the radiant future of Weierstrassian epsilontics'.[57]

The ideology of ontological minimalism manifests as matterphobia, a fear of dirt, pollution and infection, of 'matter out of place'.[58] Georg Cantor, for example, described infinitesimals as a

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[51] Judith Grabiner, *The Origins of Cauchy's Rigorous Calculus* (Cambridge MA: MIT Press, 1981)
[52] Robert E. Bradley and C. Edward Sandifer, 'Translator's Preface', *Cauchy's Cours d'analyse: An Annotated Translation* (Dordrecht: Springer, 2009), pp. vii-xv (p. vii).
[53] Bradley and Sandifer, 'Translator's Preface', *Cauchy's Cours d'analyse*, p. vii.
[54] Nicolas Bourbaki, *Elements of the History of Mathematics*, trans. by John Meldrum (Berlin: Springer, 1999), p. 201.
[55] Bourbaki, *Elements of the History of Mathematics*, p. 153.
[56] Piotr Błaszcyzk, Mikhail G. Katz and David Sherry, 'Ten Misconceptions from the History of Analysis and their Debunking', *Foundations of Science* 18.1 (2013), 43-74 (p. 44).
[57] Błaszcyzk et al, 'Ten Misconceptions', p. 43.
[58] As in Mary Douglas's anthropology of dirt – 'if uncleanness is matter out of place, we must approach it through order. Uncleanness or dirt is that which must not be included if a pattern is to be maintained. To recognise this is the

'Cholera-Bacillus' infecting mathematics.[59] Cauchy's *Cours d'analyse* did deploy the rhetoric of purity and danger, but his matterphobia was not directed at infinitesimals. Rather, Cauchy sought to reinforce the boundaries of analysis by enforcing a strict, even ontological, separation between the domain of mathematics and the domains of empirical, political and social reality.

The image of Cauchy's textbook as the source, foundation and emblem of a newly rigorous discipline, modern analysis, was in fact 'first nourished by Cauchy himself', Umberto Bottazzini writes.[60] As a textbook, the *Cours d'analyse* was a failure. Cauchy joined the faculty of the École Polytechnique in 1815, following the Bourbon regime's return to power. The curriculum of the École Polytechnique required that the teacher cover 'algebraic analysis' before teaching differential and integral calculus.[61] Cauchy's textbook is based on that course: its full title is *Cours d'Analyse de L'École Royale Polytechnique I.er Partie. Analyse Algébrique (1821*). Cauchy intended to write a second part, but a year after the first part was published the *École Polytechnique* changed curriculum, rendering Cauchy's textbook obsolete. Therefore, Bottazzini considers that 'more than a textbook, Cauchy's *Cours d'analyse* apparently served as the *manifesto* for a new attitude in research. For some thirty years Cauchy himself hardly missed an opportunity to refer to it in his papers, thus turning his *Cours* into the *manifesto* for a new image of rigour in mathematics'.[62]

Why, however, treat an 1821 analysis textbook as a 'manifesto' in the first place? What are the conditions for belonging to the genre of the manifesto? Michael J. Barany argues that it is specifically Cauchy's Introduction to the *Cours d'analyse* that ought to be read as a manifesto. Indeed, if considered as a manifesto, it 'becomes a new sort of emblem – not of the dawn of modern mathematical rigor, but of the specific rhetorical and philosophical negotiation such a revolution entails'.[63]

Membership of any genre is assessed not by reference to a definite, fixed set of necessary and sufficient properties: rather, recognising members of a genre involves 'polythetic' classification. [64] Genres are kinships, composed of chains of intricate, sporadic 'family

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first step towards insight into pollution' – in *Purity and Danger: An Analysis of Concepts of Pollution and Taboo* (London: Routledge, 1966), p. 41.

[59] Georg Cantor, Letter to Giulio Vivanti, 13 Dec 1893, transcribed in Herbert Meschkowski, 'Aus den Briefbüchern Georg Cantors', *Archive for History of Exact Sciences* 2.6 (1965), 503-519 (p. 505).

[60] Umberto Bottazzini, 'From Paris to Berlin: Contrasting Images of Nineteenth-Century Mathematics', in *Changing Images in Mathematics: From the French Revolution to the New Millennium*, ed. by Umberto Bottazzini and Amy Dahan Dalmedico (London: Routledge, 2001), pp. 31-49 (p. 34).

[61] I am drawing here on Jesper Lützen's 'The Foundation of Analysis in the 19th Century', in *A History of Analysis*, ed. by Hans Niels Janke (Providence, RI: American Mathematical Society, 2003), pp. 155-197 (pp. 160-173).

[62] Bottazzini, 'From Paris to Berlin: Contrasting Images of Nineteenth-Century Mathematics', p. 34.

[63] Michael J. Barany, 'God, King and Geometry: Revisiting the Introduction to Cauchy's *Cours d'analyse*', *Historia Mathematica* 38 (2011), 368-388 (p. 369).

[64] Rodney Needham's work on polythetic classification in anthropology draws on Wittgenstein's 'family resemblances' and the classifications of biologists. Needham's polythetic series show how such chains of resemblance can evolve: in the absence of a set of attributes that its members must all have in common, a polythetic class may develop as a chain or sequence of linked attributes: e.g. three members of class P have the attributes

resemblances'. In literary critical taxonomies, the manifesto has wandered between many families. Galia Yanoshevsky argues that the manifesto's blurred boundaries have made it a particularly appealing epistemic object for literary critics. She charts the eclectic classificatory methods that were used to construct the genre of the manifesto and the ways in which the manifesto's domain has been extended by retrospective reclassification and by the identification of manifesto-like qualities that transcend generic boundaries.[65] The manifesto has been classified, for example, according to its tone as a type of polemical discourse and grouped with pamphlets and satire; it has been defined in terms of its association with crisis and rupture and grouped with other forms of future writing, such as utopias and prophetic texts; it has been classified according to its programmatic function, and grouped with prefaces and other critical texts that communicate the ideas of new literary movements; and it has been understood as a performative, public speech act, and associated with other functional discursive practices, such as advertising and propaganda. In turn, Yanoshevsky points out, the manifesto has gathered a wide corpus of texts into its own polythetic class: prefaces, declarations, petitions, pamphlets, essays, poems and works of performances art have been recognized for their manifesto-like characteristics and classified or reclassified as manifestos in anthologies and works of literary criticism.[66]

Both the introduction or preface and the manifesto often involve boundary work, negotiate with authority and offer instructions to the reader: how to read the text; how to behave after reading the text. Indeed, Genette included the hybrid form of the 'preface-manifesto' in his typology of the paratext. The paratext is a '*threshold*' space – 'a zone not only of transition but also of *transaction*: a privileged place of a pragmatics and a strategy, of an influence on the public'.[67] Jean-Marie Gleize adds that the manifesto and the preface are both prescriptive enunciations. The prescriptive is a discourse of legitimation: of justificatory gestures, whether generic or genealogical. Prefaces, Gleize writes, 'like manifestos, are always writing the history of literature – in the mode of a *mythic* tale'.[68] Gleize's argument applies not just to the literary preface. Mathematical prefaces, too, tell mythic tales. John Dee's 'Mathematicall Praeface' to the first English translation of Euclid's *Elements* is one of the most famous and most extraordinary pieces of writing in the history of mathematics. The translation was to serve mathematics in the vernacular: introducing Euclidean geometry to new audiences. Dee sought to present Euclid's

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abc/cbd/def; all may be classed as P, but the first and last terms in the sequence share no attributes. See Rodney Needham, 'Polythetic Classification', in *Against the Tranquility of Axioms* (Berkeley, CA: University of California Press, 1983), pp. 36-65.

[65] Galia Yanoshevsky, 'Three Decades of Writing on Manifesto: The Making of a Genre', *Poetics Today* 30.2 (2009), 257-286.

[66] See Yanoshevsky's 'Three Decades of Writing on Manifesto' for more such examples.

[67] Gérard Genette, *Paratexts: Thresholds of Interpretation*, trans. by Jane E. Lewin (Cambridge: Cambridge University Press, 1997), p. 2.

[68] Jean-Marie Gleize, 'Manifestes, préfaces: sur quelques aspects du prescriptif', *Littérature* 39 (1980), 12-16 (p. 16). See also *Prefaces and Literary Manifestoes / Préfaces et manifestes littéraire*, ed. by E. D. Blodgett and A. G. Purdy and S. Tötösy de Zepetnek (Edmonton: University of Alberta, 1990).

geometry as transcendent: to disassociate it from the pragmatic, mercantile arts of measurement. Dee objected to the very name 'geometry' – 'a name to base and scant, for a Science of such dignitie and ampleness' – and claimed that the name carries with it the 'perpetuall memorye' of its origin: commemorating the violent history of popular land measurement out of which geometry (a force for social order) emerged. This murky origin myth was an argument for renaming geometry '*Megethologia*':

> But, well you may perceiue by Euclides Elementes, that more ample is our Science, then to measure Plaines: and nothyng lesse therin is tought (of purpose) then how to measure Land. An other name, therfore, must nedes be had, for our Mathematicall Science of Magnitudes: which regardeth neither clod, nor turff: neither hill, nor dale: neither earth nor heauen: but is absolute *Megethologia*: not creping on ground, and dasseling the eye, with pole perche, rod or lyne: but liftyng the hart aboue the heauens, by inuisible lines, and immortall beames meteth with the reflexions, of the light incomprehensible: and so procureth Ioye, and perfection vnspeakable.[69]

Euclid's geometry ought not to be muddied and muddled with land measurement. Dee sought to bestow upon it a new name, a new origin myth, and a new state of epistemic grace. As Denise Albanese argues:

> While Dee's mythic anecdote codes the origins of geometry in material and pragmatic terms, the renaming effaces that history, and rescues geometry from being mired in the contingent, the practical, the artisanal – a visionary history, as it were, most visible to the practitioner working at a remove from the ground of the social.[70]

Dee's 'Mathematicall Praeface' used myth, parable, classical quotation and myriad other tactics to convey his vision of geometry's epistemic virtues.

In turn, Cauchy's introduction to the *Cours d'analyse* used geometry's symbolic value – its perceived dematerialised nature; its epistemic virtues; its distance from social life and practical application – to rescue another mathematical discipline, analysis, from being mired in the physical, the practical and the algebraic. In an oft-quoted passage of the introduction, Cauchy distanced himself from his predecessors, from their pragmatic philosophy of analysis, their imprecision and looseness of expression:

> As for the methods, I have sought to give them all the rigor which one demands from geometry, so that one need never rely on arguments drawn from the generality of algebra. Arguments of this kind, although they are commonly accepted, especially in the passage from convergent to divergent series, and from real quantities to imaginary expressions, may be considered, it seems to me, only as examples serving to introduce the truth some

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[69] John Dee, 'The Mathematicall Praeface' to *Elements of Geometrie of Euclid of Megara*, trans. by H. Billingsley (London: Iohn Daye, 1570).
[70] Denise Albanese, 'Mathematics as Social Formation: Mapping the Early Modern Universal', in *The Culture of Capital* ed. by Henry S. Turner (New York: Routledge, 2002), pp. 255-273 (p. 267).

> of the time, but which are not in harmony with the exactness so vaunted in the mathematical sciences.[71]

Cauchy invoked geometry's accrued cultural meanings to sanction his programme. At the same time, he tried to divest his work of algebra's accrued cultural meanings: to distance analysis from the image of algebra and its brute utility. Though on the surface his textbook is 'thoroughly algebraical' in its mathematics – as is its reputation – Barany notes that geometrical intuition encroaches: 'Cauchy's introduction sought to replace a philosophical algebraism with a philosophical geometrism'.[72]

For Cauchy, algebraic arguments, though they perform an occasional useful service (introducing the truth 'some of the time'), are too general and 'tend to grant a limitless scope to algebraic formulas, whereas, in reality, most of those formulas are valid only under certain conditions or for certain values of the quantities involved'.[73] Barany points out that Cauchy's introduction, with its list of faults and necessary restrictions, 'takes the form of a Catholic confession, moving from an accounting of sins to a program for their absolution'.[74] Cauchy, as Barany notes, was a reactionary Catholic and staunch Bourbon royalist.

Cauchy's rules, his strict methods, offered formal algebra a path to redemption. By delimiting the scope of algebraic formulas 'and in establishing precisely the meaning of the notation that I will be using, I will make all uncertainty disappear', he wrote.[75] The eradication of uncertainty required acts of penance: 'in order to remain consistently faithful to these principles, I will have to accept several propositions which may appear to be a bit rigid at first'.[76] Cauchy's restriction of the generality of algebra, his purification of the discipline, was thus rhetorically imbued with a sense of religious discipline.

This act of disciplinary purification was also politically motivated. The Bourbon regime wanted mathematics to be done in isolation.[77] Cauchy's assertion of mathematics' disciplinary autonomy was a conservative response to the principle of universal reason: to the reformist, revolutionary attempts to apply mathematics to social and political life. First in France, then in other European contexts such as Naples, the two sides of the hostile debate between geometrical and algebraic schools of analysis correlated politically with, respectively, Bourbon traditionalism and the Jacobin revolutionary movement. Against the conservative, antimodern ideal of a pure mathematics held by the geometers, the analytic, algebraic school proposed new textbooks that

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[71] *Cauchy's Cours d'analyse: An Annotated Translation*, trans. by Robert E. Bradley and C. Edward Sandifer (Dordrecht: Springer, 2009), pp. 1-2.
[72] Michael J. Barany, 'God, King and Geometry', p. 373.
[73] *Cauchy's Cours d'analyse: An Annotated Translation*, p. 2.
[74] Michael J. Barany, 'God, King and Geometry', p. 375.
[75] *Cauchy's Cours d'analyse: An Annotated Translation*, p. 2.
[76] *Cauchy's Cours d'analyse: An Annotated Translation*, p. 2.
[77] See, for example, Ivor-Grattan Guinness, 'The "Ecole Polytechnique", 1794-1850: Differences over Educational Purpose and Teaching Practice', *The American Mathematical Monthly*, 112.3 (2005), 233-250 (p. 237).

presented mathematics as a universal, and universally applicable, language: for revolutionary mathematicians such as Lazare Carnot (and his equivalents in, for example, Naples) even the human sciences and political life could be mathematised and reach, as Massimo Mazzotti puts it 'the degree of certainty proper to mathematics […] the existing social and political order could be criticized as "unscientific" and […] could legitimately be rebuilt on the basis of the new theorems of the sciences of politics and economics'.[78] Mathematics, in other words, was the universal rational language in which Europe could rewrite itself.

In contrast to these entanglements, Cauchy enforced a strict separation between the plane of pure mathematics and the domain of its potential applications. Mathematics, history and ethics are divided into distinct orders of reality:

> We should thus believe that there are truths other than algebraic truths, and realities other than tangible objects. Let us cultivate with ardor the mathematical sciences, without wishing to extend them beyond their domain; and let us not imagine that we are able to attack history with formulas, nor to make moral judgments with theorems of algebra or integral calculus.[79]

To breach these boundaries would be an act of revolutionary hubris.

Kairos and Crisis

'Brouwer – that is the Revolution!' Hermann Weyl declared in his 1921 manifesto 'On the New Foundational Crisis of Mathematics'.[80] Here, the genre of the manifesto is no longer appended to that of the textbook. Weyl's manifesto opens with a forceful, synoptic vision of the state of mathematics imagined as a politically unstable nation state: 'The antinomies of set theory', he begins, 'are usually treated as border conflicts concerning only the most remote provinces of the mathematical realm, and in no way endangering the inner soundness and security of the realm'.[81] The mathematician's sense of security is, however, merely a state of false consciousness, one

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[78] Massimo Mazzotti, 'The Geometers of God: Mathematics and Reaction in the Kingdom of Naples', *Isis*, 89.4 (1998), 674-701 (pp. 689-690).

[79] *Cauchy's Cours d'analyse: An Annotated Translation*, p. 3.

[80] Hermann Weyl, 'Über die neue Grundlagenkrise der Mathematik', *Mathematische Zeitschrift* 10, 1921, trans., by Benito Müller as 'On the New Foundational Crisis of Mathematics', in *From Brouwer to Hilbert: The Debate on the Foundations of Mathematics in the 1920s*, ed. by Paulo Mancosu (Oxford: Oxford University Press, 1998), 86-119 (p. 99). My interpretation of Weyl's manifesto is indebted to Dirk van Dalen's work on the history and philosophy of intuitionism. I will refer to and quote from van Dalen often in this section. His monumental biography of L. E. J. Brouwer, the founder of intuitionism, contains a very helpful account of the personal relationship between Brouwer and Weyl and gives elegant, precise and non-technical explanations of the key mathematical concepts invoked in Weyl's manifesto (ideas about the continuum, real numbers, choice sequences and continuous functions, for example). See Dirk van Dalen, *Mystic, Geometer, and Intuitionist: The Life of L. E. J Brouwer*, 2 vols (Oxford: Clarendon Press, 1999/2005). Indeed, though the Brouwer biography covers the same material in greater depth, van Dalen's article on 'Hermann Weyl's Intuitionistic Mathematics' is recommended to the reader primarily interested in Weyl and his manifesto: Dirk van Dalen, 'Hermann Weyl's Intuitionistic Mathematics', *The Bulletin of Symbolic Logic*, 1.2 (1995), pp. 145-169.

[81] Weyl, 'On the New Foundational Crisis of Mathematics', p. 86.

reinforced by the propaganda of 'authoritative sources'. The paradoxes of set theory are in fact the harbingers of a coming crisis. The border conflicts of set theory 'reveal what is hidden by the outwardly shining and frictionless operation in the center: namely, the inner groundlessness of the foundations upon which rests the superstructure of the realm'.[82] So far, the struggle 'to eradicate the evil' has fallen to Weyl and Brouwer alone. Weyl's text is an unveiling of the threat facing mathematics and an exhortation to a new way of thinking about and doing mathematics. The opening vignette is followed by a critical survey of the state of analysis, in which its current dispute is represented as the recurrence of an ancient and fundamental split in the philosophy of mathematics: the division between two ways of understanding the continuum. The problem of the continuum is, as Dirk van Dalen reminds us, the problem of 'the nature of the real numbers'.[83] Weyl juxtaposes the 'atomistic' conception of the continuum – in which, as van Dalen puts it 'the continuum is made up of individual real numbers which can be sharply distinguished'[84] – with Brouwer's version of the continuum: 'which', Weyl explained, 'although containing individual real numbers, does not dissolve into a set of real numbers as finished beings [*fertig seiende*]; we rather have a *medium of free Becoming*'.[85] Weyl then subjects the weak points of classical mathematics to an 'intuitionist' critique: he shows, in particular, the failures of the logical principle of the excluded middle. In keeping with the – albeit loose – structural formula of the manifesto as a genre, Weyl's diagnostic section is followed by a more prescriptive section that announces the new programme to re-ground mathematics according to intuitionist principles. Weyl's 'New Crisis' polemic was an attempt to compel mathematicians to face up to the impending collapse of their discipline's foundations and to make them believe, as Weyl did at the time, that only an intuitionist revolution could save mathematics from the threat of dissolution.

Weyl sent a copy of the manuscript of 'Über die neue Grundlagenkrise der Mathematik' to Brouwer on 6 May 1920 with the qualification that: 'It should not be viewed as a scientific publication, but as a propaganda pamphlet, thence the size. I hope that you will find it suitable for this purpose, and moreover suited to rouse the sleepers; that is why I want to publish it'.[86] Indeed, Weyl poured the all of the anxieties of the Weimar Republic into his tropological account of the threat facing mathematics. He compared the doctrines of the formalist mathematicians to German monetary policy: the suspension of the gold standard and the mass printing of increasingly worthless bank notes. The abstract, existential statements made by contemporary mathematicians are, he writes, like 'paper money' — like the Papiermark banknotes that were

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[82] Weyl, 'On the New Foundational Crisis of Mathematics', p. 86.
[83] Dirk van Dalen, *Mystic, Geometer, and Intuitionist: The Life of L. E. J. Brouwer,* 2 vols (Oxford: Clarendon Press, 1999/2005), *Volume 1: The Dawning Revolution* (Oxford: Clarendon Press, 1999, repr. with corrections 2002), p. 323.
[84] van Dalen, *Mystic, Geometer, and Intuitionist*, vol. 1., p. 321-22.
[85] Weyl, 'On the New Foundational Crisis of Mathematics', p. 94.
[86] Weyl to Brouwer, 6 May 1920, in *The Selected Correspondence of L. E. J. Brouwer*, ed. by Dirk van Dalen and others, trans. by J. W. Nienhuys and others (London: Springer-Verlag, 2011), pp. 216-7 (p. 216).

printed in increasingly large quantities and denominations as their value fell. Mathematical statements are 'worthless', in Weyl's opinion, unless they can be cashed in for actual judgements: unless they can be tested and redeemed in the construction of successful proofs. Contemporary mathematics thus 'appears as a monstrous "paper economy."'[87] Analysis must be given new foundations – a new gold standard – it must be made to conform to the 'the intuitive character of the continuum', and made to hold firm to its dependency on the nature of the natural numbers.

Hilbert answered Weyl's call for a 'revolution' in mathematics with highly charged political rhetoric of his own. Hilbert described Weyl and Brouwer's programme as a just another 'attempted coup' (*Putsch*) and declared: 'now that the power of the state has been armed and strengthened by Frege, Dedekind, and Cantor, this coup is doomed to fail'.[88] Such rhetoric, as Dirk van Dalen points out, was neither abstract nor playful. The language of revolutions, border conflicts and coups invoked the political reality of the German readers of the early 1920s: the *Kapp Putsch* of March 1920 and the border troubles in the Baltic, for example.[89] For the modern, post-Kuhnian reader, the metaphor of a mathematical 'revolution' carries additional connotations that were unavailable to Weyl and to the readers of the 1920s. Uses of the term revolution in relation to science and mathematics are scattered throughout history from the eighteenth century onwards: in the *Encyclopédie* of Diderot and d'Alembert; in Kant's *Critique of Pure Reason*; in Butterfield's construction of '*the* Scientific Revolution'.[90] Yet, such is the allusive power of Thomas Kuhn's *The Structure of Scientific Revolutions* that talk of revolutions in science is now habitual, conventional, worn-in or even worn-out and, inescapably, doubly haunted by Kuhn's image of science and by our image of Kuhn. Along with paradigms, revolutions were part of the vocabulary that escaped the confines of Kuhn's book and seeped into academic discourse and public culture. That vocabulary dragged with it the contours of Kuhn's cyclic model in which 'normal science' is pursued according to an established paradigm (paradigm being both an exemplary model and a socially shared disciplinary framework) until the emergence of anomalies leads to a crisis in the research community and then to a revolution: the old paradigm shatters, and existing knowledge, concepts and categories are reorganised and eventually solidified into a new paradigm, which will, in turn, collapse as the cycle begins anew. Weyl's manifesto thus offers a particular temptation to anachronism, because the 'New Crisis' seems to offer its own

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[87] Weyl, 'On the New Foundational Crisis of Mathematics', p. 98.

[88] David Hilbert, 'The New Grounding of Mathematics: First Report', in *From Brouwer to Hilbert: The Debate on the Foundations of Mathematics in the 1920s*, ed. by Paulo Mancosu (Oxford: Oxford University Press, 1998), pp. 198-214 (p. 200)

[89] Dirk van Dalen, *Mystic, Geometer, and Intuitionist*, vol. 1, p. 323. Dennis E. Hesseling also gives a contextual account of the use of political metaphors in the foundational debate in *Gnomes in the Fog: The Reception of Brouwer's Intuitionism in the 1920s* (Basel: Birkhäuser, 2003).

[90] Many more examples are given in I. Bernard Cohen's *Revolution in Science* (Cambridge, MA: Belknap Press of Harvard University Press, 1985). Steven Shapin's *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), meanwhile, opens with the justifiably famous first line: 'There was no such thing as the Scientific Revolution, and this is a book about it'.

historiographic map: to advocate for a revolution in Kuhnian terms and thus to contain the terminology and analytic categories through which its history might be written.

Weyl's political, military and economic metaphors mobilised the exigencies of the moment. Crisis was his rhetorical opening: his *kairos*. Kairos is both a spatial concept and a temporal concept: both a kind of place and a kind of time. In the *Iliad*, 'kairois' named a vulnerable place on the body: an opening – 'a spot most mortal' – such as that at the collarbone, 'between neck and chest', where a warrior might aim their final blow.[91] The Latin version of kairos, *occasio*, is, Cicero writes, 'of the same genus as *time*', though it 'belongs to a different species'.[92] Time is defined by its ability to be measured, while '*occasion* is a period of time offering a convenient opportunity for doing or not doing something': it adds a qualitative sense of possibility or potential to the fixity of temporal periods.[93] The temporal and the spatial intertwine in E. C. White's definition of *kairos* as 'a passing instant when an opening appears which must be driven through with force if success is to be achieved'.[94] In the work of ancient rhetoricians, kairos often referred both to a skill (the ability to recognise and seize the opportune moment; a sensitivity to occasion) and to the conditions of possibility for that skill: the constraints of 'kairoi', of 'the times'.[95] Kairos is a form of qualitative time defined by a thickening of possibility — but it also binds possibility to temporality. The rhetorician, as described by Isocrates and by Plato, must synchronise themselves with kairotic time: with the 'opportune' moment. Yet, in order to discern such moments of possibility, the rhetorician must also inhabit a kind of polytemporality: standing outside of any one time scale or temporal idiom. Kairos names, too, the time of revolutions and of Gods: interstitial ruptures in ordinary, chronological time (*chronos*); moments wrenched from linearity and filled with Walter Benjamin's 'presence of the now'.[96]

Weyl's 'New Crisis' manifesto is saturated with different temporal idioms: with kairos, with the 'nowness' of the avant-garde manifesto, with Weyl's fidelity to Husserl's phenomenological time, with his depiction of mathematical history as cyclical and prophetic, and with his vision of the intuitionist redemption of mathematics. Through his political rhetoric and his deployment of history as prophesy, Weyl linked his manifesto to the genre's political history

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[91] *Iliad 8.325*. Quotes in English are from *The Iliad of Homer*, trans. by Richmond Lattimore (Chicago: University of Chicago Press, 1951), Book Eight, lines 325-326, p. 191.

[92] Cicero, Marcus Tullius, *De Inventione: De Optimo Genere Oratorum*, trans. by H. M. Hubbell (London: Heinemann, 1949), I. 40.

[93] Cicero, *De Inventione*, I. 40.

[94] Eric C. White, *Kaironomia: On the Will-to-Invent*, (Ithaca, NY: Cornell University Press 1987), p. 13.

[95] For Isocrates and his teacher, Gorgias, kairos was a principle of situational awareness that ought to guide rhetorical invention, innovation and improvisation. Isocrates insisted that 'oratory is good only if it has the qualities of fitness for the occasion, propriety of style, and originality of treatment' (Isocrates, *Isocrates* Vol. II, trans. by George Norlin, Loeb Classical Library 229 (Cambridge, MA: Harvard University Press, 1929), p. 171). Socrates in Plato's *Phaedrus,* meanwhile, argues that the rhetorician must learn to differentiate between various types of person, learn which forms of speech work best on which sorts of person, and be able to distinguish timeliness from untimeliness. The art of persuasion lies in bringing rhetorical form into timely correspondence with a typology of character.

[96] Walter Benjamin, 'Theses on the Philosophy of History', in *Illuminations: Essays and Reflections*, ed. by Hannah Arendt, trans. by Harry Zohn (New York: Schocken, 2007), pp. 253-64 (p. 261).

and, in particular, to the canonical model of *The Communist Manifesto*. The necessity of Weyl's revolution is predicated not on the history of class struggle, but on the history of a different struggle. The problem of the continuum, of the nature of the natural numbers, is rooted, for Weyl, in the ancient conflict between being and becoming. Dedekind, Cantor and Hilbert are the modern philosophers of rigid being, representing the 'atomistic' conception of the continuum, while Brouwer stands on the side of flux: his continuum is an unsplittable '*medium of free Becoming*'. The arithmetisation of analysis shattered the continuum into discrete points (albeit infinitely many of them), thus creating a rift between the ordinary, intuitive idea of a continuum and the mathematical construction of the continuum. Brouwer has constructed, in Weyl's view, a mathematical continuum that retains the intuitive sense of continuousness.

Weyl's history of this struggle is also personal history: a conversion narrative. In his own work on the continuum, Weyl had 'tried to find solid ground in the impending dissolution of the State of analysis […] without forsaking the order upon which it is founded', but found that '*this order is in itself untenable*'.[97] The fracture in the foundations of analysis is exposed by the struggle between the atomists and the intuitionists over the nature of the continuum: 'It would have been wonderful had the old dispute led to the conclusion that the atomistic conception as well as the continuous one can be carried through. Instead, the latter triumphs for good over the former'.[98] Confronted by a sense of historical necessity, Weyl renounces his old allegiances — to Hilbert, in particular — and his own programme for analysis, which he had laid out in his 1918 monograph *Das Kontinuum*, in the name of a new faith: 'So now I abandon my own attempt and join Brouwer'.[99] The final entreaty that Weyl makes to the 'sleepers' is based in emotion: it is an appeal not to logos but to ethos. His post-revolutionary mathematics is a vague utopia in which 'everyone' – even the formalists – 'will again feel how truly the new analysis conforms to the intuitive character of the continuum'. Indeed, 'for whoever has maintained any sense for intuitively given facts in the abstract formalism of mathematics', Brouwer's new world 'must have the effect of a deliverance from a nightmare'.[100]

Weyl sought to redraw the boundaries of mathematics: to restore the discipline's lost connection to phenomenal experience, and thus to reject the ideal of a fully autonomous mathematics. At the same time, he denounced the pollution of mathematics by unstable and unreal metaphysical notions. Under the intuitionist regime, certain mathematical concepts — sets of functions and sets of sets, for example — 'shall be wholly banished' and there will be 'no place' in the new analysis 'for a general set theory, as little as there is room for general statements

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97 Weyl, 'New Crisis', p. 98.
98 Weyl, 'New Crisis', p. 99.
99 Weyl, 'New Crisis', p. 98.
100 Weyl, 'New Crisis', p. 117.

about functions'.[101] In defence of such restrictive measures, Weyl echoes Cauchy's theological rhetoric of hubris, discipline and punishment:

> The new conception, as one can see, brings with it far-reaching restrictions with respect to the generality that enthusiastically leads into vagueness and that we have become used to through traditional analysis. We must learn again to be modest. With the intention to storm the heavens we merely piled up mists upon mists, unable to support anyone who was seriously trying to stand on them.[102]

Weyl's phrase, 'storm the heavens', echoes, of course, Karl Marx's characterisation of the élan of the Paris Commune. Despite proclaiming the revolutionary nature of his constructivist programme, Weyl situates that programme within his discipline's established moral economy. By invoking the 'generality of analysis' and 'general statements about functions', Weyl is drawing a parallel with an emblematic episode in the history of analysis, a canonical parable: the rigorization of the calculus. This disciplinary self-reflexivity links Weyl's manifesto to prior foundational retrenchments and ritual acts of purification. Weyl's manifesto might denounce the current state of mathematics and announce a rupture with the old order, with the mathematical mainstream, but this vivid metaphorical layer of rupture, revolution and crisis coexists with another figural order: with a layer of allusion and diachronic resonance that implies disciplinary continuity.

Weyl's proposals still sounded, to David Hilbert, like a wild, paranoid reformation theology – 'he is seeing ghosts', Hilbert wrote.[103] In his response to Weyl's manifesto, Hilbert argued that Weyl and Brouwer 'seek to ground mathematics by throwing overboard all phenomena that make them uneasy and by establishing a dictatorship of prohibitions *à la* Kronecker'.[104] Indeed, as Adam Phillips points out in his review of David Trotter's *Paranoid Modernism*, much of the writing of the modernist period 'has a manifesto-like quality, and the manifesto — the address to the enemy — is the paranoid genre par excellence'.[105] Leopold Kronecker, in Hilbert's portrait of him, is 'the classical prohibiting dictator'.[106] Citing Kronecker's slogan 'God created the integer, everything else is the work of man', Hilbert described Kronecker as a man who 'despised […] everything that did not seem to him to be integer' and consequently embarked on a failed, myopic mission to rid mathematics of irrational numbers, of those numbers that are neither integers nor expressible as ratios of integers.[107] Hilbert thus sought to discredit Weyl and Brouwer: to paint them as fanatics who would fail as Kronecker had failed. Yet, by speaking with and on behalf of 'the power of the state', Hilbert's own text, 'The New

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[101] Weyl, 'New Crisis', p. 109.
[102] Weyl, 'New Crisis', p. 109.
[103] David Hilbert, 'The New Grounding of Mathematics: First Report', in *From Brouwer to Hilbert*, ed. by Mancuso, pp. 198-214 (p. 200).
[104] Hilbert, 'The New Grounding of Mathematics', p. 200.
[105] Adam Phillips, 'Hauteur', *London Review of Books* Vol. 25. No. 10 (22 May 2003).
[106] Hilbert, 'The New Grounding of Mathematics', p. 201.
[107] Hilbert, 'The New Grounding of Mathematics', p. 201.

Grounding of Mathematics', is a kind of paranoid manifesto in its own right, in the old meaning of 'manifesto' as a proclamation of sovereign will.



Figure 1 – ***Märzgefallenen-Denkmal***, 'Monument to the March Dead', designed by Walter Gropius, Weimar cemetery, 1920-1922 (destroyed by the NSDAP in 1933 and reconstructed in 1946). Commissioned by the Weimar Gewerkschaftskartell (Trade Union Federation), the monument commemorates the workers who were killed in the aftermath of the Kapp Putsch.

A few years later, when faced with the consequences of the 'war of the factions', Weyl retreated from his revolutionary posturing and sought a truce: a middle way between Brouwer and Hilbert. The 'war' had led to sacrifices on both sides. In order to restore meaning to mathematics, Brouwer banished much of set theory and classical mathematical analysis: 'With Brouwer, mathematics gains the highest intuitive clarity; his doctrine is idealism in mathematics thought to the end. But, full of pain, the mathematician sees the greatest part of his towering theories dissolve into fog'.[108] In order to save those towering theories of classical mathematics – and to preserve its consistency and reputation – Hilbert, in Weyl's opinion, had sacrificed the meaning of mathematics: emptying it of content, and severing its connection to phenomenal knowledge. As a result of Hilbert's programme: 'Mathematics is no longer knowledge but a *game of formulae*, ruled by certain conventions […] comparable to the game of chess'.[109] As such, Weyl

[108] Hermann Weyl, 'The Current Epistemological Situation in Mathematics' in *From Brouwer to Hilbert: The Debate on the Foundations of Mathematics in the 1920s*, ed. by Paulo Mancuso (Oxford: Oxford University Press, 1998), pp. 123-143 (p. 136).
[109] Weyl, 'The Current Epistemological Situation in Mathematics', p. 136.

writes, 'if mathematics is to remain a serious cultural concern then some *sense* must be attached to Hilbert's game of formulae'.[110]

Looking back on his manifesto more than thirty years after it was published, Weyl could no longer see himself in it. A single-volume selected edition of his work was planned in honour of Weyl's seventieth birthday. For this *Selecta Hermann Weyl*, Weyl wrote an addendum to 'Über die neue Grundlagenkrise der Mathematik', dated shortly before his death. In the 'Nachtrag Juni 1955', Weyl distanced himself from his manifesto and the intuitionist lectures on which the manifesto was based:

> Only with some hesitation do I acknowledge these lectures, whose style is in places quite bombastic, reflecting the mood of an excited time – the time immediately after the First World War. Shortly after I held these lectures preaching Intuitionism, Hilbert came out with his formalist 'New Grounding of Mathematics'.[111]

Weyl's 'Nachtrag' falls into Genette's category of the 'delayed – or preposthumous, or testamentary' paratext. The delayed paratext is often autobiographical: a retrospective project of justification or disavowal that both seeks and denies control.[112] In the unfolding of time, the manifesto's moment is folded back into a linear narrative. Its rhetoric is enclosed in and determined by its historicity. In his 'New Crisis' manifesto, Weyl's metaphors gathered their rhetorical force both from disciplinary memory and from the wider culture in which his manifesto was embedded. In its strident tone, Weyl's manifesto resembles the manifestos of his contemporaries in literature and the arts, many of whom used mathematical analogies to emphasise, variously, their modernity, originality and autonomy.

Geometrical Sensibilities

Wyndham Lewis adopted a similar attitude of disavowal in the essays published alongside his reprinted vorticist manifestos: relegating them to history and reading their style as an inevitable product of the cultural dynamics of the period immediately preceding the First World War. Those manifestos used the 'methods of the mob-orator' because they had to: '1914 was not 1939 – if you were a "movement" you were expected to shout. One was surrounded – one was hemmed-in – by mob-orators. To lift his voice, in 1914, was as essential to a *chef de bande*, as it was

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110 Weyl, 'The Current Epistemological Situation in Mathematics', p. 140.

111 'Nur mit einigem Zögern bekenne ich mich zu diesen Vorträgen, deren stellenweise recht bombastischer Stil die Stimmung einer aufgeregten Zeit widerspiegelt – der Zeit unmittelbar nach dem ersten Weltkrieg. Kurz nachdem ich diese den Intuitionismus predigenden Vorträge hielt, trat Hilbert mit seiner formalistischen *Neubegründung der Mathematik* hervor', 'Nachtrag Juni 1955', in Hermann Weyl, *Gesammelte Abhandlungen Band II* (Berlin: Springer, 1968), p. 179.

112 Genette, *Paratexts*, pp. 330-332; pp. 247-251.

in 1915 to a drill-sergeant'.[113] In *Blasting and Bombardiering*, Lewis parodied the hyperbolic tenor of the pre-war manifesto moment:

> *Putsches* took place every month or so. Marinetti for instance, you may have heard of him! It was he who put Mussolini up to fascism. Mussolini admits it. They ran neck and neck for a bit, but Mussolini was the better politician. Well, Marinetti brought off a futurist *Putsch* about this time.
>
> It started in Bond street. I counter-putsched. I assembled in Greek street a determined band of miscellaneous anti-futurists. Mr. Epstein was there: Gaudier Brzeska, T. E. Hulme …[114]

The *Blast* manifestos attacked Marinetti using the genre he had claimed and promoted. *Blast* was a rear-guard action, Puchner argues, using the form of the manifesto to oppose the will to radical, rapid change that manifestoes embody. Puchner also points out that Pound's later 'ABC's' and 'How To' texts circumvent the manifesto by being modelled on another down-market genre: the user's manual or introductory guide.[115]

From the early months of 1939, Lewis looked back on the avant-garde movements of the pre-war years. He surveyed a 'panorama of defeat': a 'stricken field […] strewn with cubes and cones, with fearsome masks with billiard balls for eyes, venomous futurist hat-pins, and bashed-in Catalan guitars'.[116] 'The promise of an intenser discipline, and less impermanent equivalents for our personal experience, was what attracted me', Lewis wrote of the pull of the vorticist, cubist, and expressionist movements.[117] In the delayed paratexts framing Lewis's reprinted pamphlets, manifestos and articles from *Blast* No. 1 (1914) and 2 (1915) and the *Tyro* No 2, Lewis sought to distance himself from his old allies in the vorticist project, and to frame his interest in geometry as an earthly, natural interest. 'I never deserted the concrete for the abstract', he claims:

> To-day I am a *super-naturalist* – so I might call myself: and I wished the reader of these *Notes and Vortices* to see what could be done by burying Euclid deep in the living flesh – that of Mr. Eliot or of Mr. Pound – rather than, at this time of day, displaying the astral geometries of those gentlemen. I am, as an examination of the plates will reveal, never unconscious of those underlying conceptual truths that are inherent in all appearances. But I leave them now where I find them, instead of isolating them in conceptual arabesques.[118]

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[113] Wyndham Lewis, 'The Skeleton in the Cupboard Speaks', in Wyndham Lewis, *Wyndham Lewis, the Artist: From 'Blast' to Burlington House* (London: Laidlaw & Laidlaw, 1939), pp. 65-95 (pp. 83-4).

[114] Wyndham Lewis, *Blasting and Bombardiering* (Berkeley, CA: University of California Press, 1967), p. 36. In fact, even Marx and Engels, the founding fathers of the manifesto, mocked the '*mania for manifestos*' in 'The Great Men of the Exile' (written in May-June 1852), a satiric expose of pseudo-revolutionary leaders.

[115] Martin Puchner, 'The Aftershocks of *Blast*: Manifestos, Satire, and the Rear-Guard of Modernism', in *Bad Modernisms*, ed. by Douglas Mao and Rebecca L. Walkowitz (Durham, NC: Duke University Press, 2006), pp. 44-67.

[116] Wyndham Lewis, 'Super-Nature versus Super-Real', in *Wyndham Lewis, the Artist*: *From 'Blast' to Burlington House* (London: Laidlaw & Laidlaw, 1939), pp. 11-65 (p. 23).

[117] Lewis, 'Super-Nature versus Super-Real', p. 23.

[118] Lewis, 'Super-Nature Versus Super-Real', p. 59.

Lewis rejects the notion that vorticism had sought in geometrical abstraction a refuge from the external world. 'Mr. Herbert Read's explanation of modern "abstractness," of "geometric art," is that it was and is an *escape*', he writes, but Read's explanation is inadequate: the vorticist's geometrical idiom, its sternness and severity, was, in Lewis's opinion, a deliberate, 'professional', technical stance and it was 'in harmony' with its 'material' – with the 'spirit of the machine' and the brutality of the machine age; with 'the hard, the cold, the mechanical and the static'.[119]

Yet, vorticism's ally, T. E. Hulme, had written that: 'The geometrical line is something absolutely distinct from the messiness, the confusion, and the accidental details of existing things'.[120] Where their contemporaries, the Italian futurists, appropriated mathematics in order to embrace the conditions of modernity, T. E. Hulme and Ezra Pound found in mathematics a way of resisting those conditions. Geometry, in particular, appeared to offer an escape from the present, from contingent circumstance, into an atemporal realm of pure form. Against Marinetti's kinetic geometrical imagination, Hulme and Pound defended a geometrical stasis.

In the years before the First World War, Hulme used geometrical metaphors to mount a revolt against the organicism, the muddy romanticism, that he felt had blurred the outlines of thought and experience, like 'a pot of treacle' poured 'over the dinner table'.[121] 'One of the main achievements of the nineteenth century', Hulme writes, 'was the elaboration and universal application of the principle of *continuity*'; this principle spread, 'implicit in the popular conception of evolution', and came to be seen as 'an inevitable constituent of reality itself' and all aspects of reality were assimilated to the organic whole. The urgent task of the present, Hulme wrote, is the 'destruction of this conception', which we 'now absorb […] unconsciously from an environment already soaked in it'. An 'objective view of reality' requires 'the re-establishment of the temper or disposition of mind which can look at a *gap* or chasm without shuddering'.[122]

The chasms, Hulme explained, lay between: '(1) The inorganic world, of mathematical and physical science, (2) the organic world, dealt with by biology, psychology and history, and (3) the world of ethical and religious values'.[123] The mathematical world and the world of values share 'an *absolute* character' – 'the perfection of geometrical figures' – and 'knowledge about them can legitimately be called absolute knowledge'. Life, meanwhile – the 'muddy' middle world – is 'essentially relative' and 'is dealt with by *loose* sciences'.[124] Epistemological ruptures have opened up the chasms between these worlds; we can see the nature of the chasms, Hulme writes, if we consider the movement away from materialism at the end of the nineteenth century. In the

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[119] Lewis, 'The Skeleton in the Cupboard Speaks', pp. 78-82.
[120] T. E. Hulme, 'Modern Art and its Philosophy', in *The Collected Writings of T. E. Hulme*, ed. by Karen Csengeri (Oxford: Clarendon Press, 1994), pp. 268-85 (p. 274).
[121] T. E. Hulme, 'Romanticism and Classicism', in *The Collected Writings of T. E. Hulme*, p. 62.
[122] T. E. Hulme, 'Humanism and the Religious Attitude', in *Speculations: Essays on Humanism and the Philosophy of Art*, ed. by Herbert Read (London: Routledge, 1924, repr. 1987) pp. 1-72 (pp. 3-4).
[123] Hulme, 'Humanism and the Religious Attitude', p. 5.
[124] Hulme, 'Humanism and the Religious Attitude', p. 6.

middle of the nineteenth century, Hulme writes, the predominant popular philosophy had obliterated the divisions between the worlds: 'There was no separating chasm', Hulme writes, 'Vital phenomena were only extremely complicated forms of mechanical change'.[125] Then, in the philosophy of Nietzsche, Dilthey and Bergson, a chasm opened up 'between the two worlds of life and matter'. Still, these new philosophers of life, though they recognised the chasm between the organic and the inorganic, ignored the second chasm, that between biology and theology. The vitalists, carried away by their 'escape from mechanism', considered all that is non-material to be vital and attempted 'to restate the whole of religion in terms of vitalism'.[126] The end of such muddled thinking can be glimpsed in avant-garde art. Art is turning, disgusted, away from vitalism and 'the trivial and accidental characteristics of living shapes' towards a '*geometrical*' use of form comparable to that found in Byzantine, Egyptian and ancient Greek art. Modern artists are 'searching after an austerity, a monumental stability and permanence, a perfection and rigidity, which vital things can never have'. This revival of the spirit of geometry leads Hulme to rethink the history of epistemology he has been relating: 'If we think of physical science as represented by geometry, then instead of saying that the modern progress has been from physics through vitalism to the absolute values of religion, we might say that it is from *geometry through life and back to geometry*'.[127] Here, we might recall Augustin-Louis Cauchy's geometrical conservatism and the chasm Cauchy, too, traced between the world of pure mathematics and the world of muddy things: life, empirical science, history.

Through history, aesthetics and metaphor, Hulme attempted to advance a new geometrical sensibility. The move toward abstraction in modern art was, for Hulme, indicative of a general epistemological shift away from vitalism and its model of the organic whole. In forming this view, Hulme was developing Wilhelm Worringer's account of the 'urge to abstraction'. For Worringer, the history of art is the history of two warring psychological urges: the urge to empathy, which expresses itself as naturalism, delights in 'the beauty of the organic', and led to the subjectivism that dominates modern aesthetics, and the 'urge to abstraction', which expresses itself in a geometrical style and 'finds its beauty in the life-denying inorganic, in the crystalline or, in general terms, in all abstract law and necessity'.[128] 'We frequently find the, at first sight astonishing idea put forward by modern art theoreticians that mathematics is the highest art form', Worringer writes, and even the romantics have come to 'this seemingly paradoxical verdict'.[129] Yet, the Romantic theory of mathematics as art is, for Worringer, weak in comparison to true geometrical abstraction in art: dimmed by philosophical reflection and lacking in

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[125] Hulme, 'Humanism and the Religious Attitude', p. 6-7.
[126] Hulme, 'Humanism and the Religious Attitude', p. 7-8.
[127] Hulme, 'Humanism and the Religious Attitude', p. 9. Emphasis in original.
[128] Wilhelm Worringer, *Abstraction and Empathy: A Contribution to the Psychology of Style*, trans. by Michael Bullock (London: Routledge, 1963). p. 4.
[129] Worringer, *Abstraction and Empathy*, p. 19.

elemental necessity. The desire to take refuge in pure mathematics is, for Worringer, a historically contingent response to a world of confused and vague sensation. The urge to abstraction and the urge to empathy are produced by and respond to different social phenomenologies of knowledge. The popular understanding of science in the nineteenth century produced a certain relation to nature that manifested in the urge to empathy: the urge to take pleasure in the objectification of vitality. In *Abstraction and Empathy*, then, Hulme found historical justification for his own theory of the contemporary moment. Empiricism's understanding of nature was coming undone, while, simultaneously, engineers were constructing a new nature. Confronted with tangled, unravelling natural kinds and bereft of a stable, tacitly understood philosophy of science, Hulme believed that his contemporaries would feel, once again, the need to take refuge in abstraction, in mathematics, even if this need had so far only been channelled into 'geometrical' artworks.[130]

As Gaston Bachelard wrote, 'abstraction is a duty'.[131] For Hulme, as for Bachelard, the task of the philosopher-critic was to 'turn the mind from the real to the artificial, from the natural to the human, from representation to abstraction'.[132] An 'over-familiar scientific idea', Bachelard writes, 'becomes weighed down by too much psychological concreteness, amassing too many analogies, images, and metaphors, and gradually losing its *vector of abstraction*'.[133] Bachelard sought to purge the scientific mind of pernicious metaphors like the sponge, salt and digestion. Hulme, too, sought to redeem abstraction by revealing and uprooting vitalist metaphors and pseudo-categories. However, where Bachelard sought to rupture scientific knowledge from ordinary, everyday knowledge, Hulme rifles through that ordinary, everyday knowledge for signs of the coming turn to abstraction. Though informed by the philosophy of science, Hulme's use of geometrical language in his aesthetics also reflects his understanding of the social nature of knowledge and of the value of amateurism. 'Cinders', a notebook of Hulme's early philosophical thoughts from 1906-7, was dedicated to the 'philosophic amateur': 'The history of philosophers we know, but who will write the history of the philosophic amateurs and readers? Who will tell us of the circulation of Descartes, who read the book and who understood it?'[134]

In a January 1914 lecture to London's Quest Society on 'Modern Art and Its Philosophy', Hulme described the shared 'tendency to abstraction' at work in the pictures of Wyndham Lewis and in Jacob Epstein's latest drawings for sculpture. The use of 'mechanical lines' in the new art ought to be understood not as a mere reflection of the world of machinery in which that art was produced, but as the product of a cultural change in the feeling for form. Of the geometrical and

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130 On Hulme's use of Worringer see Michael H. Levenson, *Genealogy of Modernism: A Study of English Literary Doctrine, 1908-1922* (Cambridge: Cambridge University Press, 1984), pp. 94-102 and Reed W. Dasenbrock, *The Literary Vorticism of Ezra Pound and Wyndham Lewis: Towards the Condition of Painting* (Baltimore, MD: Johns Hopkins University Press, 1985), pp. 54-5.

131 Bachelard, *The Formation of the Scientific Mind*, p. 21.

132 Bachelard, *The Formation of the Scientific Mind*, p. 21.

133 Bachelard, *The Formation of the Scientific Mind*, p. 26.

134 Hulme, 'Cinders', in *The Collected Writings of T. E. Hulme*, p. 7.

mechanical 'character of the art that is coming', Hulme said: 'I believe it to be the precursor of a much wider change in philosophy and general outlook on the world'.[135] Hulme argued that the shift to the new geometrical sensibility has so far expressed itself, as all new sensibilities do, indirectly. When a shift in sensibility is in its early stages, epithets are, 'by a kind of tacit convention', the harbingers of the new attitude that cannot yet be fully stated. Hulme proposed that a new abstract, anti-empirical, anti-humanist and geometrical attitude is indicated by the change in value of certain adjectives: 'Instead of epithets like graceful, beautiful, etc., you get epithets like austere, mechanical, clear cut, and bare, used to express admiration'.[136] Hulme risks self-contradiction, borrowing a metaphor from biology to express his ambivalent response to cubist pictures: 'If I may be allowed to go against my own principles for a minute, and to describe abstract things in a metaphor borrowed from organic life, I should say they look rather like embryos. I think they will soon open out and grow distinct'. Hulme then drops his organic metaphor in order to describe a future in which 'cubism ceases to be analytical, and is transformed into a constructive geometrical art'.[137]

Ezra Pound, too, drew a distinction between different geometries in order to define and to defend imagism and vorticism. Pound's 1914 essay on 'Vorticism' constructed a scale of mathematical abstraction through which to articulate judgements of aesthetic worth.[138] While the 'symbolist's *symbols* have a fixed value, like numbers in arithmetic, like 1, 2, and 7', the 'imagiste's images have a variable significance, like the signs *a*, *b*, and *x* in algebra'.[139] Vorticism's superiority to futurism is also articulated in mathematical terms. 'Futurism is […] a kind of accelerated impressionism. It is a spreading, or surface art'. Vorticism, on the other hand 'is an intensive art. I mean by this, that one is concerned with the relative intensity, or relative significance of different forms of expression'. Pound uses mathematics to explain what 'relative intensity' means. Even the 'ordinarily intelligent undergraduate', he writes, is aware of four forms of 'mathematical expression': arithmetic, algebra, Euclidean geometry and analytic geometry. Each of these forms of mathematical expression is matched, in order of intensity, with a non-mathematical form of expression: arithmetic with ordinary conversation, algebra with the abstract language of philosophy, Euclidean geometry with the derivative, descriptive language of the critic, and analytic geometry with the formal inventions of the artist.[140]

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135 Hulme, 'Modern Art and Its Philosophy', in *The Collected Writings of T. E. Hulme*, p. 285.
136 Hulme, 'Modern Art and Its Philosophy', p. 278.
137 Hulme, 'Modern Art and Its Philosophy', pp. 281-2.
138 Ezra Pound, 'Vorticism', *Fortnightly Review* XCVI (N.S.). 573 (1 Sept. 1914): 461-471; reprinted in *Gaudier Brzeska* (1916), 94-109 and in *Ezra Pound's Poetry and Prose: Contributions to Periodicals, Volume I: 1902-1914*, ed. by Lea Baechler, A. Walton Litz and James Longenbach (New York: Garland, 1991), pp. 274-285. Page numbers here refer to *Ezra Pound's Poetry and Prose: Contributions to Periodicals, Volume I*.
139 Pound, 'Vorticism', p. 277.
140 Ian Bell notes that though there is not enough evidence to conclusively claim that Pound drew his thoughts on analytic geometry and the art of vortex from Oliver Lodge's book of lectures on astronomy, *Pioneers of Sciences*,

An arithmetical statement, whether written as '$3 \times 3 + 4 \times 4 = 5 \times 5$, or, differently, $3^2 + 4^2 = 5^2$', is, Pound writes, 'merely conversation or "ordinary common sense." It is a simple statement of one fact and does not implicate any other'. Faced with a collection of separate facts (like '$3^2 + 4^2 = 5^2$, $6^2 + 8^2 = 10^2$, $9^2 + 12^2 = 15^2$, $39^2 + 52^2 = 65^2$'), 'one may wish to mention their underlying similarity; it is a bore to speak about each one in turn'. To avoid arithmetic's dull monologues, '[o]ne expresses their "algebraic relation" as $a^2 + b^2 = c^2$'. Algebra, therefore 'is the language of philosophy. It MAKES NO PICTURE. This kind of statement applies to a lot of facts, but it does not grip hold of Heaven'. Upon studying Euclid: 'one finds that the relation of $a^2 + b^2 = c^2$ applies to the ratio between the squares on the two sides of a right-angled triangle and the square on the hypotenuse. One still writes it $a^2 + b^2 = c^2$, but one has begun to talk about form'. In arithmetic and algebra 'one had dealt only with numbers', but here, in Euclidean geometry, a new 'property or quality of life' creeps in. Yet, 'even this statement does not *create* form. The picture is given you in the proposition about the square on the hypotenuse of the right-angled triangle being equal to the sum of the squares on the two other sides'. As such, Pound argues, statements in Euclidean geometry – which he also refers to as 'plane or descriptive geometry' – 'are like talk about art. They are a criticism of the form'. Creation only begins at the fourth level of mathematical intensity:

> *Fourthly,* we come to Descartian or 'analytical geometry.' Space is conceived as separated by two or by three axes (depending on whether one is treating form in one or more planes). One refers points to these axes by a series of co-ordinates. Given the idiom, one is able *actually to create*.
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> Thus, we learn that the equation $(x - a)^2 + (y - b)^2 = r^2$ governs the circle. It is not a particular circle, it is any circle and all circles. It is nothing that is not a circle. It is the universal, existing in perfection, in freedom from space and time. Mathematics is dull ditchwater until one reaches analytics. But in analytics we come upon a new way of dealing with form. It is in this way that art handles life. The difference between art and analytic geometry is the difference of subject-matter only. Art is more interesting in proportion as life and the human consciousness are more complex and more interesting than forms and numbers.
>
> This statement does not interfere in the least with 'spontaneity' and 'intuition,' or with their function in art. I passed my last *exam.* in mathematics on sheer intuition. I saw where the line *had* to go, as clearly as I ever saw an image, or felt *caelestem intus vigorem.*
>
> The statements of 'analytics' are 'lords' over fact. They are the thrones and dominations that rule over form and recurrence. And in like manner are great works of art lords over fact, over race-long recurrent moods, and over tomorrow.
>
> Great works of art contain this fourth sort of equation. They cause form to come into being. By the 'image' I mean such an equation; not an equation of mathematics, not something about *a*, *b*, and *c*, having something to do with form, but about *sea*, *cliffs*, *night*, having something to do with mood.[141]

Pound's idea of analytic geometry is close to that presented by Lodge in the lecture on 'Descartes and His Theory of Vortices'. See Ian F. Bell, *Critic as Scientist: The Modernist Poetics of Ezra Pound* (London: Methuen, 1981), pp. 12-15.

[141] Pound, 'Vorticism', pp. 282-283. Pound may have taken this interpretation of pure thought too far: though he claims that he passed the exam in Analytic Geometry 'on sheer intuition', A. David Moody's biography points out that the transcript records a mark of zero for the exam in Analytic Geometry and that Pound failed the course

Euclid's geometry solved problems with straight lines and circles traced on a plane surface. Pound's fourth mode of mathematical intensity, analytical geometry, abandoned the concrete diagram. Geometrical figures were no longer visualised, no longer to be traced on paper with the Greek ruler and compass. For the analytic geometer, geometrical entities are general equations on a co-ordinate plane. Gaston Bachelard called analytic geometry 'the geometry of thought', since 'it gives us curves as they are thought, as they are constructed by thinking them, by connecting the variable and the ordinate by their reciprocal function'.[142]

Vorticism was a short-lived movement. Wyndham Lewis published its inaugural manifesto in the first issue of *Blast* in the summer of 1914 but *Blast* would have only one more issue and Lewis himself would later remark that the movement had been 'snuffed out by the Great War'.[143] However, Miranda Hickman argues that the vorticist 'geometrical idiom' had a lasting influence on the late modernist work of Pound, H. D., and Yeats. Hickman argues that geometry accrued a distinctive constellation of values during the vorticist movement and that when Pound, H. D., and Yeats used geometrical language in the 1930s and early 1940s, that language was still, for them, linked with the constellation of values that vorticism and its advocates (including T. E. Hulme) had attributed to geometry. Within vorticism, Hickman argues, geometry stood at once for 'precision, rigor, and analytical detachment' and for 'force, aggression, and action': 'Framed by the rhetoric of Vorticism and employed in Vorticist paintings, Vorticist geometry thus came to suggest a disciplined condition of both maximum intensity and dynamic force'. [144] Yet the vorticist geometrical idiom co-existed with radically different geometrical idioms and rhetorics of number, such as F. T. Marinetti's futurist 'new numeric sensibility', his lyrical equations and Fascist 'qualitative mathematics', Velimir Khlebnikov's mathematical utopianism, Yevgeny Zamyatin's revolutionary mathematical manifestos and Zamyatin's later mathematical dystopianism.

Zamyatin updated Pound's mathematical coordinates in 'On Literature, Revolution, Entropy and Other Matters' (1923). Zamyatin's revolutions in mathematics included non-Euclidean geometry ('Lobachevsky cracks the walls of the millennia-old Euclidean-world with a single book, opening a path to innumerable non-Euclidean spaces: this is revolution') and Minkowski's spacetime. The new, revolutionary art must project itself onto new coordinates, as the new mathematics had done:

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overall. See A. David Moody, *Ezra Pound: Poet, A Portrait of the Man & His Work, Vol. I: The Young Genius 1885-1920* (Oxford: Oxford University Press, 2007), p. 20, fn. 1.

142 Gaston Bachelard, *The Philosophy of No: A Philosophy of the New Scientific Mind*, trans. by G. C. Waterston (New York: Orion Press, 1968), p. 64.

143 Lewis, 'The Skeleton in the Cupboard Speaks', p. 68.

144 Miranda Hickman, *The Geometry of Modernism: The Vorticist Idiom in Lewis, Pound, H. D., and Yeats* (Austin: University of Texas Press, 2005), p. 9.

> Science and art both project the world along certain coordinates. Differences in form are due only to differences in the coordinates. All realistic forms are projections along the fixed, plane coordinates of Euclid's world. These coordinates do not exist in nature. Nor does the finite, fixed world: this world is a convention, an abstraction, an unreality. And therefore Realism – be it 'socialist' or 'bourgeois' – is unreal. Far closer to reality is projection along speeding, curved surfaces – as in the new mathematics and the new art.[145]

Speeding, of course, was futurism's religion. F. T. Marinetti burst onto the pages of *Le Figaro* on 20 February 1909 to proclaim 'the beauty of speed': 'to exalt movement and aggression, feverish insomnia, the racer's stride, the mortal leap, the slap and the punch', 'to hymn man at the steering wheel', and to announce that '[t]ime and space died yesterday. We already live in the absolute, for we have already created velocity which is eternal and omnipresent'.[146]

Marinetti's early futurist manifestos sought to demolish the old myth of aesthetic autonomy, to tear down the boundaries between literature and the new world of speed, dynamism and technics. As such, these manifestos are anthems for the quantified world and are permeated by numbers and mathematical notation. In 'Geometrical and Mechanical Splendor and the Numerical Sensibility', for example, Marinetti wrote: 'Love of precision and essential brevity have given me a natural taste for numbers, ciphers that live and breathe upon the page like living beings within our new **numeric sensibility**'.[147] Marinetti's 'Technical Manifesto of Futurist Literature' (May 1912), along with announcing the abolition of adjectives, adverbs and punctuation, announced: 'To accentuate certain movements and indicate their directions, mathematical signs will be used: + - × : = ><'.[148] By stealing the mathematician's tools, the futurists would speed up literature. In 'the abstract aridity of mathematical signs', Marinetti saw a shortcut to futurist prose. Those signs 'render quantitative relations by epitomizing a longer explanation, without any fillers'.[149] This is a new economy of language for a new age: deploy mathematical signs, Marinetti urges, and avoid 'the dangerous mania for wasting time in all the crannies of the sentence, in the minute labors of the mosaic maker, the jeweler, or the shoeshine boy'.[150] The 'Technical Manifesto of Futurist Literature' has an absurdist combinatorial attitude: it recommends the scattering of parts of words and the dispersal of parts of self, and announces:

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145 Yevgeny Zamyatin, 'On Literature, Revolution, Entropy and Other Matters' (1923) in *A Soviet Heretic: Essays by Yevgeny Zamyatin*, ed., and trans., by Mirra Ginsburg (Chicago: University of Chicago Press, 1970), pp. 107-112.
146 F. T. Marinetti, 'The Founding and Manifesto of Futurism', *Le Figaro* (Paris), 20 February 1909, trans. by Lawrence Rainey in *Futurism: An Anthology*, ed. by Lawrence Rainey, Christine Poggi and Laura Wittman (New Haven, CT: Yale University Press, 2009), pp. 49-53.
147 F. T. Marinetti, 'Geometrical and Mechanical Splendor and the Numerical Sensibility' (18 March 1914), trans. by Lawrence Rainey in *Futurism: An Anthology*, pp. 175-180 (p. 179). Emphasis in the original.
148 F. T. Marinetti, 'Technical Manifesto of Futurist Literature' (May 1912), trans. by Lawrence Rainey in *Futurism: An Anthology*, pp. 119-125 (p. 120).
149 F. T. Marinetti, 'A Response to Objections' (11 August 1912), trans. by Lawrence Rainey in *Futurism: An Anthology*, pp. 125-129 (p. 127).
150 'A Response to Objections', p. 127.

'we are preparing the creation of the mechanical man with interchangeable parts'.[151] Elsewhere, Marinetti praised the variety theatre, the way in which its interchangeable 'numbers', the turns or parodies, dismantled and mocked classical works.[152]

The tone and the political valence of Marinetti's literary mathematics had shifted markedly by 1941. 'Qualitative Imaginative Futurist Mathematics', co-authored with the mathematician Marcello Puma, is, as its title indicates, a move away from quantification. Here, there are no more hymns to number. Instead, we find Mussolini's 'qualitative mathematics', in which individual lives and individual deaths are no longer worthy even of the equalising force of counting, of quantification, of statistics.[153]

Notation for a New World Order

If Marinetti's early use of mathematical notation was an embrace of the present and of excess, for the Russian futurist, Velimir Vladimirovich Khlebnikov, mathematical notation (mixed with a strong dose of numerology) yielded a blueprint for utopia: a *mathesis universalis*. Broadly speaking, the *mathesis universalis* refers to two different ideas. Descartes's *mathesis universalis*, for example, was understood by Jean-Paul Weber and Giovanni Crapulli as an iteration of a sixteenth-century idea of 'first mathematics': the general mathematics that both precedes and transcends the discipline's divisions (for example, that has the requisite level of abstraction to cope both with multitude and magnitude, and thus both arithmetic and geometry).[154] Mathematical method, Descartes wrote, ought to be 'divested of the multiplicity of numbers and incomprehensible figures which overwhelm it'. Behind its appearance of numerical chaos, 'the exclusive concern of mathematics is with questions of order or measure' and as such 'it is irrelevant whether the measure in question involves numbers, shapes, stars, sounds, or any other object whatever'. Obscured by those chimerical particulars, therefore, 'there must be a general science which explains all the points that can be raised concerning order and measure irrespective of the subject-matter' and 'this science should be termed *mathesis universalis*'.[155]

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151 F. T. Marinetti, 'Technical Manifesto of Futurist Literature', p. 125.
152 F. T. Marinetti, 'The Variety Theatre', trans. by Lawrence Rainey in *Futurism: An Anthology*, pp. 159-164.
153 F. T. Marinetti with Marcello Puma and Pino Masnata, 'Qualitative Imaginative Futurist Mathematics' (1941), pp. 298-304. 'Fascism is the purest kind of democracy, so long as people are counted qualitatively and not quantitatively', Mussolini wrote in his article on 'Fascism' for the *Enciclopedia italiana di scienze, lettere ed arti* (Rome: Istituto Giovanni Treccani, 1929–1939), s.v. "Fascismo." Quoted and translated by Rainey in *Futurism: An Anthology*, pp. 37-8.
154 Jean-Paul Weber, *Constitution du texte des regulae* (1964) and Giovanni Crapulli, *Mathesis universalis: Genesi di una idea nel XVI secolo* (Rome: Ed. dell'Ateneo, 1969).
155 René Descartes, 'Rules for the Direction of Mind', *The Philosophical Writings of Descartes*, Vol. I, trans. by John Cottingham, Robert Stoothoff and Dugald Murdoch (Cambridge: Cambridge University Press, 1985), pp. 7-78 (p. 19).

Chikara Sasaki likens the *mathesis universalis* to Cantor's set theory and Hilbert's formalism as an early example of foundation building in mathematics.[156] The *mathesis universalis* also denotes a conceptual system modelled on mathematics: the translation of mathematics, in other words, into a prototypical formal language with a universal jurisdiction. Frege's *Begriffsschrift* (concept-script or concept-notation), for example, was 'a language modelled on arithmetic's formal language of pure thought' ('eine der arithmetischen nachgebildete Formelsprache des reinen Denkens').[157] As Daston and Galison describe in *Objectivity*, Rudolf Carnap sought to translate that formal logic into a system that could unite the sciences and end subjectivism and perspectival diversity by creating a structuralist shared knowledge.[158] Peter Galison argues that Carnap's movement, logical positivism, and the Bauhaus movement reinforced each another's projects: they both 'sought to instantiate a modernism' of '"transparent construction"': 'a manifest building up from simple elements to all higher forms that would, by virtue of the systematic constructional program itself, guarantee the exclusion of the decorative, mystical, or metaphysical, or metaphysical'.[159] As it was based on the combination of only 'simple, accessible units' (for the logical positivists, 'protocol statements' and connectives 'if/then', 'or', 'and'; for the Bauhaus, elementary geometrical forms and colour relations), this method of construction might also 'banish incorporation of nationalist or historical features'.[160]

Frege and Carnap both likened formal logic to Leibniz's plans for a *characteristica universalis*. Leibniz imagined the *characteristica universalis* (or 'spécieuse générale') as a universal, formal, pasigraphy that would be used to express or represent mathematical, scientific and metaphysical concepts (and that would be usable within the framework of universal logical calculation, the *calculus ratiocinator*, a proto-computer).[161] The early developers of automated theorem proving also often referred back to Leibniz because, as Donald MacKenzie writes in *Mechanizing Proof*, the digital computer offered a 'mechanization of Leibniz's dream': the dream of 'a formal system that would reduce reasoning to calculation, enabling the validity of arguments to be checked without reference to the content being reasoned about'.[162]

Khlebnikov, too, imagined a universal language project based on mathematics, and looked to Leibniz's *characteristica universalis* and *calculus ratiocinator* when planning his project. In his

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156 Chikara Sasaki, *Descartes's Mathematical Thought* (Dordrecht: Kluwer, 2003), p. 7.
157 Gottlob Frege, *Begriffsschrift: eine der arithmetischen nachgebildete Formelsprache des reinen Denkens* (Halle: Verlag von Louis Nebert, 1879).
158 Rudolf Carnap, *The Logical Structure of the World: Pseudoproblems in Philosophy* (Berkeley, CA: University of California Press, 1967). See also Daston and Galison, *Objectivity*, chapter 5, 'Structural Objectivity', 253-309.
159 Peter Galison, 'Aufhau/Bauhaus: Logical Positivism and Architectural Modernism', *Criticial Inquiry* 16.4 (1990), 709-752 (p. 710).
160 Galison, 'Aufhau/Bauhaus', p. 711.
161 For accounts of the history of the computer that see Leibniz's *calculus ratiocinator* as a forerunner, see Norbert Wiener, *Cybernetics: Or, Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1948; revised ed., 1961) and Martin Davis, *The Universal Computer: The Road from Leibniz to Turing* (London: W. W. Norton, 2000).
162 Donald MacKenzie, *Mechanizing Proof: Computing, Risk, and Trust* (Cambridge, MA: MIT Press, 2001), p. 71.

notebooks, Khlebnikov outlined the problem with language, and sketched the aspiration for its (numerical) solution:

> In verbal thinking, no basic condition of measurement is present – no constancy in the units of measurement. […] Every name is merely an approximate measurement, a mere comparison of several quantities, of certain equals signs. Leibniz, in his exclamation 'The time will come when people, instead of engaging in abusive disputes, will calculate', Novalis, Pythagoras, and Amenophis IV all foresaw the victory of numbers over the word as a method for thinking.[163]

In Khlebnikov's 'Self-Statement', an apologia for his prose works, he described his search for a 'self-sufficient language' that 'stands outside historical fact and everyday utility':

> I observed that the roots of words are only phantoms behind which stand the strings of the alphabet, and so my second approach to language was to find the unity of the world's languages in general, built from units of the alphabet. A path to a universal beyonsense language.[164]

Khlebnikov laid out his vision for a universal language project in his 1919 manifesto 'Artists of the World! (a written language for Planet Earth: a common system of hieroglyphs for the people of our planet)'. He described the project as a 'lens' designed to focus the 'rays' of the world's languages through a single point.[165] 'Languages have betrayed their glorious beginnings', Khlebnikov lamented: the proliferation of languages had created multiple, competing economies of worth, leading to 'tariff wars' and 'spectral wars'. A 'common written language' will end these conflicts: it shall be 'the new vortex that unites us, the new integrator of the human race. Mute graphic marks will reconcile the cacophony of languages'. The artists of the world must all do their part to help build this language of the future. Khlebnikov orders the following division of labour:

> To the artists who work with ideas falls the task of creating an alphabet of concepts, a system of basic units of thought from which worlds may be constructed.
>
> The task of artists who work with paint is to provide graphic symbols for the basic units of our mental processes.[166]

In fact, Khlebnikov notes, 'the artists of China and Japan' have already completed the first stage of the thinker's task. Indeed, many writers and philosophers, Ezra Pound and Ernst Mach among them, have idealised Chinese 'ideographic' language: seeing in Chinese characters a potential

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163 Khlebnikov, *Sobranie sochinenii*, III, pp. 446-47. This passage is translated and quoted by Steven Cassidy in 'Mathematics, Relationalism, and the Rise of Modern Literary Aesthetics', *Journal of the History of Ideas* 49.1 (1988), 109-132 (p. 129).

164 Khlebnikov, 'Self-Statement', *Collected Works of Velimir Khlebnikov*, Vol. I: Letters and Theoretical Writings, ed. by Charlotte Douglas (Cambridge, MA: Harvard University Press, 1987), pp. 146-150 (p. 147).

165 Khlebnikov, 'Artists of the World! (a written language for Planet Earth: a common system of hieroglyphs for the people of our planet)', *Collected Works of Velimir Khlebnikov*, Vol. I, pp. 364-372.

166 Khlebnikov, 'Artists of the World!', p. 365.

model for a universal language or a way of bridging disciplinary boundaries. 'Language', Mach wrote, 'is itself an economic contrivance. Experiences are analysed, or broken up, into simpler and more familiar experiences, and then symbolised at some sacrifice of precision'.[167] Written language was mutating, Mach speculated, into a universal conceptual language: numerals, algebraic signs, chemical symbols, musical notes and phonetic alphabets were the harbingers and components of this future 'universal character'.[168]

Alongside Khlebnikov's futurist utopianism, there was also a distinct strain of mathematical dystopianism in Russian and Soviet literature, particularly during the 1920s and 1930s. Novels and short stories were set, for example, in future societies ordered according to a curdled, oppressive social mathematics. In the work of Sigizmund Krzhizhanovsky and Yevgeny Zamyatin, mathematics was a satirical, allegorical literary vernacular. Krzhizhanovsky's short stories are layered realities: oscillating between the theoretical and the empirical (between 'metaphysics' and 'sandwiches', as one of his narrators puts it).[169] In these stories, mathematical abstractions come to life. The narrator of 'Autobiography of a Corpse', author of a manuscript on 'The Axiomatism Crisis', describes how one such abstraction haunted him:

> From a fairly young age, you see, I had been visited by a strange figment: 0.6 person. One day, while leafing through a geography book, I came across this line: 'In the country's northern latitudes the population per square mile is 0.6 person.' It stuck in my mind's eye like a splinter. […] And in every square, where the diagonals intersect, *it*, a stooped, thread-paper body bent low to the bare, ice-covered ground: 0.6 person.[170]

Krzhizhanovsky's mathematical entities lead lives, too, of political allegory. In 'Seams', for example, the Soviet method of internal administrative exile is invoked as the narrator describes his life in the margins, the seams, of Moscow:

> People whom Moscow has tried in its courts and banished from the city are said to have been: sentenced to 'minus 1.' No one has passed such a sentence on me: 0-1. […] Yet I am fully and firmly aware […] They are in Moscow and I am in minus-Moscow.[171]

Meanwhile, in Zamyatin's novel *We* (1921), the futurist's dream of a fully mathematised society is realised as a totalitarian dystopia. That mathematical dystopia is a space of political satire. In his literary criticism, Zamyatin argued that utopias are characterised by 'two generic and invariable features':

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[167] Ernst Mach, *The Science of Mechanics*, trans. by Thomas J. McCormack (Chicago: Open Court, 1919), p. 481.
[168] Mach, *The Science of Mechanics*, p. 481.
[169] Sigizmund Krzhizhanovsky, 'Seams', in *Autobiography of a Corpse* (1925), trans. by Joanne Turnbull and Nikolai Formozov (New York: New York Review Books, 2013), pp. 61-86 (p. 64).
[170] Sigizmund Krzhizhanovsky, 'Autobiography of a Corpse', in *Autobiography of a Corpse*, pp. 1-30 (pp. 9-10).
[171] Krzhizhanovsky, 'Seams', p. 69.

> One is the content: the authors of utopias paint what they consider to be ideal societies; translating this into the language of mathematics, we might say that the utopias bear a + sign. The other feature, organically growing out of the content, is to be found in the form: a utopia is always static; it is always descriptive, and has no, or almost no, plot dynamics.[172]

In Zamyatin's opinion, H. G. Wells had created a new literary form that differed from the classical utopia 'as $+A$ differs from $-A$'. Wells's 'sociofantastic novels' were examples of this new hybrid genre, which combined social satire with science fiction. As satire, such works were 'instruments for exposing the defects of the existing social order, rather than building a picture of a future paradise' and as science fiction, they were dynamic, kinetic and accelerating toward the future.[173] Zamyatin's novel *We* was similarly dystopian: futuristic, satirical and structured by conflict. That conflict, Bruce Clarke argues, is the product of tensions between and within scientific and mathematical regimes, which are played out allegorically via, for example, 'the ironic gap dramatized in *We* between One State's archaic arithmetic and Euclidean orthodoxy and the Mephi rebels' superior mathematical culture'.[174]

It is, of course, impossible to read Marinetti, Khlebnikov or Zamyatin innocently now, distanced as we are from their time by the terrible events of the middle decades of the twentieth century. Interviewed in 1997, the algebraic geometer and group theorist Pierre Cartier (a Bourbaki member from 1955 to 1983) pointed out that the Bourbaki group and the Soviet Union collapsed around the same time. The twentieth century 'from 1917 to 1989 has been a century of ideology', Cartier said.[175] Indeed, Cartier cited Wells's *A Modern Utopia* as the best exposé of that ideological age. He remarked that 'Hilbert, I think, reflected this *Zeitgeist*'. Moreover, Cartier argued that, although its members (André Weil in particular) were loath to acknowledge it, Bourbaki, too, were a product of this epoch of ideology: the epoch of utopias, of abstraction and of manifestos. Bourbaki's stated goal was, Cartier pointed out, 'to create *a new mathematics*. He didn't cite any other mathematical texts. Bourbaki is self-sufficient. Of course at the time the communists in the Soviet Union were claiming the same. We know now it was a lie'. Unlike the leaders of the Soviet Union, however, Cartier does not accuse Bourbaki of consciously lying. Nonetheless, he said, 'the spirit was the same': 'Bourbaki was to be the New Euclid, he would write a textbook for the next 2000 years'.[176] Though Bourbaki (with the exception of Claude Chevalley) may not have embraced the connections between their group's work and the ideologies of avant-garde groups in art and politics, these connections, for Cartier, were clear:

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[172] Yevgeny Zamyatin, 'Eight Writers and One Painter', in *A Soviet Heretic*, ed. and trans. by Mirra Ginsberg (London: Quartet, 1991), pp. 205-300 (p. 287).
[173] Zamyatin, 'Eight Writers and One Painter', pp. 287-8.
[174] Bruce Clarke, *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* (Ann Arbor: University of Michigan Press, 2001), p. 203.
[175] Marjorie Senechal, 'The Continuing Silence of Bourbaki – An Interview with Pierre Cartier, June 18, 1997', *The Mathematical Intelligencer* 20.1 (1998): 22-28 (p. 27)
[176] 'The Continuing Silence of Bourbaki', p. 27.

'Bourbaki's abstractions and disdain for visualization were part of a global fashion, as illustrated by the abstract tendencies in the music and the paintings of that period'.[177]

While the manifestos of the early twentieth century European avant-gardes may have formed and epitomized the genre, the neo-avant-garde movements of the 1960s brought with them a second wave of manifestos. For Peter Wollen, however, that wave merely prefigured the genre's death. He described the Situationist International both as the 'summation' of 'Western Marxism' and as the last of the avant-gardes:

> Its dissolution in 1972 brought to an end an epoch which began in Paris with the Futurist Manifesto of 1909 – the epoch of the historical avant-gardes with their typical apparatus of international organization and propaganda, manifestoes, congresses, quarrels, scandals, indictments, expulsions, polemics, group photographs, little magazines, mysterious episodes, provocations, utopian theories and intense desires to transform art, society, the world and the pattern of everyday life.[178]

For many critics, therefore, the manifesto's status as a distinct literary genre is confined to history: bound to the epoch of the avant-garde, or to a culture of revolutionary ferment that no longer exists. The First World War, Mary Ann Caws argues, 'put an end to that poetic shout of the Great Age of the Manifesto'.[179] The form of the manifesto survived the war, but not unchanged. Later manifestos lacked the energy of Caws's 'manifesto moment'. She argues that they were haunted by their own belatedness and a sense of nostalgia or of irony crept in and dissipated their force: the 'nowness', 'newness' and 'againstness' that, for Caws, defined the manifesto.[180] As understood by Caws, 'the manifesto is Modernist rather than ironically Postmodernist. It takes its own spoof seriously'.[181]

Though Perry Anderson points out that modernism is a troubled historical category that retrospectively unifies disparate practitioners, forms and movements under its banner, he nonetheless argues that the 'high modernists' shared a world with the avant-garde movements of symbolism, futurism, expressionism, constructivism and surrealism:

> This was a world of sharp demarcations, whose frontiers were staked out by the instrument of the manifesto: declarations of aesthetic identity peculiar not only to the avant-gardes, but also in more oblique and style characteristic of writers like Proust or Eliot, that separated the elective ground of the artist from the *terrains vagues* beyond.[182]

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177 'The Continuing Silence of Bourbaki', p. 27.
178 Peter Wollen, 'The Situationist International', *New Left Review*, 174.1, (March-April 1989), 67-95 (p. 72).
179 Mary Ann Caws, 'The Poetics of the Manifesto: Nowness and Newness', in *Manifesto: A Century of Isms*, ed. by Mary Ann Caws (Lincoln: University of Nebraska Press, 2001), pp. xix-xxxiii (p. xxi).
180 Caws, 'The Poetic of the Manifesto', p. xxii.
181 Caws, 'The Poetics of the Manifesto', p. xxi.
182 Perry Anderson, *The Origins of Postmodernity* (London: Verso, 1998), p. 93.

In Anderson's analysis, the decline of the idea of the avant-garde, the growing suspicion of collective movements and 'isms', and the emergence of a postmodern sensibility, brought about the end of the epoch of the manifesto:

> For the universe of the postmodern is not one of delimitation, but intermixture – celebrating the cross-over, the hybrid, the pot-pourri. In this climate, the manifesto becomes outdated, a relic of an assertive purism at variance with the spirit of the age.[183]

Martin Puchner disagrees with Anderson, pointing out that many avant-garde manifestos were works of hybridity, intermixture and montage that incorporated drawings, doodles, architectural plans and so on.[184] Puchner is right to challenge Anderson's characterisation of the manifesto. Italian futurism, for example, with its desire to dissolve boundaries, does not fit neatly into Anderson's analysis. Yet Lawrence Rainey – who, like Mary Ann Caws, edited an anthology of manifestos – came away with the feeling that perhaps both the manifesto and modernism were dead-ends, offering:

> not a history of beginnings and developments, but a protracted series of endings, innovations that swiftly exhausted themselves, corridors that always had 'no exit' written irrevocably on the farthest wall. Futurism was just that. Alluring, vulgar, ludicrous, chilling, monstrous, farcical, grim—it remains one of the great dead ends of modernism.[185]

Indeed, Puchner's broader claim – that the manifesto's hybridity enables its continuing survival as a vibrant cultural form – requires the dissolution of the manifesto as a distinct literary genre. Puchner documents how floating manifesto qualities have percolated into other genres and other media (films, architecture and visual art, for example) to create new hybrid forms ('manifesto urbanism' is one of Puchner's examples). In other words, it is by only dissolving into its qualities (tone, insistent performativity, blurring of art and politics, antagonistic stance, list of commands, orientation towards the future) that the manifesto could survive. The issues that divide Puchner and Anderson cannot be addressed fully here. However, if, as I suggest, we can read several of Bourbaki's writings as manifestos, and juxtapose them with the archival records of the Bourbaki group, we can certainly see hybridity. Bourbaki – conventionally seen as the epitome of formalism in modern mathematics – was by no means always serious: their austere published texts overflowed in private surreal humour.

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183 Anderson, *The Origins of Postmodernity*, p. 93.
184 Martin Puchner, *Poetry of the Revolution: Marx, Manifestos and the Avant-Gardes* (Princeton, NJ: Princeton University Press, 2006).
185 Rainey, *Futurism: An Anthology*, p. 47.

Clean Slates

'If you put the manifesto of the surrealists and the introduction of Bourbaki side by side, as well as other manifestos of the time, they look very similar', Cartier observed in that 1997 interview.[186] 'My daughter is currently translating a book about the birth of cinematography, and in a chapter about the Italian futurists there is a very similar statement', he said.[187] Indeed, each volume of Bourbaki's *Éléments de mathématique* includes a manifesto: the address to the reader. This 'Mode d'emploi' or 'directions for use' asserts:

> 1. This treatise takes up mathematics at the beginning and gives complete proofs. In principle, it requires no particular knowledge of mathematics on the part of the reader, only a certain familiarity with mathematical reasoning and a certain capacity for abstraction.[188]

The first volume of *Éléments de mathématique* with the 'Fascicule de résultats' of the *Théorie des ensembles* was published in 1939. With its fictional author, the mysterious 'N. Bourbaki', and its grandiose proclamations, *Éléments de mathématique* was, Jacques Roubaud writes, a 'provocative and avant-gardist treatise'; even 'a sort of mathematical surrealism'.[189] Bourbaki's mathematical surrealism is perhaps most evident in the absurdist humour of their internal bulletin, 'La Tribu'; whose subtitle ('*Bulletin oecuménique apériodique et bourbachique*') Liliane Beaulieu translates as 'an ecumenical, deadbeat and Bourbakic bulletin'.[190] While the humour of 'La Tribu' tends towards a kind of surrealism, Bourbaki's treatise, *Éléments de mathématique*, and their 'manifesto' proper, 'L'Architecture des Mathématiques', reveal the group's affiliations with other valences of the avant-garde: with formalism, with revolutionary ambition, with modernist utopianism, with the *mathesis universalis* and other universal language projects, and with the desire to create an autonomous, unified work of art.

Roubaud's *Mathématique:* is an act of reckoning with the legacy of Bourbaki.[191] Roubaud's story begins on Paris's 'Montagne' Sainte-Geneviève, site of the Panthéon and historic home of the École Polytechnique and École Normale Supérieure. The setting is the lecture hall of the

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186 'The Continuing Silence of Bourbaki', p. 27.
187 'The Continuing Silence of Bourbaki', p. 27.
188 'Le traité prend les mathématique à leur début, et donne des démonstrations complètes. Sa lecture ne suppose donc en principe, chez le lecteur, aucune connaissance mathématique particulière, mais seulement une certaine habitude du raisonnement mathématique, et un certain pouvoir d'abstraction', Bourbaki, 'Mode d'emploi de ce traité', Delr 007BIS, *Archives de l'Association des Collaborateurs de Nicolas Bourbaki*, compiled and digitised at <http://sites.mathdoc.fr/archives-bourbaki/> (UMS 5638 CNRS/ UJF), documents held in Paris and Nancy (Paris, Académie des Sciences: le fonds du secrétariat de l'Association des Collaborateurs de Nicolas Bourbaki; papers donated by former members including Henri Cartan, André Weil, Pierre Samuel and Armand Borel; Nancy: Institut Elie Cartan, fonds Jean Delsarte).
189 Roubaud, 'Mathematics in the Method of Raymond Queneau', p. 80.
190 Liliane Beaulieu, 'Bourbaki's Art of Memory', *Osiris*, 14 (1999), 219-251 (p. 226).
191 Roubaud, *Mathématique:* (Paris: Seuil, 1997), trans. by Ian Monk as *Mathematics: (a novel)* (London: Dalkey Archive Press, 2012).

Institut Henri Poincaré (certificate 'Differential and Integral Calculus') one winter morning in 1954:

> I have waited over thirty-seven years before daring to stop and stare deliberately at that image or handful of images: the board, benches, heads, chalk drawings, charged with meaning. I remove it from hell, or its limbo. I remove it from my memory so as to erase it, as I do with all the memories that I fix by writing them down, like the chalk 'potatoids' drawn by 'Choquet' on the blackboard, long ago. But before erasing it, I charge it with meaning.[192]

Roubaud's memories are of the Bourbaki revolution: of his encounters with Bourbaki as mathematical legend and with their monumental treatise. By the time Roubaud was writing his memoir, in the 1990s, Bourbaki had become, he says, a 'museum piece'. Yet, the branches and interpollations of Roubaud's book mimic Bourbaki's axiomatic presentation, his book's many beginnings refract their attempts to erase the past of mathematics, and his own abandoned great Project was, he acknowledges, indebted to their Treatise. Bourbaki tried to wrench mathematics out of history: 'Apparently, a clean slate had just been made of the past of mathematics', Roubaud writes of the rumours that circulated around the lecture theatres of the Institut Henri Poincaré. Bourbaki seemed to be tearing down the entire edifice of existing mathematics in order to built it anew: they were a kind of catastrophe, a revolution that seemed closer and more plausible than political revolution. Roubaud remembers being 'gripped by the vertigo of beginning' as he read Bourbaki's advice to the reader of the Treatise: 'This series of volumes […] takes up mathematics at the beginning, and gives complete proofs'. 'I needed the illusion of an absolute beginning', Roubaud writes. Yet, this absolute beginning proved elusive: how were you to know that the real beginning had been reached without first examining the 'pre-beginning'? How to begin with the 'beginning' of the Treatise when Book I, in which the famous theory of sets was to be presented, had not yet been finished? (A 'Summary of Results' had appeared in 1939, but the four chapters on set theory were published in final form only between 1954 and 1957). Roubaud, in fact, didn't know how to read Bourbaki's General Topology when he first sat down to it: he could determine no narrative thread. Indeed, Peter Galison suggests in 'Structures of Crystal, Buckets of Dust' that 'reading as such, the sequential absorption, seems to pull against the Bourbakian ideal'.[193] The Bourbaki members, Galison writes, 'aimed their story of mathematics to be the non-narrative narrative, the account outside time, a structure, an architecture to be contemplated as it ordered "mathematic" from set theory on out'.[194] Roubaud thus says he decided to read the Treatise like poetry, which he would re-read and commit to

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[192] Roubaud, *Mathematics: (a novel)*, pp. 15-16.
[193] Peter Galison, 'Structures of Crystal, Buckets of Dust', in *Circles Disturbed: The Interplay of Mathematics and Narrative*, ed. by Apostolos Doxiadis and Barry Mazur (Princeton, NJ: Princeton University Press, 2012), pp. 52-78 (pp. 56-7).
[194] 'Structures of Crystal, Buckets of Dust', p. 53.

memory until he had 'repositioned all of its elements in the present, in the simultaneity of inward time'.[195]

Michel Serres, too, describes his Bourbakian re-education (which took place at the *École Normale*) as an 'extraordinary upheaval' that shaped his whole life. In conversation with Bruno Latour, Serres recounted this 'profound transformation of a world'.[196] Before entering the *École Normale*, the algebra and analysis Serres had studied were traditional: essentially continuous with seventeenth and particularly late eighteenth century algebra and analysis. His encounter with what was going on in the Bourbaki seminar – modern mathematics, the notion of 'structure' – was, therefore, an encounter with something deeply new and deeply strange:

> Imagine the experience: I was coming from history, from a half-dead past, as though dressed in lace and ruffles, and I entered a palace at the very moment when it was being rebuilt. I can only compare this thunderbolt – for so it truly felt to me – to the thrice-blessed moment when my teacher forced my left-handed self to write with the right hand: it was a dazzling discovery of a new world.[197]

Bourbaki's thunderbolt, the *Éléments de mathématique*, began its life as a somewhat more modest, conventional project. Henri Cartan and André Weil were two young mathematicians responsible for teaching courses on differential and integral calculus at Strasbourg. In his memoir, Weil describes Cartan constantly complaining about the lack of a good analysis textbook and pestering Weil with questions about how to teach the calculus course. Weil proposed solving the problem for good: they would get a group of mathematicians together (friends of theirs who were teaching the same topics at various universities) and collectively write what they thought of as a new *Cours d'analyse*: a new analysis textbook.[198] The group met on 10 December 1934 to discuss this 'Traité d'Analyse'. The minutes of this meeting record:

> WEIL presents his project – to establish the content of the certificate in differential and integral calculus for the next 25 years by jointly writing a treatise on analysis.
>
> It is agreed that this treatise will be as modern as possible.[199]

At the Committee's meeting on 14 January 1935, the analyst and functional theorist Szolem Mandelbrojt proposed 'un principe de généralité': that all the necessary general and abstract theories should be given at the beginning of the book. 'We must', Weil said, 'write a treatise that could be used by anyone: by researchers (university lecturers or not), by students, by future

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[195] Roubaud, *Mathematics: (a novel)*, pp. 186-187.
[196] Michel Serres with Bruno Latour, *Conversations on Science, Culture, and Time*, trans. by Roxanne Lapidus (Ann Arbor: The University of Michigan Press, 1995), pp. 10-11.
[197] Michel Serres with Bruno Latour, *Conversations on Science, Culture, and Time*, pp. 10-11.
[198] André Weil, *The Apprenticeship of a Mathematician*, trans. by Jennifer Gage (Basel: Birkhäuser, 1992), pp. 99-100.
[199] 'WEIL expose son projet – fixer pour 25 ans les matières du certificat de Calcul différentiel et intégral en rédigeant en commun un traité d'Analyse. Il est entendu que ce traité sera aussi moderne que possible', 'Réunion du 10/12/1934,' Delta 001, *Archives de l'Association des Collaborateurs de Nicolas Bourbaki.*

educators, by physicists and by all engineers'.[200] As such, the tools of mathematics were to be given in the most universal form. This abstract section grew until it engulfed the treatise on analysis. Bourbaki's project was reimagined as, to repeat Corry's wonderful phrase, 'writing the ultimate mathematics textbook'.[201] Even Bourbaki's choice of title for this textbook, *Éléments de mathématique*, was provocative: they use '*mathématique*' in the singular (rather than the conventional *mathématiques*). An unpublished draft of 'Introduction au Livre I' opened on an even stronger note: 'IL Y A une mathématique, une et indivisible: voilà la raison d'être du présent traité, qui prétend en exposer les éléments à la lumière de vingt–cinq siècles'.[202]

In the introduction to their volume on set theory, Bourbaki invoked the rigour of the ancients to defend the essential stability of mathematics: the invariance of the discipline's paradigm of legitimacy and its concepts of proof and rigour, and – one is forced to add – an essentially Western (and not Babylonian, Indian, Chinese or Arabic) genealogy.[203] They write:

> Ever since the time of the Greeks, mathematics has involved proof; and it is even doubted by some whether proof, in the precise and rigorous sense which the Greeks gave to this word, is to be found outside mathematics. We may fairly say that this sense has not changed, because what constituted a proof for Euclid is still a proof for us; and in times when the concept has been in danger of oblivion, and consequently mathematics itself has been threatened, it is to the Greeks that men have turned again for models of proof. But this venerable bequest has been enlarged during the past hundred years by important acquisitions.[204]

Bourbaki sought to identify and to codify the essential, invariant aspects of mathematical language:

> By analysis of the mechanism of proofs in suitably chosen mathematical texts, it has been possible to discern the structure underlying both vocabulary and syntax. This analysis has led to the conclusion that a sufficiently explicit mathematical text could be expressed in a conventional language containing only a small number of fixed 'words', assembled according to a syntax consisting of a small number of unbreakable rules: such a text is said to be *formalized*.[205]

Bourbaki claim, then, that proofs can always be recognised as proofs because beneath the local variations in the surface layer of the text, they share an underlying structure. Yet, since the

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[200] 'Il faut faire un traité utile à tous: aux chercheurs (patentés ou non), aux "trouveurs", aux candidats aux fonctions de l'enseignement public, aux physiciens et à tous les techniciens', Traité d'Analyse - Réunion du 14/01/1935, Delta 002, p. 2-3, *Archives de l'Association des Collaborateurs de Nicolas Bourbaki.*

[201] Leo Corry, 'Writing the Ultimate Mathematics Textbook: Nicolas Bourbaki's *Éléments de mathématique*', in *The Oxford Handbook of the History of Mathematics*, ed. by Eleanor Robson and Jacqueline Stedall (Oxford: Oxford University Press, 2009).

[202] 'R145. Introduction au Livre I (Etat 2: Nunke)', *Archives de l'Association des Collaborateurs de Nicolas Bourbaki.*

[203] Q.v., for example, Karine Chemla and Gue Shuchun, *Les neuf chapitres: Les classique mathématique de la Chine ancienne et ses commentaires* (Paris: Dunod, 2004).

[204] Bourbaki, *Elements of Mathematics: Theory of Sets*, p. 7.

[205] Bourbaki, *Elements of Mathematics: Theory of Sets*, p. 7.

mathematical text is defined by its hypothetical formalisation, the underlying structure of proof exists only in the realm of potentiality. In practice, mathematicians do not and cannot make Leibniz's dream real: they never write out their proofs in an entirely formal language. Such a project would be, Bourbaki point out, 'absolutely unrealizable' as 'the tiniest proof at the beginning of the Theory of Sets would already requite several hundreds of signs for its complete formalization'. Bourbaki, therefore, must appeal to their implied reader's 'intuition', to their 'common sense' and to their 'confidence' ('a confidence analogous to that accorded by a calculator or an engineer to a formula or a numerical table without any awareness of the existence of Peano's axioms').[206]

The rigour of a proof is, nonetheless, judged on 'the possibility of translating it unambiguously into such a formalized language'.[207] The arts of reading and of writing mathematics require a kind of double vision: 'Thus, written in accordance with the axiomatic method and keeping always in view, as it were on the horizon, the possibility of a complete formalization, our series lays claim to perfect rigour'.[208] The reader assesses the rigour or correctness of a text 'by comparing it, more or less explicitly, with the rules of a formalized language'.[209] The writer, meanwhile, composes texts for translation: 'The *axiomatic method* is, strictly speaking, nothing but this art of drawing up texts whose formalization is straightforward in principle'.[210]

Bourbaki's mathematical structuralism sounds rather like linguistic structuralism here (they could be discussing the *langue* and *parole* of mathematical language) and indeed they reference linguistics in defence of their project:

> Just as the art of speaking a language correctly precedes the invention of grammar, so the axiomatic method had been practised long before the invention of formalized languages; but its conscious practice can rest only on the knowledge of the general principles governing such languages and their relationship with current mathematical texts.[211]

Bourbaki, however, were not concerned with 'languages' in the plural. Bourbaki describe their 'axiomatic method' as a way to transcend the limitations of specialisation. When faced with 'complex mathematical objects', Bourbaki 'separate their properties' (algebraic properties,

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[206] *Elements of Mathematics: Theory of Sets*, pp. 10-11. Peano's axioms are the canonical formalisation of the natural numbers and thus of arithmetic.
[207] *Theory of Sets*, p. 8.
[208] *Theory of Sets*, p. 12.
[209] *Theory of Sets*, p. 8.
[210] *Theory of Sets*, p. 8.
[211] *Theory of Sets*, p. 9. Bourbaki's mathematical structuralism did occasionally cross paths with other structuralisms. André Weil, for example, worked with Claude Lévi-Strauss and wrote a mathematical appendix to part one of *The Elementary Structures of Kinship*: 'Sur l'étude algébrique de certains types de lois de mariage' ('On the algebraic study of certain types of marriage laws (Murngin system))'. For an extended analysis of Bourbaki's links with French structuralism, see David Aubin, 'The Withering Immortality of Nicolas Bourbaki: A Cultural Connector at the Confluence of Mathematics, Structuralism, and the Oulipo in France', *Science in Culture*, 10.2 (1997), 297-342.

topological properties, and so on) and 'regroup them around a small number of concepts': they 'classify them according to the *structures* to which they belong'. Indeed, where it was once thought that the results in each branch of mathematics were dependent on that branch's distinctive form of mathematical intuition, it is now, Bourbaki argue, logically possible 'to derive practically the whole of known mathematics from a single source, the Theory of Sets'. In light of this, Bourbaki give the principles of a single formalised language, and then specify how set theory 'could be written in this language', before showing how various other branches of mathematics might fit in to their unified language project.

Bourbaki's doctrine of potential formalisation inspired and justified the Oulipo's project of 'potential literature'. For Queneau and Jacques Roubaud, recognising that formalisation exists only as potential, as a limit toward which writing tends, allowed them to see all writing, whether it declared its mathematical credentials or not, as existing in a continuum of formalisation. In his essay on Queneau, Roubaud quoted Bourbaki's description of the axiomatic method at length:

> '*Strictly speaking, the axiomatic method is nothing other than the art of drafting texts whose formalization is easy to conceive. This is by no means a new invention, but its systematic use as an instrument of discovery is one of the original traits of contemporary mathematics. It matters little whether the formalized text is to be written or read, whether one attaches such and such a meaning to the words or signs of this text or rather none at all; only the correct observation of the rules of syntax matters. It is thus that the same algebraic calculation may, as everyone knows, serve to solve problems involving kilograms or francs, parabolas or uniformly accelerated movements. The same advantage, and for the same reasons, accrues to any text drafted according to the axiomatic method*'.[212]

Bourbaki do write in rather loose, general terms here: they claim that 'any text' can use the axiomatic method and accrue its advantages. And when mathematicians claim their methods are universally applicable, Queneau and Roubaud are likely to take those claims as challenges and as adventures. Queneau's treatment of David Hilbert's *Foundations of Geometry*, which I discussed earlier, is a case in point. Roubaud's essay uses Bourbaki's definition of the axiomatic method to define the project of the Oulipo:

> One might say that the Oulipean method *imitates* the axiomatic method, that the former is a transposition of the latter, a transfer to the field of literature.
> *Proposition 14:* A constraint is the axiom of a text.
> *Proposition 15:* Writing under Oulipean constraint is the literary equivalent of the drafting of a mathematical text, which may be formalized according to the axiomatic method.[213]

The term 'perimathematical', as I noted previously, is taken from Raymond Queneau's manifesto for the Oulipo, 'Potential Literature', in which he claims that Oulipo's work is: '(1) *Naive*: I use the work "naive" in its perimathematical sense, as one speaks of the naive theory of sets. We

[212] Roubaud, 'Mathematics in the Method of Raymond Queneau', pp. 88-89.
[213] Roubaud, 'Mathematics in the Method of Raymond Queneau', p. 89.

forge ahead without undue refinement'.[214] Queneau's manifesto defended Oulipo's playful use of mathematics to create what the group call 'potential literature'. After all, the history of mathematics shows us that ludic, impure uses of mathematics are often, in the end, vindicated:

> Let us remember that topology and the theory of numbers sprang in part from that which used to be used to be called 'mathematical entertainments,' 'recreational mathematics.' […] Let us also remember that the calculation of probabilities was at first nothing other than an anthology of 'diversions,' as Bourbaki states in the 'Notice Historique' of the twenty-first fascicle on Integration. And likewise game theory until von Neumann.[215]

Oulipo draw on mathematics – combinatorial techniques, Boolean algebra and Bourbaki's axiomatic method, for example – in their literary practice. Their objective is to create 'potential literature': to 'propose new "structures" to writers, mathematical in nature' or 'invent new artificial or mechanical procedures that will contribute to literary activity'.[216] However, Queneau's manifesto also implies that Oulipean writing and 'naïve' mathematical writing exist in the same state of potentiality: both look like mere 'parlour games' until they are realised as literary texts or as formalised mathematics. 'Since we as yet have no Kolmogoroff, I will now present our diversions to you', Queneau declares in his manifesto before demonstrating a few Oulipean exercises: 'Redundancy in Mallarmé', 'The S + 7 Method' and 'Isomorphisms'. As I discuss later in the thesis, A. N. Kolmogorov established the basic axioms of probability theory in his 1933 *Grundbegriffe der Wahrscheinlichkeitsrechtung*, thus converting probability theory into pure mathematics.

The name 'Bourbaki' connotes mathematical structuralism and an austere, formalist, axiomatic style (and indeed, for those old enough to remember it, the short-lived, heavily set-theoretic 'New Math' of 1960s curriculum reform).[217] Yet, both Bourbaki's structuralism and their axiomatic style were ambivalent, even contradictory. Bourbaki's structures led double lives. 'Structure' had both a formal and a nonformal meaning in Bourbaki's work, as Leo Corry explains:

> On the one hand, it suggested a general organizational scheme for the entire discipline, which turned out to be very influential. On the other hand, it comprised a concept that was meant to provide the underlying formal unity but was of no mathematical value whatsoever either within Bourbaki's own treatise or outside it.[218]

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[214] Raymond Queneau, 'Potential Literature', in *Oulipo: A Primer of Potential Literature*, ed. and trans. by Warren Motte (London: Dalkey Archive Press, 2014), pp. 51-65 (p. 51).
[215] Queneau, 'Potential Literature', p. 52.
[216] Queneau, 'Potential Literature', p. 51.
[217] In Germany the backlash against the New Math made the cover of *Der Spiegel* on 25 March 1974: the headline 'Macht Mengenlehre krank?' ('Sickened by set theory?') was emblazoned across the face of an unhappy-looking child. In the United States, meanwhile, Morris Kline denounced the Bourbaki-inspired educational reforms in *Why Johnny Can't Add: The Failure of the New Math* (New York: St. Martin's Press, 1973).
[218] Corry, 'Writing the Ultimate Mathematics Textbook', p. 579.

For the working mathematician, including Bourbaki's members, formal structures were a dead-end.[219] Corry points out that Bourbaki's 'structures' were already, at their inception, being usurped by the subtly different formulations of category theory. In fact, categorical formulations (which, Corry says, proved 'more flexible and effective' than structural formulations) appeared throughout Bourbaki's work, Corry writes, 'despite the group's refusal to explicitly recognize this fact', and despite their public adherence to the structure as universal explanatory discourse.[220] Bourbaki's published writings and their archives show the tangled visions and discordant notes of their utopianism. Nonetheless, Bourbaki's nonformal structuralist image of mathematics gained traction both inside and outside the discipline of mathematics. Oulipo's concept of structure, for example, was based on 'the Bourbakian' mathematical structure, as Roubaud explains: 'the object in the mathematical case is a (or several) set(s) with something "on it" (one or several algebraic laws, proximities in topology…); in the case of the Oulipo, the object is linguistic, and its structure is a mode of organization'.[221]

Bourbaki's structuralist image of mathematics, then, belongs to their perimathematical writing: to their histories, parables, prefaces and manifestos. In particular, the image belongs to Bourbaki's manifesto, 'The Architecture of Mathematics', which was written by Jean Dieudonné and published in 1948, in a special issue of *Cahiers du Sud* edited by François Le Lionnais on 'Les grands courants de la pensée mathématique'. Le Lionnais would go on to become a founding member of Oulipo and to write the first manifestos of the Oulipo movement. His commentary is woven throughout the two existing volumes of *The Great Currents of Mathematical Thought* (an encyclopaedic project that was never, in fact, completed). Le Lionnais sketched the outline of the first part of the project using an architectural metaphor:

> *Before exploring in turn the different chapels of the Temple of Mathematics, it is appropriate to tell, in so far as possible, of its general plan, to specify the materials employed, to describe the architectural styles which are juxtaposed in it. This is the aim of the first book of Part I, entitled "Structures".*[222]

Bourbaki's article is introduced as a manifesto, offering an image of the 'totality' of mathematics:

> *In order to disentangle the meaning of the totality of mathematics, we addressed ourselves to Nicolas Bourbaki, that many-headed mathematician who has undertaken the reformulation of the exposition of mathematics from its origins – not historical but logical – and endeavors to reconstruct it in all its complexity with materials passed through the sieve of axiomatic critique. Understood thus, mathematics*

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[219] The 'working mathematician' is a figure frequently invoked in discussions of the philosophy of mathematics: he or she simply 'gets on with the job', developing new concepts and proving new theorems without focusing on philosophical questions. To my knowledge, the term's current usage began with Saunders Mac Lane's textbook *Categories for the Working Mathematician* (New York: Springer, 1971).

[220] Leo Corry, 'Nicolas Bourbaki and the Concept of Mathematical Structure', *Synthese* 92.3 (1992), 315-348 (p. 336).

[221] Roubaud, 'Mathematics in the Method of Raymond Queneau', p. 93

[222] *Great Currents of Mathematical Thought, 2 Vols; Vol. 1. Mathematics: Concepts and Development*, ed. by François Le Lionnais, trans. by R. A. Hall and Howard G. Bergman (New York: Dover, 1971), p. 9.

> *reduces to the study of very general laws that apply to collections of elements which are no longer necessarily numbers or points. Bourbaki's article could serve as a manifesto for an entire school which follows his teaching and as preface to a work of which we have as yet only six fascicules and whose completion is awaited with impatience.*[223]

Bourbaki's manifesto argues that despite the apparent splitting of mathematics into specialised branches, the discipline can and will retain its unity. The 'axiomatic method' is Bourbaki's insurance against the threat of the discipline's fragmentation: against the possibility of mathematics becoming 'a tower of Babel of autonomous disciplines'.[224] Bourbaki's axiomatic method enables 'a systematizing of the relations existing among the various mathematical theories'.[225] Bourbaki's project will show the underlying unity of mathematics by a process of analysis and synthesis. Each theory will be decomposed into its constituent elements, and the relations among those elements will be uncovered and reordered into a hierarchy of types of mathematic 'structure'. As such, 'mathematical structures become, properly speaking, the *sole "objects"* of mathematics'.[226] Bourbaki use two metaphors of modernisation to explain their reconstruction project: Haussmann's Paris and Frederick Winslow Taylor's factory line, as Peter Galison points out.[227] Mathematics, Bourbaki write, is:

> Like a great city whose suburbs never cease to grow in a somewhat chaotic fashion on the surrounding lands, while its center is periodically reconstructed, each time following a clearer plan and a more majestic arrangement, demolishing the old sections with their labyrinthine alleys in order to launch new avenues toward the periphery, always more direct, wider and more convenient.[228]

The axiomatic method enables, Bourbaki argue, an '*economy of thought*': 'It can thus be said that the axiomatic method is nothing but the "Taylor System" – the "scientific management" – of mathematics'.[229] Yet the factory line metaphor proves inadequate and Bourbaki immediately retract their claim: 'this comparison is not sufficiently close; the mathematician does not work mechanically as does the worker on the assembly line; the fundamental role that a special *intuition* plays in his research cannot be overestimated'.[230] The manifesto is full of moments of disavowal. While proclaiming themselves the heirs to Hilbert's formalism, Bourbaki seek to absolve themselves from the charges levelled at formalism (that it is a 'lifeless skeleton', machine-like, divorced from physical reality, somehow inhuman) by deploying an organic register of biological

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223 *Great Currents*, p. 10.
224 Bourbaki, 'The Architecture of Mathematics', in *Great Currents of Mathematical Thought, 2 Vols; Vol. 1. Mathematics: Concepts and Development*, ed. by François Le Lionnais, trans. by R. A. Hall and Howard G. Bergman (New York: Dover, 1971), pp. 23-37 (p. 24).
225 Bourbaki, 'The Architecture of Mathematics', p. 25.
226 Bourbaki, 'The Architecture of Mathematics', p. 29n.
227 See Galison, 'Structures of Crystal, Buckets of Dust'.
228 Bourbaki, 'The Architecture of Mathematics', p. 34.
229 Bourbaki, 'The Architecture of Mathematics', p. 31.
230 Bourbaki, 'The Architecture of Mathematics', p. 31.

language (they talk of organisms, 'mother-structures', 'nourishing sap' and so on) alongside the inorganic, modernist, often architectural register of structure and form. In fact, Bourbaki's biological language echoes Hilbert's own rhetoric. He, too, used the romanticist, biological metaphor of the organic whole to defend the unity of mathematics: 'Mathematical science is in my opinion an indivisible whole, an organism whose vitality is conditional upon the connection of its parts'.[231]

The manifesto's method of tropological substitution enables mathematical 'modernism' to co-exist with intuition, with romanticism, with the organic: in other words, with everything that modernism is said to have erased from mathematics. Bourbaki's project, the unification of mathematics, is thus played out in their manifesto at the tropological level: the unity of mathematics is brought about – albeit uneasily – by the unification of images of mathematics and different metaphors for mathematical unity. Indeed, François Le Lionnais hinted at this discursive unification project in his commentary: '*Bourbaki's message, so rich and so dense with meaning, has as its overall aim a systematic inventory of the analogies in mathematics and at the same time an elucidation of their validity and of their significance*'.[232]

Fascination with Bourbaki infected Oulipean writing. Bourbaki's structures are central to François Le Lionnais's two manifestos for the Oulipo. In 'Lipo: First Manifesto', he writes:

> Mathematics – particularly the abstract structures of contemporary mathematics – proposes thousands of possibilities for exploration, both algebraically (recourse to new laws of composition) and topologically (considerations of textual contiguity, openness and closure). We're also thinking of anaglyphic poems, texts that are transformable by projection, etc.[233]

Le Lionnais's first manifesto begins as many manifestos do: by spoofing the genre's typically overblown rhetoric. The manifesto announces a new movement while simultaneously crafting the conditions of possibility for that movement: fashioning the movement's preconditions and prescribing the terms of its reception. 'Potential Literature' is announced as imminent, necessary and urgent: witness 'the impatience of the starving multitudes'.[234] Le Lionnais's manifesto then takes on an oppositional tone. He invents a battleground, 'the Quarrel of the Ancients and the Moderns', in which Oulipo, of course, fight for the 'Moderns'. The quarrel also functions as a grandiose prehistory of and justification for the Oulipo. The manifesto confronts its reader with absurd, overblown questions: 'Do you remember the polemic that accompanied the invention of language?'; 'And the creation of writing, and grammar, do you think that happened without a

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231 David Hilbert, 'Mathematical Problems' (1902), trans. by M W Newson in *BAMS* 8, 437-479 (pp. 478-479).
232 *Great Currents*, p. 11.
233 François Le Lionnais, 'Lipo: First Manifesto' (1962) in *Oulipo: A Primer of Potential Literature*, ed. and trans. by Warren Motte (London: Dalkey Archive Press, 1998, rept. 2014), pp. 26-29 (p. 27).
234 Le Lionnais, 'Lipo: First Manifesto', p. 26.

fight?'; 'Should humanity lie back and be satisfied to watch new thoughts make ancient verses?'.[235] After getting the hortatory part over with, Le Lionnais proceeds to present the two aspects of Oulipo's project: its 'Analysis and Synthesis'. 'Analoulipsm' will examine the formal qualities of past literature, looking for any latent potentialities, anything that could become an Oulipean structure, while 'Synthoulipism' will invent new constraints and structures for potential literature.[236]

Bourbaki's presence is felt far more strongly in Le Lionnais's 'Second Manifesto' for Oulipo (1973). Indeed, this 'Second Manifesto' is as much a response to Bourbaki's 'The Architecture of Mathematics' as it is a statement of purpose for the Oulipo movement. Le Lionnais's 'Second Manifesto' addresses the question of 'the efficacy and the viability of artificial (and, more generally, artistic) literary structures'.[237] So far, he writes, the Oulipo have been concerned with bringing a syntactic, structural focus to bear on 'the formal aspects of literature'. It is time, Le Lionnais writes, 'to try and broach the question of semantics'.[238] Le Lionnais's response to those who would criticise the Oulipo's project (which involves reconstructing literary history by dismantling old works to find their 'structures' and creating 'constraining structures' that can generate new works of literature) draws on the rhetorical play of Bourbaki's 'The Architecture of Mathematics'. Le Lionnais invokes an organic, biological register. Those sceptical of the Oulipo might ask:

> But can an artificial structure be viable? Does it have the slightest chance to take root in the cultural tissue of a society and to produce leaf, flower, and fruit? Enthusiastic modernists are convinced of it; diehard traditionalists are persuaded of the contrary. And there we have it, arisen from its ashes: a modern form of the old Quarrel of the Ancients and the Moderns.[239]

Le Lionnais's wry response unites vital, biological language with the language of artificial structures, formal play and empty syntactic innovation not by tropological substitution, but by invoking the creation of life in the scientific laboratory:

> One may compare this problem – *mutatis mutandis* – to that of the laboratory synthesis of living matter. That no one has ever succeeded in doing this doesn't prove a priori that it's impossible. […] The Oulipo has preferred to put its shoulder to the wheel, recognizing furthermore that the elaboration of artificial literary structures would seem to be infinitely less complicated and less difficult than the creation of life.[240]

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[235] Le Lionnais, 'Lipo: First Manifesto', pp. 26-7.
[236] 'Lipo: First Manifesto', pp. 27-28.
[237] François Le Lionnais, 'Second Manifesto' (1973) in *Oulipo: A Primer of Potential Literature*, ed. and trans. by Warren Motte, pp. 29-31.
[238] Le Lionnais, 'Second Manifesto', p. 29.
[239] Le Lionnais, 'Second Manifesto', p. 30.
[240] Le Lionnais, 'Second Manifesto', pp. 30-31.

If most artificial structures created by the Oulipo exist in a potential state, awaiting their cultural animation, some of those structures are discovered or uncovered in existing cultural forms: we stumble upon them in nature, so to speak. Le Lionnais's point recalls Bourbaki's remarks about mathematical structures and their relationship to empirical reality:

> From the axiomatic point of view mathematics appears on the whole as a reservoir of abstract *forms*—the mathematical structures; and it sometimes happens, without anyone really knowing why, that certain aspects of experimental reality model themselves after certain of these forms, as if by a sort of preadaptation.[241]

Indeed, it remains surprising – even astonishing – that the structures, equations and other paraphernalia that mathematicians invent for their own purposes so often turn out to be accurate models of natural processes or extremely useful tools for understanding physical reality.[242] Jean Piaget even considered the correspondence between Bourbaki's 'mother structures' (these are the algebraic structures, structures of order and topological structures) and the elementary 'operations' that children use as they begin to interact with the world.[243] What Bourbaki call 'preadaptation', Le Lionnais refers to as 'plagiarism by anticipation'. On occasion, he writes, the members of the Oulipo 'discover that a structure we believed to be entirely new had in fact already been discovered or invented in the past'. When this happens, Oulipo 'make it a point of honour to recognize such a state of things in qualifying the text in question as "plagiarism by anticipation"'.[244]

Indeed, 'plagiarism by anticipation' is also a rather apt description of Bourbaki's historiographic method. 'Historical Notes' were appended to many of the chapters of Bourbaki's treatise. The 'Mode d'emploi' explains the rationale for the bracketing off of history from mathematics proper:

> Since in principle the text consists of the dogmatic exposition of a theory, it contains in general no references to the literature. Bibliographical references are gathered together in *Historical Notes*, usually at the end of each chapter. These notes also contain indications, where appropriate, of the unsolved problems of the theory.[245]

In fact, rather than useful collections of references, these histories are strange pieces of prose, markedly different in style from the rest of the text: often highly subjective, sometimes lyrical, they oscillate between hagiography of individual, proto-modern mathematicians and appeals to

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241 Bourbaki, 'The Architecture of Mathematics', p. 36.
242 This phenomena is often referred to as 'unreasonable effectiveness', after Eugene Wigner's essay 'The Unreasonable Effectiveness of Mathematics in the Natural Sciences', *Communications in Pure and Applied Mathematics* 13 (1960), 1-14.
243 Jean Piaget, *Structuralism*, trans. by Chaninah Maschler (London: Routledge and Keagan Paul, 1971), p. 28. Piaget gave further evidence for the belief that these structures were 'natural' in his 'Comments on Mathematical Education' in *Developments in Mathematical Education – Proceedings of the Second International Congress on Mathematical Education*, ed. by A. G. Howson (Cambridge: Cambridge University Press, 1973), pp. 79-87 (p. 83).
244 Le Lionnais, 'Second Manifesto', p. 31.
245 Bourbaki, *Elements of Mathematics: Theory of Sets*, p. vi.

the unstoppable, de-individualised force of ideas. Bourbaki's historical notes often spanned a wide expanse of time: sometimes reaching all the way back to the ancient Greeks or to the Babylonians. They tended to give the history of mathematics as the prehistory of Bourbaki. Jacques Roubaud describes them as 'teleologically conceived in order to create the feeling that, since the very origins of humanity, mathematics has been converging inevitably toward a single point (the world had been created to produce one book, and it was to be by Bourbaki)'.[246]

A 1947 'La Tribu' bulletin invented an incident of a mock-historical report given as a mock-inaugural speech in order to mock both algebra and the style of Bourbaki's historiography:

> The historical note to chapters 2-3 of the *Algebra*, read in the guise of an augural address, put the congress "in the right mood" for algebra: it glorified Fermat, obediently followed the meandering of the linear and examined the influence of Mallarmé on Bourbaki.[247]

Paradoxically, the strictures of axiomatic style that were imposed on Bourbaki's treatise also generated the semantic excesses of 'La Tribu': an overflow of non-formal, playful language; of pastiche, parody, puns, nonsense and poetry, in which words grabbed the multiple meanings they were denied in the *Éléments*. Bourbaki's absurdist sense of humour, hidden in their archives, is missing from many characterisations of the group. Roubaud, for example, claimed that the Oulipo were at once 'an homage to Bourbaki' and 'a parody of Bourbaki, even a profanation of Bourbaki', since:

> Bourbaki's initial plan - to rewrite Mathematics in its entirety and provide it with solid foundations using a single source, Set Theory, and a rigorous system, the Axiomatic Method - is at once serious, admirable, imperialistic, sectarian, megalomaniac, and pretentious. (Humor has not been one of its prime characteristics.)[248]

Yet, the issues of Bourbaki's bulletin were full of jokes, nonsensical stories, hoaxes, neologisms and ridiculous anecdotes about the various Bourbaki congresses. Many Bourbaki members were *normaliens*, and 'La Tribu' abounds with the particular slang and the *canular* humour of the École Normale. Even the lists of members present at the Bourbaki congresses were defiantly odd: they sometimes included 'extras' (wives, children, locals, farm animals, etc.) and 'props' (cars, bicycles, prams, binoculars, aspirin and other paraphernalia were listed alongside standards like the blackboard and its duster).[249] Indeed, Liliane Beaulieu recounts that 'Bourbaki once even "borrowed" French poet Jacques Prévert's racoon for its own imitation of his famous poem

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[246] Jacques Roubaud, *Mathematics: (a novel)*, p. 144.

[247] 'Note historique des chap. II-III d'Algèbre, lue en guise de discours inaugural, mit le Congrès "in the right mood" quant à l'Algèbre: il glorifia Fermat, suivit docilement les méandres du linéaire et scruta l'influence de Mallarmé sur Bourbaki.' 'La Tribu (Bulletin oecuménique, apériodique et bourbachique)', 'Compte-rendu du Congrès de Noël' (1947), *Archives Bourbaki*.

[248] Jacques Roubaud, 'The Oulipo and Combinatorial Art' (1991), trans. by Harry Mathews, in *Oulipo Compendium*, ed., by Harry Mathews and others and trans., by Harry Mathews and others (London: Atlas, 2005).

[249] As Beaulieu details in 'Bourbaki's Art of Memory', p. 226.

"The Inventory" as these lists, with their overabundance of ill-assorted objects, were highlighted by a hint of the absurd or surrealistic'.[250] Beaulieu remarks on the strange, Rabelaisian atmosphere of Bourbaki's conference proceedings: 'La Tribu' recounts events without any clear narrative sequence in a style that, she writes, 'verges on the grotesque'.[251] It was precisely by such surrealist tactics, Beaulieu argues, that the Bourbaki group crafted a collective identity and a collective memory: a shared past that was invented and transmitted via a 'vast fable' of mnemonic humour, myth and parody. 'Thus', Beaulieu writes, 'the Bourbaki collective cast itself in a memorial limbo, lingering between an undefined past and a neverending future'.[252] The issues of 'La Tribu' were also scattered with poetry: pastiches of, for example, Paul Valéry or Stéphane Mallarmé, that created a mythic genealogy for the figure of Bourbaki, or gave a mock-heroic account of his past triumphs.

'La Tribu' was often self-parodic. Issue 29, the report from the 'Congrès de l'incarnation de l'Ane qui trotte' ('Congress of the incarnation of the trotting ass'), is one such example: the 'trotting ass' is a plodding mathematical exposition, and the report heaps further scorn upon Bourbaki's style in a satirical ballad. This chanson paillarde is to be sung, its author suggests, to the tune of 'J'ai une histoire à raconter' or 'En descendant le rue d'Alger'. It mocks the preface-manifesto, the 'directions for use', of Bourbaki's *Éléments*:

Le mod' d'emploi de ce Traité (bis)
Est d'la plus grand' simplicité (bis)
Si quelqu'chos' n'est pas clair
Eh bien
Il vous suffit d'abstraire
Et la lumière revient (bis).

L'alphabet de tout' les nations (bis)
Sera mis à contribution (bis)
On a, pour êtr' plus clair
Souvent
Mis en p'tits caractères
Les passages importants (bis).

Les exercic' sont alléchants (bis)
Leur énoncé est séduisant
N'essayez pas d'en faire
Beaucoup
Car on dit qu'les deux tiers
Sont faux ou au d'ssous d'tout (bis).

Les notations, vous le verrez (bis)
Ont été fort améliorées (bis)

[250] Beaulieu, 'Bourbaki's Art of Memory', p. 226.
[251] 'Bourbaki's Art of Memory', p. 249.
[252] 'Bourbaki's Art of Memory', p. 249.

Et le meilleur critère
Eh bien
C'est que sur tout'la Terre
Personn' n'y comprend rien (bis).

L'ordre suivi dans l'exposé (bis)
A été longu'ment médité (bis)
On met les points s'condaires
Devant
Et puis, en corollaires
C' qui doit servir tout l'temps (bis).[253]

The chanson, roughly translated, goes something like this:

The directions for using this treatise (x2)
Are the height of simplicity (x2)
If there's something you still can't see,
Never fear!
Just think more abstractly
And it will all become clear (x2).

The alphabets of every nation (x2)
Will be used in explanations (x2)
For clarity's sake, we have
Often enough
Used the smallest font
For the most important stuff (x2).

The exercises are tantalising (x2)
Their wording is so enticing (x2)
But don't bother trying to do
A lot!
We've heard two thirds of them
Are false, or worse, are nonsense (x2).

Our notations, as you'll see (x2)
Are as improved as they can be (x2)
According to the best of criteria
Which is?
That in the whole wide world
No one can understand a single word (x2).

The order of the presentation (x2)
Was the subject of long meditation (x2)
We've put the secondary points
In front!
What's more, we've buried in corollaries
All the necessities: so you'll have to hunt (x2).

[253] 'La Tribu: an ecumenical, irregular and bourbakic bulletin' (no. 29, report on the 'Congrès de l'incarnation de l'Ane qui trotte', Celles-sur-Plaine, 19-26 Oct. 1952) in *Archives de l'Association des Collaborateurs de Nicolas Bourbaki.*

Bourbaki were, therefore, already in the business of parodying Bourbaki (and doing so in verse) before Oulipo came on the scene. The Bourbaki movement was, at least in part, a series of experiments in genre: from their (admittedly minor) works of literary pastiche, through their parables and historiography, to the grand experiment of the *Éléments*, which turned the humble analysis textbook into the bearer of a utopian vision.

For David Aubin, Jean-François Lyotard and Michel Serres, Bourbaki were fundamentally modernists. Over the course of the 1970s, Bourbaki's cultural influence declined dramatically. Aubin argues that where once Bourbaki (and their 'structures') had been a 'cultural connector', invoked by practitioners across various disciplines; after the 'postmodernist turn', Bourbaki were replaced in the role of cultural connector by new mathematicians and mathematical ideas, such as René Thom's catastrophes and Benoit Mandelbrot's fractals.[254] In Benoit Mandelbrot's no doubt artful account he was opposed to Bourbaki from the start. Mandelbrot claims he spent only one day as a student of the École Normale Supérieure in 1945: resigning after the first day because he saw that the 'Bourbaki cult' was taking over the school.[255] He writes that his uncle, the Bourbaki member Szolem Mandelbrojt, was 'upset and afraid' by his nephew's decision to change schools: 'the way any fanatic, scientific purist fears new alloys'.[256]

There was, certainly, no place for Bourbaki's formalism in Lyotard's 'postmodern science', which 'by concerning itself with such things as undecidables, the limits of precise control, conflicts characterized by incomplete information, "*fracta*", catastrophes, and pragmatic paradoxes – is theorizing its own evolution as discontinuous, catastrophic, nonrectifiable, and paradoxical'.[257] The era of formalism was over for Serres too. In 1980, he wrote: 'mathematics globally veered to formalism at the beginning of the century. It forsook intuition. It forgot intuition. […] Physicists or philosophers, sociologists or biologists, we were all formalists'; yet 'intuition' and 'space' have staged a comeback – we now speak of 'Catastrophes *à la* Thom or fractals *à la* Mandelbrot. For five to ten years, again it's been a party'.[258] Yet, alongside their will to abstraction and formal purity, Bourbaki displayed a playful attitude to mathematical style – a certain fluidity, an inclination to pastiche – that can be understood as an homage to an ancient

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254 Aubin, 'The Withering Immortality of Nicolas Bourbaki', pp. 332-3.

255 Benoit B. Mandelbrot, *The Fractalist: Memoir of a Scientific Maverick* (New York: Pantheon Books, 2012), pp. 92-3.

256 Mandelbrot, *The Fractalist*, pp. 92-3. In an interview with Donald MacKenzie, Mandelbrot also said that a crucial turning point in his work was reading a review he found in his uncle Szolem's wastepaper basket. The review was of George K. Zipf's *Human Behaviour and the Principle of Least Effort: An Introduction to Human Ecology* (Cambridge, MA: Addison-Wesley, 1949), in which Zipf reported the multi-language word-frequency known as 'Zipf's law', and which served for Mandelbrot as the prototype of his emphasis on 'power law' distributions with their 'heavier tails' (higher frequencies of extreme events) than the normal or Gaussian distribution discussed below in my chapter on 'The Literary Phenomenology of Probability'.

257 Jean-François Lyotard, *The Postmodern Condition*, trans. by G. Bennington and Brian Massumi (Minneapolis: University of Minnesota Press, 1984), pp. 43-60.

258 Michel Serres, *Hermes V: Le passage du Nord-Ouest* (Paris: Minuit, 1980), passage trans. by Aubin in 'The Withering Immortality of Nicolas Bourbaki', pp. 332-333.

Greek age of 'ludic proof', to borrow Reviel Netz's phrase, as avant-garde, or even as post-modern. Bourbaki were both meta-mathematical and meta-fictional. By inventing their own, self-consciously fictive origin myths, they drew attention to the mechanisms of disciplinary construction: to the ways in which images of mathematics are built by cultural bricolage.

LITERATURE'S MATHEMATICAL VERNACULARS

SAMUEL BECKETT'S NUMBERS

> But we don't know what a number is, so we don't know what we are.
>
> Alain Badiou, *Number and Numbers*.[1]

Beckett's Numbers

In the *Philosophical Investigations*, Wittgenstein saw the various kinds of number (the cardinal numbers, the rational numbers, the real numbers and so on) as a 'family':

> Why do we call something a 'number'? Well, perhaps because it has a – direct –affinity with several things that have hitherto been called 'number'; and this can be said to give it an indirect affinity with other things that we also call 'numbers'. And we extend our concept of number, as in spinning a thread we twist fibre on fibre. And the strength of the thread does not reside in the fact that some one fibre runs through its whole length, but in the overlapping of many fibres.[2]

When looking at literature's worlds of number and comparing its myriad mathematical vernaculars, certain family resemblances emerge and begin weaving 'a complicated network of similarities overlapping and criss-crossing'.[3] Samuel Beckett's work is threaded through the following sections. By following the entanglements of Beckett's literary mathematics, I will trace several of the mathematical idioms at work in modern literature: mathematical folklore, numerical nonsense, vaudeville combinatorics and arithmetical consolation. As Beckett's prose work is braided though my reflections on literary numbers, so numbers and numerals are woven into the texture of Beckett's prose. His numbers traverse the boundaries between domains: crisscrossing novels, characters and periods.

Beckett's work displays a particular and peculiar tropism toward mathematics.[4] Many critics have picked up on the mathematical references scattered throughout Beckett's work.[5]

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[1] Badiou, *Number and Numbers*, p. 3.

[2] Ludwig Wittgenstein, *Philosophische Untersuchungen/Philosophical Investigations*, trans. by G. E. M. Anscombe, P. M. S. Hacker, and Joachim Shulte, rev. 4th ed. by P. M. S. Hacker and Joachim Shulte (Oxford: Blackwell, 2009), p. 36.

[3] Wittgenstein, *Philosophische Untersuchungen/Philosophical Investigations*, p. 36.

[4] Indeed, Hugh Kenner, one of the founding figures of Beckett studies was particularly interested in this aspect of Beckett's work. Kenner's analysis of the place of mathematics in Beckett's novels is both wonderfully lyrical and much too Platonic to be accurate: he speaks of 'number's realm of the spectrally perfect, where enmired existence may be annihilated by essence utterly declared'. Kenner's insistence that Beckett was a Pythagorean about number seems to me somewhat misguided, given that Beckett so often derided Pythagoreanism and used it as a trope for oppressive literary and artistic conventions. See *Samuel Beckett: A Critical Study* (New York: Grove, 1961), p. 109.

[5] For example, C. J. Ackerley, 'Samuel Beckett and Mathematics', *Cuadernos de literatura Inglesa y Norteamericana*, 3. 1-2 (1998), 77-102; Brett Stevens, 'A Purgatorial Calculus: Beckett's Mathematics in "Quad"', *A Companion to Samuel*

Andrew Gibson, in particular, makes the striking claim that Beckett's work is in fact 'much closer to mathematics than it is to most literature':

> Like mathematics, it is characterized by its powerful will to abstraction; its radical withdrawal from a world of which it none the less retains a residual trace; its frequent concern with extraordinary paradoxes and what seem to be irreducible problems and impossibilities; and its formalization of material that is threatened with drastic inconsistency.[6]

Gibson also points out that Beckett responded to different forms of mathematics in very different ways. Beckett's irony, for example, was directed primarily at Pythagoreanism and Euclidean geometry. Molloy and Moran, meanwhile, stand for different mathematical sensibilities. Molloy lacks a feeling for 'limits': he stands for 'actual infinity' and 'as a great ironist of the finite calculation'. Moran, before his unravelling, 'acquiesces in a finite, State representation of himself': he 'knows himself in and as calculation'.[7]

In *Rules for the Direction of Mind*, Descartes associated the low arts of weaving, tapestry and embroidery 'in which threads are interwoven in an infinitely varied pattern', with the low mathematics of arithmetic and number games.[8] Low mathematics – the everyday mathematics of arithmetic, schoolroom geometry, permutations and calculations – is a broken tool in Beckett's world and it is broken in interesting ways. Ian Hacking remarks of this everyday mathematics that:

> Kant took for granted that '5+7=12' is a truth which we know to be true. His conundrum would seem less pressing if we took this formula to be an instruction about the manipulation of information. And if we think common or garden mathematics is about rules, rather than propositions, we shall be less tempted to engage in what Wittgenstein called 'mathematical alchemy' that transmutes numbers into objects.[9]

Beckett, ed. by S. E. Gontarski (Chichester: Wiley-Blackwell, 2010), pp. 164-181; Elizabeth Klaver, '*Proof*, π, and *Happy Days*: The Performance of Mathematics', *Journal of the Midwest Modern Language Association*, 38.1 (2005), 5-22; Enoch Brater, 'Mis-takes, Mathematical and Otherwise, in The Lost Ones', *MFS* 29.1 (1983), 93-109; Jeremy Parrott, 'Infinity Minus One: Mathematics and the Search for Self in the Works of Samuel Beckett', *B. A. S.* 4.1 (1999), 23-33; Hugh Culik, 'Science and Mathematics', *Samuel Beckett in Context* (Cambridge: Cambridge University Press, 2013), pp. 348-361; Céline Surprenant 'An Occult Arithmetic: the "Proustian Equation" according to Beckett's Proust', *Journal of Romance Studies*, 7.3 (2007), 47-58; Angela Montgomery, 'Beckett and Science: *Watt* and the Quantum Universe', *Comparative Literature 13: Literature and Science* (1991), 171-185; Reuben J. Ellis, '"Matrix of Surds": Heisenberg's Algebra in Beckett's *Murphy*'. *Papers on Language and Literature* 25.1 (1989), 120-123; and Brian Macaskill, 'The Logic of Coprophilia: Mathematics and Beckett's *Molloy*', *SubStance: A Review of Theory and Literary Criticism*, 17.3 (1988), 13-21.

[6] Andrew Gibson, *Beckett and Badiou: The Pathos of Intermittency* (Oxford: Oxford University Press, 2006), p. 32.

[7] Gibson, *Beckett and Badiou*, pp. 34-5.

[8] René Descartes, 'Rules for the Direction of Mind', *The Philosophical Writings of Descartes*, vol. I, trans. by John Cottingham, Robert Stoothoff and Dugald Murdoch (Cambridge: Cambridge University Press, 1985), pp. 7-78 (p. 35).

[9] Hacking, 'Why is there Philosophy of Mathematics AT ALL ?', *South African Journal of Philosophy*, 30.1 (2011), 1-15 (p. 13).

Demotic mathematics ought, then, to be a collection of basic instructions and rules: a user's manual for the operation of data. Yet these rules, in Beckett's world, have a jarring *unreadinesstohand* (to borrow a suitably ungainly word from Heidegger).

Beckett's literary mathematics began as a series of myths, metaphors and puns in his early novels (*Dream of Fair to Middling Women*, written in 1932 and published posthumously in 1992, and *Murphy*, from 1938), literary criticism, letters and notebooks. Beckett's ironic and semantic treatment of mathematics in *Dream* and *Murphy* is coupled with and overtaken in *Watt* by a syntactic mathematics. Chris Ackerley traces the old conflict between arithmetic and geometry as it is staged within Beckett's novels but also as it divides those novels from one another: *Murphy*, for Ackerley, 'is a geometrical novel', while *Watt* 'is ostentatiously arithmetical'.[10] Indeed, Beckett's mathematical vernacular has many regional variants and modalities: puns, nonsense, romantic irony, elegy, burlesque, and the bleak rhythm of *How It Is* in which arbitrary large numbers produce and punctuate boredom. In the following sections, I will unravel some of the ways in which mathematical concepts appear and are experienced in Beckett's work, beginning with the many literary lives of Pythagoras.

Pythagoras's Literary Lives

> We have become Pythagoreans once again; all things are numbers.
>
> Michel Serres, *The Parasite*.[11]

Pythagorean lore is a repository of invented pasts. Pythagoras has become an emblem or, as Martínez puts it, 'a kind of currency'.[12] He is both symbol and synecdoche. Images of Pythagoras and Pythagoreanism have been variously deployed as origin myths, as insults, as guides to living and as scapegoats. 'Most tales of Pythagoras', Martínez argues, 'are symptoms of our unwillingness to confront uncertainty, to plainly admit: I don't know what happened'.[13] We project into the gap left by the silence of the historical Pythagoras, who wrote no books and whose contemporaries left no detailed records of his thought. There is no shortage, however, of doxography, rumour or literature about Pythagoras and the Pythagoreans: he has led many

[10] Chris Ackerley, 'Samuel Beckett: The Geometry of the Imagination', in *Samuel Beckett: Debts and Legacies*, ed. by Peter Fifield and David Addyman (London: Bloomsbury, 2013), pp. 85-109 (p. 93).
[11] Michel Serres, *The Parasite*, trans., by Lawrence R. Schehr (Baltimore, Maryland: The Johns Hopkins University Press, 1982), p. 172.
[12] Alberto A. Martínez, *The Cult of Pythagoras: Math and Myths* (Pittsburgh: University of Pittsburgh Press, 2012), p. 211.
[13] Martínez, *The Cult of Pythagoras*, p. 214.

fictional lives throughout the centuries. In Iamblicus's *On the Pythagorean Life* mathematics is offered, Liba Taub writes, as a guide to living. Pythagoras's own life is given as a parable.[14]

In literary culture, invocations and characterisations of Pythagoras have had many valences. Pythagoras has both personified the oppressions of literary tradition and embodied a mythic literary ideal. In '*The Difficulties* Interview', Susan Howe quoted a few lines from Melville's *Moby Dick* (lines of tribute to Pythagoras) before articulating the tension she feels between 'the pull of Melville's mythical ideal' and her own sense of 'otherness': 'When I call a book *Pythagorean Silence*, the title, for me, is implicitly ambiguous. In the whole wideness of the Literary Constitution of the West I have seldom felt supported by a silence of Fathers'.[15] Howe's poem *Pythagorean Silence* (1982) is layered with allusions to Pythagoras's other literary lives.[16] Her line 'Long Pythagorean lustrum' echoes Emerson's 'Literary Ethics', in which he urged silence, solitude and contemplation:

> But out of our shallow and frivolous way of life, how can greatness ever grow? Come now, let us go and be dumb. Let us sit with our hands on our mouths, a long, austere, Pythagorean lustrum. Let us live in corners, and do chores, and suffer, and weep, and drudge, with eyes and hearts that love the Lord. Silence, seclusion, austerity may pierce deep into the grandeur and secret of our being, and so diving, bring up out of secular darkness, the sublimities of the moral constitution.[17]

Howe also alludes to Pythagoras's speech in Ovid's *Metamorphoses*. John F. Miller remarks on the 'metaliterary resonance' of Pythagoras's speech. Miller argues that Ovid is treating Pythagoras ironically (he is a long-winded speaker with a somewhat faulty memory) and satirising the literary tradition of Pythagoras: 'Pythagoras recalls an event which he "lived" in the *Iliad*'.[18] Pythagoras's faulty memory is, perhaps, a product of the many contradictory accounts of his own life.

The mathematical culture of the doxographers, their world of rumours, parables and myths, is woven into Beckett's 1938 novel Murphy. Beckett's characters inhabit mathematical folklore. Murphy, Neary and Wylie have a strange cultural memory of a Pythagorean tradition of thinking about mathematics and fragments of a loosely Pythagorean vocabulary: 'demented particulars' like surd, tetrakyts, isonomy, limit, circumference and apmonia. Beckett's characters are broken Greek minds, speaking their inheritance imperfectly. Neary is a latter-day disciple of

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[14] See Liba Taub, 'Presenting a "Life" as a Guide to Living: Ancient Accounts of the Life of Pythagoras', *The History and Poetics of Scientific Biographt*, ed. by T. Söderqvist (Ashgate), pp. 17-36.
[15] Susan Howe, '*The Difficulties* Interview', *The Difficulties* 3.2, 'Susan Howe Issue', ed. by Tom Beckett (1989), 17-27 (p. 18).
[16] Susan Howe, *Pythagorean Silence* (New York: Montemora Foundation, 1982), repr. in *The Europe of Trusts* (New York: New Directions, 1990), pp. 15-85.
[17] Ralph Waldo Emerson, 'Literary Ethics', July 24 1839, in *Nature; Addresses, and Lectures* (Boston, MA: James Munroe and Company, 1849), p. 169.
[18] John F. Miller, 'The Memories of Ovid's Pythagoras', *Mnemosyne* 47.4 (1994), 473-487 (p. 476).

Pythagoras. *Murphy*, indeed, opens with Murphy having lately left Neary's 'Pythagorean Academy' in Cork. Beckett borrowed Neary's Pythagorean lexicon, as C. J. Ackerley chronicles, from John Burnet's *Early Greek Philosophy* and *Greek Philosophy: Thales to Plato.*[19] Neary's practice of 'Pythagorean arts' apparently allows him to stop his heart at will, through a process of 'mediation between extremes' that he called 'the Apmonia' and 'when he got sick of calling it the Apmonia he called it the Isonomy. When he got sick of the sound of Isonomy he called it the Attunement'.[20] Apmonia, Ackerley points out, is a misspelling of *ἁρμονία*, a Greek word that Burnet tells us means first 'tuning' and then 'scale': a blend of opposites that is found in medicine and in music and that acts as evidence of a conception of the world ordered numerically through the application of the limit to the unlimited (Neary's tractate, indeed, is titled 'The Doctrine of the Limit').[21] Murphy poses a problem for Neary because he 'had such an irrational heart no physician could get to the root of it': a pun on the mathematical sense of the irrational root that Beckett twists again into an image of Murphy's mind as a '[m]atrix of surds'.[22] Neary's synonyms, Isonomy and Attunement, are also borrowed from Burnet's *Greek Philosophy*: Burnet describes the doctrine of the limit applied to health as an isonomy, a harmonic mean in the body, and as an attunement: the body strung like a musical instrument to a certain pitch.[23] 'Numbers it is', as Leopold Bloom puts it in *Ulysses*: 'All music when you come to think. Two multiplied by two divided by half is twice one […] Musemathematics. And you think you're listening to the ethereal. But suppose you said it like: Martha, seven times nine minus x is thirtyfive thousand. Fall quite flat'.[24]

Neary uses the old story of Hippasos – who was purportedly drowned for revealing the secrets of the Pythagorean sect (specifically, for revealing the existence of irrational numbers such as π and the square root of two that cannot be expressed as either as wholes or as the ratios of wholes) – as a drunken threat:

> 'But betray me', said Neary, 'and you go the way of Hippasos.'
> 'The Akousmatic, I presume,' said Wylie. 'His retribution slips my mind.'
> 'Drowned in a puddle,' said Neary, 'for having divulged the incommensurability of side and diagonal.'
> 'So perish all babblers,' said Wylie.
> 'And the construction of the regular dodeca – hic – dodecahedron,' said Neary. 'Excuse me'.[25]

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[19] C. J. Ackerley, *Demented Particulars: The Annotated* Murphy (Edinburgh: Edinburgh University Press, 2010), p. 33.
[20] Samuel Beckett, *Murphy*, ed. by J. C. C. Mays (London: Faber and Faber, 2009), p. 4.
[21] John Burnet, *Greek Philosophy Part I: Thales to Plato* (London: Macmillan, 1928), pp. 44-45.
[22] Beckett, *Murphy*, p. 4; p. 72.
[23] Burnet, *Greek Philosophy*, p. 50.
[24] James Joyce, *Ulysses* (Oxford: Oxford University Press, 1993), p. 359.
[25] Beckett, *Murphy*, p. 32.

Hippasos dies a rather different death in Beckett's essay 'Les Deux Besoins' (1938), which offers an extended geometrical parable for – or pseudo-geometrical proof of – the difficulties of artistic creation. This time, Hippasos is not merely drowned in a puddle: he is killed by a mob in a public sewer. Nonetheless, Hippasos's dark secret is also the genesis of creative work: 'Side and diagonal, the two needs, the two essences, the being that is need and the necessity of its being so, the hell of unreason whence arises the blank cry, the series of pure questions, the work'.[26] Beckett invoked the image of Pythagoras, too, when discussing the history of painting. That history, he said, was the history of attempts to flee from failure by an 'estheticised automatism' and 'with a kind of Pythagorean terror, as though the irrationality of pi were an offence against the deity, not to mention his creature'.[27]

In *Dream of Fair to Middling Women* Pythagorean thought stood as a symbol of the kind of novel that Beckett's characters refused to let him write: the 'little book that would be purely melodic, think how nice that would be, linear, a lovely Pythagorean chain-chant of cause and effect, a one-figured teleophony that would be a pleasure to hear'.[28] This Pythagorean novel – linear, coherent and melodic – is impossible, the narrator remarks, because of the 'reluctance of our refractory constituents to bind together and give us a synthesis'.[29] *Dream*'s characters 'are no good from the builder's point of view, firstly because they will not suffer their systems to be absorbed in the cluster of a greater system, and then, chiefly, because they themselves tend to disappear as system. Their centres are wasting'.[30] Unlike Balzac's 'clockwork cabbage' characters, the characters in *Dream* resist their roles in the machinery of the novel. Belacqua and the others cannot be counted on to 'perform like decent indivisibilities' and as such the narrator answers his own question – 'Can we measure them once and for all and do sums with them like those imposters that they call mathematicians?' – resoundingly in the negative: 'We can not. We can state them as a succession of terms, but we can't sum them and we can't define them. They tail off vaguely at both ends and the intervals of their series are demented'.[31]

The narrator of *Dream of Fair to Middling Women* expresses his opinions about the aesthetic value of the novel he narrates through the idea of 'literary mathematics'. The accusation levelled by the Mandarin at Belacqua – 'You simplify and dramatise the whole thing with your literary mathematics' – is levelled, too, by *Dream*'s narrator at Balzac: 'The whole thing, from beginning to end, takes place in a spellbound backwash. We all love and lick up Balzac, we lap it up and say it is wonderful, but why call a distillation of Euclid and Perrault *Scenes from Life*? Why *human*

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[26] Samuel Beckett, 'Les Deux Besoins' in *Disjecta: Miscellaneous Writings and a Dramatic Fragment*, ed. by Ruby Cohn (New York: Grove, 1984), pp. 55-8.
[27] Samuel Beckett, *Proust and Three Dialogues with George Duthuit*, p. 125.
[28] Samuel Beckett, *Dream of Fair to Middling Women*, ed. by Eoin O'Brien and Edith Fournier (New York: Arcade, 1993), p. 9.
[29] *Dream*, p. 118-119.
[30] *Dream*, p.119.
[31] *Dream*, p. 113, pp. 124-125.

comedy?'[32] For its narrator, *Dream*'s formal problems, its structural failures and complexities, make it superior to Balzac's mechanistic novels. As such, 'literary mathematics' works both as a term of abuse and as the grounds on which *Dream*'s place in literary history might be established. *Dream*'s literary mathematics expresses the structural relationship between systems: the narrator's metafictional system, Belacqua's system and the systems of the other characters: their academic and pseudo-academic disciplines (bibliomania, palaeography, arithmomania, communist decoration, and so on) and their disciplined and undisciplined bodies.

'Literary mathematics', then, is both shorthand for novelistic structure and metaphor for Belacqua's attempts to understand and quantify his experience. Belacqua tries to organise and distil his experiences of beauty, to wring a general, basic concept of beauty from the comparison between two women, but this system of reduction and quantification fails him:

> Kindred items, cognate ones, like in kind, these I fancy can be reduced to a deep common point of divergence. Somewhere is the magic point where skirted beauty forks […] But to relate, say, volume to line, a beautiful hen, say, to a beautiful dry-point … Get along with you! No node can branch, here to the beauty of a bird, there to the beauty of a dry-point […] I cannot establish on a base *Aa*, where *A* is hen and *a* dry-point, a triangle with the desired apex, because, and you will appreciate this disability, I am unable to imagine the base *Aa*.[33]

Belacqua's own system, his use of mathematics as conceptual metaphor, is a synecdochic part of *Dream*'s demented, self-cancelling literary mathematics. As Belacqua's system breaks down so, too, do the mathematical metaphors used to describe him. Belacqua's mathematics of beauty is impossible, for the narrator, because all categories and terms, in the world of the novel, refer back to Belacqua:

> Unfortunately, Belacqua, you miss our point, *the* point: that beauty, in the final analysis, is not subject to categories, is beyond categories. There is only one category, yours, that furnished by your stases […] so all categories of beauty must be transelemented into yours […] with a centre everywhere and a circumference nowhere.[34]

The novel's mathematical problems are recursive: they refer to and require the Belacqua-equation, which, impossible to satisfy, is the novel's wasting centre. The narrator states that Belacqua is 'A trine man! Centripetal, centrifugal and … not'. This 'not', Belacqua's third aspect or being, has, like beauty and like God, 'its centre everywhere and periphery nowhere'.[35] However, this description, this solution to the Belacqua-equation, is qualified: 'Only for the sake of convenience is he presented as a cubic unknown. *At his simplest trine*, we were at pains to say

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[32] *Dream*, p. 120.
[33] *Dream*, p. 35.
[34] *Dream*, p. 35.
[35] *Dream*, pp. 120-121.

so, to save our bacon […] He is no more satisfied by the three values, Apollo, Narcissus and the anonymous third person, than he would be by fifty values, or any number of values'.[36] Once again, the Belacqua-equation cannot be solved: 'little by little Belacqua may be described, but not circumscribed; his terms stated, but not summed. And of course God's will be done should one description happen to cancel the next, or the terms appear crazily spaced'.[37] The mathematical images used by the narrator are part of what Ewa Plonowska Ziarek calls Beckett's 'rhetoric of failure': they are self-correcting, self-conscious, inconsistent and provisional.[38]

In *Dream of Fair to Middling Women*, therefore, mathematics is a mode of romantic or formal irony: it is a metafictional analogy that at once creates and destroys itself. 'Formal irony', Walter Benjamin writes, 'represents the paradoxical attempt still to construct the edifice by de-constructing it, and so to demonstrate the relationship of the work to the idea within the work itself'.[39] *Dream*'s mathematics produces Schlegel's infinite proliferation of systems: it generates metaphors – 'literary mathematics'; 'distillation of Euclid'; 'Pythagorean chain-chant' and so on – that refer to literary structures and, at the same time, as these metaphors break down, they gesture towards a chaotic, unstructured literary ideal. As Benjamin writes, 'the ironization of form is like the storm which lifts up the curtain of the transcendental order of art and reveals it for what it is, in this order as well as in the unmediated existence of the work'.[40] Beckett's ironic use of mathematical metaphor becomes a general structuring impulse – a more fully formal irony – in Beckett's later work, in which 'in order to abolish the real', Gilles Deleuze writes, Beckett must 'exhaust' both 'the greatest exactitude and the most extreme dissolution; the indefinite exchange of mathematical formulations and the pursuit of the formless or the unformulated'.[41]

Literary mathematics echoes, too, in Beckett's critical work. In *Proust* (1931), he writes that the 'Proustian equation is never simple. The unknown, choosing its weapons from a hoard of values, is also the unknowable'.[42] Proust's forced concessions to literary convention are described in mathematical terms: 'He accepts regretfully the sacred ruler and compass of literary geometry. But he will refuse to extend his submission to spatial scales, he will refuse to measure

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[36] *Dream*, p. 120, p. 124.
[37] *Dream*, p. 125.
[38] Ewa Plonowska Ziarek, *The Rhetoric of Failure: Deconstruction of Skepticism, Reinvention of Modernism* (Albany, NY: State University of New York, 1996).
[39] Walter Benjamin, *Der Begriff der Kunstkritik in der deutschen Romantik*, this passage translated and quoted by Paul de Man in *Aesthetic Ideology*, ed. by Andrzej Warminski (Minneapolis: University of Minnesota Press, 1996), p. 183.
[40] *Aesthetic Ideology*, p. 183.
[41] Gilles Deleuze, 'The Exhausted', trans. by Anthony Uhlmann, trans. rev. by Daniel W. Smith and Michael A. Greco in *Essays Critical and Clinical*, trans. by Daniel W. Smith and Michael A. Greco (London: Verso, 1988), pp. 152-175 (p. 154).
[42] Beckett, *Proust*, p. 11. Céline Surprenant argues that Beckett's 'comical exaggeration of the mathematical features of *À la recherche* enables him 'to underscore what in the novel refuses or exceeds quantification', while Beckett's similarly 'exaggerated insistence' on 'Schopenhauer's rejection of the Leibnizian view of music as "occult arithmetic"' serves 'as an invitation to read *À la recherche* as inventing its own compelling, "occult arithmetic"'. See Surprenant, 'An Occult Arithmetic', p. 56.

the length and weight of man in terms of his body instead of in terms of his years'.[43] 'Literary geometry' is a way of talking about literature's formulas and conventions and about the philosophy of structure. In Beckett's analysis of the Proustian equation, he describes the 'scaffolding' of Proust's 'structure', in which the 'miracle' of 'involuntary memory' recurs as 'a neuralgia', 'persistent and monotonous', that:

> disappears beneath of the surface and emerges a still finer and more nervous structure, enriched with a strange and necessary incrustation of grace-notes […] and climbs through a series of precisions and purifications to the pinnacle from which it commands and clarifies the most humble incident of its ascent and delivers its triumphant ultimatum.[44]

The recurrence of episodes of involuntary memory in *À la recherche du temps perdu* produces a structure that becomes evident to the reader retrospectively, in 'its culminating and integral expression'. As such, for Beckett, 'the germ of the Proustian solution is contained in the statement of the problem itself'.[45]

Beckett was frustrated by his own structuralist analysis of *À la recherche du temps perdu*. He expressed that frustration by comparing the experience of reading through his *Proust* to Stephen Dedalus's experience of doing equations in Joyce's *Portrait of the Artist as a Young Man* (1916). In a letter thanking Thomas McGreevy for his appreciation of *Proust*, Beckett writes of his essay:

> It's too abstract because my head comes breaking through every now & then through the epidermis […] It has the plausibility of a pattern, a kind of flat syllogistic drift, like the fan of the long division sum in 'Portrait of the Artist': at its best a distorted steam-rolled equivalent of some aspect or confusion of aspects of myself. That is what you see & what pleases you […] you see your intuition as a formula.[46]

In the schoolroom, as he daydreams about indulging his 'sin-loving soul' in the 'soft perfumed flesh' of 'whores', Stephen's mathematics problem unfolds itself as a metaphor. First, as a peacock's tail – 'The equation on the page of his scribbler began to spread out like a widening tail, eyed and starred like a peacock's: and, when the eyes and stars of its indices had been eliminated, began slowly to fold itself together again' – [47] then as a 'vast cycle of starry life' that 'bore his weary mind outward to its verge and inward to its centre, a distant music accompanying him outward and inward'; and, finally, the equation becomes a metaphor for Stephen's sin-loving soul:

> The dull light fell more faintly upon the page whereon another equation began to unfold itself slowly and to spread abroad its widening tail. It was his own soul going forth to experience, unfolding itself sin by sin, spreading abroad the bale-fire of its burning stars

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[43] *Proust*, p. 12.
[44] *Proust*, p. 36.
[45] *Proust*, p. 36.
[46] Letter to Thomas McGreevy, 11 March 1931, in *The Letters of Samuel Beckett, Volume 1: 1929-1940*, p. 72.
[47] James Joyce, *The Portrait of the Artist as a Young Man*, ed. by Hans Walter Gabler (New York: Garland, 1993), pp. 125-6.

> and folding back upon itself, fading slowly, quenching its own light and fires. They were quenched: and the cold darkness filled chaos.[48]

As in an earlier modernist *Bildungsroman*, Robert Musil's *The Confusions of Young Törless*, schoolroom mathematics in *Portrait* is a symbolic site for the development of character. Young Törless and Stephen Daedalus experience the mathematics classroom as they do the brothel: as a site of epistemological and moral epiphany. Mathematics often functions symbolically in coming-of-age narratives: whether, as in Stendhal's *The Life of Henry Brulard*, as the hero's mode of self-differentiation ('My enthusiasm for mathematics was based principally perhaps on my horror of hypocrisy'); or, as in Goethe's *Wilhelm Meister,* as a trope of the society into which he must assimilate.[49]

In Beckett's letter to McGreevy mathematics is part of the thwarted development of literary criticism: it is a metaphor for a failed attempt to express understanding. For Peter J. Murphy, Beckett's rejection of epiphany is crucial to his attempt 'to come to terms with and move beyond the aesthetic theory formulated in *A Portrait of the Artist as a Young Man*'.[50] Beckett's early works have, for Murphy, a basic pattern: 'an initial assumption that the modernist moment of revelation is fundamentally inadequate' is expressed by 'dramatization of the aporias of a modernist aesthetic' before the 'initial series of critical reservations about the theory of epiphany […] quickly terminates in an impasse of one sort or another'.[51] In *Dream* and in Beckett's later novels the idea of mathematics as a route to self-knowledge is retained but in a muddied and ironic form. 'Extraordinary how mathematics help you to know yourself', Molloy says, counting his farts.[52] *Dream*'s description of the 'demented perforation of the night colander' takes *Portrait*'s equation sequence – its description of Stephen's mind coming to know itself in reference to mathematics, music, poetry and the night sky – and drives it to its extremes:

> The night firmament is abstract density of music, symphony without end, illumination without end, yet emptier, more sparsely lit, than the most succinct constellations of genius. Now seen merely, a depthless lining of hemisphere, its crazy stippling of stars, it is the passional movements of the mind charted in light and darkness. The tense passional intelligence, when arithmetic abates, tunnels, skymole, surely and blindly (if only we thought so!) through the interstellar coalsacks of its firmament in genesis, it twists through the stars of its creation in a network of loci that shall never be co-ordinate.[53]

This pile-up of metaphors and reference points thwarts understanding. It also contains, for Chris Ackerley, the nascent impulses of Beckett's mathematical world. *Dream*, for Ackerley, with 'its

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[48] Joyce, *The Portrait of the Artist as a Young Man*, p. 126.
[49] Stendhal, *The Life of Henry Brulard*, trans. by John Sturrock (New York: New York Review Books, 2002), p. 368.
[50] Peter J. Murphy, *Beckett's Dedalus: Dialogical Engagements with Joyce in Beckett's Fiction* (Toronto: University of Toronto Press, 2009), p. 44.
[51] Murphy, *Beckett's Dedalus*, p. 44.
[52] Samuel Beckett, *Molloy*, ed. by Shane Weller (London: Faber and Faber, 2009), p. 28.
[53] Beckett, *Dream*, p. 16.

arithmetical and geometrical modalities, informs the works to come'. The night firmament passage of *Dream*, with its image of arithmetic abating, sets up a scholastic conflict between arithmetical sequence and geometrical setting that persists in Beckett's later work and produces the universe of *The Unnamable* in which: 'Arithmetic (time) has abated, so narrative (virtually) disappears; geometry lacks dimension, so space becomes (almost) indefinite; logic is in abeyance, so relationship is (mostly) fraught'.[54]

Dream's use of mathematics as an analogy, or series of analogies, for literary production – the creation and dismantling of character, the ravelling and unravelling of plot – is reworked in Beckett's 9 July 1937 letter to Axel Kaun. Beckett proposes ludic mathematics as a model for literature and in doing so echoes the mathematical vernacular of *Dream*: 'Let's do as that crazy mathematician who used to apply a new principle of measurement at each individual step of the calculation. Word-storming in the name of beauty'.[55] Beckett's injunction is prompted by his feeling that language – 'formal English'; 'Grammar and style!' – is a 'veil' to be 'torn' or a 'mask' to be ripped off: 'To drill one hole after another into it until that which lurks behind, be it something or nothing, starts seeping through – I cannot imagine a higher goal for today's writer'.[56] Joyce's recent work (the *Work in Progress*) 'has nothing at all to do with such a programme', Beckett writes, rather it is a rival *transition* author who is drilling the necessary holes in language: 'Gertrude Stein's Logographs come closer to what I mean. The fabric of language has at least become porous, if regrettably only quite by accident'.[57]

Arithmomania

In Stein's 'Are There Arithmetics' (1927), grammar and referential meaning break down as the poem moves through syntactical permutations, picking words apart:

> Are there arithmetics, irresistible, a part.
> Are there arithmetics irresistible resisted a part.
> Are there arithmetics irresistible apart.
> […]
> No sense in no sense innocence of what of not and what of delight
> […]
> Alright.
> Don't you think it would go into arithmetic nicely.

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[54] Ackerley, 'Samuel Beckett: The Geometry of the Imagination', pp. 102-4.
[55] Beckett to Axel Kaun, 9 July 1937, in *The Letters of Samuel Beckett Volume 1: 1929-1940*, ed. by Fehsenfeld and Overbeck (Cambridge: Cambridge University Press, 2009), pp. 516-520 (p. 520). Hugh Culik argues, though without adequate evidence, that the mathematician in question is Kurt Gödel and that Beckett is referring to Gödel's incompleteness theorems. See Hugh Culik, 'Mathematics as Metaphor: Samuel Beckett and the Esthetics of Incompleteness', *Papers on Language and Literature* 29.2 (1993), pp. 131-51.
[56] Beckett to Axel Kaun, 9 July 1937, in *The Letters of Samuel Beckett Volume 1*, p. 518.
[57] Beckett to Axel Kaun, 9 July 1937, in *The Letters of Samuel Beckett Volume 1*, p. 519.

> If and intend if and intend, if and to attend, if and if to attend if to attend if and intend, or and nearly equal, two ahead and four behind, two ahead and two behind, two ahead as two, and two, and two ahead and have to, and have it or in needles in case of.[58]

Stein's poetry shares certain general aspects of style with Beckett's *Watt* and *How It Is*: repetition, permutation, exhaustive and exhausting series and lists. As Tram Nguyen points out, Beckett and Stein also share certain defamiliarising 'grammatical drives', such as 'unpunctuated ambiguity and aposiopesis'.[59]

Numbers, too, have a particular power in Beckett and in Stein: to run away with their sentences, to repeat – as with the number 'two' in the above extract from 'Are There Arithmetics' – and to make those sentences into a strange sound poetry. In Stein's 'An Instant Answer or A Hundred Prominent Men', the list of the prominent men and their qualities – 'The twenty-sixth has many ordinary happinesses'; 'The twenty-seventh does measure very well indeed the height of hills'; 'The twenty-eighth is perceptibly loving' – breaks out into numbers:

> The forty-sixth prominent man is the one who connected them to their country. My country all the same they have their place there. And why do you tell their names. I tell their names because in this way I know that one and one make a hundred. It is very difficult to count in a foreign language.[60]

Stein's counting out of a hundred, her 'one and one and one', carries on the counting out of ten by the White Queen in Lewis Carroll's *Through the Looking Glass*:

> 'Can you do Addition?' the White Queen asked. 'What's one and one and one and one and one and one and one and one and one and one?'
> 'I don't know," said Alice. "I lost count'
> 'She ca'n't do Addition,' the Red Queen interrupted.[61]

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[58] Gertrude Stein, 'Are There Arithmetics', in *The Gertrude Stein Reader*, ed. by Richard Kostelanetz (New York: Cooper Square Press, 2002), pp. 398-402.

[59] Tram Nguyen, 'Porosities: Aesthetic Correlations between Gertrude Stein and Samuel Beckett', in *Samuel Beckett Today/Aujourd'hui* (2013).

[60] Gertrude Stein, 'An Instant Answer or A Hundred Prominent Men', in *The Gertrude Stein Reader*, pp. 34-50 (p. 40).

[61] Lewis Carroll, *Alice's Adventures in Wonderland and Through the Looking-Glass and What Alice Found There*, ed. by Hugh Haughton (London: Penguin, 1998), p. 221.

The Red Queen's interruption, Connor writes, discloses something fundamental about numbers – their 'flat indifference' – that we learn to 'overlook' by 'being mathematical'. Connor's explanation of this paradox might help us to understand how Gertrude Stein uses numbers as the undoing or unravelling of mathematics in her poetry. Mathematics can function for Stein and for Beckett as non-propositional language: as automatism or as pathological habit. In cases of aphasia, Henri Bergson remarks, language 'works after the manner of a reflex': 'Aphasics, incapable of uttering a word spontaneously […] will fluently repeat a prayer, a series of numbers, the days of the week'.[62]

'Although', Connor points out, 'mathematics is made of number, and works in and through it, it is fundamentally opposed to it, precisely because it is the redemption of number'. Against the 'horror of number', number's 'absolute equivalence', which Connor imagines as a kind of death (death here, 'the absence of any difference that would *make* a difference between one mode of being and another'), mathematics, particularly number theory, 'shows that numbers are not just numbers – that they are tied together by hidden webs of relationship and entailment'.[63]

The tension between Stein's mathematical poetics and her numerical prose poetry presents us with the paradox of mathematics that Connor describes: the paradox of mathematics as made of but opposed to numbers; of mathematics as the attempt to redeem numbers from their shallow, undifferentiated death. Stein describes her own work as 'mathematical', yet she uses nonsense, listing and the repetition of numbers to estrange mathematics just as she uses nonsense, listing and the repetition of words to estrange language. As she counts out a hundred in 'An Instant Answer or a Hundred Prominent Men', Stein exposes and explores the 'flat indifference' of equivalence that mathematics, even demotic mathematics and literary mathematics, necessarily overlooks. In *The Geographical History of America* the paradox of numerical equivalence is revealed in and through Stein's denial of that equivalence:

> I wish very seriously were I I to have eight be an audience.
> Do you mind eight.
> What is the relation of human nature to the human mind.
> Has it anything to do with any number.
> The thing about numbers that is important is that any of them have a pretty name.
> Therefore they are used in gambling in lotteries in plays in playing in scenes and in everything.
> Numbers have such a pretty name.

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[62] Henri Bergson, *Matter and Memory*, trans. by Nancy Margaret Paul and W. Scott Palmer (New York: Zone Books, 1991), p. 86.
[63] Steven Connor, '"What's one and one and one and one and one and one and one and one and one and one?" Literature, Number and Death', a talk given at the University of Oxford, 4 December 2013 <http://stevenconnor.com/oneandone/oneandone.pdf> [accessed 10 September 2015].

> It can bring tears of pleasure to one's eyes when you think of any number eight or five or one or twenty seven, or sixty three or seventeen sixteen or eighteen or seventy three or anything at all
> […]
> Tears of pleasure numbers have such pretty names.
> They have something to do with money and with tears and flat land, not with mountains or lakes, yes with blades of grass, not much a little but not much with flowers, some with birds not much with dogs.[64]

Stein takes emotional and aesthetic pleasure in the 'names' of numbers and as she does so she drifts between singular and plural ('Numbers have such a pretty name'; 'numbers have such pretty names') and between a redeemed idea of number (numbers with singular names, embedded in webs of significance) and an idea of number as flat, meaningless equivalence (this idea of number haunts the strange phrasing 'any of them'). The arithmetic of *The Geographical History of America* thus brings to mind Wittgenstein's remark about '[a]rithmetic as the natural history (mineralogy) of numbers. But *who* talks like this about it. Our whole thinking is penetrated with this idea'.[65] Despite her estranging mathematical vernacular, Stein looked back on her career as that of a mathematical poet:

> While I was writing I didn't want, when I used one word, to make it carry too many associations. I wanted as far as possible to make it exact, as exact as mathematics; that is to say, for example, if one and one make two, I wanted to get words to have as much exactness as that. When I put them down they were to have this quality. The whole history of my work, from *The Making of Americans*, has been a history of that.[66]

As Stein describes the history of her poetic development as the history of literature approaching the condition of mathematics, she both complicates her poetic use of number and claims the epithet 'mathematical' from her critics. Beckett gives us some insight into the tensions and complications in Stein's mathematical poetics. He wrote that Stein is 'still in love with her vehicle', with language, 'if only as a mathematician is with his numbers; for him the solution to his problem is of very secondary interest, yes, as the death of numbers, it must seem to him indeed dreadful'.[67]

Indeed, both Beckett and Stein have a tendency to 'wallow in number', to borrow a phrase from Reviel Netz.[68] Arithmomania – the obsession with manipulating numbers – pervades Beckett's work, from the pronouncements of the 'arithmomaniac' at the party in *Dream*, Murphy's 1.83 cups of tea, the radiant permutations of Murphy's biscuits and Mr Knott's socks,

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[64] Stein, *The Geographical History of America or The Relation of Human Nature to the Human Mind*, in *Gertrude Stein: Writings 1932-1946*, ed. Catharine R. Stimpson and Harriet Chessman (New York: Library of America, 1998), p. 406.
[65] *Remarks on the Foundations of Mathematics*, p. 229.
[66] Gertrude Stein, *How Writing is Written*, in *The Gertrude Stein Reader*, pp. 438-450 (p. 446).
[67] Beckett to Axel Kaun, 9 July 1937, *The Letters of Samuel Beckett Vol I*, p. 519.
[68] Reviel Netz, *Ludic Proof: Greek Mathematics and the Alexandrian Aesthetic* (Cambridge: Cambridge University Press, 2009), p. 117.

Mr Nackybal's cube roots, the 'doubly erroneous' Lynch family mathematics, Molloy's sucking-stones and Saposcat's mental arithmetic, to the algebraic reckoning of *How It Is* and the elegiac mathematics of 'Enough' and *Company*. Beckett's prose works contain pages of numbing, seemingly pointless calculations. These resemble 'the carnival of calculation' Netz found in Hellenistic mathematics: 'the fascination […] with creating a rich texture of obscure and seemingly pointless numerical calculation. The treatises occasionally lapse, as it were, so as to wallow in number'. [69]

There are many striking resemblances between Beckett's work and Netz's carnival of calculation. One aspect of this carnival was 'the capturing of the unbounded as an exercise in impossibility', in which mathematicians sometimes even began with emblematic tropes of 'futile counting' (Archimedes tries to count the grains of sand; Hipparchus tries to count the stars), and, in the act of calculation, though they don't end up with a solution as such, they display the 'unboundedness' of the object or the problem. In the *Sand-Reckoner*, for example, Archimedes tries to measure the number of grains that would fill the universe. He invents a counting tool for such 'extravagant calculation' of big numbers:

> This is based on the principle of iteration: myriad myriads are taken as the unit of the 'second numbers,' myriad myriad those as the unit of the third numbers, etc., and then myriad myriads of the myriad-myriad numbers are taken as the unit of the first numbers of the 'second period,' the unit of the second period being myriad-myriads of the myriad-myriads numbers of the second period, etc., until one hits myriad myriads of the myriad-myriad numbers of the myriad-myriads period, which is a very big number indeed if you pause to think of it.[70]

Archimedes' number system, of course, fails to reach infinity: nonetheless, the thick texture of that failed calculation, and the 'absurdly big and yet finite number' it ends up with illustrate the treatise's art of failure: Netz even calls this art 'failing better and better', an indirect homage to Beckett. [71] Archimedes' next failure is the calculation of the size of the universe: 'The astronomical calculation provides an absurdly big, heliocentric universe – and can only provide an asymptotic, bounding measure of it', while '[t]he actual calculation of the grains of sand succeeds by reducing the problem (appearing to be that of providing a number) to a mere boundary problem'. As such, these three failures illustrate Archimedes' approach: 'he not merely ends up with an asymptotic result but also underlines the impossibility of going beyond it'.[72]

In *Rules for the Direction of Mind*, Descartes wrote that the route to mathematical knowledge had been obscured by mathematics itself: by its 'numerical disorder'. Reading the 'customary lore' passed on by mathematical writers in their arithmetical and geometrical texts, Descartes felt 'there

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[69] Netz, *Ludic Proof*, p. xi.
[70] Netz, *Ludic Proof*, p. 31.
[71] *Ludic Proof*, p. 32.
[72] *Ludic Proof*, pp. 33-3.

is really nothing more futile than so busying ourselves with bare numbers and imaginary figures that we seem to rest content in the knowledge of such trifles'.[73] Behind this numerical chaos lay the real mathematical method, a path to truth which requires that: '*every single thing relating to our undertaking must be surveyed in a continuous and wholly interrupted sweep of thought, and be included in a sufficient and well-ordered enumeration*'.[74] As such, proof depends on memory and, therefore, one must guard against the lapses and 'sluggishness' of memory.[75] Beckett's characters let Descartes down on both counts: either their memories fail or their enumerations do.

Vaudeville Combinatorics

Watt is a novel of obsessive enumerative combinatorics. Combinatorics is concerned with finite or countable discrete structures. Enumerative combinatorics, in particular, is the branch of mathematics that counts the number of ways that patterns can be formed (permutations, combinations and partitions). In *Watt* the structures studied are, indeed, mostly finite. Nonetheless, the novel resembles Beckett's own description of vaudeville: 'which at least inaugurates the comedy of an exhaustive enumeration'.[76] Permutations of sets of dogs, servants, footwear and meals are enumerated as lived abstractions in Watt's attempts to contemplate the everyday problems of life in Mr. Knott's establishment. In the matter of Mr. Knott's meals: 'Watt's instructions were formal: On those days on which food was left over, the food left over was to be given to the dog, without loss of time'.[77] Yet, bringing the dog and food together at the right time is, for Watt, a tremendously difficult combinatorial problem. In fact, the problem has already been solved, but Watt applies himself to it anyway:

> So Watt considered, not only some of those solutions that had not apparently prevailed, but also some of those objections that were perhaps the cause of their not having done so, distributed as follows:

Solution	*Number of Objections*
1st	2
2nd	3
3rd	4
4th	5

[73] Descartes, 'Rules for the Direction of Mind', pp. 17-18.
[74] Descartes, 'Rules for the Direction of Mind', p. 25.
[75] Descartes, 'Rules for the Direction of Mind', p. 38.
[76] Beckett, *Proust*, p. 92.
[77] Samuel Beckett, *Watt*, ed. by C. J. Ackerley (London: Faber and Faber, 2009), p. 77.

Number of Solutions	*Number of Objections*
4	14
3	9
2	5
1	2

The set of numbers in the first table tabulates, for each of Watt's most recent solutions (*n*), the number of objections (*n+1*).[78] The second table gives the cumulative number of objections: according to Ackerley, the formula for that sequence is *n(n+3)/2*.[79]

Watt 'is an unsatisfactory book', Beckett famously wrote to George Reavey after the war, 'written in dribs and drabs, first on the run, then of an evening after the clodhopping, during the occupation. But it has its place in the series, as will perhaps appear in time'.[80] Indeed, the exercise book that appears in *Malone Dies* does somewhat resemble *Watt*, or one of Beckett's notebooks containing plans for *Watt*. 'It is ruled in squares', Malone explains: 'The first pages are covered with ciphers and other symbols and diagrams, with here and there a brief phrase. Calculations, I reckon. They seemed to stop suddenly, prematurely, at all events. As though discouraged'.[81] Malone perceives himself as a series: 'having been nothing but a series or rather a succession of local phenomena all my life'. Yet, he is also dimly aware that he is a term in another series: one that exceeds the boundaries of his local domain. Malone speculates that he might nonetheless be the final term in this series too, and that when he dies 'it will be all over with the Murphys, Merciers, Molloys, Morans and Malones, unless it goes on beyond the grave'.[82]

After calculating the series of dogs, the series of servants and the series of pictures, Watt is thinking 'in search of rest, of the possible relations between such series as these', when he remembers the sounds of permutation he heard when he was young.[83] Watt remembers three frogs croaking 'Krak!, Krek! and Krik!' in intervals of eight, five and three, respectively. The following notation of the Frog song deploys those exclamation points too: they connote, in mathematical combinatorics, the factorials.[84] Ackerley points out that Watt hears the Frog Song

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[78] *Watt*, p. 82.
[79] C. J. Ackerley, *Obscure Locks, Simple Keys: The Annotated* Watt (Edinburgh: Edinburgh University Press, 2010), p. 111.
[80] Beckett to George Reavey, 14 May 1947, *The Letters of Samuel Beckett Volume II: 1941-1956*, ed. by Craig et al, (Cambridge: Cambridge University Press, 2011), p. 55.
[81] Samuel Beckett, *Malone Dies*, ed. by Peter Boxall (London: Faber and Faber, 2010), p. 35.
[82] Beckett, *Malone Dies*, pp. 62-63.
[83] *Watt*, pp. 116-7.
[84] *Watt*, pp. 117-8.

as structured by the Fibonacci sequence: as the frogs start at the same time, after 120 intervals – 3 x 5 x 8 – the independent croaking series will coincide.[85]

Heath Lees, meanwhile, points to a long passage on the peal of bells from an unpublished draft (B) of *Watt* to suggest that the intervals of the frog song are the textual remainder of that earlier description of the permutations of church bells in the art of change ringing.[86] Change ringing is a combinatorial art in which a set of bells is rung in a mathematical pattern of permutations (the 'changes'). The bells are rung in rows: each bell can ring only once per row, and the order in which the bells are rung cannot be repeated. Change ringing continues, in theory, until all the permutations of a given number of bells have been exhausted. Seventeenth-century 'campanologists' such as Fabian Stedman used mathematical notation and combinatorial techniques like the factorial to tabulate all the possible permutations of a given number of bells. Like Murphy with his packet of biscuits, campanologists imagined a group of bells 'dancing the radiant measure of its total permutability'. In 'Campanologomania', Katherine Hunt describes how the proliferation of large numbers generated by change ringing could induce a particular sense of numerical amazement.[87] To appreciate change ringing, Hunt observes, requires 'mathematical listening: a sort of deep aural counting in which those rows of numbers are somehow heard, and understood'. On the page, that counting often overflowed the bounds of real bells and real ringers: leading to excessive, exhausting proliferations of number. 'In Stedman's calculations', Hunt writes, 'bells speak: not the signalling language of their old uses, but a language of permutated units with dizzyingly vast numbers of possibilities'. Yet, such numerical excess also played a role in the realm of real bells and real listeners in post-Reformation England. By turning the ringing of church bells into a complicated cascade of calculation, permutation and enumeration, Hunt argues that change ringing divested the bells of their older meanings: of the theological and emotive signifying power that church bells had in pre-Reformation England. Watt's affinity for such deep aural counting is evident in his habit of combinatorial perception and even combinatorial speech: he evacuates the sense of his sentences and his words as he rearranges their order.

Inside Mr. Knott's house and on Mr. Knott's grounds, incidents occur with 'great formal brilliance and indeterminate purport'.[88] Each incident resembles all the others: 'in the sense that it was not ended, when it was past, but continued to unfold, in Watt's head, from beginning to end, over and over again, the complex connexions of its lights and shadows', until, in repetition it

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[85] Ackerley, *Obscure Locks, Simple Keys,* p. 138.
[86] Heath Lees, 'Watt: Music, Tuning and Tonality', in *The Beckett Studies Reader*, ed. by S. E. Gontarski (Gainesville, FL: University Press of Florida, 1993), pp. 167-185 (pp. 172-3).
[87] Katherine Hunt, 'Campanologomania', *Cabinet* 53 (2014), <http://www.cabinetmagazine.org/issues/53/hunt.php> [accessed 10 Sept 2015].
[88] *Watt*, p. 61.

loses 'all meaning, even the most literal'.[89] In *Murphy*, 'permutability' was bounded by the forces of habit and desire and by the small numbers involved. Murphy calculated all the possible orders in which he could eat his five daily biscuits, but 'prejudice against the anonymous' biscuit and 'his infatuation with the ginger' prevented the assortment from 'dancing the radiant measure of its total permutability, edible in a hundred and twenty ways!' [90] *Watt*'s brute-force calculations, its proofs by exhaustion, increasingly fail to establish boundaries: the combinatorial calculations become harder to control, to express and to read. 'The combinatorial is the art or science of exhausting the possible', Deleuze writes, and 'Beckett's great contribution to logic is to have shown that exhaustion (exhaustivity) does not occur without a certain physiological exhaustion'.[91] Indeed, the bell ringers of seventeenth-century England made a blunt, bodily version of this argument many years earlier: attempts to exhaust the permutations of the bells led to and were bound by the physiological exhaustion and physical limits of the ringers. Beckett's stage directions for *Quad* insist 'All possible light combinations given', 'All possible percussion combinations given' and so on.[92] These directions heighten *Quad*'s feeling of imprisonment, shutting down the potential for escape or change: *Quad*'s is a 'purgatorial calculus', as Brett Stevens writes.[93]

The idea of digestion was crucial to Renaissance theories of copia and combination. Terence Cave points out that in Quintillian's Institutiones, for example, 'this notion of incorporation or consubstantiality transfers to language the possibility of a process by which alien, external materials may be transformed so that they may re-emerge as a function of […] the speaker's nature'.[94] Rhetorical exercises in the Renaissance tradition were combinatorial exercises of imitation by variation. They were conducted in accordance with the quadripartite ratio: the four categories of change (addition, subtraction, transposition and substitution). In Erasmus's *Copia: Foundations of the Abundant Style*, he demonstrated hundreds of ways of saying 'Your letter pleased me greatly'.[95] Combinatorial procedures were key to the Oulipo, too: the set of variations in Raymond Queneau's *Exercises in Style* (in which the same story is told ninety-nine times) owes as much to rhetorical combinatorics as it does mathematical combinatorics. Beckett's characters also respond to the Renaissance rhetorical tradition of copia. Yet, instead of digestion there is emesis: they vomit out the traces of their education.

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[89] *Watt*, pp. 59-60.
[90] Beckett, *Murphy*, p. 62.
[91] Deleuze, 'The Exhausted', p. 154.
[92] Samuel Beckett, 'Quad', in Beckett, *The Complete Dramatic Works* (London: Faber and Faber, 2006), pp. 449-455 (p. 452).
[93] Brett Stevens, 'A Purgatorial Calculus: Beckett's Mathematics in "Quad"', in *A Companion to Samuel Beckett*, ed. by S. E. Gontarski (Chichester: Wiley-Blackwell, 2010), pp. 164-181.
[94] Terence Cave, *The Cornucopian Text: Problems of Writing in the French Renaissance* (Oxford: Oxford University Press, 1985, rept. 2011), p. 37.
[95] Desiderius Erasmus, *Copia: Foundations of the Abundant Style*, trans. by Betty I. Knott, in *The Collected Works of Erasmus*, Vol. 24, ed. by Craig R. Thompson (Toronto: University of Toronto Press, 1978), pp. 279-660.

Watt, as Steven Connor points out, can be read as a modernist version of nineteenth-century nonsense poetry: as 'quantical nonsense' that plays with the 'subjunctive mood' of quantification – with the felt absurdity of commensuration.[96] Lewis Carroll is the canonical author of such arithmetical nonsense: remember the Mock Turtle's school with its four 'different branches of arithmetic – Ambition, Distraction, Uglification, and Derision'.[97] Lewis Carroll's *Alice* books depict the nonsensical delights and cruelties of life among many arbitrary, conventional logical systems: the looking glass world where the rules of the game – whether of number, naming, identity, reference or chess – can shift at any moment. Andrea Henderson argues that Carroll's nonsense fiction was responding to nineteenth-century developments in mathematical logic: in particular, to the symbolic logic of George Boole and Augustus de Morgan.[98] In an 1835 review of *A Treatise on Algebra* by George Peacock, de Morgan himself articulated the discomfort that British mathematicians had felt when first confronted with algebra: 'At first sight it appeared to us something like symbols bewitched, and running about the world in search of a meaning'.[99] Carroll's final work of fiction, *Sylvie and Bruno*, is just as steeped in nonsense as the *Alice* books (more so, perhaps, as it removes the framing narrative that gave those books a certain grounding). Yet, Henderson argues that *Sylvie and Bruno* is 'undeniably a redemption narrative'.[100] Carroll's novel seeks 'recompense' for the looking-glass world of relativism that the logicians had created: for the feeling of 'ungroundedness'.[101] *Sylvie and Bruno* finds such recompense: in the end, its 'hero' is 'the capacity of formal structures to reveal meaningful similarities'.[102] Carroll found consolation in the latticework of relations revealed by formal logic.

In Beckett's work, calculation is at once a curse, a compulsion and a source of habitual consolation. 'The art of combining is not my fault. It's a curse from above', we hear in Beckett's 'Enough', 'for the rest I would suggest not guilty'.[103] This doubled experience is expressed in the double meaning of the narrator's remark in *How It Is*: 'I always loved arithmetic it has paid me back in full'.[104] The pun on pay back as both recompense and revenge is telling of the experience of demotic mathematics that Beckett's characters have. Sianne Ngai reads the 'wry double meaning' of the narrator's remark as part of the novel's mathematical 'stuplimity'. In *How It Is*, Ngai writes: 'large but finite numbers take the place of the infinity we associate with Kant's

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[96] Steven Connor, 'Quantum Writing: Literature and the World of Numbers', lecture given at the Institute of Continuing Education, Cambridge, 13 June 2013. <http://www.stevenconnor.com/quantumwriting/quantumwriting.pdf> [accessed 10 Sept 2015]

[97] Carroll, *Alice's Adventures in Wonderland and Through the Looking-Glass and What Alice Found There*, p. 85.

[98] Andrea Henderson, 'Symbolic Logic and the Logic of Symbolism', *Critical Inquiry* 41.1 (2014), 78-101.

[99] Augustus de Morgan, 'Review of *A Treatise on Algebra*', *Quarterly Journal of Education* 9 (1835), 91-110 and 293-311 (p. 311).

[100] Henderson, 'Symbolic Logic and the Logic of Symbolism', p. 81.

[101] Henderson, 'Symbolic Logic and the Logic of Symbolism', pp. 81-2.

[102] Henderson, 'Symbolic Logic and the Logic of Symbolism', p. 92.

[103] Samuel Beckett, 'Enough' in *Texts for Nothing and Other Shorter Prose, 1950-1976*, ed. by Mark Nixon (London: Faber, 2010), pp. 91-99 (p. 94).

[104] Beckett, *How It Is* (London: Faber and Faber, 2009), p. 30.

mathematical sublime, yet the effect of these enumerations is […] to call attention to representational or conceptual fatigue, if not collapse.'[105] The narrator of *How It Is,* trying to explain how information is communicated between the torturers and the tortured in his mud-plane, constructs a combinatorial problem:

> for take twenty consecutive numbers
>
> no matter which no matter which it is irrelevant
>
> 814326 to 814354
>
> number 814327 may speak misnomer the tormentors being mute as we have seen part two may speak of number 814326 to number 814328 who may speak of him to number 814329 who may speak of him to number 814330 and so to number 814345 who in this way may know number 814326 by repute
>
> similarly number 814326 may know by repute number 814345 number 814344 having spoken of him to number 814343 and this last to number 814342 and this last to number 814341 and so on back to number 814326 who may know number 814345 by repute.[106]

The narrator's explanatory mathematics breaks down: 'so to what purpose | moreover the thing would appear to be impossible […] something wrong there'.[107] Stuplimity, for Ngai, is 'a response to encounters with vast but bounded artificial systems, resulting in repetitive and often mechanical acts of enumeration, permutation, and combination, and taxonomic classification […] comic exhaustion rather than terror'.[108]

For Kant, the mathematical sublime could only be accessed through the failure of number. 'Sublime is the name given to what is *absolutely great*'.[109] When attempting to comprehend magnitude, we naturally turn first to mathematics: choosing a unit of measurement (a foot, a perch, a German mile, the earth's diameter) and proceed by 'the successive aggregation of units'.[110] Yet, no matter which unit we choose, and no matter how we aggregate, our numerical series will continue *ad infinitum* with nothing to stop it except the inner voice of reason (the mind's demand for totality or completeness): there is no 'absolutely great' in mathematics and as such the sublime cannot be reached by counting.

Kant's mathematical sublime is a product of the conflict between the concept of the infinite and the process of endless enumeration, the stuttering numbers, through which one attempts and fails to reach and understand the infinite. In *Though Gently*, Laura Riding explores

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[105] Sianne Ngai, *Ugly Feelings* (Cambridge, MA: Harvard University Press, 2005), p. 275.
[106] Beckett, *How It Is*, p. 104.
[107] *How It Is*, p. 105.
[108] Ngai, *Ugly Feelings*, p. 36.
[109] Immanuel Kant, *Critique of Judgement*, trans. by James Creed Meredith; revised and ed. by Nicholas Walker (Oxford: Oxford University Press, 2007), p. 78.
[110] Kant, *Critique of Judgement*, p. 84.

this conflict. First, she establishes her symbolism: 'Let the sign ⊥ stand for that which all understand and express differently. ⊥ is the unmistakable. ⊥ is the exact fulcrum. Let the sign T stand for the interpretive world of leverage'.[111] Then, in the first stanza of 'NUMBERS', Riding writes:

> Numbers attempt to arrive at finity through infinity.
> According to numbers ⊥ is T+.
> Numbers cannot describe totality but only the composition of totality.
> The enumeration of four essences does not lead to the discovery of an essential but of a fifth essence.
> Numbers are life, imitation, or analogy and they lead only to further numbers.
> Numbers are detail.[112]

Faced with the impossible task of 'ever arriving at absolute totality by the progressive measurement of things in the sensible world', Kant argues that the mind is driven beyond numbers and the sensible. A violent conflict takes place between the temporality of unfolding understanding – the time it takes to count or measure – and the intuition of the whole.[113] The failure to invent an aesthetic unit of measurement for the infinite forces the mind to turn inwards, and to find in that failure a revelation of its true vocation, which is to take the infinite itself as a unit, elevating rationality and its laws into the standards through which to judge nature. 'The sublime may be described in this way', Kant writes: 'It is an object (of nature) *the representation of which determines the mind to regard the elevation of nature beyond our reach as equivalent to a presentation of ideas*'.[114] That object 'is received as sublime with a pleasure that is only possible by means of a displeasure'.[115]

The Kantian mathematical sublime can, then, be considered as a form of consolation: the experience of the sublime – the 'compensatory pleasure' of reason – is predicated on the failure of mathematics and the inability to imagine infinity. It is also predicated on the end of counting. Beckett's characters tend, however, to get stuck in mathematics, in the successive aggregation of unites, in counting. And yet, defying both Kant and Ngai, they also find a certain compensatory pleasure, a certain consolation, in arithmetic itself.

The collapsing enumerations of *How It Is* recall and darkly rewrite the Unnamable's arithmetic of partial understanding. The Unnamable's arithmetic exhausts itself, veering away from its original explanatory function into a comedy of diversion and thick enumeration. 'I'll seek, what is wanting, to make everything clear', the Unnamable tells us, but this search is diverted into an unworkable, absurd arithmetic:

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[111] Laura Riding, *Though Gently* (Deya, Majorca: The Seizin Press, 1930), p. 2.
[112] Laura Riding, *Though Gently*, p. 3.
[113] Kant, *Critique of Judgement*, pp. 88-90.
[114] Kant, *Critique of Judgement*, p. 98
[115] Kant, *Critique of Judgement*, p. 90.

> how I manage to understand, it's a lie, what would I understand with, that's what I'm asking, how I manage to understand, oh not the half, nor the hundredth, nor the five thousandth, let us go on dividing by fifty, nor quarter millionth, that's enough, but a little nevertheless, it's essential, it's preferable, it's a pity, but there it is, just a little all the same, the least possible, it's appreciable, it's enough, the rough meaning of one expression in a thousand, in ten thousand, let us go on multiplying by ten, nothing more restful than arithmetic, in a hundred thousand, in a million, it's too much, too little, we've gone wrong somewhere, no matter, there is no great difference here between one expression and the next, when you've grasped one you've grasped them all.[116]

The prose divides and rearranges itself: proliferating commas parallel the novel's failed mathematics, splitting meaning into units that resist the clarifying purpose of their division and taxonomy. The Unnamable's units of calculation resist commensuration, quantification and the promised 'summing up':

> the all of all and the all of nothing, never in the happy golden, never, always, it's too much, too little, often, seldom, let me now sum up, after this digression, there is I, yes, I feel it, I confess, I give in, there is I, it's essential, it's preferable, I wouldn't have said so, I won't always say so, so let me hasten to take advantage of being now obliged to say, in manner of speaking, that there is I, on the one hand, and this noise on the other […] I sum up, now that I'm there it's I will do the summing up, it's I will say what is to be said and then say what it was, that will be jolly, I sum up, I and this noise, I see nothing else for the moment, but I have only just taken over my functions, I and this noise, and what about it, don't interrupt me.[117]

The Unnamable's mathematics, like that of the narrator in *How It Is*, is a punctuating device itself punctuated by the repetition of 'enough' and 'I'll sum up'. Both narrators conjure a numerical world, a world of words that can be exchanged for each another, and find some solace in these worlds even as they collapse, even as the system of commensuration and enumeration falters, stutters and breaks down.

Refuge in Arithmetic: A Refrain

'Nothing more restful than arithmetic': the Unnamable's startling and confusing feeling for mathematics echoes in *How It Is* – 'I always loved arithmetic it has paid me back in full' – and across Beckett's work. The flightless lovers of 'Enough', for example, take flight in arithmetic:

> His talk was seldom of geodesy. But we must have covered several times the equivalent of the terrestrial equator. At an average speed of roughly three miles per day and night. We took flight in arithmetic. What mental calculations bent double hand in hand! Whole ternary numbers we raised in this way to the third power sometimes in downpours of rain. Graving themselves in his memory as best they could the ensuing cubes

[116] Samuel Beckett, *The Unnamable*, ed. by Steven Connor (London: Faber and Faber, 2010), p. 105.
[117] Beckett, *The Unnamable*, pp. 105-6.

> accumulated. In view of the converse operation at a later stage. When time would have done its work.[118]

The line 'We took flight in arithmetic' is 'Nous nous réfugiions dans l'arithmétique' in the French 'Assez', or, 'We took refuge in arithmetic'.[119] The line is a refrain. In 'Enough' and *Company* it is part of an elegiac mathematical vernacular: 'Simple sums you find a help in times of trouble. A haven', reminds the voice in *Company*, 'Even still in the timeless dark you find figures a comfort'.[120] Yet the refrain echoes, too, in Malone's bored description of Sapo's schooldays. Indeed, in *Malone Dies*, even the memory of counting counts. Through Saposcat, Malone records the 'old days' in which he had the time to count and the ability to master time simply by counting:

> In the old days I used to count, up to three hundred, four hundred, and with other things too, the showers, the bells, the chatter of the sparrows at dawn, or with nothing, for no reason, for the sake of counting, and then I divided, by sixty. That passed the time, I was time, I devoured the world. Not now, any more. A man changes. As he gets on.[121]

The image of demotic mathematics as refuge or consolation is a knot, a persistent interruption, in Beckett's writing. Lévinas describes interruptions in speech as knots: 'The interruptions of the discourse found again and recounted in the immanence of the said are conserved like knots in a threat tied again, the trace of a diachrony that does not enter into the present, that refuses simultaneity'.[122] While for Lévinas repeated interruptions form a diachronic trace or remainder, a knot in the thread of pure present-tense enunciation ('A book', he writes, 'is interrupted discourse catching up with its own breaks'), in Beckett's work the mathematical refrain is a knot in the tangled texture of plot, a knot that ties disparate prose works together and that resists unravelling and *dénouement* ('unknotting').[123] Knot problems, in mathematics, are a part of topology: part of what Michel Serres called the 'science of nearness and rifts'.[124]

What kind of a refuge, then, does mathematics offer? A possible answer to this question lies in the mathematician's *apologia*. Alfred North Whitehead, while he defends pure mathematics as the 'most original creation' in the history of ideas, writes that 'the pursuit of mathematics is a divine madness of the human spirit, a refuge from the goading urgency of contingent

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[118] Beckett, 'Enough', p. 95.
[119] Samuel Beckett, *Assez* (Paris: Les Éditions de Minuit, 1966), repr. 'Assez' in *Têtes-mortes*, (Paris: Les Éditions de Minuit, 1967, édition augmentée 1972), pp. 31-49.p. 38.
[120] Beckett, *Company* (London: John Calder, 1980), pp. 54-5.
[121] *Malone Dies*, p. 27.
[122] Emmanuel Lévinas, *Otherwise than Being or Beyond Essence*, trans. by Alphonso Lingis (Pittsburgh, PA: Duquesne University Press, 1998), p. 170.
[123] Lévinas, *Otherwise than Being*, p. 171. Peter Fifield explores the 'trace' and the 're-commencement' as conceptual and rhetorical structures shared by Beckett and Lévinas in *Late Modernist Style in Samuel Beckett and Emmanuel Levinas* (London: Palgrave Macmillan, 2013).
[124] Michel Serres with Bruno Latour, *Conversations*, p. 60.

happenings'.[125] Whitehead's mathematician takes refuge in abstraction. 'Mathematics', Whitehead writes, 'is thought moving in the sphere of complete abstraction from any particular instance of what it is talking about'.[126] Yet, paradoxically, 'as mathematics withdrew increasingly into the upper regions of ever greater extremes of abstract thought, it returned back to earth with a corresponding growth of importance for the analysis of concrete fact'.[127] The seventeenth century – 'some vivid dream of Plato and Pythagoras' in Whitehead's telling of it – produced formal systems and concepts (trigonometry, periodicity, and so on) whose very degree of abstraction gave them their usefulness. Whitehead concludes from this that 'the utmost abstractions are the true weapons with which to control our thought of concrete fact'.[128] G. H. Hardy, writing after the beginning of the Second World War, thought that Whitehead had got this wrong. For Hardy, pure mathematics offered a refuge from war and it did so precisely because it refused to produce ideas that could be used as weapons. 'Real mathematics', he wrote in 1940's *A Mathematician's Apology*, 'has no effects on war':

> No one has yet discovered any warlike purpose to be served by the theory of numbers or relativity, and it seems very unlikely that anyone will do so for many years. It is true that there are branches of applied mathematics, such as ballistics and aerodynamics, which have been developed deliberately for war and demand a quite elaborate technique: it is perhaps hard to call them 'trivial', but none of them has any claim to rank as 'real'.[129]

Beckett's arithmomaniacs aren't, in Hardy's terms, doing real mathematics. The protagonist of one of Malone's stories, Saposcat, takes defiant pleasure in rejecting the abstractions of even elementary algebra:

> He liked sums, but not the way they were taught. What he liked was the manipulation of concrete numbers. All calculation seemed to him idle in which the nature of the unit was not specified. He made a practice, alone and in company, of mental arithmetic. All the figures then marshalling in his mind thronged it with colours and with forms.
>
> What tedium. [130]

Arithmetic offers a prosaic solace. The mathematics of Beckett's world is often a demotic, everyday mathematics. Beckett's refrain – arithmetic as consolation or refuge – might be read as a vernacular version of the mathematician's apology for abstraction. However, the refrain also has

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[125] Alfred North Whitehead, *Science and the Modern World* (1926; repr. London: Free Association Books, 1985), p. 27.
[126] *Science and the Modern World*, p. 27.
[127] *Science and the Modern World*, p. 41.
[128] *Science and the Modern World*, p. 41.
[129] G. H. Hardy, *A Mathematician's Apology* (1940; repr. Cambridge: Cambridge University Press, 1967), p. 140. History is on Whitehead's side: number theory, which Hardy describes as 'beautifully useless', generated prime number cryptography, while the atomic bomb is, fundamentally, the realisation of a relativistic equation.
[130] Samuel Beckett, *Malone Dies*, p. 11.

a long cultural history and through that history is entangled with early modern melancholy, ancient scepticism and the alchemy of the Greek geometers.

Samuel Johnson, like Beckett's characters, found solace in arithmetic. Beckett recorded Samuel Johnson's habits in his notebooks and composed part of a play, 'Human Wishes', on Johnson's relationship with Hester Thrale (Hester Lynch Piozzi after her second marriage). Beckett's play drew on Hester Piozzi's *Anecdotes of the late Samuel Johnson* (1786), in which she reported: 'When Mr. Johnson felt his fancy, or fancied he felt it, disordered, his constant recurrence was to the study of arithmetic'.[131] Piozzi described one of Johnson's calculations – 'so vast was the plan of it, and so very intricate were the figures' – in which he worked out: 'that the national debt, computing it at one hundred and eighty millions sterling, would, if converted into silver, serve to make a meridian of that metal, I forget how broad, for the globe of the whole earth, the real *globe*'.[132] Johnson's arithmomania prompted Piozzi to ask him for his opinion on a controversy in the philosophy of mathematics: 'the question between Paschal and Soame Jennings about number and numeration'. Pascal, Piozzi related, held that infinity appeared most astonishing when it was connected with the idea of number: the idea of infinite number stretches the mind even further than the idea of infinite space. Soame Jenyns, on the other hand, considered infinite number to be a 'contradiction in terms' as 'whatever is once numbered we all see cannot be infinite'.[133] Mr. Johnson settled the matter in the following way: '"numeration is certainly infinite, for eternity might be employed in adding unit to unit; but every number is in itself finite as the possibility of doubling it easily proves: besides, stop at what point you will, you find yourself as far from infinitude as ever"'.[134]

As Johnson (and Beckett's characters) divert their thoughts with calculations, they are following the advice Robert Burton gave in *The Anatomy of Melancholy*. Burton commended geometry and 'arithmetick' as cures for melancholy.[135] Let 'him that is melancholy', Burton advises, 'divert his melancholy thoughts': 'let him demonstrate a proposition in Euclide in his five last books, extract a root, or studie algebra'.[136] *The Anatomy of Melancholy* gives a list of suggestions:

> you may contemplate the variation of the 23 letters, which may be so infinitely varied, that the words complicated and deduced thence will not be contained within the compass of the firmament; ten words may be varied 40320 severall wayes: by this art may you examine how many men may stand one by another in the whole superficies of the earth: some say 148456800000000, *assignando singulis passum quadratum* ; how many men,

131 Hesther Lynch Piozzi, *Anecdotes of Samuel Johnson, LL. D. During the Last Twenty Years of His Life* (London: T. and J. Allman, 1826), p. 59
132 *Anecdotes*, p. 60.
133 *Anecdotes*, p. 60.
134 *Anecdotes*, p. 60-61.
135 Robert Burton, *The Anatomy of Melancholy* (16th edition, London: B. Blake, 1838) p. 352-358.
136 *Anatomy of Melancholy*, p. 356.

> supposing all the world as habitable as France, as fruitfull, and so long lived, may be born in 60000 years.[137]

If the melancholic is 'more mathematically given' he might, Burton suggests, 'calculate, or peruse Napiers Logarithmes, or those tables of aritificiall sines and tangents, not long since set out by […] M. Edmund Guntur, which will perform that by addition and subtraction only, which heretofore Regiomontanus tables did by multiplication and division'.[138] Burton's mathematical cure is complicated, Carla Mazzio argues, both by the terms of affinity between mathematics and melancholy – mathematics in the Renaissance was imagined as both cure and cause of melancholy – and by the style of Burton's writing. As Burton's list of mathematical cures lengthens, Mazzio argues, 'what emerges is a "cure" for disorientation that is itself deeply disoriented'.[139] Burton wrote under the name of 'Democritus Junior', thus aligning his 'theory of psychic disorientation' with 'a theory of spatial disorientation': Democritus's atomism. The structure of *The Anatomy of Melancholy* is paradoxical: 'the concept of melancholy becomes that which draws together an otherwise random, heterogeneous and discontinuous universe: it becomes a kind of cure for the ruins of quantitative order'.[140]

Beckett's characters find refuge in mathematical ruins. 'Lessness', indeed, explicitly pairs 'ruins' and 'refuge' in lines like 'Ruins true refuge long last towards which so many false time out of mind', 'Scattered ruins same grey as the sand ash grey true refuge' and 'True refuge long last scattered ruins same grey as the sand'.[141] The image of mathematics as a refuge is an ancient one and Beckett's refrain can be traced back to the second century CE: to the first blow struck by the Greek skeptic Sextus Empiricus in his 'Against the Geometers'. 'The Geometers', Sextus writes, 'perceiving the multitude of difficulties which beset them, take refuge in a method which seems to be free from danger and safe, namely, to beg by "hypothesis" the principles of geometry'.[142] Sextus condemns this flight to safety: 'the Mathematicians do no good by assuming *ex hypothesi* the principles of proof and of each theorem, repeating the formula "Let it be granted"'.[143]

Alchemy

Wittgenstein, as he imagines a society for whom numbers are spirits and arithmetic is the means of summoning those spirits, begins to wonder about the strange alchemy even of our

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137 *Anatomy of Melancholy*, p. 357.
138 *Anatomy of Melancholy*, p. 358.
139 Carla Mazzio, 'The Three-Dimensional Self: Geometry, Melancholy, Drama', in *Arts of Calculation: Quantifying Thought in Early Modern Europe*, ed. David Glimp and Michelle R. Warren (New York: Palgrave, 2004), pp. 39-65 (p. 43).
140 Mazzio, 'The Three-Dimensional Self', p. 58.
141 Beckett, 'Lessness', in *The Complete Short Prose, 1929-1989*, pp. 197-202.
142 Sextus Empiricus, 'Against the Geometers' in *Sextus Empiricus IV Against the Professors*, trans. R. G. Bury (London: Heinemann), pp. 244-304 (p. 245).
143 'Against the Geometers', p. 253.

disenchanted mathematics. 'The comparison with alchemy seems natural', he writes, and it leads him to a startling idea: 'We might speak of a kind of alchemy in mathematics. Is it already mathematical alchemy, that mathematical propositions are regarded as statements about mathematical objects,– and mathematics as the exploration of these objects?'[144] Alchemy, here, is a metaphor for the practice of making something hypothetical, imagined or abstract into something actual. While Penelope Maddy finds it 'alarming' that 'Wittgenstein held mathematical realism – the view that mathematics is the science of a mind-independent reality – to be no better than alchemy', Ian Hacking comes to alchemy's defence: 'Maybe we do need alchemy, name magic, whatever derogatory epithetic you choose', he writes, 'in order to advance human culture'. [145] Alchemy, for Hacking, is another name for C. S. Peirce's concept of 'hypostatization' – '*making abstract concepts actual, or counting them as real*' – and it suggests a new philosophy of number. [146] The new philosophy is neither platonist nor nominalist. It says neither that numbers are real (as the platonist does) nor that numbers cannot be real (the nominalist's view). Rather, the alchemist or hypostasizer 'counts them as real, or makes them actual. To hypostatize is to do something: it is thought in action'.[147]

Mathematical alchemy in Samuel Beckett's world is a flickering sight: an unstable chemical transformation. His numbers lurch uneasily into objects, his objects into numbers, revealing, as they do so, traces of the cultural history of mathematical ideas, entities and practices: traces of the mathematical sociolect. The fiat 'Let it be granted' or 'Let x be' is an example of the mathematician's rhetorical alchemy. That alchemy is volatile in *How It Is* and *Molloy*. Mathematics in *How It Is* is drawn back into the mud, its alchemy reversing or disintegrating. The fiat becomes a plea: the narrator begins with 'let us be numbered 1 to 1000000' and goes on to ask 'let me for example be numbered 1 it's not asking a great deal'.[148] The narrator's procession towards, perhaps, 'the open air the light of day the regimen of grace' is 'a slowness of which figures alone however arbitrary can give a feeble idea', though those figures end in mistaken calculations ('something wrong there') or are abandoned as futile hypotheticals ('either I am alone and no further problem or else we are innumerable and no further problem either'). Mathematical possibility and brute actuality muddle in the painstaking, muddied, rejected calculations of *How It Is* as they do in *Molloy* when Molloy, at the seaside and very hungry, proposes a mathematical problem. He asks us to imagine that he has sixteen sucking-stones (a play, perhaps, on the

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[144] Ludwig Wittgenstein, *Remarks on the Foundations of Mathematics*, ed. by G. H. von Wright , R. Rhees and G. E. M. Anscombe, trans. by G. E. M. Anscombe (London: Blackwell, 1956), p. 274.
[145] Penelope Maddy, 'Mathematical Alchemy', *The British Journal for the Philosophy of Science* 37.3 (1986), pp. 279-314 (p. 279). Hacking, *Why Is There Philosophy of Mathematics At All?* (Cambridge: Cambridge University Press, 2014),p. 271.
[146] Ian Hacking, *Why Is There Philosophy of Mathematics At All?* p. 270.
[147] Hacking, *Why Is There Philosophy of Mathematics At All?* p. 270.
[148] *How It Is*, 102

etymology of calculus – from the Latin for small stone or pebble) and that these stones must be rotated between his pockets in such a manner as to ensure that each stone is sucked equally:

> I had say sixteen stones four in each of my four pockets. […] Taking a stone from the right pocket of my greatcoat, and putting it in my mouth, I replaced it in the right pocket of my greatcoat by a stone from the right pocket of my trousers, which I replaced by a stone from the left pocket of my greatcoat, which I replaced by the stone which was in my mouth, as soon as I had finished sucking it.[149]

This first 'solution' proves unsatisfactory for Molloy as he may just be sucking the same four stones over and over again. So Molloy works through various alternative solutions: moving the stones in groups of four, for example, or dividing his pockets in two with safety pins. These solutions all fail until Molloy is struck by a sudden intuition: he might be able to solve his problem without increasing the number of his pockets or reducing the number of his stones ('an admission of defeat') 'simply by sacrificing the principle of trim'.[150] 'The meaning of this illumination', he says, 'which suddenly began to sing within me like a verse of Isaiah or Jeremiah, I did not penetrate at once, and notably the word trim, which I had never met with, in this sense, long remained obscure'.[151] After passing through 'heartbreaking stages', Molloy 'finally reached a solution, inelegant assuredly, but sound, sound'.[152] He must sacrifice the equal distribution of stones in pockets. Instead of four groups of four, one group in each pocket, he realises that:

> All (all!) that was necessary was to put for example, to begin with, six stones in the right pocket and of my greatcoat, or supply-pocket, five in the right pocket of my trousers, that makes the lot, twice five ten plus six sixteen, and none, for none remained, in the left pocket of my greatcoat, which for the time being remained empty, empty of stones that is, for its usual contents remained, as well as occasional objects. For where do you think I hid my vegetable knife, my silver, my horn and the other things that I have not yet named, perhaps shall never name.[153]

Molloy elides the possible and the actual: the hypothetical world of his mathematical problem (of 'I had *say* sixteen stones', of 'ifs' and 'for examples') is muddled with the world of his vegetable knives. Molloy's final solution, in fact, is 'to throw away all the stones but one, which I kept now in one pocket, now in another, and which of course I soon lost, or threw away, or gave away, or swallowed'.[154]

As Molloy's stones flicker between possibility and actuality they mimic, absurdly, the rhetoric of ancient Greek mathematics. That rhetoric was a kind of unstable alchemy. Reviel Netz has traced the use of imagination and its rhetoric in Greek mathematical writings. By

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[149] Beckett, *Molloy* (London: Faber and Faber, 2009), p. 69. Kenner, too, notes the etymology: 'Lat. *calculus*, a stone used in reckoning'. See Kenner, *Samuel Beckett*, p. 111.
[150] *Molloy*, 71.
[151] *Molloy*, 71.
[152] *Molloy*, 72.
[153] *Molloy*, 72.
[154] *Molloy*, 75.

analysing usage of the verb *noein* and the imperative construction 'let *x* be', Netz illuminates the ontological structure of those mathematical writings: 'against the assumed context of ordinary reality, a moment of more explicit imagination projects an extra layer of reality. Immediately following that, however, the projected, more imaginary reality is absorbed into the assumed context of ordinary reality, its imaginary origins forgotten'.[155] Netz's wonderful figurative account of this 'decay into the real' might also be used to describe the play of possibility and actuality in Beckett's literary mathematics:

> It is as if the Greek mathematical text was a rare isotope, imagino-active: it keeps emitting a certain radiation of the imaginary, pulses of the verb *noein*, of the possible, the conditional, the third-person imperative. But these emissions have an extraordinarily short half-life. A sentence following the emission of the imaginary pulse – and the imaginary quantity has already decayed into a lump of ordinary reality (which then, of course, emits further and further pulses of the imagination that once again decay into the real). Thus by continuous pulses of the imagination and their continuous decay into the lumps of ordinary reality is Greek mathematical reality constructed.[156]

For Netz, Sextus Empiricus's attack on the mathematician's refuge tells us something fundamental about Greek geometers. Those geometers, Netz writes, 'used the hypothetical specifically so as to "take refuge" in it' because the only way 'to maintain the certainty of Greek geometry was to resort time and again to the fiction of an object precisely answering to a certain description, and then engaging in a discourse where the fictional is always taken on a par with the real'.[157] After he has demolished the mathematician's refuge, Sextus goes after each of the principles of their 'false and incredible art': 'let us speak first about the point, next about line, and after that about the surface and body; for if these are destroyed Geometry will not be an Art, as not possessing the conditions upon which success in its construction seems to depend'.[158] Once he has shown the basic principles of geometry to be inconceivable, Sextus abolishes arithmetic. If number 'is destroyed', he argues, 'the art which is constructed to handle it will not exist'.[159] He destroys number by destroying the 'Monad' (and, for good measure, the principles of addition and subtraction) and concludes that, against the Pythagoreans, 'one must declare that number is nothing'.[160]

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[155] Reviel Netz, 'Imagination and Layered Ontology in Greek Mathematics', *Configurations*, 17.1-2 (2009), 19-50 (p. 42).
[156] Netz, 'Imagination and Layered Ontology', p. 42.
[157] 'Imagination and Layered Ontology', p. 47.
[158] 'Against the Geometers', p. 255.
[159] 'Against the Arithmeticians', in *Sextus Empiricus IV Against the Professors*, pp. 304-322 (p. 305).
[160] 'Against the Arithmeticians', p. 321.

Pascal's Ends and Poincaré's Ruins

Despite the announcements of mathematics' demise or rejection – such as *Dream*'s 'when arithmetic abates' and *The Unnamable's* 'Enough concessions, to the spirit of geometry' – it remerges as a refrain.[161] Indeed, 'Enough concessions, to the spirit of geometry' is an ending, an unknotting, distracted by a comma and troubled by the grammatical ambiguity of its internal joint. Perhaps, Connor proposes, the comma's key function in *The Unnamable* is 'like that of the fly': 'to *distract*, to draw apart or internally divide an utterance that both does and does not wish to round on, to come round to itself'.[162] In *How It Is*, mathematics resists both its ending and its ends: 'all measures vague yes vague impressions of length length of space length of time vague impressions of brevity between the two and hence no more reckoning save possibly algebraical yes I hear yes then no'.[163] Despite that 'no', the narrator continues with his calculations, though his attempts to sum up and give account remain provisional, secular sketches in the absence of a proper 'ending': a proper occasion for moral reckoning. As such, though Melanie Foehn and Anthony Cordingley take the Unnamable's remark, 'Enough concessions, to the spirit of geometry', as a definite rejection of Pascal's spirit of geometry, I would urge a note of caution: such endings have a troubling habit of unravelling.[164] Beckett, Foehn argues, 'dismissed the "esprit de géométrie" in the same way that he derided Cartesianism, Corneille, and realist writers such as Balzac. He defended the idea that reality is fundamentally incoherent and unfathomable'.[165]

Pascal was certainly no stranger to the unfathomable. For Pascal, the proper 'end' of geometry ought to be a recognition (and a dismaying recognition at that) of its and therefore of our limits. The limits of our mathematics are the limits of our world: 'what passes geometry surpasses us', he writes.[166] In his consideration of double infinity (the infinitely small and infinitely great) in the *Pensées,* Pascal, as Matthew Jones writes, 'aimed to upset and to depress the polite audiences Descartes, the Jesuits, and others sought to console and comfort'.[167] Rather than 'revealing the greatness of human ability' and offering consolation or refuge, mathematics 'ought

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161 *The Unnamable*, p. 74.
162 Steven Connor, *Beckett, Modernism and the Material Imagination* (Cambridge: Cambridge University Press, 2014), p. 57.
163 Beckett, *How It Is*, p. 43.
164 *The Unnamable*, p. 74. Cordingley argues that 'Beckett's reference to "*l'esprit de géométrie*" is certainly ironic' because Beckett subsumes Pascal's *esprit de finesse* into its opposite, *l'esprit de géométrie*, as he attributes the 'spirit of geometry' to the theological instructors of *The Unnamable*. See Anthony Cordingley, 'Beckett's Ignorance: Miracles/ Memory, Pascal/ Proust', *Journal of Modern Literature* 33.4 (2010), 129-152 (p. 139).
165 Melanie Foehn, *Samuel Beckett and the Writers of Port-Royal* (unpublished doctoral thesis, Université de la Sorbonne, nouvelle – Paris III and University of Kent at Canterbury, 2012), p. 109.
166 Blaise Pascal, 'De L'Esprit Géométrique', in *Oeuvres Complètes* Vol II, ed. by Michel Le Guern (Paris: Gallimard, 2000), pp. 154-177 (p. 155). ['ce qui passe la géométrie nous surpasse'].
167 Matthew L. Jones, *The Good Life in the Scientific Revolution: Descartes, Pascal, Leibniz, and the Cultivation of Virtue* (Chicago: University of Chicago Press, 2006), p. 10-11.

to encourage the recognition of human incapacity': to 'generate emotions of worthlessness and despair'.[168]

Beckett quoted from Pascal's *Réflexions sur la géométrie en général* in the 'Whoroscope' Notebook. He quoted Pascal quoting Wisdom 11.21: 'mouvement, nombre et espace … qui comprennent tout l'univers, selon ces paroles: *Omnia in mensura et numero et pondere disposuisti*'.[169] This line – 'You have arranged all things in measure, number, and weight' – preoccupied Saint Augustine. He meditated on the problem of priority:

> let the soul which can do so think about whether these three, measure, number, and weight […] were somewhere or other before the whole nature cosmos was created, or whether they too were created; and if they existed beforehand, where were they? After all, before creation there was nothing except the creator. Therefore they were in him. But how?[170]

God isn't measure, number or weight in the ordinary sense of those terms, as we apply them to 'stones and planks and similar masses of material', rather, 'insofar as measure sets a limit to everything, and number gives everything its specific form, and weight draws everything to rest and stability, he is the original, true and unique measure'.[171] Measure, weight and number are also moral acts, as in the 'measured way of doing things', the 'numbering of the spirit's passions and powers' and the 'weighing for the will and for love, which shows what should be weighed and for how much in seeking or avoiding it'.[172] These moral acts of measure, number and weight are bound by, formed by and drawn to God's Platonic mathematics:

> the measure without measure is the standard for what derives from it, while it does not itself derive from anything else; the number without number, by which all things are formed, is not formed itself; the weight without weight to which are drawn, in order to rest there, those whose rest is pure joy is not itself drawn to anything else beyond it.[173]

Augustine's God creates the conditions of possibility for mathematics. To 'only know the words "measure" and "number" and "weight"' with reference to visible objects is to 'have a slave's knowledge of them', yet to understand measure, number and weight purely 'as referring to higher things' is to fall prey to a false habit of mind, a false aversion to ordinary reality. Reason, therefore, must understand the 'likeness these lower things have to those higher realities': the

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168 Jones, *The Good Life in the Scientific Revolution*, p. 10-11.
169 Samuel Beckett, '*Whoroscope* Notebook', Beckett International Foundation, University of Reading, MS 3000
170 Augustine, 'The Literal Meaning of Genesis', in Saint Augustine, Bishop of Hippo, *On Genesis*, trans. by Edmund Hill and ed. by John E. Rotelle (New York: New City Press, 2002), pp. 155-506 (p. 246).
171 'The Literal Meaning of Genesis', p. 246.
172 'The Literal Meaning of Genesis', pp. 246-7.
173 'The Literal Meaning of Genesis', p. 247.

relationship between measured, numbered and weighed objects and measure, number and weight as ideas instantiated in God's acts of creation.[174]

Pascal, on the other hand, found the definition of measure, number and weight to be a more trenchant philosophical problem with a less consoling answer. Geometry in Pascal's *Réflexions sur la géométrie en général; De l'esprit géométrique et de l'Art de persuader* is a model of the perfect and methodical demonstration, despite the fact that it treats the 'reciprocal and necessary connection' between basic or primitive terms such as motion, number, space and time that cannot themselves be defined.[175] The indefinable terms of elementary geometry are nonetheless known to everyone: not in their natures or essences but as relations between name and thing, 'so that at the expression *time*, all direct their thoughts towards the same object'.[176] As he evades Sextus Empiricus's sceptical deconstruction of the basic terms of mathematics, Pascal reworks Augustine's metaphors of movement. Augustine's language of the placeless movement of the will – of turning toward (conversion) and away from (aversion), of being drawn by the pull of God's weight – is translated into a more pessimistic language of convention or habit. Pascal's line, '*tous portent la pensée vers le même objet*', shows, for Paul de Man, that the basic terms of mathematics function not as signs but as tropes or vectors: 'a directional motion that is manifest only as a turn, since the target toward which it turns remains unknown'.[177] If Beckett's seemingly endless pages of enumeration are a kind of litany, counting in *Company* has a particularly incantatory quality. The one, the addition to company, returning to 'naught anew': all suggest a mathematical genesis. *Company*'s narrator uses number, weight and measure as ways of worldmaking. This world is created and measured simultaneously: it is dependent on habit, on habitual counting, and subject to lapses of memory, will and belief.

In *Science and Hypothesis* Henri Poincaré built an imagined world, a world of beings of no thickness, and described those beings constructing their geometry. Poincaré's imagined world was designed to show that the axioms of geometry are '*neither synthetic à priori intuitions nor experimental facts*. They are conventions'.[178] 'What, then', Poincaré asks, 'are we to think of the question: "Is Euclidean geometry true?" It has no meaning. We might as well ask if the metric system is true, and if the old weights and measures are false […] One geometry cannot be more

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[174] 'The Literal Meaning of Genesis', p. 247.

[175] Pascal's *Réflexions sur la géométrie en général; De l'esprit géométrique et de l'Art de persuader* were published under the general heading 'De L'Esprit Géométrique' in Pascal, *Oeuvres Complètes*, Vol. II. The English translation quoted here is O. W. Wight's translation, 'Of the Geometrical Spirit', in *Blaise Pascal: Thoughts, Letters and Minor Works*, trans. by W. F. Trotter, M. L. Booth and O. W. Wight (New York: Harvard Classics/P. F. Collier & Son, 1910), pp. 427-444 (p. 436).

[176] Pascal, 'Of the Geometrical Spirit', p. 433.

[177] Paul de Man, *Aesthetic Ideology*, p. 56.

[178] Henri Poincaré, *The Value of Science: Essential Writings of Henri Poincaré*, 3 vols in 1, *Science and Hypothesis*, translator unknown, *The Value of Science*, trans. by George Bruce Halsted and *Science and Method*, trans. by Francis Maitland (New York: The Modern Library, 2001), *Science and Hypothesis*, p. 45.

true than another; it can only be more convenient'.[179] In the celestial mechanics of *The Unnamable*, Malone wheels 'like a planet about its sun' and in this geometry: 'All is possible, or almost. But the best is to think of myself as fixed and at the centre of this place, whatever its shape and extent may be'.[180] As Ackerley points out, the geometry of *The Unnamable* begins as a response to, or a meditation on, an analogy between stars and atoms drawn in Poincaré's *La valeur de la science*, a book Beckett took extensive notes from in his 'Whoroscope' Notebook.[181] Poincaré's history of mathematical physics in *The Value of Science* begins with the birth of mathematical physics out of celestial mechanics. He writes:

> if our senses were sufficiently keen to show us all the details of the bodies which the physicist studies, the spectacle thus disclosed would scarcely differ from the one the astronomer contemplates. There also we should see material points, separated from one another by intervals, enormous in comparison with their dimensions, and describing orbits according to regular laws. These infinitesimal stars are the atoms. Like the stars proper, they attract or repel each other, and this attraction or this repulsion following the straight line which joins them, depends only on the distance.[182]

Indeed, Beckett's use of mathematics as a persistent refrain might help us to understand an apparent contradiction in Poincaré's philosophy. Poincaré's conventionalism in *The Value of Science* as in *Science and Hypothesis* is coupled with a structural realism. These two strands of thought appear in the first instance to contradict one another. Conventionalism seems to tend towards anti-realism, even nominalism, while structural realism asserts that while science cannot penetrate things themselves, it can access the relations between those things, and these structural relations, expressed in mathematical terms, persist across revolutions.

Poincaré describes the birth and collapse of the physics of central forces in order to show a continuity of structure. The ruins of the physics of central forces are read as a sketch of the physics of principles, and as such as an allegory for structural continuity, as insurance against the collapse of physics of principles. 'In the midst of so much ruin, what remains standing?', we might wonder. Well, Poincaré writes:

> I have shown you that in the second mathematical physics, that of the principles, we find traces of the first, that of central forces; it will be just the same if we must know a third. Just so with the animal that exuviates, that breaks its narrow carapace and makes itself a fresh one, under the new envelope one will recognize the essential traits of the organism which have persisted.[183]

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179 Poincaré, *Science and Hypothesis*, p. 45.
180 *The Unnamable*, p. 5.
181 Ackerley, 'Samuel Beckett: The Geometry of the Imagination', p. 100.
182 *The Value of Science*, p. 291.
183 *The Value of Science*, p. 313.

Poincaré's mathematics in the future perfect has provided the philosophy of physics with an allegory to insure itself against loss. 'The ruins may still be good for something', as he wrote.[184] The shift from Fresnel's ether theory to Maxwell's electromagnetic field theory, for example, doesn't require us to conclude that all of our current theories will collapse, as ether, caloric, crystalline spheres and the humours did; rather, though the field in no clear sense approximates the ether, disturbances in it do obey *formally* similar laws to those obeyed by elastic disturbances in a mechanical medium. The old equations become limit cases of the new equations. In other words, Poincaré's structural or syntactic realism offers us a way of reading ruins: of perceiving the continuity, expressed in mathematical equations, that runs through the history of our errors. Poincaré's 'vision of knowledge', Peter Galison writes, 'had two simultaneous goals': 'Manipulate the flexible aspects of knowledge as tools; choose the form that makes the problem at hand simple. Then seize those relations that stand fast despite the choices made. Those fixed relations stand for knowledge that endures'. [185] Like Mr Knott, who '*abides*' (as Ackerley puts it) while his servants '*come and go*', the underlying relations – knots, saddle points and vortices, for example – are an economy of the unlost.[186] Poincaré's conventionalism preserves mathematics by protecting it from empirical testing, while his structural realism allows mathematics to function as an abiding refrain: both philosophies are ways of reading ruins, languages of recuperation and refuge.

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184 *Science and Hypothesis*, p. 122.

185 Peter Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time* (London: Hodder and Stoughton, 2003), p. 79.

186 Ackerley described Mr Knott and his servants thus while glossing a passage on Greek philosophy from Windelband's *A History of Philosophy*: 'According to Windelband (1901: 111), the two categories of corporeal being are *ousia*, ever the same with itself, and *genesis*, in process of change […] Greek ethics, he notes, began with a problem that paralleled the initial problem of physics: the essence of things that abide and survive all change. The Greek mind, seeking a permanent in the mutation of occurrence, found it in the great relations, such as the revolution of the stars, which *abide* (ibid., 57). Like the stars, or Godot, Mr Knott *abides*; like Estragon and Vladimir, his servants *come and go*'. C. J. Ackerley, 'Samuel Beckett and Science' in *A Companion to Samuel Beckett*, ed. by S. E. Gortanski, Wiley-Blackwell, 2010, pp. 143-164 (p. 146).

DEMOTIC MATHEMATICS AND THE QUANTIFIED WORLD

THE LITERARY PHENOMENOLOGY OF PROBABILITY

Literature and Quantification

'*Quantification*', Lorraine Daston reminds us, 'is a portmanteau term that holds a multitude of meanings. It is part of our number fetishism that we seldom distinguish among them'.[1] Quantification is performative work that has been practiced, valued and understood in different ways across different cultures and eras. For Theodore Porter, the reverence for quantitative testimony in twentieth-century political discourse and social science is evidence not of an autonomous community of mathematicians steadily expanding their influence over society but of the weakness of disciplines, expertise and social authority.[2] Quantified data and numerical objectivity are techniques that, in Porter's analysis, thrive both on the weakness of community and on their own conceptual thinness: '[t]he remarkable ability of numbers and calculations to defy disciplinary and even cultural boundaries and link academic to political discourse owes much to this ability to bypass deep issues', he writes.[3] Yet, as the history of social mathematics has taught us, the values commonly associated with quantification – objectivity, impersonality and impartiality – are not essential properties of numbers. In the hands of statisticians, politicians and numerologists, as Daston points out, numbers exude personality, individuality and partiality.[4] Number's neutrality is a fiction. The affective logics of number and quantification are, I argue, woven into twentieth-century life and literature. These affective valences are crucial to understanding literature's quantified worlds. Demotic mathematics names the mathematical ideas and practices that are woven into everyday life and literature: counting, statistics, half-forgotten schoolroom geometry, measurement and risk. Demotic mathematics gathers the 'bad numbers' cast out of Alain Badiou's set-theoretical paradise. For Badiou, impure numbers (quantified social data, polling numbers, accounts, audience ratings, budgets, credits, stock options, print runs, salaries and so on) are not just evidence that we live in the era of number's despotism, they also a 'banalisation of number' and 'intransitive to the mathematical thought of Number'.[5]

In the following sections, I consider some of the valences of demotic mathematics in the twentieth century: literary engagements with probability, statistics, normalcy, accounting and the

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[1] Daston, 'The Moral Economy of Science', p. 8.
[2] Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton University Press, 1995).
[3] Porter, *Trust in Numbers*, p. 86.
[4] Daston, 'The Moral Economy of Science', pp. 9-10.
[5] Alain Badiou, *Number and Numbers*, p. 213.

law of large numbers. Demotic mathematics often looks a lot less 'numerical' than might be expected, and a lot more like the daydreams of David Foster Wallace's IRS agent:

> Sylvanshine's window seat was in 8-something, an emergency row, beside an older lady with a sacklike chin who could not seem despite strenuous efforts to open her nuts. The core accounting equation A= L+E can be dissolved and reshuffled into everything from E= A- L to beyond. The craft rode the updrafts and downdrafts like a dinghy in a gale.[6]

Probability's demotic registers are a part of literature's mornings (Gregor Samsa wakes up as an insect and thinks immediately of the insurance doctor) and a part of literature's accidents (the shipwrecks of Hopkins and Mallarmé) and its near misses (as Leopold Bloom narrowly avoids being run down in the street, he thinks: 'Close shave that but cured the stitch. Must take up Sandow's exercises again. On the hands down. Insure against street accident too. The Providential').[7] Beyond this ubiquitous mathematical weather (of course, even weather is mathematical now), probability and insurance are also matters of grammar, matters of style and matters of reading.

The statistician Adolphe Quetelet believed that the mean values of society's gathered facts could form the contours both of the 'average man' and of a refined literary method. The average man did not, of course, lead quite the literary life that Quetelet imagined for him. Nonetheless, the average man, the Gaussian distribution and the 'law of large numbers' have had a literary history. The 'mathematisation' of the world, its becoming-numerical, began a new phase with the rise of statistics and formalised insurance and this demotic mathematics is intertwined with literature.

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[6] David Foster Wallace, *The Pale King* (New York: Little, Brown & Co., 2011), p. 5.
[7] James Joyce, *Ulysses* (Oxford: Oxford University Press, 1993), p. 414.

> Why should not the only application of the integral and differential calculus etc., be for patterns on wallpaper? Suppose they were invented just because people like a pattern of this kind. This would be a perfectly good application.
>
> Ludwig Wittgenstein, *Lectures on the Foundations of Mathematics*.[8]

> 'Wouldn't it be lovely to be dissolved by statistics?' she said. 'It's been such a long time since love could do it!'
>
> Robert Musil, *The Man Without Qualities*.[9]

Probability's Snares

When, as we make excuses for ourselves, we talk of 'causing', 'the word snares us', J. L. Austin told the Aristotelian Society: 'we are struggling to ascribe to it a new, unanthropomorphic meaning, yet constantly, in searching for its analysis, we unearth and incorporate the lineaments of the ancient model'.[10] Words, for Austin, have 'trailing clouds of etymology' that drag with them a clutter of old models and past climates of thought. In speaking of causes and accidents, we get tangled in ancient maps of how to move around inside thought. The etymology of words like 'cause' and 'accident' is an archive of those maps. Where Austin warns of the traps laid in words by old maps, Peter de Bolla offers a definition of 'the architecture of concepts' that enables those old maps to be read. Concepts, de Bolla writes, are 'the names we give to particular routes for thinking'. They are like 'tube maps projected into multiple dimensions', their 'complex geometries' forged both by cultural utility and internal 'wiring'. We need to pay attention to a concept's architecture, to the structure of its complex geometry, so that we can recognise 'why a particular concept helps us to think *this* rather than that' and 'why we are *unable* to think otherwise'.[11] De Bolla's maps and Austin's snares are possible ways of reading the architectures of probability concepts in modern literature: ways of looking for the lineaments of ancient models in concepts like risk, normalcy, accident, chance and credence. Probability is a lived-with form of understanding and a clutter of lived-in modal worlds. The history of probability is knit with the history of ordinary speech, with its rhythms, modalities, tenses and aspects. I will unravel the referential texture of probability with particular attention to three mathematical tools – the

[8] Ludwig Wittgenstein, *Wittgenstein's Lectures on the Foundations of Mathematics, Cambridge, 1939: From the Notes of R. G. Bosanquet, Norman Malcolm, Rush Rhees, and Yorick Smythies* (Ithaca, NY: Cornell University Press, 1976), ed. by Cora Diamond (Chicago: University of Chicago Press, 1989), p. 24.
[9] Robert Musil, *The Man Without Qualities*, trans. by Sophie Wilkins and Burton Pike (London: Picador, 2011), p. 785.
[10] J. L. Austin, 'A Plea for Excuses: The Presidential Address', *Proceedings of the Aristotelian Society*, 57 (1956-1957), p. 28.
[11] Peter de Bolla, *The Architecture of Concepts*: *The Historical Formation of Human Rights* (New York: Fordham University Press, 2013), p. 4.

normal curve, the law of large numbers and the sample space – and how they work as analogies, metaphors and allegories in the writings of applied mathematicians – Adolphe Quetelet, Gustav Fechner, C. S. Peirce, Karl Pearson and Max Planck – and literary authors: Robert Musil and Wallace Stevens. I argue that Musil and Stevens offer a phenomenology of probability – an archive of ways of living with and through mathematical models and curves – and that the literary treatment of probability in the 1930s and 1940s is distinctive: it resists the terms of probability's own modernism and it draws on the accrued literary and rhetorical history of probability to investigate what it means for the world of probabilities to become coterminous with the world as such. The probability concepts used by modern literature are cultural entities with stylistic histories. They are also snares.

Probability itself is a split concept: a snare. 'The history of the theory of probability' for Rudolf Carnap in 1945 'is the history of attempts to find an explication for the pre-scientific concept of probability'.[12] Carnap sought to replace the ordinary, muddled concept of probability with a 'new, more exact concept'.[13] He called this renovation work '*explication*':

> in each case of an explication, we call the old concept, used in a more or less vague way either in every-day language or in an earlier stage of scientific language, the *explicandum*; the new, more exact concept which is proposed to take the place of the old one the *explicatum*.[14]

The old concept of probability proves resistant to explication because it is essentially dual. Condorcet, Poisson and Cournot had all attempted to divide probability into two concepts. Carnap attempts to explicate and codify the division. He calls probability's two forms probability$_1$ and probability$_2$. Both forms are 'a function of two arguments' and 'their values are real numbers belonging to the interval 0 to 1': probability$_1$ is concerned with 'degree of confirmation', while probability$_2$ is concerned with 'relative frequency' in the long run.[15] Carnap, drawing on Ernest Nagel, orders the history of probability theory into three strands: the 'classical conception' of Jacob Bernoulli and Laplace, for whom 'probability is defined as the ratio of the number of favourable cases to the number of all possible cases'; the logical conception of probability represented by John Maynard Keynes and Harold Jeffreys; and the relative frequency conception developed by Richard von Mises and Hans Reichenbach.[16] Carnap traces this history in order to argue that the conflict between these strands is a 'futile controversy' because 'the two sides start

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[12] Rudolf Carnap, 'The Two Concepts of Probability: The Problem of Probability', *Philosophy and Phenomenological Research*, 5.4 (1945), 513-532 (p. 516).
[13] Carnap, 'The Two Concepts of Probability', p. 513.
[14] Carnap, 'The Two Concepts of Probability', p. 513.
[15] Carnap, 'The Two Concepts of Probability', pp. 521-2.
[16] Carnap, 'The Two Concepts of Probability', pp. 516-7. Carnap cites: Ernest Nagel, *Principles of the Theory of Probability* (Chicago: University of Chicago Press, 1939); International Encyclopedia of Unified Science, Vol. I, No. 6), John Maynard Keynes, *A Treatise on Probability* (1941), Harold Jeffreys, *Theory of Probability* (1939), Richard von Mises, *Probability, Statistics, and Truth* (orig. 1928, 1939) and Hans Reichenbach, *Wahrscheinlichkeit* (1935).

from different explicanda' – different concepts of probability – and refuse to recognise the doubled nature of probability.

Carnap's rift outlasted his concepts. David Lewis also finds 'two kinds of probability' but replaces probability$_1$ with credence and probability$_2$ with chance or propensity.[17] For Lewis, credence and chance are distinct but related: chance 'obeys the laws of mathematical probability theory' because credences obey those laws. 'The chance distribution' at a given time and in a given world, Lewis writes, 'comes from any reasonable initial credence function by conditionalizing on the complete history of the world up to the time, together with the complete theory of chance for the world'. That 'reasonable initial credence function' is 'a probability distribution: a nonnegative, normalized, finitely additive measure. It obeys the laws of mathematical probability theory […] Whatever comes by conditionalizing from a probability distribution is itself a probability distribution'.[18] Lewis binds objective chance or propensity to reasonable belief and in the process creates 'hybrid probabilities': degrees of belief in 'propositions about chance'.[19] By replacing relative frequency with propensity in the role of probability$_2$, Lewis allows probability$_2$ to make sense of single cases. Charles Sanders Peirce suggested a propensity theory of probability in 1910 by drawing an analogy between the inclination of a die to yield a certain outcome and human habit. Suppose, he puts to us, a die is thrown from a dice box: what does it mean to say that the '*probability*' of that die 'turning up a number divisible by three, is one-third'?[20] It means:

> that the die has a certain 'would-be'; and to say that a die has a 'would-be' is to say that it has a property, quite analogous to any *habit* that a man might have. Only the 'would-be' of the die is presumably as much simpler and more definite than the man's habit as the die's homogeneous composition and cubical shape is simpler than the nature of the man's nervous system and soul.[21]

On the one hand, then, probability is degree of reasonable belief, where a reasonable belief is a belief demanded by the evidence, and on the other, probability is the habit that dice, atoms and experiments have of behaving in ways that can be predicted using limit theorems.

The philosophers' rift, however, never quite sticks: the two sides of probability muddle and blur. 'Something about the concept of probability precludes the separation which, Carnap thought, was essential to modern progress', Ian Hacking writes in *The Emergence of Probability*.[22]

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[17] David Lewis, 'A Subjectivist's Guide to Objective Chance', in *Studies in Inductive Logic and Probability* ed. by Richard C. Jeffrey, 2 vols (Berkeley, CA: University of California Press, 1971 and 1980), Vol. 2. (1980) pp. 263-293.
[18] Lewis, 'A Subjectivist's Guide', p. 277.
[19] Lewis, 'A Subjectivist's Guide', p. 264.
[20] Charles S. Peirce, *The Collected Papers of Charles Sanders Peirce*, *Vol. II: Elements of Logic*, ed. by Charles Hartshorne and P. Weiss (Cambridge, MA: Harvard University Press, 1932), §664.
[21] Peirce, *The Collected Papers of Charles Sanders Peirce*, *Vol. II*, §664.
[22] Ian Hacking, *The Emergence of Probability: A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference* (Cambridge: Cambridge University Press, 1975), p.16

That 'something', for Hacking, is the concept's preconditions: its space of emergence. Hacking proposes that the 'space of possible theories about probability […] has been rather constant from 1660 to the present'. The concept of probability emerged as a 'striking mutation' of an existing conceptual structure: the Renaissance doctrine of natural signs and seventeenth-century ideas about testimony and authority. 'What happened to signs, in becoming evidence,' Hacking writes, 'is largely responsible for our concept of probability'. The 'epistemological' and the 'aleatory' aspects of probability are muddled because the concept drags with it the lineaments of the old model: 'some characteristics of that prior structure, themselves quite forgotten, have impressed themselves on our present scheme of thought'.[23]

Modern probability is etched with the conditions of possibility for its emergence and for its revolution. Hacking's *The Taming of Chance* maps the nineteenth-century conceptual shifts that enabled the twentieth-century 'imperialism of probabilities'.[24] Probability's imperialism spans philosophy, physics – 'The most decisive event of twentieth century physics has been the discovery that the world is not deterministic' – and politics: 'Society became statistical. A new type of law came into being, analogous to the laws of nature but pertaining to people. These new laws were expressed in terms of probability'. The space was cleared for probability's imperialism by a gradual 'erosion of determinism' and by the 'avalanche of printed numbers' at the end of the Napoleonic era.[25] 'This imperialism of probabilities', Hacking writes, 'could only occur as the world itself became numerical'. That imperialism, in turn, created a new epistemic space. In an extraordinary love letter to C. S. Peirce, Hacking writes:

> He did argue against the doctrine of necessity, but it was not an argument that convinced him that chance is an irreducible element of reality. *He opened his eyes, and chance poured in* – from a world which, in all its small details, he was seeing in a probabilistic way. In this respect, although he was very much a nineteenth century man, he was already living in a twentieth-century environment. His working days of experimental routine, and his voyages of the mind, took place in a new kind of world that his century had been manufacturing: a world made out of probabilities.[26]

This 'world made out of probabilities' becomes, at the turn of the century, coterminous with the world as such. *The Taming of Chance* ends by invoking Mallarmé: 'We cannot suppose that Peirce saw the 1897 copy of *Cosmopolis* containing the poem by Mallarmé, three years his junior. But he was at one with the thought, "A throw of the dice will never abolish chance"'.[27]

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[23] Hacking, *The Emergence of Probability*, p.16. Hacking's argument hasn't, of course, gone uncontested. Barbara Shapiro questions Hacking's reduction of probability to just two faces and finds a proliferation of operative concepts of probability in seventeenth-century English letters (*Probability and Certainty in Seventeenth-Century England: A Study of the Relationships between Natural Science, Religion, History, Law and Literature* (Princeton, NJ: Princeton University Press, 1983)).

[24] Ian Hacking, *The Taming of Chance* (Cambridge: Cambridge University Press, 1990), p. 5.

[25] Hacking, *The Taming of Chance*, p. 5.

[26] *The Taming of Chance*, p. 201.

[27] *The Taming of Chance*, p. 215.

Peirce and Mallarmé thus mark the beginning of probability's modernism. Literary modernism confronts a world made out of probabilities. The architecture of that world was formed by historical mutations in the concept of probability. These mutations have been uncovered and analysed by historians and philosophers of science, foremost among them Hacking and Lorraine Daston. Rüdinger Campe, however, finds Hacking and Daston guilty of conducting this analysis in accordance with a misleading disciplinary assumption: in their work, Campe writes, 'the axiomatic definition of probability', which I will discuss shortly, 'remains the hidden telos of the history of mathematical probability'.[28] This hidden telos, Campe argues, has warped the history of probability: it has led historians to elide the role literary verisimilitude – the theory and practice of 'aesthetic semblance' or mimesis – played in the emergence of the concept of epistemic probability between 1660 and 1800. For Campe, the nature of the problem of probability's emergence 'gives the literary history of probability – the history of probability and verisimilitude in rhetoric and poetics – a chance to intervene in the history of epistemological probability'.[29] Where Hacking defined emergent probability as at once epistemological (concerned with degree of belief) and stochastic (concerned with the measurable frequencies of chance devices), Campe further divides epistemological probability into two intertwining strands: 'Between 1660 and 1800, probability constituted itself as a measurement of scientific knowledge and as a theory of aesthetic semblance'. The literary history of probability and the mathematical history of probability intertwine in Campe's argument: 'Two things turn out to be essentially related in this mode of investigation: the interpretation of theories of gaming chance as the theory of probability, and the phenomenologization of verisimilitude'.[30] This latter phrase, 'the phenomenologization of verisimilitude', denotes probability's development towards the appearance of truth. Probability snares us, then, not just because its objective and subjective sides keep getting muddled, but because literary history and mathematical history are woven together in the word's meaning (the German word, *Wahrscheinlichkeit*, means both probability and verisimilitude) and in the concept's formation.

It is tempting to read 'modern probability' as 'modernist probability': axiomatisation not as a telos but as a historically located style. Indeed, Hacking and Daston argue persuasively that historical mutations in the concept of probability were shifts in the style of thinking about probability. 'We believe', Daston writes, 'that prosody or architecture may evolve through classical, romantic, or modernist styles, but not mathematics […] Contrary to this view […] the classical theory of probability was coherent and distinct in just this stylistic sense'.[31] Classical

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[28] Rüdinger Campe, *Literature and Calculation from Pascal to Kleist*, trans. by Ellwood H. Wiggins, Jr. (Stanford, CA: Stanford University Press, 2013), p. 17.
[29] Campe, *Literature and Calculation from Pascal to Kleist*, p. 16.
[30] Campe, *Literature and Calculation from Pascal to Kleist*, p. 9.
[31] Lorraine Daston, *Classical Probability in the Enlightenment* (Princeton, NJ: Princeton University Press, 1988), p. xii.

probabilists like Bernoulli and Laplace, Daston writes, 'aimed at a model of rationality under uncertainty – of the intuitions of an elite of reasonable men': their field was 'a mathematical model of a certain set of phenomena' ('common sense reduced to calculus', in Laplace's famous phrase) not 'an abstract theory independent of its applications'.[32] The relationship between classical probability and literature has been variously conceived. Both Campe and Kavanagh find homologies between classical probability theory and the early eighteenth-century novel: for Campe, both forms 'phenomenologize' verisimilitude and for Kavanagh 'classical probability theory paralleled and in a very real sense sustained the emergence and hegemony of the modern novel'.[33] Jesse Molesworth, however, unpicks this homology. The early realist novel, through the 'fictional capital' it offers the ordinary reader, resists classical probability's vision of rational man: 'the fantasy, however unlikely, of participating in a narrative of significant events […] is the principle by which a materialist or secular cosmos re-enchants itself'.[34] If the eighteenth-century novel confronts and variously resists and collaborates with the architecture of classical probability, more recent literature confronts, creates and resists a different conceptual architecture.

'Modernist probability' refers to two different ideas. First, it refers to modernist literature understood as embedded in Hacking's post-1900 'world made out of probabilities': embedded in statistics, risk assessment, insurance, normalism, quantum mechanics – the various demotic registers of probability. Secondly, it refers to probability's own apparent modernism: its conversion to pure mathematics between 1900 and 1933. A. N. Kolmogorov's axiomatic system of probability was published in 1933. After the establishment of the basic axioms of probability theory, Kolmogorov writes, 'all further exposition must be based exclusively on these axioms, independent of the usual concrete meaning of these elements and their relations'.[35] With Kolmogorov's definitive axiomatisation, Jan von Plato argues, probability became fully mathematical and therefore fully modern. Von Plato traces the conditions of possibility for Kolmogorov's measure theoretic modernism: developments in statistical physics (which required probability to accommodate infinities) and the metamathematical foundation crisis.[36] Jeremy Gray's argument for mathematics' modernism could thus be extended to include probability's axiomatisation. As I discussed in the introduction, Gray argues that mathematics underwent a modernist transformation similar to but independent of the modernist transformations in

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[32] Daston, *Classical Probability*, p. xii.
[33] Thomas M. Kavanagh, *Enlightenment and the Shadows of Chance: The Novel and the Culture of Gambling in Eighteenth-Century France* (Baltimore, MD: Johns Hopkins University Press, 1993), p. xi.
[34] Jesse Molesworth, *Chance and the Eighteenth-Century Novel: Realism, Probability, Magic* (Cambridge: Cambridge University Press, 2010), p. 9.
[35] A. N. Kolmogorov, *Grundbegriffe der Wahrscheinlichkeitsrechtung*, 1933, trans. by Nathan Morrison as *Foundations of the Theory of Probability* (New York: Chelsea, 1950), p. 1.
[36] Jan von Plato, *Creating Modern Probability: Its Mathematics, Physics, and Philosophy in Historical Perspective* (Cambridge: Cambridge University Press, 1994).

literature, art and music. Gray's modernism involves a turn to 'autonomous ontology': novels, paintings and mathematical proofs rejected 'outward reference' for self-contained formalism and in doing so had a 'complicated – indeed, anxious – rather than a naïve relationship with the day-to-day world'.[37] Given that Kolmogorov modelled his infinite-measure theoretic system on a canonical work of modernist mathematics (Hilbert's *Foundations of Geometry*) and given the fully abstract, axiomatised form his system takes, *Foundations of the Theory of Probability* can be read as a modernist text in Gray's terms.

Kolmogorov, however, was a more complex figure than might be suggested by classing him as a Gray-style modernist. He was sceptical about Hilbert's definition of existence as consistency and remained a committed intuitionist throughout his career. The first 'Act' of intuitionism, as conceived by Hilbert's arch-foe, L. E. J. Brouwer, is that mathematics ought to be:

> *an essentially languageless activity of the mind having its origin in the perception of a move of time. This perception of a move of time may be described as the falling apart of a life moment into two distinct things, one of which gives way to the other, but is retained by memory. If the twoity thus born is divested of all quality, it passes into the empty form of the common substratum of all twoities. And it is this common substratum, this empty form, which is the basic intuition of mathematics.*[38]

Von Plato picks out a particular passage from the *Foundations* in which Kolmogorov's intuitionism – his commitment to constructive proof – can be glimpsed. Discussing sets 'that are infinite unions or disjunctions of other sets', Kolmogorov writes:

> we consider these sets in general only as 'ideal events' to which nothing corresponds in the world of experience. But if a deduction uses the probabilities of such events, and if it leads to the determination of the probability of a real event, the determination will obviously be unobjectionable also from an empirical point of view.[39]

Von Plato reads this passage as a continuation of the version of intuitionism Kolmogorov outlined in a 1932 paper which sought to present constructive logic to those who, Kolmogorov writes, 'do not share the intuitionistic epistemological preconditions'. In this paper, Kolmogorov writes that: 'Every assertion not without content must refer to one or several fully determined matters of fact [Sachverhalte] accessible to our experience'.[40] In a 1970 address, Kolmogorov gives an account of the 'intuitive' content of mathematics: 'this state of affairs is deeply grounded in the structure of our consciousness, which operates with great facility with intuitive ideas of

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[37] Jeremy Gray, *Plato's Ghost: The Modernist Transformation of Mathematics* (Princeton, NJ: Princeton University Press, 2008), p. 1.
[38] L. E. J. Brouwer, *Brouwer's Cambridge Lectures on Intuitionism*, ed. by D. van Dalen (Cambridge: Cambridge University Press, 1981), pp. 4-5.
[39] *Foundations of the Theory of Probability*, p. 16.
[40] Trans. by Jan von Plato in *Creating Modern Probability*, p. 203.

unbounded sequences, limit passages, continuous and even "smooth" manifolds, and so on'.[41] Intuitionism is, of course, perfectly modern (although it represents a different strand of mathematical modernity than Hilbert's modernism); indeed, it is tempting to draw an analogy between this strand – the writings of Brouwer on time intuition in particular – and literary modernism's streams of consciousness. However, Brouwer's 1905 *Life, Art and Mysticism* gives a rather comically damning account of most contemporary literature – 'duty-bound to act as the obedient servant of the lie that is human culture'; 'poetry is the garb of the courtesan, appealing to the lowest sensibility of the time-bound intellect, its sense of rhythm' – though he does praise drama for its ability to present 'the self-destruction of the illusion of time […] from the viewpoint of a frozen *now*' and the 'immanent truth' of Flaubert's depiction of mysticism in *The Temptation of Saint Anthony*.[42]

Whatever the degree of the homology of style between modernist literature and modernist mathematics, the examples of modern literature I discuss in this chapter resist the terms of probability's modernism. Literature presents and interrogates the conditions of possibility for and of the 'world made out of probabilities'. This interrogation happens in a number of different ways: through invocation of the accrued cultural and stylistic history of probability and statistics, through a literary 'phenomenology' of the architecture of probability concepts and through an engagement with probability's application – its imperialism – in physics, social organisation and insurance.[43] The majority of the works I will be discussing were roughly contemporary with Kolmogorov's 1933 *Foundations of the Theory of Probability*: Robert Musil's *The Man Without Qualities* (1930, 1933, 1943); poetry and prose by Wallace Stevens from the 1930s to the 1950s; and Simone Weil's 'Reflections on Quantum Theory' (1942). As they interrogate their probabilistic world, Musil, Stevens and Weil negotiate with prior literary treatments of probability – Emerson's 'Quetelet Fate', Mallarmé's '*Hasard*' and Pascal's decision theory – and represent applied mathematics in terms far from the pure and anxious axiomatics of mathematical formalism. I will draw out the connections between literature's probability concepts and the alternative philosophies of probability offered by phenomenology, pragmatism and theology. Applied mathematics in my analysis resembles the mixed mathematics it supplanted in the late nineteenth century. 'By 1875', Gary Brown writes, 'theories were no longer "mixed" with

[41] Trans. by Jan von Plato in *Creating Modern Probability*, p. 203.
[42] L. E. J. Brouwer, *Life, Art and Mysticism*, trans. by Walter P. van Stigt *Notre Dame Journal of Formal Logic*, 37.3 (1996), pp. 389-429 (p. 405, 406, 425).
[43] See the growing body of literature on modernism and risk for more of these valences: Ian Patterson, 'Time, Free Verse, and the Gods of Modernism', in *Tradition, Translation, Trauma. The Classic and the Modern*, ed. by Jan Parker and Timothy Mathews (Oxford: Oxford University Press, 2011), pp. 175-191, Paul Crosthwaite, 'Anticipations of the Accident: Modernist Fiction and Systemic Risk', *Textual Practice* 24.2 (2010), 331-352 and Jason Puskar, *Accident Society: Fiction, Collectivity, and the Production of Chance* (Stanford: Stanford University Press, 2012).

experience, they were applied to experience'.[44] Francis Bacon's 'mixed mathematics' – '*Perspective, Musicke, Astronomie, Cosmographie, Architecture, Inginarie*, and divers others' – was both mathematics mixed with experience and a way of analysing those areas of experience in which the ideal and the prosaic, the axiomatic and the demotic, were already muddled.[45] The phrase 'mixed mathematics' – mingling of substances, elements, kinds – carries with it a different sense of craft than that carried by 'applied mathematics', with its sense of pure mathematics applied to nature, technology and social life. I wish, therefore, to expand the category of mixed mathematics to include literature's vernacular mathematics and to trace the historical entanglement of literature's probability concepts with the demotic mathematics of statistics, insurance and physics.

The Consolations of Statistics

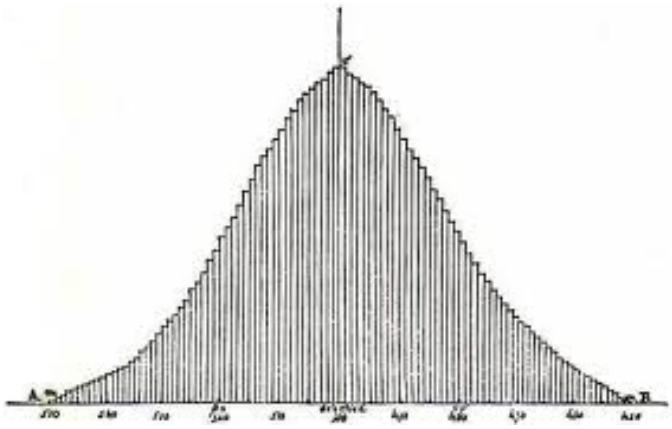


Figure 2 – The normal curve. Quetelet's graph represents the normal curve as the limit of a binomial distribution.[46]

Robert Musil's *Der Mann ohne Eigenschaften* (1930-43) is a sustained investigation of the conditions of possibility for and the consequences of the post-1900 stochastic universe. *The Man Without Qualities* opens with an automobile accident in August 1913. The description of the accident is filtered through an ironically banal demotic mathematics: the languages of weather forecasting and of statistics – registers of the taming of chance. 'A barometric low hung over the Atlantic' is the somewhat unromantic first sentence of the novel:

> It moved eastward toward a high-pressure area over Russia without as yet showing any inclination to bypass this high in a northerly direction. The isotherms and isotheres were

[44] Gary Brown, 'The Evolution of the Term "Mixed Mathematics"', *Journal of the History of Ideas*, 52.1 (1991), 81-102 (p. 102).
[45] Francis Bacon, *The Oxford Francis Bacon, Vol. 4: The Advancement of Learning*, ed. by Michael Kiernan (Oxford: Oxford University Press, 2000), p. 88.
[46] Adolphe Queletet, *Lettres à S. A. R. Le duc règnant de Saxe-Cobourg et Gotha, sur la théorie des probabilités, appliquée aux sciences morales et politiques* (Brussels: M. Hayez, 1846), p. 103.

> functioning as they should. The air temperature was appropriately relative to the annual mean temperature and to the aperiodic monthly fluctuations of the temperature.[47]

Meteorology was still poised in the early twentieth century between an empirical science of observation and a statistical, probabilistic system of modelling. Modern meteorology is built on an idea of universal and universally communicable nature (cloud atlases, mass data, standardised measurement) that necessarily effaces the local and affective elements of weather. Statistics are woven into the fabric of Musil's novel, as they are into the fabric of social being, not just as 'tamed chance' but also as a large-scale model of everyday life to which experiences are referred and through which they are narrated and understood. A man being hit by a truck is the actualisation of a statistical probability:

> 'According to American statistics,' the gentleman said, 'one hundred ninety thousand people are killed there every year by cars and four hundred fifty thousand are injured.'
> 'Do you think he's dead?' his companion asked, still on the unjustified assumption that she had witnessed something unusual.
> 'I expect he's alive,' he answered, 'judging by the way they lifted him into the ambulance'.[48]

Accidents in a statistical society are registered both on the body and in a body of data. The gentleman's knowledge of that data is an awareness, then, of the institutional large numbers present in what his companion naïvely sees as a shocking chance event. Musil's use of statistics as a frame for his novel is motivated by his perception that, as he writes in 'The Mathematical Man': 'All the life that whirls about us, runs, and stops is not only dependent on mathematics for its comprehensibility, but has effectively come into being through it and depends on it for its existence'.[49] The world as it appears – or, at least, Vienna as it appears to a technical librarian in 1913 – just *is* the world of mathematical operations, relations and rules. Probability as immanent and performative mapping is the terrain of *The Man Without Qualities*: the background weather, so to speak, of a novel that tends to dwell in the realm of the possible and the hypothetical (and whose mood is often subjunctive).[50] Statistics are also a form of consolation and a philosophy for Ulrich. 'What we still refer to as a personal destiny,' Ulrich informs his sister, 'is being displaced by collective processes that can finally be expressed in statistical terms'. Agathe, the sister, 'thought this over and had to laugh. "I don't understand it, of course, but wouldn't it be lovely to be dissolved by statistics? [...] It's been such a long time since love could do it!"'[51] In order to try to understand how statistics came to structure the everyday and its literary refraction in this way,

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[47] Robert Musil, *The Man Without Qualities*, trans. by Sophie Wilkins and Burton Pike (London: Picador, 2011), p. 3.
[48] Musil, *The Man Without Qualities*, p. 5.
[49] Musil, 'The Mathematical Man', p. 41.
[50] On Musil's use of the subjunctive mood, see Albrecht Schöne's classic essay 'Zum Gebrauch des Konjunktivs bei Robert Musil', *Euphorion*, 55 (1961), 196-220, repr. in *Robert Musil*, ed. by Renate Heydebrand (Darmstadt: Wissenschaftliche Buchgesellschaft, 1982), pp. 19-53.
[51] Musil, *The Man Without Qualities*, p. 785.

and to understand the philosophy that Ulrich eventually draws from the law of the large numbers and the statistical theory of gases, I will sketch the literary and affective history of statistics and draw on Musil's notes on probability in the *Tagebücher* and his doctoral dissertation on Ernst Mach's philosophy of physics.

In Musil's 'Heft 10' (Notes from 1918-1921, 1929 and 1939), he begins investigating probability under a dual rubric: 'A theoretical study of the concept of probability' and 'the arbitrary in the law of nature'. The technical ability and historian's eye evident in Musil's mathematical notes inflects the complex literary uses of probability in *The Man Without Qualities*. Musil's investigation into the concept of probability and the nature of chance in the *Tagebücher* places the definitions of chance made by Mill, Schopenhauer, Kant, Spinoza and Hume in dialogue with readings in early and classical probability theory (Cardano, Laplace, d'Alembert) and post-classical probability theory and statistics. Musil's bibliography in this area is extensive and lists, among other works: H. E. Timerding's *Die Analyse des Zufalls*, Lexis's work on 'Moralstatistik', Quetelet's 'Lettres sur la théorie d. prob. appliquée aux sciences moral et politiques', Fechner's *Kollektivmasslehre* and articles by the British statistician Karl Pearson. The provisional summary that Musil makes of the field of 'probability and induction' throws up questions of scale that he addresses in literary terms in *The Man Without Qualities*:

> Measurement results in dispersion around the most probable value. This is among the known conditions of possibility. The theory is calculated. A priori (as required) it is preceded by the assumption that it exists. But it [the standard deviation] is also grounded on a not-yet noticed scale-relation [*Grüßenrelation*].

'For large variations', Musil writes, 'we distinguish errors and interference; in other words: we already have an idea of the area of the value sought. This is well known and explained'. Musil gives astronomy as an example of a 'macroscopic' presentation of a 'law of deviations', but proposes that we might come closer to an understanding of the 'idea' by looking at the 'superposition of various laws in individual cases' at the level of microscopic observation (Musil's example is the random Brownian motion of minute particles). This allows us to glimpse 'the random and human moment in the concept of the law'.[52] The theory of probability that Musil develops in his *Tagebücher* and in which Ulrich finds an ironic consolation is neither the epistemic theory of a classicist like Laplace, nor is it Kolmogorov's axiomatic theory: it is a literary device, forged in careful opposition to Nietzsche and to Emerson, and it is statistical.[53]

The invention and rise of statistics in the nineteenth century altered the architecture of probability theory: its scale, its range of applications, its aesthetics and its epistemology. With the

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[52] Robert Musil, 'Heft 10', *Tagebücher*, ed. by Adolf Frisé (Hamburg: Rowohlt, 1976), pp. 460-467.

[53] Several critics have noted Musil's extensive engagement with mathematics. See, for example, Allen Thiher, *Understanding Robert Musil* (Columbia, SC: Columbia University Press, 2009).

rise of statistics, Daston writes, came the 'decline of the reasonable man, as probability theory shifted its sights from the psychology of the rational individual to the sociology of the irrational masses'.[54] Theodore Porter describes the early statisticians as liberal generalists who lived in 'a world of progress and discontent, of surveys and census figures' and 'were impressed by the power and dynamism of that complex entity, society, and were pleased to find evidence that it exhibited a stability which seemed not to be dependent on the intermittent wisdom of governing authorities'.[55] This evidence took the form of the normal or Gaussian distribution – a bell-shaped curve that bunches around an intermediate value – and the 'law of large numbers'. 'A picaresque novel could be written about the fortunes of the normal curve' Daston remarks, 'as it wandered from astronomy to social statistics to physics (the statistical theory of gases) to psychology (the measurement of intelligence) on the strength of ever stranger analogies.[56] The normal curve accrued symbolic, mythic and affective traces during its picaresque travels.

The normal distribution began as a law of error in sciences of measurement such as astronomy but in the hands of Adolphe Quetelet it became the statistical expression of social regularity: a curve plotting the physical and moral anatomy of man. The mean values of society's gathered facts – heights, crimes, suicides, marriages, births and deaths – became the contours of Quetelet's *homme moyen*: his average man.[57] Quetelet's 'social physics' was built on an analogy between the laws governing society and the laws of gravity governing celestial mechanics: 'The average man', Quetelet writes, 'is in a nation what the centre of gravity is in a body; it is by having that central point in view that we arrive at the apprehension of all the phenomena of equilibrium and motion'.[58]

Quetelet believed that his invention of the average man had profound implications even for literature. The statistical determination of the average man would allow writers to refine the method they had been using all along:

> The necessity to be true, to represent faithfully the physiognomy, the habits and the mores of peoples of different periods, has, from time immemorial, led artists and writers to grasp among the individuals they observe the characteristic traits of the period in which they live, or, in other words, to deviate as little as possible from the average man.[59]

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[54] Daston, *Classical Probability*, p. 187.
[55] Theodore M. Porter, *The Rise of Statistical Thinking, 1820-1900* (Princeton, NJ: Princeton University Press, 1986), p. 5.
[56] Lorraine Daston, 'Why statistics tend not only to describe the world but to change it', *London Review of Books*, 22.8 (2000), 35-36
[57] Adolphe Quetelet, *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale* (Paris: Bachelier, 1835).
[58] Adolphe Quetelet, *A Treatise on Man and the Development of his Faculties*, trans. by R. Knox and Thomas Smibert, ed. by Thomas Smibert (Edinburgh: Chambers, 1842), p. 96.
[59] Quetelet, *A Treatise on Man*, p. 96 [translation modified].

The statistical laws that govern human life – how tall we are likely to be, how long we are likely to live, how brave we are likely to be in youth and old age, how likely we are to murder one another, and so on – ought, therefore, to form the basis of a writer's education:

> It would allow them to know, in a more precise manner, things they know vaguely already; it would teach them others of which they are ignorant, or, indeed, free their judgement from a mass of prejudices. They would receive these notions as a painter learns perspective, which, in its geometric form, is also pretty far from being *picturesque*.[60]

The statistical revolution that Quetelet desires for literature is predicated on an earlier 'grande révolution': Romanticism. In his telling of it, Romanticism has overthrown a classicism that was doomed to imitate the ancients' perfect rendering of *their* average man. In the process, the Romantics revealed human nature to be historically contingent, giving 'the most irrefutable proof of the variability of the human type or the average man in different peoples and in different centuries'. The romantics recognised 'the need to have a literature that would be truly *the expression of society*' ('le besoin d'avoir une littérature qui fût véritablement *l'expression de la société*') and it is this need that statistics can help fulfil.[61]

The literary future that Quetelet imagined for his average man did not, of course, play out quite as he expected. The average man and the law of large numbers met with a barrage of literary and philosophical attacks for their perceived embodiment of, variously, statistical determinism, the mediocrity of the masses, liberal foolishness and the mathematisation of everyday life. Charles Dickens's anti-statistical imagination is given form in *Hard Times* (1854) as the 'eminently practical' Mr Gradgrind, who, when he learns that his son is a thief, exclaims that 'If a thunderbolt had fallen on me, it would have shocked me less than this'. 'I don't see why', his son replies, 'So many people are employed in situations of trust; so many people, out of so many, will be dishonest. I have heard you talk, a hundred times, of its being a law. How can *I* help laws? You have condemned others to such things, Father. Comfort yourself'.[62] The rebellion staged by Gradgrind's children was happening throughout nineteenth-century letters.

George Eliot's 1856 essay on 'The Natural History of German Life' proposed a doctrine of sympathy – a moral realism – that would counter the utopianism of the statisticians:

> The tendency created by the splendid conquests of modern generalization, to believe that all social questions are merged in economical science, and that the relation of men to their neighbours may be settled by algebraic equations, – the dream that the uncultured classes are prepared for a condition which appeals principally to their moral sensibilities

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[60] Quetelet, *A Treatise on Man*, pp. 97-8 [translation modified].
[61] Quetelet, *A Treatise on Man*, pp. 97-100 [translation modified].
[62] Charles Dickens, *Hard Times* (London: Bradbury and Evans, 1854), p. 335.

> […] none of these diverging mistakes can co-exist with a real knowledge of the People, with a thorough study of their habits, their ideas, their motives.[63]

Eliot's *Middlemarch*, to borrow Audrey Jaffe's wonderful phrase, depicts 'the affective life of the average man'.[64] As her characters understand and define themselves in relation to a set of social norms, Eliot shows both the limitations and the pervasiveness of statistical thinking. If for Eliot statistics had a hopelessly simplistic and utopian idea of 'the people', for Nietzsche, the problem was that it focused on 'the people' at all. The statistician's way of reasoning order from chaos, social unity from the mess of individuals, gave false priority and agency to the 'masses' (at the expense, of course, of greatness): 'let the Devil and statistics take them!' Nietzsche exclaimed in 'On the Uses and Disadvantages of History for Life'.[65] To write one's history of man by inductive reason from statistical laws, indeed, to historicise 'man' at all, is to drastically miss the point: 'What, can statistics prove that there are laws in history? Laws? They certainly prove how vulgar and nauseatingly uniform the masses are: but are the effects of inertia, stupidity, mimicry, love and hunger to be called laws?'[66]

For Emerson, Quetelet's analogy forged yet another bond in our 'adamantine bandages'. The 'new science of Statistics', Emerson wrote in 'Fate', gives us further 'hints of the terms by which our life is walled up'.[67] To describe those walls, Emerson paraphrased Quetelet's *Sur l'homme et le développement de ses facultés: ou, Essai de physique sociale* and in the notes to Emerson's essay we find the following quotation:

> 'Everything which pertains to the human species, considered as a whole, belongs to the order of physical facts. The greater the number of individuals, the more does the influence of the individual will disappear, leaving predominance to a series of general facts dependent on causes by which society exists, and is preserved.' – Quetelet.[68]

Necessity – given form as 'Quetelet Fate' in Emerson's journals – 'compels every atom to serve an universal end': Quetelet's statistical laws bind us to the 'arc' of necessity, to the probabilistic curve, and as such create and guarantee progress and greatness.[69] 'I accept the Quetelet statistics',

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63 George Eliot, 'The Natural History of German Life', *Westminster Review* (July 1856), reprinted in *George Eliot: Selected Critical Writings*, ed. by Rosemary Ashton (Oxford: Oxford University Press, 2000), pp. 260-295 (p. 265).
64 Audrey Jaffe, *The Affective Life of the Average Man: The Victorian Novel and the Stock-Market Graph* (Columbus: Ohio University Press, 2010).
65 Friedrich Nietzsche, 'On the Uses and Disadvantages of History for Life' (1874), in *Untimely Meditations*, ed. by Daniel Breazeale and trans. by R. J. Hollingdale (Cambridge: Cambridge University Press, 1997), pp. 57-124 (p. 113).
66 Nietzsche, 'On the Uses and Disadvantages of History for Life', p. 113.
67 Ralph Waldo Emerson, 'Fate', in *The Complete Works of Ralph Waldo Emerson, Vol. 6: The Conduct of Life* (Boston: Houghton, 1903-4), pp. 1-51 (p. 17).
68 Ralph Waldo Emerson, *The Complete Works of Ralph Waldo Emerson, Vol. 6*, pp. 341-342.
69 Emerson, *The Complete Works of Ralph Waldo Emerson, Vol.* 6, p. 48.

Emerson wrote in his journal in 1854: 'In a million men, one Homer, & in every million'.[70] In 1855, he wrote:

> Most men are rubbish, & in every man is a good deal of rubbish. What quantities of fribbles, paupers, bed-ridden or bed-riding invalids, thieves, rogues, & beggars, of both sexes, might be advantageously spared! But Quetelet Fate knows better; keeps everything alive, as long as it can live; that is, so long as the smallest thread of public necessity holds it on to the tree Igdrasil.[71]

Emerson perceives the whole, composed of all the 'brute atoms' subject to statistical law, as fundamentally necessary.[72] Where for statisticians such as Francis Galton, impatience with necessity became eugenics; in Emerson's essays the translation of submission into power is a matter of revelation. 'Because the history of nature is charactered in his brain', Emerson writes in *Nature*, man 'is the prophet and discoverer of her secrets': natural necessity, here, is 'Proteus' and 'publishes itself in creatures, reaching from particles and spicula, through transformation on transformation to the highest symmetries, arriving at consummate results without a shock or a leap'.[73]

To engage with the history of probability is to engage with the epistemology of Quetelet's analogy and the history of the allegory of Proteus. Ulrich, in his arguments with the fervent young nationalist Gerda, takes refuge in the vision of social regularity and gradual, passive historical progress articulated by nineteenth-century liberal statisticians. That refuge is built out of a series of references to statistical ideas: 'Statistical series can sometimes have the same regularity that we associate with natural law', he tells Gerda:

> 'Are you trying to explain progress to me?' she cried out, doing her best to sound sarcastic.
> 'But of course,' Ulrich came back at her, without breaking stride. 'It's called the law of large numbers, a bit nebulously.'[74]

However, as Ulrich borrows Quetelet's rhetoric – borrows, indeed, from the same passage that Emerson cited in 'Fate' – he undercuts the determinism of Quetelet's analogy. Quetelet had written that 'moral phenomena, when observed on a great scale, are found to resemble physical phenomena' and as such '*the greater the number of individuals observed, the more do individual peculiarities*

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[70] *The Journals and Miscellaneous Notebooks of Ralph Waldo Emerson: 1852-1855*, ed. by William H. Gilman and others (Cambridge, MA: Cambridge University Press, 1977), p. 340.
[71] *The Journals and Miscellaneous Notebooks of Ralph Waldo Emerson*, p. 440.
[72] Emerson, *The Complete Works of Ralph Waldo Emerson, Vol. 6*, p. 252.
[73] Ralph Waldo Emerson, *Essays and Lectures* (New York: Library of America, 1983), p. 546. Laura Walls gives a fuller account of the meaning that Quetelet and his statistics held for Emerson in *Emerson's Life in Science: The Culture of Truth* (Ithaca, NY: Cornell University Press, 2003).
[74] *The Man Without Qualities*, p. 532.

[…] *become effaced*', thus revealing the causal laws of social progress.[75] Ulrich, meanwhile, says to Gerda:

> 'Suppose the moral sphere works more or less like the physical, as suggested by the kinetic theory of gases: everything whirling around at random, each element doing what it will, but as soon as you work out rationally what is least likely to result from all this, that's precisely the result you get! […] So suppose we assume that there is a certain number of ideas circulating in our day, resulting in some average value that keeps shifting, very slowly and automatically – it's what we call progress, or the historical situation. What matters most about this, however, is that our personal, individual share in all this makes no difference; whether we individually move to the right or to the left, whether we think and act on a high or a low level, in an unpredictable or a calculated fashion, a new or old style, does not affect this average term, which is all that God and the world care about'.[76]

The terms in which moral phenomena can be said to resemble physical phenomena shift in Ulrich's speech. The scale offered by statistics provides a relief and a degree of liberation from the burden of small-scale moral choices: perhaps it can be lovely, as Agathe put it, to be dissolved by statistics. Michel Serres talks of Ulrich as 'Ulrich-nuages': Ulrich-clouds. He is a radio skip refracted in drifting atmospheric patterns – the 'signal' – the 'sharp-edges' of a tangle of sounds – of 'the one without qualities. Passive'.[77] The conflicting textures of Serres's image – clouds and sharp edges – are particularly apt for the precise, cold way in which Ulrich submits to his own vaporous metaphor. Through the intrusion of the metaphor of the kinetic theory of gases (to which Brownian motion belongs), Emerson's 'Quetelet-Fate' becomes an unwilled randomness.[78]

This shift in the terms of Quetelet's analogy both mediates and is mediated by Musil's reading of Emerson. Quetelet means something different in Musil's novel to what he meant in Emerson's essays and that difference is modulated by the different philosophies of form held by each author. It is also a product of history. 'We are as lawgivers; we speak for Nature; we prophecy and divine': Emerson's idea is retained, but stripped of its sweeping rhetoric, its romance and its religion in Musil's modernist account of statistical man. Emerson and Musil stand separated by a metamorphosis in the concept of probability. There was 'a time lag', as Lorenz Krüger points out, 'between the widespread use of statistics and probability' in the sciences, social sciences and experimental psychology and 'the adoption of a probabilistic view

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[75] Quetelet, *A Treatise on Man and the Development of his Faculties*, p. 6.
[76] Musil, *The Man Without Qualities*, p. 535.
[77] Michel Serres, *Hermès V: Le Passage du Nord-Ouest* (Paris: Minuit, 1980), pp. 30-1. 'Passif' has, of course, an added meaning in French: liabilities, or debt.
[78] Donald MacKenzie and Taylor Spears give a description of Brownian motion in their account of how it moved into finance and became the Black-Scholes-Merton share-pricing model. Ulrich's metaphor has become one of the engines of modern finance capitalism. MacKenzie and Spears write: 'Brownian motion is the random movement of tiny particles, for example of dust and pollen, that results from collisions with the molecules of the gas or liquid in which they are suspended. The standard mathematical-physics model of this had been imported into finance, with a simple modification to remove the possibility of the prices of shares becoming negative, which is an impossibility because of limited liability: the owners of a corporation's shares cannot lose more than their initial investment'. '"The Formula That Killed Wall Street"? The Gaussian Copula and the Material Cultures of Modelling' (manuscript, July 2012), pp. 13-14.

of, or attitude toward, reality'.[79] Krüger attributes this delay to three entrenched patterns of thought: first, early nineteenth-century determinism had merged epistemology and empirical science into a unified and compelling theory whereby 'all regularities must naturally appear as expressions of the lawlike character of reality, hence as something to be explained within the framework of a deterministic theory'; secondly, the concept of 'cause' is complicated ('it snares us', as Austin put it) and therefore could be used as a weapon by the determinists; and, finally, it is simply very difficult to understand the nature of statistical laws.

Musil's investigation into 'the theory of the concept of probability' in his notebooks begins with Fechner's liberation of the Gaussian distribution from 'the limits of symmetrical probability' in *Kollektivmasslehre*. Using probability was, for Gustav Fechner, the art of wrestling with 'a Proteus' who, when asked for his predictions 'seems to withdraw from any answer through the changing forms he assumes; but it suffices to remain undeterred, steadfast, to hold him to one point, and thus force from him a reliable answer'.[80] Fechner's metaphor sheds light on probability's 'liminal period' and on the mysterious epistemology of statistical laws. For Francis Bacon, the fable of Proteus was an allegory of the scientist's taming of matter:

> And whereas it is added in the fable that Proteus was a prophet and knew the three times; this agrees well with the nature of matter: for if a man knew the conditions, affections, and processes of matter, he would certainly comprehend the sum and general issue (for I do not say that his knowledge would extend to the parts and singularities) of all things past, present, and to come.[81]

For Fechner, the myth of Proteus – as prophet of future, past and present and as arithmetician obsessively counting his flock of seals – becomes an allegory of the work of the statistician: for Quetelet's 'almosting' and Fechner's 'wavespeech', to borrow Joyce's Protean vocabulary.

Probability's liminal period finds its way into *The Man Without Qualities* through Musil's reading of Fechner and H. E. Timerding. Timerding in *Die Analyse des Zufalls* (1915) considered the 'law of large numbers' a still-unexplained empirical fact.[82] Ulrich describes the law of large numbers to Gerda as follows:

> 'one person may commit suicide for this reason and another for that reason and another for that reason, but when a great number is involved, then the accidental and the personal elements cancel each other out, and what's left […] but that's just it: what *is* left? I ask

[79] 'The Slow Rise of Probabilism: Philosophical Arguments in the Nineteenth Century', in *The Probabilistic Revolution Vol 1: Ideas in History*, ed. by Lorenz Krüger, Lorraine J. Daston and Michael Heidelberger (Cambridge, MA: MIT Press, 1987), pp. 59-89 (p. 60).
[80] Gustav Fechner, *Elemente der Psychophysik*, Vol 1 (Leipzig: Breitkopf und Härtel, 1860), p. 78.
[81] Francis Bacon, *Of the Wisdom of the Ancients*, trans. by James Spedding, in *The Works of Francis Bacon Vol. VI., Literary and Professional Works, Vol. I*, ed. by James Spedding, Robert Leslie Ellis and Douglas Denon Heath (London: Longman and Co, 1858, repr. Cambridge: Cambridge University Press, 2011), pp. 687-764 (p. 726).
[82] H. E. Timerding, *Die Analyse des Zufalls* (Braunschweig: Friedr. Vieweg & Sohn, 1915).

> you. Because you see, what's left is what each of us as laymen calls, simply, the average, which is a "something", but nobody really knows exactly *what*'.[83]

Ulrich then gestures towards the litany of attempted explanations for the law of large numbers that Musil borrows from Timerding and works through in 'Heft 10'. Timerding called these explanations 'statistischer Ausgleich' – statistical compensation – and Musil re-interprets these 'compensations' as 'consolations' or consoling narratives. His author shared Ulrich's doubt about the ontology of statistical laws. Jacques Bouveresse considers Musil's doubt on this matter to be a manifestation of his philosophical scepticism. 'I am not sure', Bouveresse writes, 'that Musil adopted a point of view on the question of knowing if statistical laws could or could not by considered as manifestations of underlying deterministic laws yet to be uncovered […] Musil is armed not just with scientific knowledge but with an instinctive doubt that I consider eminently philosophical'.[84] This explanation is, I think, less persuasive than the explanation Bouveresse gives for the indeterminism of the world of *The Man Without Qualities*. In this interpretation, Musil isn't concerned with working out whether chance is objective or epistemic, rather, he is interested in posing an experimental response to a hypothesis: 'If one supposes or imagines that things (particularly human things) are governed fundamentally by chance, what would be the consequences resulting from that hypothesis?'[85] Bouveresse's interpretation can be translated into literary terms: Musil creates a literary world in response to a hypothesis, and that literary world has its own aleatory epistemology.

However, there is another potential reason why the uncertainty Musil expresses in his notebooks regarding philosophical explanations for statistical regularities is not resolved in his novel: Musil's hypothesis, indeterminism, structured the world of probabilities in which he lived. Statistical laws were (and still are) performative and immanent to social life: *The Man Without Qualities* thus investigates the conditions of possibility for probability's world making through a layered depiction of the contemporary and historical vernaculars of probability. Despite the elusive ontology of the 'average', and despite the inability of statisticians to fully account for the reasons behind the statistical laws that apparently govern society, Ulrich tells Gerda that 'any possibility of leading an ordered life depends on this law of large numbers'.[86] This surprising claim is an inward, privatised version of a claim Musil makes in the *Tagebücher*: 'The possibility of economic and political life rests on the fact of the law of large numbers' (*'Auf der Tatsache des G d g Z. ruht die Möglichkeit wirtschaftlichen u. staatlichen Lebens'*). The laws of statistics often veer, in Ulrich's lectures, into the realm of personal moral action, and Poisson's proof of a 'law of large

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[83] Musil, *The Man Without Qualities*, p. 532.
[84] Jacques Bouveresse, *Robert Musil: L'Homme Probable, Le Hasard, La Moyenne et L'Escargot de L'Histoire* (Paris: Editions de L'Éclat, 2004), p. 12.
[85] Bouveresse, *Robert Musil*, p. 11.
[86] *The Man Without Qualities*, p. 533.

numbers' (coining the phrase though not the idea) was a work of moral as well as mathematical science and was concerned with the reliability of jury judgements made by simple majority and those made by a majority of 8 to 4. To assess this, there had to be some way of making the reliability of an individual juror into a value that could be used in calculation: reliability varies from juror to juror, of course, so Poisson needed a 'law' for the distribution of 'reliabilities' around the mean of their probabilities. Poisson defined what he meant by the law of large numbers in 1835 as follows:

> Things of every kind are subject to a universal law that we may call *the law of large numbers*. It consists in this: if one observes a very considerable number of events of the same kind, depending on causes that vary irregularly, that is to say, without any systematic variation in one direction, then one finds that the ratios between the numbers of events are very nearly constant.[87]

Poisson's law of large numbers consoles Ulrich as it allows him to hypothesise that the errors of his contemporaries might, when collated, reveal a kind of truth. 'Suppose', he says to Gerda, that:

> every one of them is stupid, but all of them together are pregnant with the future? […] In that case the final balance, the sum total of all the experiments, no longer rests with the individual, who becomes unbearably one-sided, but with the experimental collective. In short, I ask you to make allowances for an old man whose loneliness sometimes drives him to excess.[88]

The liberal generalist world of the nineteenth century French statisticians has resonance for Ulrich, then, both in its belatedness, as nostalgia, and as a justification for his own passivity. Ulrich's lecture bears the traces of the cultural history of the law of large numbers and the normal curve. Musil might accuse, for example, of animism in his notebooks, but animisms and philosophical missteps in general can still have literary value.

Musil's experiments in novelistic 'essayism' involved working through the implicit philosophy of the essay as literary form inherited from Emerson and Montaigne. Emerson, in his essay on the essay's patriarch, 'Montaigne; or, the Skeptic', writes:

> I play with the miscellany of facts, and take those superficial views which we call skepticism; but I know that they will presently appear to me in that order which makes skepticism impossible. A man of thought must feel the thought that is parent of the universe; that the masses of nature do undulate and flow.[89]

The thought moves the other way in Musil's 'On the Essay': here, rather than the essay proceeding through scepticism to natural order, the sceptical form of the essay is written back

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[87] 'Recherches sur la probabilité des jugements principalement en matière criminelle', *Comptes rendus hebdomadaires des séances de l'Académie des Sciences* 1 (1835), p. 478. Passage translated by Ian Hacking in *The Taming of Chance*, p. 95.
[88] Musil, *The Man Without Qualities*, p. 534.
[89] Emerson, 'Montaigne; or, the Skeptic', in *Nature and Selected Essays*, ed. by Larzer Ziff (Harmondsworth: Penguin, 1982), pp. 313-337 (p. 334).

into and undercuts natural order. Musil quotes from Maeterlinck – 'Instead of a truth the essay gives three good probabilities' – and asks: 'How can there be areas in which it is not truth that dominates, and in which probability is something more than an approach to truth?'.[90] Musil's answer seems to be that the essay is founded not on epistemic probability but on the probability that lies 'in the nature of objects'. Emerson's image, masses, is repeated, but used to mean the 'diffuse dispositions of feeling' that compose the individual and 'a series of complexes interwoven with trains of thought'.[91] Musil's rhetoric in 'On the Essay' shows traces of his training in experimental psychology and the philosophy of science: particularly, it shows the influence of Gustav Fechner and Ernst Mach.

The 'dispositions of feeling' and 'complexes interwoven with trains of thought' that Musil invokes in his philosophy of the probabilistic essay recall Ernst Mach's physics of sensations. Mach's *Contributions to the Analysis of the Sensations*, which is guided by the principle '*of the complete parallelism of the psychical and the physical*', imagines existence as a phenomenal flow of sensation:

> Colors, sounds, temperatures, pressures, spaces, times, and so forth, are connected with one another in manifold ways; and with them are associated moods or mind, feelings, and volitions. Out of this fabric, that which is relatively more fixed and permanent stands prominently forth, engraves itself in the memory, and expresses itself in language. Relatively greater permanency exhibit, first, certain *complexes* of colors, sounds, pressures, and so forth, connected in time and space, which therefore receive special names, and are designated *bodies*. Absolutely permanent such complexes are not.[92]

Judith Ryan has surveyed the influence of Mach's psychology, particularly his field of perception, on literary modernism.[93] Ryan considers Musil, alongside Proust and Woolf, as the culmination of 'empiricist modernism': 'Musil's "daylight mysticism"', she writes, 'was an attempt to substitute a monistic conception of experience for the Romantic dualism'.[94] The relationship that Musil has with the images he borrows from Mach in 'On the Essay' is complicated by three factors: first, Musil's criticism of Mach in his dissertation, secondly Musil's remarks on Mach in his diaries – which suggest that he thought of Mach as a guide for how to live a scientific life, rather than how to conduct philosophy – and thirdly, Mach's attitude to mathematics, which was utterly opposed to that of Musil. In his doctoral dissertation, which was written under the supervision of Carl Stumpf (no great lover of Mach), Musil appears to defend a realist philosophy of physics and the notion of natural necessity (the idea that the laws of physics are present not just in thought but in

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[90] Musil, 'On the Essay', in *Precision and Soul*, p. 49.
[91] Musil, 'On the Essay', p. 50.
[92] Ernst Mach, *Contributions to the Analysis of the Sensations*, trans. by C. M. Williams (Chicago: Open Court, 1897), p. 2.
[93] Judith Ryan, *The Vanishing Subject: Early Psychology and Literary Modernism* (Chicago: University of Chicago Press, 1991).
[94] Ryan, *The Vanishing Subject*, p. 15.

nature).[95] However, he does so not through presenting an alternative to Mach's system but through unpicking the logic of Mach's phenomenal conception of physics – for Mach, science is produced by perception and cannot get back to a reality that precedes perception – in accordance with a vernacular scientific assumption that Musil never fully unpacks or defends. Michio Imai explains:

> Musil when defending natural necessity did not adopt either Immanuel Kant's identification of natural laws as something given or determined by a priori categories of the mind, or Platonic Forms, or Stumpf's own emphasis on abstract equations, but with a basic assumption which all law-focused scientists seem to take for granted, but which has little or no true status in the field of epistemology, namely, what is called 'the uniformity of nature'.[96]

This assumption, indeed, 'could easily be handled by Mach as a useful heuristic tool to fit into his theory of *Denkökonomie* as if applied to science, but also as something not having any real epistemological, ontological, or causal significance'.[97] It is difficult to use Musil's thesis to specify the extent of his philosophical affinity with Mach, given that thesis's muddled epistemology and the fact that Stumpf required Musil to revise it extensively.

Indeed, Musil's early diaries suggest that the affinity he felt for Mach was less a matter of philosophical identity than one of admiration for Mach's scientific life and the integrity of his popular books: 'Today I came across Mach's lectures on popular science which proved to me at just the right time that it is possible to base an existence on the understanding, and for that existence still to be deeply significant'.[98] Musil takes Mach as a model for a life well lived – lived with integrity, rationality and influence – but elsewhere in his writing he casts another figure in this role: the modern mathematician. 'Mathematics is the bold luxury of pure reason, one of the few that remain today', he writes in 'The Mathematical Man': 'After the Enlightenment the rest of us lost our courage. A minor failure was enough to turn us away from reason'. The mathematicians do in their field 'what we ought to be doing in ours. Therein lies the significant lesson and model of their existence; they are an analogy for the intellectual of the future'.[99] Ulrich is a lapsed mathematician and though he no longer loves his old profession it spills out into his philosophy, his politics and his personal life. He had 'loved mathematics because of the kind of people who could not endure it. He was in love with science not so much on scientific as on

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[95] Robert Musil, *On Mach's Theories*, trans. by Kevin Mulligan (Washington, DC: Catholic University Press, 1982), English edition of *Beitrag zur Beurteilung der Lehren Machs* (Munich: Philosophia Verlag, 1982), presented in 1908 to the Friedrich-Wilhelms-University in Berlin.
[96] Michio Imai, 'Musil between Mach and Stumpf' in *Ernst Mach's Vienna 1895-1930: Or Phenomenalism as Philosophy of Science*, ed. by J. Blackmore, R. Itagaki and S. Tanaka (Dordrecht: Kluwer, 2001), pp. 187-210 (p. 196.)
[97] Imai, 'Musil between Mach and Stumpf', p. 196.
[98] Robert Musil, 'Notebook 4' (1899? to 1904 or later), translated in *Diaries 1899-1941*, ed. by Mark Mirsky and trans. by Phillip Payne (New York: Basic Books, 1998), pp. 1-36 (p. 16).
[99] 'The Mathematical Man', p. 42.

human grounds'.[100] In this he resembles his author who was impatient with anti-mathematical jeremiads (those who 'testify that the soul has been destroyed by mathematics') and with literature that fails to take the constitutive nature of mathematics into account: 'We beat the drums for feeling against intellect and forget that without intellect […] feeling is as dense as a blockhead. In this way we have ruined our imaginative literature to such an extent that, whenever one reads two German novels in a row, one must solve an integral equation to grow lean again'.[101] 'Lean' is telling. It suggests clean lines, moderation: mathematics as a healthy daily practice. The equation of mathematics with physical and spiritual health is made, too, in Musil's *Diaries*: 'It will only be when logic has become exact, mathematical, cool, that it will mean anything to us. Like getting up on one occasion before the others do and going for an early morning walk'.[102]

The conflict between Musil's two models – Mach and the mathematician – arises from Mach's attitude to mathematics. Mach considered mathematics to be tautology without empirical value and lamented, as Jaakko Hintikka points out, the mathematisation of the sciences.[103] How is it possible then, Hintikka asks, for Husserl to have had a philosophy of mathematics given that the theory guiding Husserl's thought, phenomenology, derives from Ernst Mach? [104] Phenomenology and mathematics appear utterly opposed, because for a theory to be phenomenological it has to lead not to acts of abstract construction but to what is given in intuition: to an immediate, direct knowledge of forms. Hintikka asks: 'Can there be a *Wesensschau*, a kind of actual seeing of completely abstract structures?'[105] Husserl came to trust that there could be, Hintikka argues. Husserl's trust in the ability of the human mind to grasp abstract structures led him to a phenomenological structuralism. Like Hilbert, Husserl was anxious that axiomatic mathematics retain some general theory of models: 'Sometimes you can form models of a theory in another theory […] But when this fails, you have to find the relevant structure without the help of existing theories, other than the "model of models" where they all come'.[106] This belief in the ability of the mind to grasp intuitively and directly the 'model of models' is the motivating belief of Gaston Bachelard's 1938 *The Formation of The Scientific Mind*. Since phenomenology has accepted basic geometry as an aspect of concrete experience, Bachelard writes:

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[100] Musil, *The Man Without Qualities*, p. 37.
[101] 'The Mathematical Man', p. 42.
[102] Musil, *Diaries*, p. 97.
[103] See Ernst Mach, *Knowledge and Error: Sketches on the Psychology of Enquiry*, ed. by Brian McGuinness, trans. by Paul Foulkes and Thomas J. McCormack from the 5th ed. of *Erkenntnis und Irrtum* (Dordrecht, Holland: D. Reidel, 1976).
[104] Jaakko Hintikka, 'How Can a Phenomenologist Have a Philosophy of Mathematics?', in *Phenomenology and Mathematics*, ed. by Mirja Hartimo (Dordrecht: Springer, 2010), pp. 91-106.
[105] Hintikka, 'How Can a Phenomenologist Have a Philosophy of Mathematics?', p. 99.
[106] Hintikka, 'How Can a Phenomenologist Have a Philosophy of Mathematics?', p. 101.

> why should we not agree to make *abstraction* the normal and productive approach of the scientific mind? […] The first geometrical representation of phenomena being essentially an *ordering*, this first ordering opens before us perspectives of an abstraction which, alert and conquering, should lead us to organise phenomenology rationally as a theory of *pure order*.[107]

For Husserl and Bachelard, then, the phenomenology of mathematics is predicated on experience having a mathematical structure and on that pure, abstract structure being accessible to intuition.

The Man Without Qualities, however, is a novel of mixed mathematics and its anxieties about that mixing lead to an alternative phenomenology: one that details the experience of living in a world made out of probabilities in ways that draw out the literary consequences of probability concepts mixing with ethics and with character. Statistical regularity is a salve for the absence of intuitively accessible stable mathematical truth: 'any possibility of leading an ordered life depends on this law of large numbers', as Ulrich has it. The idea that probability is a kind of compensation and ought to enable a well-ordered life stretches back to Pascal. Yet, when Musil in his diaries notes a plan to write an autobiography ('*Das eigene Leben*, von Robert Musil'), he indicates that the idea came to him not when reading Pascal but when reading the autobiography of another early probabilist: Girolamo Cardano's *De propria vita*.[108] *The Book of My Life* is an often-hilarious account of Cardano's adventures in various predictive arts (gambling, mathematics, medicine and astronomy): despite the missteps noted in a short chapter on 'Things in Which I Feel I Have Failed', the ups and downs of his gambling addiction and the violent attempts of others to end his career by poisoning him, Cardano's career in the predictive arts is presented as a successful one.[109] His decision to give up his career as a lecturer, he writes, was prefigured by an otherwise gentle dog tearing his public lectures to shreds:

> It is ever legitimate to draw inferences from even the most insignificant events, when they are uncommonly persistent, since, as I have elsewhere declared, even as a net consists of meshes, all things in the life of man consist in trifles repeated and massed together now in one figure now in another like cloud formations.[110]

Cardano's *Liber De Ludo Aleae* (*Book on Games of Chance*, completed around 1564, though published only in 1663) was the first systematic treatment of the elementary rules of the calculus of probabilities: Cardano works with, for example, what are now called the law of large numbers and the sample space. Cardano offers the first definition of the sample space as follows:

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[107] Gaston Bachelard, *The Formation of the Scientific Mind: A Contribution to a Psychoanalysis of Objective Knowledge*, trans. by Mary McAllester Jones (Manchester: Clinamen, 2002), pp. 17-18.
[108] Musil, 'Heft 34' (1934), p. 856.
[109] Girolamo Cardano, *De vita propria liber*, trans. by Jean Stoner as *The Book of My Life* (repr. New York: New York Review of Books, 2002).
[110] Cardano, *The Book of My Life*, p. 171.

> So there is one general rule, namely, that we should consider the whole circuit, and the number of those casts which represents in how many ways the favourable result can occur, and compare that number to the rest of the circuit, and according to that proposition should the mutual wagers be laid so that one may contend on equal terms.

Cardano's use of the calculus of probabilities for financial and professional gain is in marked contrast to Pascal's later use of that calculus: for Pascal, as I discussed previously, probability ought to dismay.

In Cardano and Pascal's early literary explorations of the calculus of probabilities, that calculus relates primarily to games of chance and to decisions made under conditions of uncertainty. The entanglement of probability with character and literary life writing, like the concept of probability itself, has moved through stylistic periods. Musil's treatment of the ways in which statistics rewrite the ground of identity has a surprising parallel in the life and writing of Karl Pearson, founder of the modern discipline of statistics in Britain, and disciple and biographer of Francis Galton.[111] Porter, Pearson's own biographer, writes of Pearson's life as a life lived in literary terms borrowed from Goethe. Pearson studied German literature in depth: he loved Goethe, wrote an semi-autobiographical novel called *The New Werther*, and lectured on German cultural history at King's College, Cambridge (though he withdrew his name from consideration for a post in this field because he feared that taking the post would cause the electors at University College London to doubt his commitment to mathematics).[112] Porter is a generous biographer, and follows Pearson's literary and ethical commitments through his mathematical career. In this telling, the sacrifices demanded of Pearson by scientific objectivity are a development of the doctrine of renunciation Pearson found in German literature and philosophy: 'if we follow Pearson's own lead in *The New Werther*', Porter writes, 'and acknowledge how desire for nature could be like love, his career appears like the early *Lehrjahre* of Wilhelm Meister, a triumph of renunciation, the abandonment of ecstatic union in favor of statistical description'.[113] Pearson's enormous biography of Galton is both hagiography and an exploration of the relationship between statistics and the generic conventions of biography. 'It would be an interesting problem', Pearson writes, 'to determine what is the likeness of man to himself, by correlating the habits and modes of thought of individuals at selected ages. We might thus obtain a measure of the permanence of individuality'.[114] Here, Pearson comes close to Quetelet's views on the usefulness of statistics for literary character. The chapter on Galton's ancestry with which

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[111] Karl Pearson, *The Life, Letters, and Labours of Francis Galton*, 3 vols. in 4 (Cambridge: Cambridge University Press, 1914, 1924, 1930).
[112] Theodore M. Porter, *Karl Pearson: The Scientific Life in Science* (Princeton, NJ: Princeton University Press, 2004), p. 92, pp. 43-69, pp. 297-314.
[113] Porter, *Karl Pearson*, p. 68. The Romantic elements of Pearson's *Grammar of Science* are also explored by George Levine in *Dying to Know: Scientific Epistemology and Narrative in Victorian England* (Chicago: University of Chicago Press, 2002).
[114] Pearson, *The Life, Letters, and Labours of Francis Galton*, vol. 3A (1930), p. 279

the Pearson biography begins shows more precisely the influence of statistics on style. In this early chapter, Pearson writes about the formation of Galton's character in terms drawn from Galton's work as the founder of eugenics and as the author of *Hereditary Genius*. 'The modern reader', Porter writes:

> finds these pages to be full of ingenious just-so stories: a quantitative disposition reflecting the hereditary business sense of the Quaker Galtons; a wanderlust – over scientific as well as terrestrial continents – inherited from two other branches of the Galton tree; and of course scientific ability from his Darwin ancestors.

The force of Galton's 'inborn traits of personality', then, allowed him to create the environment in which those traits could flourish into a 'eugenic life' which, Porter writes, 'meant a triumph of personal character over environmental influences'.[115] The mess of philosophies of fate and chance that forged the narrative conventions of heroic biography and the *Bildungsroman* is tidied into a statistical model of character that retains and even amplifies those conventions.

At the end of his biography, Porter describes Pearson's disillusionment with scientific specialisation and with the culture of impersonal quantification that he had helped to found: 'Not the metaphysics of science but the increasing narrowness and thoughtless careerism of its practitioners defined Pearson's tragedy'.[116] Porter perceptively connects Pearson's disillusionment with that of Ulrich in *The Man Without Qualities*: 'Pearson may never have read Musil, but he was in some ways the man of "precision and soul" whom the novelist idealized and gently mocked'.[117] Pearson may, indeed, never have read Musil, but Musil read Pearson: his probability bibliography lists 'Pearson in Transactions of the Royal Society 1894-1903 (Vol 185-198)' and 'Philos. Magazine 1900, 01 (Vol 50, 1) The chances of death, Lond.' Musil followed British statistical developments (his notebooks cover the controversy around Galton's fingerprinting techniques under the heading 'Intellectual Bad Luck, An Example – Incidentally, also an example of English decency') and remarks that 'The development of the empirical method builds on W. Lexis, GTh Fechner, K Pearson'. It would be mistaken to conclude from this slight evidence that Pearson's often-awkward literary reflections on the statistical life made their way into Musil's great modernist novel. Indeed, *The Man Without Qualities* warns against enthusiastic visions of unity like that of Pearson's New Werther, who rushes:

> from science to philosophy, and from philosophy to our old friends the poets; and then, over-wearied by too much idealism, I fancy I become practical in returning to science. Have you ever attempted to conceive all there is in the world worth knowing — that not one subject in the universe is unworthy of study? The giants of literature, the mysteries of many-dimensional space, the attempts of Boltzmann and Crookes to penetrate Nature's

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115 Porter, *Karl Pearson*, p. 13.
116 Porter, *Karl Pearson*, p. 298.
117 Porter, *Karl Pearson*, p. 299.

> very laboratory, the Kantian theory of the universe, and the latest discoveries in embryology, with their wonderful tales of the development of life — what an immensity beyond our grasp! […] Mankind seems on the verge of a new and glorious discovery. What Newton did to simplify the planetary motions must now be done to unite in one whole the various isolated theories of mathematical physics.[118]

Through the character of Arnheim, a wealthy Jewish-Prussian industrialist who has written many books and pamphlets on the union of 'soul and economics', Musil satirises a potential pitfall of Pearson's road not taken: a helpless, confused and morally stultifying encyclopaedism. In Arnheim's writings:

> there was talk of algebraic series and benzol rings, the materialist philosophy of history and the universalist one as well, bridge-piles, the evolution of music, the spirit of the motor-car, Hata 606, the theory of relativity, Bohr's atomic theory, autogenous welding, the flora of the Himalayas, psychoanalysis, individual psychology, experimental psychology, physiological psychology, social psychology and all the other achievements that prevent a time that has been enriched by them from producing good, whole, integral human beings.[119]

Nonetheless, both Musil and Pearson bear witness to what they perceive as an epistemological crisis – the dissolution of 'whole' knowledge into incoherent, fragmented, autopoetic specialisations – and both, in their responses to this crisis, remain committed to the principles (moral as much as methodological) of applied mathematics, and to the ideal of a culture in which mathematical '*Genauigkeit*' (precision or exactness) and literary sensibility could be integrated. In their applied mathematics can be traced the lineaments of the old model: application as appeal, attention and therapeutics.

The Man Without Qualities is layered with the styles and affective registers of probability's literary and conceptual history. It is a sustained investigation of both the conditions of possibility for and the consequences of mixed mathematics. Stanley Corngold and Benno Wagner wish to claim Kafka's 'poetics of the accident' as the paradigmatic modernist articulation of a statistically-informed literature, and though their analysis of Kafka's curve-landscape is precise and persuasive, they wrongly accuse Musil, by comparison, of a superficial treatment of statistics: 'The discourse of statistics *appears* in Musil's account as a diegetic motif – a topic of conversation – but this discourse *informs* Kafka's account right from the start'.[120] Musil's deep engagement with statistics, as I hope I have shown, does indeed inform *The Man Without Qualities* right from the start. Nonetheless, the conclusions Corngold and Wagner draw from their comparison are provocative. Whereas Kafka, they write, 'moves in the epistemic space of the *probable* event, a

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118 'Loki' [Karl Pearson], *The New Werther* (London: Kegan Paul, 1880), p. 6, p. 96.
119 Musil, *The Man Without Qualities*, p. 230.
120 Stanley Corngold and Benno Wagner, *Franz Kafka: The Ghosts in the Machine* (Evanston, IL: Northwestern University Press, 2011), p. 179.

type of event that, by a continuous scale of probabilities, erodes the distinction between fiction and reality', Musil moves in the realm of 'allegory' and aims 'at a representational relation between fiction and reality'.[121] Andy Egan and Brian Weatherson give a clear definition of 'epistemic space' as follows: 'When it is epistemically possible (for a subject) that *p*, there is an epistemically possible scenario (for that subject) in which *p*. The epistemic scenarios together constitute *epistemic space*'.[122] Epistemic space, then, is yet another terrain subject to the imperialism of probabilities, to accident insurance and to the law of large numbers. As such, the 'epistemic space of the *probable* event' is part of the texture of post-statistical life, part of the mathematised 'real' and part of the structure of Musil's novel. Kafka's writing, for Corngold and Wagner, 'arises from the permanent *oscillation between the real space of the factual event and the virtual space of the probable event*'.[123] In *The Man Without Qualities*, it is permanently not-yet-war, and Ulrich's hypothetical lives and Austria's hypothetical futures compose an epistemic space that the reader of the novel knows to have been foreclosed.

Life in the Landscape of the Curve

Epistemic space is a philosophical translation of a concept from probability theory: the sample space. The sample space of an experiment is the set of all possible results of that experiment. It is part of the language of modern insurance: its future tense. The handbook of *Probability for Risk Management* shows the sample space at work, as a language for the time of death:

> **Example 2.8** An insurance company sells life insurance to a 30-year-old female. The company is interested in the age of the insured when she eventually dies. If the company assumes that the insured will not live to 110, the sample space is $S = \{30, 31, \ldots, 109\}$.[124]

Insurance gathers the techniques of probability theory and the masses of statistics into an embedded economy: a habitus of domesticated risk. The modern insurance market began in Lloyd's Coffee House (now Lloyd's of London) in the late seventeenth century as the shipping industry community met to pool and spread risk. Insurance did not rely much on mathematical techniques for the calculation of risk until the nineteenth century. The symbiosis between belief in the law of large numbers and confidence in insurance developed as the nineteenth century did, and this new moral technology translated the vocabularies of ordinary time, fate, property, safety and loss into a series of cognates whose common root is, precisely, insurance. Insurance is both a form and an agent of demotic mathematics. It relies on the law of large numbers: on vernacular

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[121] Corngold and Wagner, *Franz Kafka: The Ghosts in the Machine*, p. 179.
[122] Andy Egan and Brian Weatherson, *Epistemic Modality* (Oxford: Oxford University Press, 2011).
[123] Corngold and Wagner, *Franz Kafka: The Ghosts in the Machine*, p. 180.
[124] Matthew J. Hassett and Douglas G. Stewart, *Probability for Risk Management*, 2nd edition (Winsted, CT: ACTEX, 2009), p. 12.

iterations (or applications) of mathematical probability and mathematical statistics. Insurance also, through its ubiquity, circulates 'mathematical' or probabilistic versions of ideas like risk, normalcy and society. In an article on Balzac's *The Illustrious Gaudissart*, Michael Tilby points out that the 'history of insurance and the history of literature (especially, but not exclusively, that of the novel) are intertwined to a greater extent than is often realized, even if in the literary texts themselves insurance remains largely an understated presence'.[125]

As Leopold Bloom narrowly avoids meeting the same fate as the man run over in the opening pages of *The Man Without Qualities*, his mind jumps around in the everyday calculus of probabilities: 'Close shave that but cured the stitch. Must take up Sandow's exercises again. On the hands down. Insure against street accident too. The Providential. (*He feels his trouser pocket*) Poor mamma's panacea. Heel easily caught in tracks or bootlace in a cog'.[126] As Ulrich filters the world through his old profession, mathematics, Bloom, a former insurance man, still navigates with the insurance man's map of risk.[127] Thinking about childbirth and the family – 'Suppose he was consumptive' – leads Bloom to concoct a social security scheme:

> Whole thing quite painless out of all the taxes give every child born five quid at compound interest up to twentyone, five per cent is a hundred shillings and five tiresome pounds, multiply by twenty decimal system, encourage people to put money save hundred and ten and a bit twentyone years want to work it out on paper come to a tidy sum, more than you think.[128]

Bloom's concern with insurance, his entanglement in its kindnesses and its tyrannies, places him among modernism's other traders in the calculus of probabilities: Wallace Stevens, vice-president of the Hartford Accident and Indemnity Company; Charles Ives, composer of both *Three Places in New England* and *Life Insurance With Relation to Inheritance Tax*; and Franz Kafka, chief legal secretary of the Workmen's Accident Institute for the Kingdom of Bohemia (later, the Workmen's Accident Insurance Institute for the Czech Lands).

François Ewald and Peter Sloterdijk both make the claim for insurance as a constitutive world-making technology. In *L'état providence* and 'Insurance and Risk' Ewald argues that the rise

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[125] In 1837, Tilby writes, Balzac 'devised a scheme to offer a share in a tontine with a subscription to an edition, *chez* Delloye and Lecou, of his collected *Études sociales*, though he dropped the idea amid derisory comments in the satirical press'. See Michael Tilby, 'Balzac, the Insurance Industry and the Creation of Finance', *Journal of European Studies* 41.2 (2011), 107-122 (pp. 108-9).

[126] Joyce, *Ulysses*, p. 414.

[127] The 'Notes on Business and Commerce' in the James Joyce archive suggest an interest in insurance and banking in general beyond that required for Joyce's job at Nast-Kolb and Schumacher: he delves into the etymology of 'clerk', works through different definitions of accident and risk and the history of defunct insurance systems such as the Tontine. The relevant notebooks are MS 38 and MS 63 in the James Joyce Collection at Cornell University Library and reproduced as 'Notes on Business and Commerce' in James Joyce, *The James Joyce Archive Vol. III*, ed. by Michael Groden, Hans Walter Gabler, A. Walton Litz and Daniel Rose (New York: Garland, 1978), pp. 474-617. For further commentary, see Jaya Savige, 'Underwriting *Ulysses*: Bloom, Risk and Life Insurance in the Nineteenth Century', in *James Joyce in the Nineteenth Century*, ed. by John Nash (Cambridge: Cambridge University Press, 2013), pp. 77-94.

[128] Joyce, *Ulysses*, p. 154.

of insurance plunged us into 'a universe where the ills that befall us lose their old providential meaning: a world without God, a laicized world where "society" becomes the general arbiter answerable for the causes of our destiny'.[129] Sloterdijk makes a similar point:

> Initially we have eliminated religions because we could replace them with social insurance. The symbolic immunity of religion was simply no longer needed once the great systems of solidarity emerged. Whoever has health insurance, needs God only half as much as before, but whoever has life insurance, doesn't need him at all.[130]

The claim for insurance as a secularising force is based on a perceived affective and structural similarity between insurance and religious practices of immunisation. The confession, Protestant technics, quietism and, very broadly, the idea of an afterlife as indemnity, can all be considered forms of immunology in Sloterdijk's terms. The 'moral ledger' of, for example, Benjamin Franklin's *Autobiography*, is translated, after the rise of insurance, into a societal technology: past sins and future happiness can all be translated into the abstract logic of insurance; into financial terms. Ewald's *L'état providence* charts the effects of the moral and political techniques of insurance: the process by which insurance brought a particular idea of society (as 'a vast system of insurance') into being; by which insurance permeated and mathematicised the old 'providential' institutions and the moral imagination of the citizen.[131]

Insurance has a poetics. Or so argues Eric Wertheimer in *Underwriting: The Poetics of Insurance in America, 1722-1872*. Wertheimer details a cultural history of the relationship between the rise of the insurance industries in the United States and the development of American literature in the eighteenth and nineteenth centuries (Phillis Wheatley, Ralph Waldo Emerson, Herman Melville, Benjamin Franklin and Noah Webster). Wertheimer makes both a historical and an analogical argument for the importance of that relationship. His major claim, that 'the four main divisions of the insurance business – marine, fire, life, and accident – may be viewed as essential to a material, ideological, and aesthetic reckoning with the emergence of American literature' is made alongside a claim for a 'poetics' of insurance, defined in terms of authenticity and trust: 'In both literary and monetary cases, investments of worth and "authenticity" are predicated on an individually assigned truth-claim, usually the ultimate symbol of thrift – the authorial name and signature (Lloyd's underwriters are still known somewhat poetically as "Names")'.[132] The epistemology of insurance in the modernist period, the epistemology that Joyce, Stevens and

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[129] François Ewald, 'Insurance and Risk', in *The Foucault Effect: Studies in Governmentality*, ed. by Graham Burchell, Colin Gordon and Peter Miller (Chicago: University of Chicago Press, 1991), pp. 197-210.
[130] Peter Sloterdijk, Liesbeth Noordegraaf-Eelens and Willem Schinkel, 'The Space of Global Capitalism and its Imaginary Imperialism: An Interview with Peter Sloterdijk' in *In Medias Res: Peter Sloterdijk's Spherological Poetics of Being*, ed. by Willem Schinkel and Liesbeth Noordegraaf-Eelens (Amsterdam: Amsterdam University Press, 2011), pp. 185-194 (p. 192).
[131] François Ewald, *L'état providence* (Paris: B. Grasset, 1986).
[132] Eric Wertheimer, *Underwriting: The Poetics of Insurance in America, 1722-1872* (Stanford, CA: Stanford University Press, 2006), p. xiii.

Kafka encounter and reconfigure, is a different epistemology to that described by Wertheimer. The rubric of personal authenticity, for example, no longer applies: by the 1920s, trust of that kind had been supplanted by institutional, legal and mathematical guarantees; by, in other words, the law of large numbers. As Doreen Densky notes in 'Proxies in Kafka', by the time Kafka entered the accident insurance business, 'social insurance' had emerged as 'the new principle that would organize, regulate, and administer risk' and the 'system of circulation' that came with it was 'based not on stories told ("Erzählungen") but rather on calculability and data collection ("Zählungen")'.[133] The Austro-Hungarian Empire replaced negligence liability with compulsory industrial accident insurance in 1887 and an extensive social insurance system followed: the scope of the accident insurance law was expanded in 1894 to include transportation and storage workers, compulsory sickness insurance for industrial workers in 1889, compulsory pensions insurance for white-collar workers in 1906 and for blue-collar workers in 1927, and compulsory unemployment insurance in 1920. The Accident Insurance Law (*österreichisches Unfallversicherungsgesetz*) of 1887 required that risk classification be based on accident statistics (article 14). These, in the early days, often had to be borrowed from the German Reich and supplemented with non-statistical probability assessments. In an article for the *Tetschen-Bodenbacher Zeitung*, Kafka describes how those faulty early statistics still, in 1911, cause problems:

> At the very beginning of Austrian workmen's accident insurance, the classification was based on statistical data that were available to the Ministry of the Interior, and we must admit that it was this material that constituted perhaps one of the most disastrous factors in the whole history of Austrian workmen's accident insurance. These data were so defective and inadequate that they did not represent the actuality and resulted in a completely unjustified distribution of the charges among the individual commercial groups. In consequence, a thoroughly skewed perspective was introduced into Austrian workmen's accident insurance from the outset, and the separate insurance institutes have suffered from these discrepancies ever since, without a way to work their way free of the consequences to this day.[134]

The problem of testimony in Kafka's writing is an abstracted, complex version of the problem of translating moral norms into mathematical ones for the purposes of risk classification. Thanks to the editorial work and the historical and legal commentaries of Corngold, Greenberg and Wagner, the practical problems Kafka's Workmen's Institute faced in this translation can be traced from *Franz Kafka: the Office Writings* through to Kafka's literary grammar of insurance. These practical problems – data collection and land surveying, the 'black-boxing' of information, and the difficulties of justifying the application of a large-scale and centralised statistical method

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[133] Doreen Densky, 'Proxies in Kafka' in *Kafka for the Twenty-First Century*, ed. by Stanley Corngold and Ruth V. Gross, (Rochester, NY: Camden House, 2011), p. 122.

[134] 'Workmen's Insurance and Employers', attributed to Franz Kafka, *Tetschen-Bodenbacher Zeitung* (13 September 1911), in *Franz Kafka: The Office Writings*, ed. by Stanley Corngold, Jack Greenberg and Benno Wagner, trans. by Eric Patton and Ruth Hein (Princeton, NJ: Princeton University Press, 2009), p. 146-7.

for calculating risk to those working on farms, in quarries and as toy manufacturers – became the aporias of the novels' insurantial imagination.

In his essay 'Imagination as Value', Wallace Stevens described imagination precisely in terms of insurance: 'A generation ago we should have said that the imagination is an aspect of the conflict between man and nature. Today we are more likely to say that it is an aspect of the conflict between man and organized society. *It is part of our security*. It enables us to live our own lives'.[135] The nature of that security, of imagination's insurance system, becomes clearer in 'The Irrational Element in Poetry' as Stevens considers what resistance poetry offers to the threatening uncertainties of contemporary life:

> We look from an uncertain present toward a more uncertain future. One feels the desire to collect oneself against all this in poetry as well as in politics. [. . .] Resistance to the pressure of ominous and destructive circumstance consists of its conversion, so far as possible, into a different, an explicable, an amenable circumstance.[136]

Poetry, like insurance, is a way of learning to live with risk: it translates ambiguity and uncertainty into positive values. Insurance's economy of the unlost becomes, with Stevens, a way of facing the sample space of the contemporary, its frightening possible worlds, and converting that space into a liveable dwelling place.

Joseph Harrington reads that conversion as an example of Stevens's liberal defence of the separation of public and private: 'the modernist poet redoubles his imaginative efforts to establish a privatizing poetics that can reduce the anxiety occasioned by current history by absorbing it in abstraction'.[137] Stevens was vice-president of a private insurance company and dealt in surety bonds (a type of insurance contract in which the surety agrees to uphold — for the benefit of the obligee — the contractual promises made by the principal if the principal fails to uphold its promises to the obligee) at a time when the role of private insurance in America was changing as a result of the introduction of Social Security.[138] Stevens's essay on 'Insurance and Social Change' is concerned precisely with the threat posed to the private insurance companies by

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[135] Wallace Stevens, 'Imagination as Value', in *The Necessary Angel: Essays on Reality and the Imagination*, repr. in *Wallace Stevens: Collected Poetry and Prose*, ed. by Frank Kermode and Joan Richardson (New York: Library of America, 1997) (hereafter *CPP*), p. 735.

[136] Stevens, *CPP*, pp. 788-789.

[137] Joseph Harrington, *Poetry and the Public: the Social Form of Modern U.S. Poetics* (Hanover, NH: Wesleyan University Press, 2002), p. 103.

[138] The political debates about the New Deal were, as Sean McCann and Michael Szalay have argued, also played out in literature. McCann argues that the hard-boiled crime fiction of Cain, Hammett and Chandler reverses the relationship between public safety and private desire that structured the classic detective story and in doing so 'became a symbolic theatre where the dilemmas of New Deal liberalism could be staged': 'Traditionally, the classic detective story celebrated the victory of public knowledge and civic solidarity over the dangers of private desire. […] In the novels of Cain, Hammett, Chandler and their peers, civil society can no longer contain private desire' (Sean McCann, *Gumshoe America: Hard-Boiled Crime Fiction and the Rise and Fall of New Deal Liberalism* (Durham, NC: Duke University Press, 2000)). Szalay finds this debate between public and private staged, too, in American modernism and considers Stevens as part of this 'New Deal Modernism'. Michael Szalay, *New Deal Modernism: American Literature and the Invention of the Welfare State* (Durham, NC: Duke University Press, 2000).

social and political change and nationalization: it examines the state of private insurance under Fascism in Italy (severely restricted) and Germany (under 'severe' supervision), summarises an English Parliamentary report on 'obligatory insurance' and the establishment of a 'central fund', and concludes that, in the case of Russia, 'In the vast monopoly of Communism, insurance is itself a monopoly. The organization, Gosstrakh, is a state department and, by government decree, no other organization has the right to do an insurance business in the territory of the Soviets'. Steven's argument, in effect, is that as the scope of insurance increases ('we may well be entering an insurance era') the possibility of nationalisation will naturally be considered and will seem more appealing in 'a period of unrest', nonetheless, if the private insurance business remains both adaptable to and profitable in this new insurance era it is 'more certain' that it will endure.[139] Stevens, like Leopold Bloom, daydreams about a world in which 'insurance had been made perfect'. 'The objective of all of us', he writes, 'is to live in a world in which nothing unpleasant can happen. Our prime instinct is to go on indefinitely like the wax flowers on the mantelpiece. Insurance is the most easily understood geometry for calculating how to bring the thing about'.[140]

These wax flowers, a domestic, slightly kitsch memento mori, suggest the still life painting as a form of insurance, an act of preserving quotidian reality against loss. The wax flowers appear, too, in 'Owl's Clover':

> Bring down from nowhere nothing's wax-like blooms,
> Calling them what you will but loosely-named
> In a mortal lullaby, like porcelain.[141]

As Bonnie Costello argues in 'Planets on a Table', Stevens is writing 'within a still life tradition', yet 'Stevens's turn to still life' is not 'a turn away from the world into the complacencies of the peignoir, into petit bourgeois concerns, or into formalism'. His fragile spaces are rather 'tentative, partial spaces of order and beauty' that register the tremors and the weather of other spheres.[142] In 'The Poems of Our Climate' the world of the carnations, the space of the still-life, is found grammatically unsatisfying:

> II
> Say even that this complete simplicity
> Stripped one of all one's torments, concealed
> The evilly compounded, vital I
> And made it fresh in a world of white,
> A world of clear water, brilliant-edged,
> Still one would want more, one would need more,

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139 Stevens, *CPP*, pp. 792-796.
140 Stevens, *CPP*, pp. 792-793.
141 Stevens, *CPP*, p. 155.
142 Bonnie Costello, 'Planets on Tables: Still Life and War in the Poetry of Wallace Stevens', *Modernism/modernity* 12.3 (2005), 443-458.

> More than a world of white and snowy scents.
> III
> There would remain the never-resting mind,
> So that one would want to escape, come back
> To what had been so long composed.
> The imperfect is our paradise.
> Note that, in this bitterness, delight,
> Since the imperfect is so hot in us,
> Lies in flawed words and stubborn sounds.[143]

'Composed', the world in passé composé, gives way to the imperfect, to the unfinished. This imperfect emerges out of the splitting of the 'still life'. Our phrase 'still life' comes from the Dutch, *stilleven*. Stilleven can be wrenched into English as an apt description of the melancholy tense of the still-life, as its plea for preservation, that something still remain even in the event of loss. The stilleven splits at the opening of the second stanza: the 'even' splits off from the 'still' and precedes it, thus that still offers itself as a rebuttal 'still one would want more' and 'There would still remain the never-resting mind'. The play of still and even here is a disruptive parsing of the grammar of making sure and of the tense of insurance as articulated in 'Insurance and Social Change'.

Sloterdijk's *Sphären* trilogy offers a way of imaging both of these aspects of the poetics of insurance – the world-making and the grammatical – at once. 'Spherology', which is Sloterdijk's name for his method, analyses the production of liveable places, both inner and outer, and the management of risks to those places, through an expanded concept of immunology. The risks of maritime exploration were insured against, in Sloterdijk's account, by portable safe spaces ('baldachins') such as the encyclopaedia, which afford a symbolic immunity to 'the role of the collector and the chronicler'. The *Sphären* trilogy starts with 'bubbles', small-interpersonal spaces, goes through the 'immune-systems' of Noah's ark, city building, etc., to the metaphysical and colonial ideas about the 'globe' and ends up with a 'foam of world-making constructions of space'. The foam, then, includes literary, mathematical and insurantial immune-systems, ways of world-making, and is a way of thinking all at once about the modal worlds of probability, the conceptual architecture of insurance and the 'spheres' generated by style.[144]

Stevens's modal construction of insured epistemic spaces, like that of Kafka, offer insights into the structure of insurance's abstract tense. 'Tense' is used imprecisely here as a name for the ways in which the 'future time' (an abstract conditional mood) of the accident or loss is related to past time (the mess of information with which probability conjures) and the present time of performative guarantee (the act of making certain, and of shoring against). As such, the

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143 Stevens, *CPP*, pp. 178-9.
144 Peter Sloterdijk, *Sphären I – Blasen, Mikrosphärologie*; *Sphären II – Globen, Makrosphärologie*; *Sphären III – Schäume, Plurale Sphärologie* (Frankfurt am Main: Suhrkamp, 1998, 1999, 2004).

'tense' of insurance might more properly be described as a mixture of modality, mood and aspect. 'Prologues To What Is Possible' is self-conscious about its own production of an epistemic space. The process of hypothesising is given form as a sea voyage ('There was an ease of mind that was like being alone in a boat at sea'), and thought is therefore imagined in the language of maritime risk:

> As he travelled alone, like a man lured on by a syllable without any meaning,
> A syllable of which he felt, with an appointed sureness,
> That it contained the meaning into which he wanted to enter.[145]

The language of the mariner's surety parallels that of the opening of another modernist sea voyage: Conrad's *Lord Jim*, in which the stars 'seemed to shed upon the earth the assurance of everlasting security'.[146] Stevens's mariner's experience of epistemic space 'stirred his fear', as:

> The object with which he was compared
> Was beyond his recognizing. By this he knew that likeness of him extended
> Only a little way, and not beyond, unless between himself
> And things beyond resemblance there was this and that intended to be recognised,
> The this and that in the enclosures of hypotheses.[147]

This phrase, 'The this and that in the enclosures of hypotheses', uses a stuttering deixis to create a mini-world within itself: 'The this and that' point inwards, at the epistemic space of the thinker's imagination. I want to relate this stuttering epistemic space to the history of literary probability in two ways: first, through comparison with another poem of hypothetical maritime risk, Mallarmé's *Un coup de dés jamais n'abolira le hasard* (1897), and secondly through Stevens's own descriptions of what epistemic space is made out of in 'Imagination as Value' and 'A Quiet Normal Life'.

In his 'Note' to 'A Throw of the Dice Will Never Abolish Chance', Mallarmé writes that '[e]verything takes place in a foreshortened, hypothetical state; narrative is avoided'.[148] As it evades the determinism of narrative, the poem, for Leland Monk, marks the beginning of 'a truly modernist interest in chance'.[149] The form that interest takes is apodictic proof. Mallarmé describes this form in his letters: 'In this poem', he writes to André Gide, 'the constellation will, fatally, assume, according to precise laws and insofar as it is possible in a printed text, the form of a constellation. The ship will list from the top of the page to the bottom of the next'. Through

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[145] *CPP*, p. 438.
[146] Joseph Conrad, *Lord Jim* (Harmondsworth: Penguin, 1983), p. 17.
[147] *CPP*, p. 438.
[148] Stéphane Mallarmé, *Collected Poems and Other Verse*, trans. by E. H. and A. M. Blackmore (Oxford: Oxford University Press, 2006), p. 263.
[149] Leland Monk, *Standard Deviations: Chance and the Modern British Novel* (Stanford, CA: Stanford University Press, 1993), p. 9.

spatial form: 'Literature thus makes *its proof*: there is no other reason to write on paper'.[150] Mallarmé's poetics aspires to the purity, simultaneity and felt necessity of a perfect mathematical proof; to what Wittgenstein calls proof's 'glitter'. The poem is built out of the grammar of mathematical supposition and hypothesis: 'Soit que' (supposing) and 'Comme si' (as if) launch the reader into a strange virtual shipwreck that 'proves' the poem's thesis; that 'A THROW OF THE DICE WILL NEVER ABOLISH CHANCE'.[151] The proof of this thesis begins 'Even when launched in eternal circumstances from the depths of a shipwreck', then splits into different hypothetical threads, distinguished typographically, listing across the page as the poem imagines an old man shipwrecked and hesitating to throw the dice he has clenched in his fist. The concluding sentence of the poem – 'Every Thought Emits a Throw of Dice' – suggests the profusion of possible worlds generated by modal logic as the 'infinite' that cannot be crystallised into a definite, actual, determined world. In this interpretation, the old man exists in the sample space that precedes the actualisation of any given probability: he is dithering in the realm of the possible as his author dithered with combinatorial and algebraic sketches for his hypothetical 'Book'.

However, Mallarmé's paean to chance is complicated by the mythic, even apocalyptic determinism of the poem's register: the astrology of 'constellation'; the 'Abyss' and the 'vortex' threatening the old man; the very idea of 'eternal circumstances'. The final word of the thesis, 'CHANCE', is woven with a bizarre, fatalistic mathematics: 'IT WAS THE NUMBER | *progeny of the stars* | WERE IT TO EXIST| otherwise than as the sparse hallucinations of agony | WERE IT TO BEGIN AND END| unheard but negated and closed when it appears finally through some profusion of dispersed rarity | WERE IT TO BE CIPHERED | evidence of the total sum is so far as there is one | WERE IT TO BE ILLUMINATED | *IT WOULD BE* | *worse not more or less indifferently but just as much* | **CHANCE**' . Infinite chance is, here, a kind of tyrannical deity foreclosing any possibility of escape from its clutches. In 'Igitur' (another Mallarmé poem in which someone refuses to throw dice) chance is described as master of a Hegelian dialectic (a game the Idea, after all, always wins): '*chance always accomplishes its own Idea in affirming or negating itself. Confronting its existence, negation and affirmation fail. It contains the Absurd – implies it, but in the latent state and prevents it from existing: which permits the Infinite to be*'.[152]

Mallarmé's 'Chance' is a modernist descendent of the Roman Fortuna: goddess both of chance and fate. 'A Throw of the Dice' rewrites the address to Fortuna common in classical

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[150] Letter to André Gide, 14 May 1897 in *Selected Letters*, p. 223 and Letter to Mauclair, 8 October 1897 in *Correspondance*, p. 635 ('la littérature fait ainsi *sa preuve*').

[151] *Un coup de dés jamais n'abolira le hasard* ('A Throw of the Dice Will Never Abolish Chance'), quotations from this poem in French and English are from 'Appendix 1' to Quentin Meillassoux's *The Number and the Siren: A Decipherment of Mallarmé's Coup de Dés*, trans. by Robin Mackay (Falmouth: Urbanomic/Sequence Press, 2012).

[152] Stéphane Mallarmé, 'Igitur', trans. by Mary Ann Caws in *Stéphane Mallarmé: Selected Poetry and Prose* (New York: New Directions, 1982), p. 99.

tragedy for a world in which chance is fundamentally mathematical. The shipwreck in Seneca's *Agamemnon* is foreshadowed by the maritime metaphors of the Chorus's address to Fortune:

> O Fortune, who dost bestow the throne's high boon with mocking hand, in dangerous and doubtful state thou settest the two exalted. Never have sceptres obtained calm peace or certain tenure; care on care weighs them down, and ever do fresh storms vex their souls [...] Whatever Fortune has raised on high, she lifts but to bring low. Modest estate has longer life; then happy he whoe'er, content with the common lot, with safe breeze hugs the shore, and, fearing to trust his skiff to the wider sea, with unambitious oar keeps close to land.[153]

The Chorus in 'A Throw of the Dice' is mocking laughter arising from a *'vortex of hilarity and horror*': '*the velvet crumpled by a dark burst of laughter | this rigid whiteness | derisory*'. Only in death, Seneca's Chorus suggest, can there be an escape from Fortuna: 'Nor fear nor storm of raging Fortune disturbs that calm'. In medieval lyrics such as the *Cantigas de Santa Maria*, Josiah Blackmore argues, the shipwreck could be a passage not just to calm but to salvation.[154] Mallarmé's old man is stuck in an 'eternal' (and hypothetical) shipwreck from which he cannot be saved, and his absurd plight is somehow also the plight of all of us: 'direct shipwreck of man this | with no ark | no matter | where vain'.

'A Throw of the Dice' weaves the shipwreck's symbolic valences – the shipwreck's literary and religious connotations – with a strange mathematical symbolism. The old man's 'supreme conjunction with probability' is not, however, a conjunction with any recognisable form of late nineteenth-century mathematics, but rather with numerology. 'Number' is enchanted and made strange in the idea of a 'unique Number that cannot be another' while the stars keep a 'total count' and 'total sum' that is never disclosed. Mallarmé's world was made out of probability's demotic mathematics and he translates that demotic into a pre-modern numerology: into, indeed, a cosmology. The 'Number' in the poem is thus a metaphor for the forms of divination supplanted by probability. If Mallarmé's numerology is an allegory of his mathematical culture, it also plays with the enchanted numbers of Christian faith and responds to the 'crisis' of quantitative, numbered verse. These latter aspects of the cultural history of number are woven into a poem commemorating a real shipwreck that happened roughly twenty years before Mallarmé's poetic shipwreck: Gerard Manley Hopkins's 'The Wreck of the Deutschland'. Hopkins's poem, which was inspired, according to his letters, by reading newspaper reports of the accident, also translates the shipwreck from one mathematical language, insurance's financial language of loss, into another: a religious salvation articulated numerically. The *Times*'s reports on the 'loss of the Deutschland' (from early December 1875) focus on the testimony given at

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153 *Seneca's Tragedies, with an English Translation* Vol II, trans. by Frank Justice Miller (London: Heinemann, 1917), pp. 9-11.

154 Josiah Blackmore, *Manifest Perdition: Shipwreck Narrative and the Disruption of Empire* (Minneapolis: University of Minnesota Press, 2002).

inquest by survivors and the ensuing legal proceedings concerning blame and corporate liability. 'The Wreck of the Deutschland' is addressed neither to Fortuna nor Chance but to God: 'three-numberèd' 'master of the tides'. The poem enacts the salvation of five drowned nuns:

> Five! the finding and sake
> And cipher of suffering Christ.
> Mark, the mark is of man's make
> And the word of it Sacrificed.
> But he scores it in scarlet himself on his own bespoken,
> Before-time-taken, dearest prizèd and priced —
> Stigma, signal, cinquefoil token
> For lettering of the lamb's fleece, ruddying of the rose-flake.[155]

The five nuns are transmuted into the five wounds of Christ, a score kept on the body, and the five-petalled cinquefoil and five signs of the stigmata translate insurance's economy of the unlost, its salvation mathematics, its price, into a divine system of exchange and numbering. Hopkins's translation between insurantial and religious mathematics is an act of translation with a long cultural history. As Sloterdijk points out, seafaring (at least until the nineteenth century) was a 'third force' between religious and insurance societies, implicated in both and blending, I would argue, their vocabularies. The 'appointed sureness' felt by Wallace Stevens's hypothetical seafarer has tones, therefore, of both the divine and the insurantial.[156] With Hopkins, as with Mallarmé, mathematics offers the escape from and alternative to itself: against probability's ubiquitous demotic mathematics might be forged an alternative kind of mathematical order. Hopkins was anxious about the meaning of statistics. His father wrote histories and manuals of insurance and corresponded with Francis Galton on the issue of 'number intuition' (the idea that we have an spatial, inherited sense of number patterns). Hopkins himself wrote an article on 'Statistics and Free Will', which has now been lost, but, as John Kerrigan argues, it is still possible to conclude that: 'Gerard M. Hopkins will have wanted to reconcile the selved instress of these patterns with his respect for the "forms" which gave the world of Wisdom II, as well as the conceptual field which he called "this picture or world", mathematical shape'.[157] 'Whether numbering syllables or counting trees, dividing a meditation or using figures to structure mneumonics', Kerrigan writes, 'Hopkins was drawn to mathematical order in ways which provided antidote to theories of

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[155] Gerard Manley Hopkins, 'The Wreck of the Deutschland', in *The Poems of Gerard Manley Hopkins*, ed. by W. H. Gardner and N. H. MacKenzie (Oxford: Oxford University Press, 4th edn, 1970), pp. 51-63 (2. 22: 169-176).

[156] In Sloterdijk's poetics of nautical risk, early transatlantic seafaring is 'an informal technique of ecstasy whereby discoverers, like shamans of an undefined religion, acquired information from a significant realm beyond. This was no longer to be envisaged as a heavenly "above", but rather a terrestrial "yonder"'. This displacement of transcendence to a horizontal 'yonder' had implication for literary genre: it made utopia possible, in Sloterdijk's account, and enabled the microcosmic poetics of the ship's hold. See Peter Sloterdijk, *In the World Interior of Capital*, trans. by Wieland Hoban (Cambridge: Polity, 2013), pp. 77-78.

[157] John Kerrigan, 'Writing Numbers: Keats, Hopkins and the History of Chance', in *Keats and History*, ed. by Nicholas Roe (Cambridge: Cambridge University Press, 1995), pp. 280-308 (p. 298).

atomistic "chance" and fateful statistics'.[158] In Hopkins's 'On the Origin of Beauty: A Platonic Dialogue', the 'Professor' finds beauty in mathematical order: the parabola, the number seven, symmetry and structural parallelism. 'What is regularity?', he asks, 'Is it not obedience to law? And what is Law? Does it not mean that several things, or all the parts of one thing, are like each other? […] Then the beauty of the oak and the chestnut-fan and the sky is a mixture of likeness and difference or agreement and disagreement or consistency and variety or symmetry and change'.[159]

The Platonic idea that the given (whether world or text) contains a mathematical code hidden in plain sight – 'Five! the finding and sake | And cipher of suffering Christ' – is given full-throated voice in Quentin Meillassoux's 'decipherment' of Mallarmé's 'A Throw of the Dice'. Meillassoux's book is less a work of literary criticism than a detective novel (or, perhaps, a conspiracy theory). By investigative counting and a slight manipulation of the arithmetic, Meillassoux claims to have uncovered the 'unique Number that cannot be another'. Mallarmé's philosophical point is given a concrete figure: 707. 'The poem is written "in 7"', Meillassoux writes, 'as a sonata is written in C minor or major'.[160] Even after the shipwreck of the alexandrine, verse remains fundamentally an act of counting. In the framing grammar that I described above as launching the reader into the world of mathematical proof (the 'Comme si'), Meillassoux finds 'the insinuation of Seven' (because *si* is the seventh note of the elementary musical scale), and that, therefore:

> our Number must begin and end with 7, since it is coded by a sequence that begins and ends with that which is "like" *si*: 'Comme si – Comme si' – '7 – 7' […] what the central text speaks of is the whirlpool or "vortex", the "gulf" that carries away everything, situated as it is in the abyssal folding of the Poem at its centre. And how best to figure a vortex, with its circular form, and an empty around which is "coiled" the insinuation (of 7 by si), if not with the cipher 0? And with that, the charade of Number gives a perfectly determinate result: *The Number of the* Coup de dés *is none other than 707*.
> Hypothesis; Prophecy; Number.[161]

With Meillassoux's 'decipherment', Mallarmé's poem re-enters the history of the philosophy of mathematics. Meillassoux transmutes fin-de-siècle hypothesis to contemporary Platonic prophecy. Meillassoux's own beliefs about mathematics and about the nature of chance might be summarised as follows: mathematics is a mode of access to the 'firstness' of the world, an 'ancestral realm' prior to appearance and human access, and there is no such thing as causal

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[158] Kerrigan, 'Writing Numbers', p. 298.
[159] Gerard Manley Hopkins, 'On the Origin of Beauty: A Platonic Dialogue', in *The Collected Works of Gerard Manley Hopkins Vol. IV: Oxford Essays and Notes*, ed. by Leslie Higgins (Oxford: Oxford University Press, 2006), pp. 136-174 (pp. 140-141).
[160] *The Number and the Siren*, p. 57.
[161] *The Number and the Siren*, pp. 66-67.

necessity; all is chaos.[162] Mallarmé's own complex Platonism can be glimpsed in his remarks on the nature of music. As Jacques Rancière writes, music with Mallarmé recovers 'its Greek meaning and its Platonic function: the transcription of mathematical harmony which creates a *kosmos* […] the play written in the folio of the sky'.[163] However, this Platonism fractures in the poems themselves: 'Instead of the pulverized idea, there is, precisely, its dust: hair of foam, clown sequins, golden fringe of light on a stage curtain, and woman's hair as flight of fame. In the place of models to copy, there are, scattered in this dust, aspects to grasp; that is, not the form of things, but events'. [164] From this dust, Meillassoux draws out and re-appropriates the mathematical Platonism of Mallarmé's poem and in doing so elides the poem's original context in the history of the philosophy of demotic mathematics: 'A Throw of the Dice' is a form of absurdist mathematical world-making, a way of using the terms of hypothesis and the grammar of proof, which responds to a newly stochastic world in which mathematical ideas of order and disorder were felt as immanent to experience.

Mallarmé's 'Chance' might, then, be compared with one of its contemporary mathematical deities, C. S. Peirce's 'absolute chance' or 'Tychism'. 'Chance itself pours in at every avenue of sense', Peirce wrote in 1893, 'it is of all things the most obtrusive. That it is absolute, is the most manifest of all intellectual perceptions. That it is a being, living and conscious, is what all the dullness that belongs to ratiocination's self can scarce muster hardihood to deny'.[165] Peirce's word for this, *tychism*, is borrowed from the Greek ('Tyche' was the Greek equivalent of the Roman Fortuna) and used to name the elementary force of an evolutionary, tripartite cosmology (the three forces are chance, law and habit). In 'The Doctrine of Necessity Examined' (1892), tychism is described as follows:

> By thus admitting pure spontaneity or life as a character of the universe, acting always and everywhere though restrained within narrow bounds by law, producing infinitesimal departures from law continually, and great ones with infinite infrequency, I account for all the variety and diversity of the universe, in the only sense in which the really *sui generis* and new can be said to be accounted for.[166]

Determinism, in Peirce's account, is a loose approximation from modern science: the ancient world had no quarrel with chance and Peirce's absolute chance is described in the above passage in terms similar to Lucretius's clinamen. From the existence of margins of error, Peirce concludes that:

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[162] See Quentin Meillassoux, *After Finitude: An Essay on the Necessity of Contingency*, trans. by Ray Brassier (Paris: Seuil, 2006; London: Continuum, 2008).
[163] Jacques Rancière, *Mallarmé: The Politics of the Siren*, trans. by Steven Corcoran (London: Continuum, 2011), p. 49.
[164] *Mallarmé: The Politics of the Siren*, p. 11.
[165] C. S. Peirce, 'Reply to the Necessitarians', *The Monist* 3.4 (1893), 526-570 (p. 560).
[166] C. S. Peirce, 'The Doctrine of Necessity Examined', *The Monist* 2.3 (1892), 321-337 (pp. 333-334).

> conformity to law exists only within a limited range of events and even there is not perfect, for an element of pure spontaneity or lawless originality mingles, or at least must be supposed to mingle, with law everywhere. Moreover, conformity with law is a fact requiring to be explained; and since law in general cannot be explained by any law in particular, the explanation must consist in showing how law is developed out of pure chance, irregularity, and indeterminacy.[167]

Peirce deduces his concept of a stochastic universe from his probabilistic world, his statistical life, and his belief in tychism is coupled with a corresponding belief that science achieves statistical probabilities, not certainties. As Hacking reminds us, Peirce made many advances in statistics and probability theory: he formulated a version of modern statistics in 'Illustrations of the Logic of Science' and 'A Theory of Probable Inference'; introduced blind, controlled, randomized experiments in 1884; worked with a 'propensity' theory of probability before Karl Popper; and was one of the first to use subjective probabilities in experimental psychology. Of the ways in which Peirce built on Gustav Fechner's use of the Gaussian curve in psychology, Hacking writes:

> one's psychological curve of error became an inferred, theoretical curve, which one cannot judge by introspection. It became a reality underneath the phenomena of consciousness […] the real world just *is* a set of stabilized relative frequencies whose formal properties are precisely those of Peirce's estimators. […] We should think […] of mental abilities as evolving parallel to the evolution of the laws of the universe. We can discover the latter because they and our minds have evolved in the same way. Peirce called this 'evolutionary love'.[168]

Hacking's Peirce came to these ideas as '[h]is working days of experimental routine, and his voyages of the mind, took place in a new kind of world that his century had been manufacturing: a world made of probabilities'.[169] Peirce's pragmatist response to this world – finding organic homologies between the probabilistic world and the probabilistic mind – is part of Wallace Stevens's intellectual inheritance as a pragmatist poet, just as Mallarmé's poetic response to it – writing poetry in the form of hypothesis, and using the resources of classical tragedy and concrete poetry to think through stochasticity – is part of Stevens's Mallarméan inheritance. Stevens's nuanced grammar of supposition in lines such as: 'As if the air, the mid-day air, was swarming| With the metaphysical changes that occur, | Merely in living as and where we live' is, in part, a response to Mallarmé's 'as if' ('comme si') and therefore to Mallarmé's poetic grammar of probability.

In 'Imagination as Value' Stevens offers a clue as to what 'The this and that in the enclosures of hypotheses' is made out of:

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[167] Charles S. Peirce, *The Collected Papers of Charles Sanders Peirce*, *Vol. I*: *The Principles of Philosophy*, ed. by Charles Hartshorne and Paul Weiss (Cambridge, MA: Harvard University Press, 1931), §407.
[168] *The Taming of Chance*, pp. 205-214.
[169] *The Taming of Chance*, p. 201.

> In the statement that we live in concepts of the imagination before the reason has established them, the word 'concepts' means concepts of normality. Further, the statement that the imagination is the power that enables us to perceive the normal in the abnormal is a form of repetition of this statement. […] The two statements together imply that the instantaneous disclosures of living are disclosures of the normal.[170]

The 'normal' is a fundamentally statistical idea: it is a probabilistic concept, the organising device of the curve-landscape. The statement with which Stevens concludes 'Imagination and Value' – that the 'chief problems of any artist, as of any man, are the problems of the normal' – reoccurs throughout his essays and letters. In a letter of January 1940, he wrote:

> I have been interested in what might be described as an attempt to achieve the normal, the central. So stated, this puts the thing out of all proportion in respect to its relation to the context of life. Of course, I don't agree with the people who say that I live in a world of my own; I think that I am perfectly normal, but I see that there is a center. For instance, a photograph of a lot of fat men and women in the woods, drinking beer and singing Hi-li Hi-lo convinces me that there is a normal that I ought to try to achieve.[171]

It was a problem that Stevens had given up on earlier in his career: in a 1935 letter he had written that 'how to write of the normal in a normal way is a problem which I have long since given up trying to solve, because I never feel that I am in the area of poetry until I am a little off the normal. The worst part of this aberration is that I am convinced that it is not an aberration'.[172] Stevens's return to a commitment to the normal still frustrates him, as evident in the cruelty of his depiction of völkisch normality ('fat men and women in the woods, drinking beer') and in the ambivalence of his poetic treatment of the 'merely', the sufficient and the ordinary. The normal is a duty, for Stevens, an 'ought', a rule often best followed in the breaking of it: in deferral – 'that I ought to try to achieve' – and in deviation – by finding the normal in the apparently abnormal or exceptional, and by looking at the normal as if it were abnormal or exceptional. The word 'normal' is tied in three direct ways to the history of mathematical probability: it derives from *normalis*, which means made according to a square, right-angled, regular (and, in modern Latin, perpendicular); it has a demotic mathematical meaning (an average or a mean); and it has a particular statistical meaning in its adjectival form: the Gaussian normal curve. Indeed, even the word's apparently non-mathematical definitions (the usual state of things, constituting or conforming to type, ordinary, healthy) are probabilistic. The power of the normal, as Hacking points out, is that it stands at once for the indifferent average and for how things ought to be. With Comte, Quetelet and Galton, the normal 'became a soothsayer, teller of the future, of progress and ends. Normality is a vastly more important idea than determinism, but they are not

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170 *CPP*, p. 738.
171 Wallace Stevens, *Letters of Wallace Stevens*, ed. by Holly Stevens (Berkeley, CA: University of California Press, 1996), p. 352.
172 *Letters of Wallace Stevens*, p. 326.

unrelated. A story of the erosion of determinacy is also an account of the invention of normalcy'.[173]

Perceiving this prophetic normal was the proper work of social science for Comte, Quetelet and Galton, and of the imagination for Stevens: 'The imagination is the power that enables us to perceive the normal in the abnormal, the opposite of chaos in chaos'.[174] Poetry becomes one of the sciences of emergence: becomes the 'disclosure' of abstract rules and ruled spaces of normalcy – ideas of order – as they emerge from and are constituted in apparent chaos and apparent atomistic disorder. Poetry's work of emergence is at once a work of revelation and of composition: Stevens's claim that 'the instantaneous disclosures of living are the disclosures of the normal' is supplemented with the claim that 'when we speak of perceiving the normal we have in mind the instinctive integrations which are the reason for living'.[175] Disclosure and integration appear on the face of it to be opposing kinds of poetic work and to rely upon opposing theories of truth: disclosure as the act of making known, of revealing secret truths; and integration as the act of making whole, of creating new truths. Making known and making whole, however, unite in the poetic science of emergence because the art of combining diverse parts into a complex whole reveals the mechanisms by which the 'normal' and its ideas of order are *immanent* to abnormality and disorder. Stevens in 'Imagination as Value' has a theory of the normal that resembles, therefore, the statistical theory of how regularity is produced by irregularity – chaotic elements taken together produce and reveal laws – but he adds another layer to that theory: the immanence of those laws to what Stevens calls 'mind'. Mind, here, is made of pre-rational 'concepts of normality' that can be perceived by the imagination and produced in poetry as 'The outlines of being and its expressings, the syllables of its law'.[176] For Stevens, as for C. S. Peirce, the normal curve is a psychological reality, is immanent to mind.

In 'A Quiet Normal Life', Stevens details the epistemic space of a normal mind: the experience of normalistic subjectivity.

> His place, as he sat and as he thought, was not
> In anything that he constructed, so frail,
> So barely lit, so shadowed over and naught,
>
> As, for example, a world in which, like snow,
> He became an inhabitant, obedient
> To gallant notions on the part of cold.
>
> It was here. This was the setting and the time
> Of year. Here in his house and in his room,
> In his chair, the most tranquil thought grew peaked

[173] Hacking, *The Taming of Chance*, pp. 160-161.
[174] *CPP*, p. 737.
[175] *CPP*, p. 738.
[176] *CPP*, p. 365.

> And the oldest and the warmest heart was cut
> By gallant notions on the part of night –
> Both late and alone, above the crickets' chords,
>
> Babbling, each one, the uniqueness of its sound.
> There was no fury in transcendental forms.
> But his actual candle blazed with artifice.[177]

The man's imagined submission to the natural laws of an imagined possible world ('a world in which, like snow, | He became an inhabitant, obedient') gives way to an obedience to the blunt, present actuality of the 'quiet normal life' ('here', 'This', 'Here'). That quiet normal life is never simply blunt actuality: its aspects are abstract, imagined values – 'his actual candle blazed with artifice' – and their perception creates modal possibilities, possible worlds: 'The poet', Stevens writes in 'Reply to Papini', 'increases the aspects of experience, | As in an enchantment'.[178] The relationship between individuality and law, between this man 'late and alone' and a communal, complex whole is figured as that between the single cricket's noise ('the uniqueness of its sound') and the 'chords' of the whole. The chords of ordered normal of life are present here not as 'transcendental forms' but as immanence: as the presence of 'artifice' in the 'actual' and the relational community in the imagination of a solitary mind. To Daniel Albright's posited categories of modernist 'quantum poetics', 'wave-poetics' and 'particle-poetics', might be added 'curve-poetics'.[179] Curve-poetics refers not to poetic responses to the idea of the curvature of space, but to poetic responses to what Jürgen Link calls the 'normalistic curve-landscape': to the *Gaußoidkurve* (Link's generalised 'symbolic Gauss-like curve'), to the physics of masses read as a physics of crowds, to statistical normality as both imperative and map, and to societies organised as insurance systems and underwritten by the law of large numbers and the normal curve.[180] As such, curve-poetics can help us to understand how mathematical ideas are experienced as collective symbolism: how, in other words, cultural concepts mediate between the scale of statistics (in which the individual is insignificant) and individual experiences of statistical ideas (what Link calls 'normalistic subjectivity'). Link defines normalistic subjectivity as 'a phenomenon that is "stretched out on curves" and whose subjective fates generate themselves on the bases of occurrences of the curve-landscape' and therefore for whom the curve-landscape 'serves as a field for orienteering, exploration, and experience – even as a complete living space and world'.[181] Link finds a literary form of his idea in the fever curves of Thomas Mann's *The Magic Mountain*. In

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[177] *CPP*, pp. 443-444.
[178] *CPP*, p. 383.
[179] Daniel Albright, *Quantum Poetics: Yeats, Pound, Eliot, and the Science of Modernism* (Cambridge: Cambridge University Press, 1997).
[180] Jürgen Link, 'The Normalistic Subject and Its Curves: On the Symbolic Visualization of Orienteering Data', trans. by Mirko M. Hall, *Cultural Critique* 57 (Spring 2004), 47-67 (p. 47)
[181] 'The Normalistic Subject', p. 59.

The Magic Mountain, the fever curve is experienced as simultaneous tightening and expansion of the time of life:

> The only unit it was possible to regard with seriousness was the smallest one of all: those seven times sixty seconds during which one held the thermometer between one's lips and continued one's curve – they, indeed, were full of matter and tenacious of life; they could expand into a little eternity; they formed small concretions of high density within the scurrying shadows of time's general course.[182]

Link's idea of phenomenological subjectivity – that, crudely put, we live in and through a collective system of symbolic abstractions such as 'normality' – is in fact quite similar to Stevens's idea in 'Imagination as Value' that we live in 'concepts of normality' and that, consequently, 'the instantaneous disclosures of living are disclosures of the normal'. The intimate, structural connection Stevens perceives between different registers of normality, different ideas of order – mathematical, physical, social, poetic and psychological – is key to his poetic phenomenology of probability. Simon Critchley, who defines phenomenology as 'a description of things as they are that seeks to elicit the sense or significance of our practical involvement with the world', thinks of Stevens's 'intricate evasions of as' in dialogue with Merleau-Ponty's recognition that 'we are condemned to meaning'.[183] In Stevens's poetry, 'the world shows itself as a place in which we are completely immersed and from which we do not radically distinguish ourselves: "Real and unreal are two in one"'.[184] To Critchley's analysis might be added the phenomenological account of the biological 'normal' given by Georges Canguilhem in his 1942 *Le Normal et le pathologique*. Life, writes Canguilhem, 'is not indifferent to the conditions in which it is possible, that life is polarity and thereby even an unconscious position of value; in short, life is in fact a normative activity'.[185] Canguilhem rewrites the history of biology as a discontinuous history of error because for Canguilhem, as Foucault remarked, 'life is what is capable of error'.[186] Those errors become norms because: 'Normal man is normative man, the being capable of establishing new, even organic norms. A single norm in life is felt privately, not positively […] the normal is not so much the old as the new form, if it finds conditions of existence in which it will appear normative'.[187]

Stevens's treatment of normality in his poems is illuminated when considered as part of a general phenomenology and a phenomenology of probability in particular: through the two-in-

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[182] Thomas Mann, *The Magic Mountain*, trans. by H. T. Lowe-Porter (London: Random House, 2011), p. 286.
[183] Simon Critchley, *Things Merely Are: Philosophy in the Poetry of Wallace Stevens* (London: Routledge, 2005), pp. 28-9.
[184] Critchley, *Things Merely Are*, p. 29.
[185] Georges Canguilhem, *On the Normal and the Pathological*, trans. by Carolyn R. Fawcett and ed. by Robert S. Cohen (Dordrecht: D. Reidel, 1978), p. 70.
[186] Michel Foucault, 'Introduction', Georges Canguilhem, *On the Normal and the Pathological*, trans. by Carolyn R. Fawcett, ed. by Robert S. Cohen (Dordrecht: D. Reidel, 1978), pp. ix-xxi (p. xix).
[187] *On the Normal and the Pathological*, p. 79.

oneness of real and unreal, Stevens is able to explore the implications of life in the landscape of the curve. 'The Bouquet' traces the ways in which abstractions are lived in and with and through:

> One enters, entering home,
> The place of meta-men and para-things,
>
> And yet still men though meta-men, still things
> Though para-things; the meta-men for whom
> The world has turned to several speeds of glass
> […]
> The infinite of the actual perceived,
> A freedom revealed, a realization touched,
> The real made more acute by an unreal.[188]

As Charles Altieri argues, abstraction and normalcy are linked in Stevens because '[a]bstraction is the cutting away of the specific contents of value in order to focus on the qualities that constitute how we value' and Stevens's poetry, for Alteiri, is a phenomenology of value, in which values are understood as 'aspects of states of being'.[189] Stevens's poetry is therefore less a celebration of 'the actual conditions of ordinariness than the discipline of imagination that makes valuing inseparable from recognizing what is involved in fully participating within conditions of "normality"'.[190] Here, Stevens again resembles Peirce, whose philosophy of evolutionary love rests on the belief that, as he put it, 'the very origin of the conception of reality shows that this conception essentially involves the notion of a COMMUNITY, without definite limits, and capable of a definite increase of knowledge'.[191] This community is a conditional future perfect: it exists in the same modal space as the 'would be' of a die in the propensity theory of probability. Stevens's own poetic mathematics both expresses and addresses a similar community. Helen Vendler comments that '[i]n *Local Objects*, as in so many other poems, Stevens experiments with writing what might be called an algebraic statement into which each reader can substitute his own values for *x* and *y* (in this poem, one's own cause for a rupture with the past and one's own precious local objects)'.[192] Two key aspects of Stevens's intellectual life, insurance and phenomenology, therefore unite in his theory of the value of poetry as the conversion of 'ominous and destructive circumstances' into 'a different, an explicable, an amenable circumstance'. Stevens's hypotheses are, when viewed in the light of his pragmatist

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188 *CPP*, pp. 384-6.
189 Charles Altieri, *Wallace Stevens and the Demands of Modernity: Towards a Phenomenology of Value* (Ithaca, NY: Cornell University Press, 2013), p. 35, p. ix.
190 Altieri, *Wallace Stevens and the Demands of Modernity*, p. 244n.
191 Charles S. Peirce, *The Collected Papers of Charles Sanders Peirce, Vol. V: Pragmatism and Pragmaticism*, ed. by Charles Hartshorne and Paul Weiss (Cambridge, MA: Harvard University Press, 1934), § 311.
192 Helen Vendler, *Wallace Stevens: Words Chosen Out of Desire* (Cambridge, MA: Harvard University Press, 1984), p. 8.

phenomenology, performative speech acts. Or, as Stevens puts it in 'Men Made Out of Words': 'Life consists | Of propositions about life'.[193]

Mallarmé's hypothetical poetry and Peirce's 'would-be' community unite as Stevens finds agency in aspectual thinking: in the poetic habit of 'seeing as'. Stevens describes the transformative potential of phenomenological poetry in commonplace, everyday terms. Of Peirce's three causal forces, chance, law and habit, Stevens is most interested in the last: in our habitual abstractions. The phrase, 'this and that', which Stevens uses for the inhabitants of hypothetical worlds, is a phatic commonplace of small talk, after all. Stevens uses the word 'dithering' for this phenomenological 'two-in-oneness'. The titular 'Bouquet' is 'a part of a dithering: | Cloud's gold, of a whole appearance that stands and is', while in 'Prologues To What Is Possible', the hypothetical mariner finds that it is:

> As if all his hereditary lights were suddenly increased
> By an access of color, a new and unobserved, slight dithering,
> The smallest lamp, which added its puissant flick, to which he gave
> A name and privilege over the ordinary of his commonplace –
>
> A flick which added to what was real and its vocabulary,
> The way some first thing coming into Northern trees
> Adds to the whole vocabulary of the South,
> The way the earliest single light in the evening sky, in spring,
> Creates a fresh universe out of nothingness by adding itself,
> The way a look or touch reveals its unexpected magnitudes.[194]

The 'as if' here, like Mallarmé's 'comme si', has an extraordinary world-making power, an ability to generate whole poetic worlds out of a 'slight dithering'. With both Stevens and Mallarmé the character of the mariner is performing the colloquial meaning of dithering – vacillating or wavering indecisively between different courses of action – and choosing to remain in a virtual sample space, in the epistemic space of 'what is possible'. However, with Stevens that dithering isn't just epistemic: it is also a state or aspect of matter. The imagination, Stevens writes in 'Imagination as Value', 'is the power of the mind over the possibilities of things; but if this constitutes a certain general characteristic, it is the source not of a certain single value but of as many values as reside in the possibilities of things'.[195] Stevens here filters a Romantic idea of dynamic, ontic, generative mind through the terms of his probabilistic world. Dithering's original meaning – to tremble, quake, quiver, thrill; as a state, therefore, of matter and of bodies – is brought into lived equivalence with its colloquial meaning relative to epistemic uncertainty:

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193 *CPP*, p. 310.
194 *CPP*, p. 387; pp. 438-439.
195 *CPP*, p. 726.

epistemic and objective states of dithering blend into one another in the poem's pragmatist curve poetics.

Stubborn Physics

Wallace Stevens concluded his 1951 Moody Lecture at the University of Chicago with an elegy to a man who 'died only four years ago at Göttingen, at the age of ninety': the physicist Max Planck.[196] Planck was, Stevens declared, 'a symbol of ourselves'. He was also a poet. 'It is unexpected', Stevens said, 'to have to recognize even in Planck the presence of the poet. It is as if in a study of modern man we predicated the greatness of poetry as the final measure of his stature, as if his willingness to believe beyond belief was what had made him modern and was always certain to keep him so'.[197] Planck will remain eternally modern because his modernism is detachment or dissent from the actual conditions of modernity in which he lived. The nature of Planck's dissent, as filtered through Stevens's encounter with him in the French literary press, is a refusal to accept the indeterminism of the world of probabilities. Like C. S. Peirce, Planck witnessed the emergence of a fully stochastic world. Yet Planck still sought in apparently stochastic phenomena evidence of determinism at work: signs, so to speak, of determinism's slow epiphany.

Stevens's lecture took his readers on a journey: he was searching for what he called the 'poetry of philosophers'. Some concepts, for Stevens, seemed to be inherently poetic: the 'idea of the infinity of the world', for example, which led Bruno to 'somewhat furious poetry'.[198] Leibniz and his 'world of monads' presented a more ambivalent case: in the end, Stevens decides that Leibniz 'was a man who thought like a poet but did not write like one'.[199] Contemporary philosophy poses a problem for Stevens's quest and, at the advice of Jean Paulhan, he turns to the contemporary philosophy of science.[200] Stevens quotes from Paulhan's response to the twin problems of the erosion of determinism and the poetics of philosophy:

> It is to be admitted, since Planck, that determinism – the relation of cause to effect – exists, or so it seems, on the human scale, only by means of an aggregate of statistical compensations and as the physicists say, by virtue of macroscopic approximations. (There is much to dream about in these macroscopic approximations.) As to the true

196 Wallace Stevens, 'A Collect of Philosophy', Moody Lecture delivered at the University of Chicago, 16 November 1951, in *CPP*, pp. 850-867 (p. 866).
197 *CPP*, p. 867.
198 *CPP*, p. 857.
199 *CPP*, p. 853.
200 Stevens justified this turn with an odd rhetorical formulation in a letter to Barbara Church: 'The philosophy of the sciences is not opposed to poetry any more than the philosophy of mathematics is opposed' (*The Letters of Wallace Stevens*, p. 726).

> nature of corpuscular or quantic phenomena, well, try to imagine them. No one has yet succeeded. But the poets – it is possible.[201]

Physics and the philosophy of physics have stalled, in Paulhan's view, because they lack poetry. Poetry resides in hypotheses:

> philosophers (particularly the philosophers of science) make, not discoveries but hypotheses that may be called poetic. Thus Louis de Broglie admits that progress in physics is, at the moment, in suspense because we do not have the words or the images that are essential to us. But to create illuminations, images, words, that is the very reason for being of poets.[202]

Stevens chose not to grapple with the task of creating a poetics of quantum theory.[203] In a letter dated 20 August 1951, he wrote: 'Jean Paulhan isolates the philosophy of the sciences. The quantum theory to which he refers is not a thing to be assimilated offhand. But I love his "approximations macroscopiques" and must think how to use them together with Jean Wahl's fausses reconnaissances. Is not the idea of the hero an "approximation macroscopique"?'[204]

Stevens was delighted with the idea of 'approximation macroscopique'. Indeed, Stevens's musing draws attention to the kinship between his poems and the scientist's tools of perception: their microscopes, magnifying glasses, projectors and telescopes. In 'Examination of the Hero in a Time of War', Stevens explores the phenomenology of heroism:

> If the hero is not a person, the emblem
> Of him, even if Xenophon, seems
> To stand taller than a person stands
> […]
> And if the phenomenon, magnified, is
> Further magnified, sua voluntate,
> Beyond his circumstance, projected
> High, low, far wide, against the distance,
> In parades like several equipages,
> Painted by mad-men, seen as magic.[205]

In 'Things of August', meanwhile, we see the hero on another scale:

> When was it that the particles became
> The whole man […]
> […] leaving an outline of the size
> Of the impersonal person, the wanderer,
> The father, the ancestor, the bearded peer,

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[201] Stevens, *CPP*, p. 861.
[202] Jean Paulhan, quoted by Stevens in *CPP*, p. 861.
[203] Joan Richardson nonetheless makes the case for a connection between Stevens's poetry and quantum theory in *A Natural History of Pragmatism: The Fact of Feeling from Jonathan Edwards to Gertrude Stein* (Cambridge: Cambridge University Press, 2007).
[204] *The Letters of Wallace Stevens*, p. 725.
[205] *CPP*, pp. 247-48.

> The total of human shadows bright as glass.[206]

Scale and magnification are both metaphor and method in 'A Collect of Philosophy'. Despite the fact that the philosopher of science 'intends his integration to be fateful', while 'the poet intends his to be effective', Stevens writes that 'these integrations […] have something in common, such as, say, a characteristic of the depth or distance at which they have been found, a facture of the level or position of the mind or, if you like, of a level or position of the feelings'.[207] This commonality, though, is visible only at a certain scale:

> If the philosopher's world is this present world plus thought, then the poet's world is this present world plus imagination. If we think of the philosopher and the poet as raised to their highest exponents and made competent to realize everything that the figures of the philosopher and the poet, as projected in the mind of their creator, were capable of or, in other words, if we magnify them, what would they compose?[208]

Under these conditions of 'extreme magnifying', the poet and the philosopher 'could not compose the same thing' – their difference would be revealed – yet Stevens believes they would still share a crucial idea: 'the idea of creating confidence in the world'.[209] Stevens extracts this phrase, 'confidence in the world', from a phrase of Paulhan's ('*la confiance que le poète fait naturellement – et nous invite à faire – au monde*') and writes:

> When we look over the shoulder of Jean Paulhan, in Paris, while he writes of "*la confiance … au monde*" and stop to consider what a happy phrase that is, we wonder whether we shall have the courage to repeat it, until we understand that there is no alternative.[210]

The philosopher's confidence is a confidence in things as they will be deduced from things as they are – Socrates's 'confidence in the immortality of what was really Socrates was no less a confidence in the world, in which he reclined and spoke, a hostile and a fatal world' – while that of the poet 'might be a more immediate certainty'.[211] The poet's confidence, in other words, is a confidence in things as they are: a performative surety.

It is, however, the unreal ground of his confidence in determinism that makes Max Planck a poet. In the matter of the poetry of modern philosophy, Planck 'is a more significant figure for us than the remote and almost fictitious figure of Pascal'. Stevens draws the evidence for this judgement from an article by André George, the French translator of Planck's *Scientific*

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[206] *CPP*, p. 421.
[207] *CPP*, p. 862.
[208] *CPP*, p. 864.
[209] *CPP*, p. 864.
[210] *CPP*, p. 865.
[211] *CPP*, pp. 864-65.

Autobiography. Stevens picks from George's article his remarks on the last few pages of one of the papers in the *Scientific Autobiography*, 'The Concept of Causality in Physics':

> The last pages of the thesis are quite curious. One feels there, as it were, a supreme hesitation; the believer henceforth is no longer able to conceal a certain trouble. The most convinced determinist, Planck declares, in so many words, is not able to satisfy himself entirely with such an interpretation.[212]

In order to try to understand that trouble and why, for Stevens, it is poetic, I will sketch out both Planck's argument and the contexts mediating Stevens's reception of it.

Planck's essay begins with two propositions. The first is a definition of causality in physics: '*An occurrence is causally determined if it can be predicted with certainty*'. The second is an empirical principle that undercuts this definition: '*It is never possible to predict a physical occurrence with unlimited precision*'.[213] There are two ways to proceed from this contradiction: either the definition of causality is retained in its exact wording, and strict causality is abandoned as impossible; or the definition is taken to refer not to occurrences in nature, but to another genre of 'occurrences' in another kind of world. The former way out is that taken, in Planck's account, by the indeterminists:

> They claim that genuine causality, strict regularity, actually does not exist in nature but is merely an illusion created by the operation of certain rules which are never of an exact validity, even though they often come very near to it. Upon closer consideration, the indeterminist discovers a statistical root in every law of physics, including the law of gravity and of electrical attraction; he regards them, one and all, as laws of probability, relating only to mean values of many similar observations, possessing only an approximate validity for individual instances.[214]

The indeterminist, in other words, sees nature as fundamentally stochastic and as such 'ruled' only by statistics. The indeterminist's world operates 'analogously' with the kinetic gas laws. In this interpretation, physics ought to be based on 'the calculus of probabilities'. This statistical theory of nature is that summarised by Jean Paulhan and quoted in Stevens's 'A Collect of Philosophy': 'It is to be admitted, since Planck, that determinism – the relation of cause to effect – exists, or so it seems, on the human scale, only by means of an aggregate of statistical compensations and as the physicists say, by virtue of macroscopic approximations'.[215] Paulhan and the French literary press mediate the version of the philosophy of physics that reaches Wallace Stevens: that Stevens thinks with and borrows from. Paulhan was director of the *Nouvelle*

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[212] *CPP*, p. 866.
[213] Max Planck, 'The Concept of Causality in Physics', in Max Planck, *Scientific Autobiography and Other Papers*, trans. by Frank Gaynor (New York: Philosophical Library, 1968), pp. 121-151 (pp. 122-4).
[214] 'The Concept of Causality in Physics', pp. 125-6.
[215] As quoted in Stevens, *CPP*, p. 861.

Revue Française from 1925-1940, and from 1946 to 1968. During his tenure as director, the *Revue*'s science section published articles on the philosophy of physics. Paulhan's remarks on the state of the discipline draw particularly on Louis de Broglie's article 'Réflexions sur l'indéterminisme en physique quantique'.[216] De Broglie's 1924 thesis *Recherches sur la théorie des Quanta* shaped the field of wave mechanics: he extended the wave-particle duality of light to all matter. Wave-particle duality is the theory that all particles also have the properties of waves, and all waves also have the properties of particles.[217] Against the Copenhagen interpretation of the wave-function, in which the measurement process actualises one of the possibilities of a state's wave-function according to that state's probability, de Broglie proposed that a configuration of that state pre-exists measurement and is causally determined. His essay in the *Nouvelle Revue* is, like Planck's 'The Concept of Causality in Physics', concerned with how the definition of causal determination must be modified in order to be retained for quantum physics. For the physicist, de Broglie writes, determinism is attendant on 'the possibility of predicting exactly future phenomena from data extracted from past or present observations'. Determinism so defined no longer exists in quantum physics at the level of individual phenomena: the idea can be retained for 'statistical phenomena' as a result of the 'laws of probability', but cannot be retained for elementary quanta. By adopting a broad definition of causality under the old saying 'Sublata causa, tollitur effectus' (the cause being removed the effect ceases), de Broglie is able to retain causality for quantum physics. Despite his desire to retain determinism, and his hope that future physicists will find the determinism underpinning the microscopic world of quantum physics, that determinism-to-come remains a 'metaphysical hypothesis, an act of faith'. De Broglie ends, like Planck, with a sceptical faith in the future slow epiphany of determinism.

The terms of Planck's sceptical faith, however, are different. Where de Broglie retains causality by lessoning the burden of predictive proof, Planck describes an alternative – and a dominant alternative, in his view – method of modulating the concept of causality: building a world in which occurrences can be predicted with certainty. This world, the 'world picture of physics', is, Planck writes, 'a conceptual structure, arbitrary to a certain degree, created for the purpose of getting away from the uncertainty involved in every individual measurement and for making possible a precise interrelation of concepts'.[218] Objects from the 'sense world' are 'translated' into symbols, and these symbols relate to one another in a manner that is strictly causally determined. This symbolic world is a source of consolation. The uncertainty of

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[216] Louis de Broglie, 'Réflexions sur l'indéterminisme en physique quantique', *La Nouvelle Revue Française*, 289 (1937), 644-650.

[217] Planck generalised Einstein's formula '$E = hf$' (where E is the total energy of a light particle, h is Planck's constant and f is the frequency of the light) and related the wavelength λ to the momentum p of a particle such that $\lambda = h/p$. See Louis de Broglie, *Recherches sur la théorie des Quanta* (doctoral thesis, University of Paris, Faculté des Sciences, 1924), <tel-00006807>.

[218] 'The Concept of Causality in Physics', p. 128.

measurement becomes the uncertainty of translating back and forth from the 'sense world' and the 'world picture'. The translator's doubt became translation's impossibility with Heisenberg's uncertainty principle, which, as Planck writes, 'fundamentally precludes the possibility of translating into the sense world, with an arbitrary degree of accuracy, the simultaneous values of the coordinates and momenta of material points, as these are conceived in the world picture of classical physics'.[219] A 'new world picture of quantum mechanics' was required to take the place of the fracturing world-picture of classical physics: the wave replaced the point as the building block of the physicist's world. However, the terms of the Copenhagen interpretation of quantum physics meant that the entire measurement apparatus of physics, including the physicists themselves, had to be translated into the new world-picture alongside the things they measured because the interaction between micro-entities and experimenters was now believed to disturb the wave function of those micro-entities.

Stevens empathised with Planck's translation problems as detailed in 'The Concept of Causality in Physics' perhaps because he had translation problems of his own: a tendency to make poetics, to make the theory of poetry, into the proper ground of poetry. The severe master of 'An Ordinary Evening in New Haven', tasked with improvising 'Subtler, more urgent proof that the theory | Of poetry is the theory of life', is in a position loosely analogous to that of Planck's determinist, tasked with mapping between the world-picture of physics and the sense world.[220] As Stevens allocates the task to the master, a poetic character, so Planck defers, at the end of his essay, to an 'ideal intellect' that could resolve the problems of translation and predict all occurrences with a certainty that would prove strict determinism. Where Planck's first attempt to escape the aporia of his contradictory propositions was to alter the object of prediction (the occurrence), his second means of escape, which Stevens reads as a poetic escape, is to alter the subject doing the predicting. By positing his ideal intellect, Planck transmutes what the indeterminists read as ontic or physical probabilities into epistemic probabilities: matters of the physicist's limitation rather than of matter itself.

The terms through which Stevens describes Planck as a poet, 'final measure' and 'belief beyond belief', place 'A Collect of Philosophy' with those poems by Stevens in which he grapples with the idea of a 'final belief'. 'Asides on the Oboe', in 1942's *Parts of a World* opens with a strange negative theology:

> The prologues are over. It is a question, now,
> Of final belief. So, say that final belief
> Must be in a fiction. It is time to choose.[221]

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[219] 'The Concept of Causality in Physics', pp. 133-4.
[220] *CPP*, p. 415.
[221] *CPP*, p. 226

The construction 'So, say' shifts the ground of final belief to hypothesis. The hypothetical ground of belief might be followed through 'Flyer's Fall', which traces the conceptual architecture of the afterlife ('Profundum, physical thunder, dimension in which | We believe without belief, beyond belief') and 'The Pure Good of Theory':

> Yet to speak of the whole world as metaphor.
> Is still to stick to the contents of the mind
>
> And the desire to believe in a metaphor.
> It is to stick to the nicer knowledge of
> Belief, that what it believes in is not true.[222]

Planck's belief in the law of causality is, for him, necessary faith, and is 'beyond belief' in a double sense: it is an untimely attempt to retain belief in an idea of causality that had seemingly been demolished by indeterminism; and it is a belief in causality no longer as a matter of truth, but as a matter of value. Faith in a deterministic interpretation of causality is the necessary condition for scientific endeavour, and as such, Planck writes, 'must therefore be judged not on the score of its truth, but only on the basis of its value'.[223] This line in Planck's essay draws him closer to Stevens's idea of poetic value and of imagination as a valuable science of emergence, perceiving, to borrow terms from 'Imagination as Value', the opposite of chaos in chaos.

If Planck's 'belief beyond belief' in determinism allows him to replace Pascal as Stevens's paradigmatic modern poet-philosopher, that belief also draws Planck, in 'The Concept of Causality in Physics', closer to Pascal and back to the lineaments of the old concept of probability, with its roots tangled in Pascal's theology. The implicit religious aspect of Stevens's definition of poetry as an act of 'conversion' is teased out in 'A Collect of Philosophy': it is precisely Planck's conversion, the turn in his essay towards deism, that makes him a poet. Despite Planck's faith and his determinism, Simone Weil wrote Max Planck into her picture of modern physics as impious, aleatory and false. Weil reviewed Planck's *Initiations à la physique* for the *Cahiers du Sud*: 'commonplace, woolly and superficial', she concluded.[224] Weil condemns Planck for a series of sins: deducing his theory of 'quanta' from the study of a macroscopic phenomenon (black body radiation); remaining in thrall to algebra; reducing physics to arbitrary conventions and divorcing probability from necessity.

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[222] *CPP*, p. 291.
[223] 'The Concept of Causality in Physics', p. 147
[224] Simone Weil [as Emile Novis], 'Réflexions à propos de la théorie des quanta', *Cahiers du Sud*, 251 (1942), 102-119, translated as 'Reflections on Quantum Theory', in Simone Weil, *On Science, Necessity, and the Love of God*, ed. and trans. by Richard Rees (Oxford: Oxford University Press, 1968), pp. 49-65.

In Weil's account, modern physicists are a group of insular, squabbling villagers for whom 'algebraic consciousness', the manipulation of symbols, has erased the search for proportions that Weil idealises in her Pythagorean remarks on the Greek science of number:

> The blind necessity which constrains us, and which is revealed in geometry, appears to us as a thing to overcome; for the Greeks it was a thing to love, because it is God himself who is the perpetual geometer. From the flash of genius of Thales until the time when they were crushed by the armed force of Rome, they searched everywhere – in the regular recurrence of the stars, in sound, in equilibrium, in floating bodies – for proportions in order to love God.[225]

Max Planck and the physicists of his generation are a disappointment for Weil. She holds them accountable 'above all for their rupture with classical science'.[226] The terms of this rupture are unflattering to both classical and modern science: classical science 'claimed to resolve the contradictions, or rather the correlations of contraries, which are integral to the human condition and from which man is forbidden to release himself'. Experience is given to us as both continuous and discontinuous: 'we think both in terms of space and of number'. Classical science attempted to 'suppress the discontinuous, so inevitably it stumbled over it and the shock was felt at the very centre of physics'.[227]

Planck stumbled over algebra and the stuttering of his numbers fractured energy into quanta and probability into a 'résumé' of clamouring statistics.[228] 'One is temped to ask', she writes, 'whether it was not the very nature of the calculation of probabilities – which starts from the game of dice and consequently from numerical relations – which led Planck to introduce whole numbers into his formulae'.[229] In Weil's view, the second law of thermodynamics led to probability's imperialism in physics 'by the simple notion that the passage from a more probable to a less probable state is practically irreversible'. Weil explains notion by drawing an analogy with a version of the cut-up technique: 'If one shuffles the printed characters of a verse of Valéry, they will be in a state of disorder; and if one shuffles them again a great many times they will not recompose a verse of Valéry'. Boltzmann and Planck were 'unembarrassed by the difficulty of using the idea of probability as a bridge between the world as it is given to us and the hypothetical and purely mechanical world of atoms'. These unembarrassed men introduced

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[225] Simone Weil, 'Classical Science and After', translation of *La science et nous*, 1941, in *On Science, Necessity and the Love of God*, pp. 3-44 (p. 21). For the theological and mystical valences of Weil's image of mathematics, see Vance Morgan, *Weaving the World: Simone Weil on Science, Necessity, and Love* (Notre Dame, IN: Notre Dame University Press, 2005) and Joseph K. Cosgrove, 'Simone Weil's Spiritual Critique of Modern Science: An Historical-Critical Assessment', *Zygon*, 43.2 (2008), 353-370..

[226] In fact, as historians of physics such as Needell, Darrigol and Staley have shown, 'classical' and 'modern' physics were created at the same moment, during the first decade of the twentieth century: 'Classical physics' is a retrospective idealization. See Richard Staley, *Einstein's Generation: The Origins of the Relativity Revolution* (Chicago: University of Chicago Press, 2008).

[227] Weil, 'Reflections on Quantum Theory', pp. 59-60.

[228] 'Reflections on Quantum Theory', pp. 60-61.

[229] 'Reflections on Quantum Theory', p. 53.

probability 'among the atoms themselves. Thus the trajectories of atomic particles are no longer called necessary but probable, and there is no necessity anywhere'. The concept of probability upon which statistical mechanics rests is, therefore, an empty, rootless conceptual structure: 'Divorced from necessity, probability is no more than a résumé of statistics, and the only justification of statistics is practical utility; a thousand facts prevail over one fact, on the analogy of election by plebiscite. So there is nothing left but raw experience'.[230] For Weil, probability's modernisms – its imperialist world making and its axiomatisation – have torn down the very conceptual architecture of the concept of probability. Weil's 'Reflections on Quantum Theory' is an attempted amodern unravelling of the world made out probabilities in which modern literature is embedded (albeit, as I have emphasised, in diverse, subtle ways that often take the form of resistance) and through which it must be read.

[230] 'Reflections on Quantum Theory', p. 61.

CONCLUSION

The history of mathematics as told by Simone Weil is a history of errors. Or, more precisely, it is a history of one error spreading, unfolding and pooling into mistakes. Physics, Weil writes in 'Classical Science and After', 'is essentially the application of mathematics to nature at the price of an infinite error'.[1] Applied mathematics, for Weil, was fallen mathematics. The modern physicist trades meaning for technique: reducing nature to its symbolic, mathematical representation and, in the process, corrupting mathematics. She described true mathematics as a pure, self-contained, axiomatic system:

> The fact is that to give oneself a perfectly closed system, which nothing is allowed to enter, with a limited number of perfectly defined conditions, and then to try to see what necessities and what impossibilities it reveals, is to practice mathematics.[2]

Simone Weil's brother, André Weil, was one of the founding members of Bourbaki. Although her image of mathematics lacks Bourbaki's playfulness, it is suffused with Bourbaki's (public) desire for purity and corresponding disdain for applied mathematics (indeed, Bourbaki excluded probability from their *Éléments de mathématique*) and for visualisation. When asked about the lack of diagrams or visual illustrations in Bourbaki's published work, Pierre Cartier said: 'The Bourbaki were Puritans, and Puritans are strongly opposed to pictorial representations of their faith'.[3] The physicists' mistake (conflating nature with its symbolic representation) was an amplification of an error that was already implicit in mathematics: 'its need of objects or images'.[4] Mathematics requires representation: the drawing of geometrical diagrams or the writing out of proofs. Simone Weil lamented this need:

> If I see two stars I think of a straight line joining them – the purest possible line, because it is not drawn; but the two stars, larger than our world, are far from being points. By pressing a chalk against a blackboard I obtain – for this time it is not a question of scale – something that differs abysmally, infinitely, from a straight line. The relation consists in this: that the chalk on the blackboard allows me to imagine a straight line.[5]

Prelapsarian mathematics – an abstract, perfect atemporal world – is undone by the need to scratch your figures in chalk: to inscribe your proof on a blackboard. The image of Simone Weil

[1] Simone Weil, 'Classical Science and After', in Simone Weil, *On Science, Necessity, and the Love of God*, ed. and trans. by Richard Rees (Oxford: Oxford University Press, 1968), pp. 3-44 (p. 34).
[2] Weil, 'Classical Science and After', p. 34.
[3] 'The Continuing Silence of Nicolas Bourbaki', p. 27.
[4] Weil, 'Classical Science and After', p. 32.
[5] Weil, 'Classical Science and After', p. 32.

with chalk in hand brings me back to where I started: to Young Törless standing, disappointed, in his maths teacher's shabby, smelly study.

Young Törless's disappointment captures only one of the many valences of literature's engagement with mathematics. Literature and mathematics interact in an uneven, episodic and wayward manner. There is no determinism here and there are no pervasive structural homologies. Yet there have been entanglements, intersections and borrowings. Mathematics has been an abundant cultural resource for modern literature, and our understanding of literary culture is enriched by explicit consideration of this borrowing. Literature, too, has its own mathematical idioms or vernaculars – its own styles of writing about and using mathematics – with their own genealogies. Moreover, literature offers resources for a phenomenology of the modern mathematical habitus or 'mathesis': of the numbers, equations, graphs and models that are immanent to experience. From the bookkeeper recording their profits and losses in a daybook to the Wall Street 'quant' building derivative pricing models, the modern mathesis encompasses a vast, dispersed and diverse array of calculative and numerical practices.[6]

In *Mathematics: (a novel)*, Jacques Roubaud, inspired by a line from Gertrude Stein, asked: 'If a book is the autobiography of its title, then […] what sort of life of mathematics will this be?'[7] The life of mathematics I have told in this thesis might, as I suggested in the introduction, be imagined as radiation from a centre: from the discipline of pure mathematics to the mathematics of everyday experience. I began with some of the stories that mathematicians have told about their discipline and about what it might mean to live a mathematical life. I followed the stories of mathematicians, mathematical ideas and mathematical practices out of their disciplinary habitus and into literature. I ended mired in the quotidian practices of the mid-twentieth century 'mathesis', analysing literary responses to the quantified world.

Yet sociologists and anthropologists have taught us to be suspicious of apparently clear-cut boundaries between pure theory and application. Calculation, in Michel Callon's account, is a dynamic process of framing and overflowing.[8] First, Callon writes: 'if calculations are to be performed and completed, the agents and goods involved in these calculations must be disentangled and framed'.[9] Prices must be agreed upon, objects treated as homogenous abstractions and local particularities set aside to create a standardised system of value within which exchanges can take place. However, Callon points out, those pruned relations and entanglements have a tendency to grow back and to erode the boundaries of the calculative

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[6] For one account of the affective life of a 'quant' and his models, see Emanuel Derman's memoir, *My Life as a Quant: Reflections on Physics and Finance* (Hoboken, NJ: Wiley, 2004).
[7] Jacques Roubaud, *Mathematics: (a novel)*, trans. by Ian Monk (London: Dalkey Archive Press, 2012), p. 41.
[8] Michel Callon, 'An Essay on Framing and Overflowing: Economic Externalities Revisited by Sociology', in Michel Callon, ed., *The Laws of the Markets* (Oxford: Blackwell, 1998), 244-270.
[9] Michel Callon, 'Introduction: The Embeddedness of Economic Markets in Economics', in Callon, ed., *The Laws of the Markets*, 1-58 (p. 16).

frame. For the calculation to be performed, new frameworks of measurement must be devised and negotiated that can take the overflows into account. The original French title of Jacques Roubaud's *Mathematics: (a novel)* was '*Mathematique:*'. With that colon, Roubaud hinted at the 'sort of life' that mathematics would lead in his book: a life that he, like Callon, thought of in terms of 'embeddedness'.[10] Roubaud's memoir explored the embedding of mathematics – particularly of Bourbaki's axiomatic, formalised mathematics – in narrative, in memory, in literature and in the lives of Roubaud and his fellow mathematics students. Embedding, interlocking and percolating are some of Roubaud's favourite metaphors and favourite narrative techniques. Mathematics, in Roubaud's memoir as in history, is an alloy: mixing with the local, the imagined and the literary and generating metaphors, images and ideas.

As Beckett's characters know all too well, we live in demotic mathematics as we do in language and in literature. Immediacy and everydayness are never transparent: they are structured by abstractions, often mathematical abstractions, which are themselves inscribed with history. Of course, the treatment of the interaction of literature and mathematics in this thesis has not been comprehensive. Indeed, if demotic mathematics is internal to literature, both as buried episteme and as subject, and demands attention as such, it can also be a mode of reading. By paying attention to repetition, frequency, unoriginality and dull, small, slow changes, Franco Moretti's 'distant reading' might allow us to read the code embedded in literary form. Literature is a mass phenomenon and, for Moretti, it is amenable to the same processes of quantitative analysis as any other mass phenomenon. Moretti argues that '[t]exts are real objects – but not objects *of knowledge*. If we want to explain the laws of literary history, we must move to a formal plane that lies beyond them: below or above; the device or the genre'.[11] Moretti's 'distant reading' constructs 'a new object of study: instead of concrete, individual works, a trio of artificial constructs – graphs, maps, and trees – in which the reality of the text undergoes a process of deliberate reduction and abstraction'.[12] Moretti explicitly embraces the fact that his method is built on artificial constructions. By emphasising its own artificiality, Moretti's methodology directs our attention to the constructed nature of all of our stages of research (categories, periods, abstractions, epistemic objects, genres, and so on). In Moretti's system, graphs model the system of narrative genres as a whole, maps model the 'road from birth to death' of particular chronotypes and trees model the microlevel of stylistic mutations. Certain phenomena can only be seen at a certain scale. Quantitative work is undeterred by boredom: a 'quantitative stylistics', Moretti argues, can 'take those units of language that are so frequent that we hardly notice them,

[10] Jacques Roubaud, *Mathematics: (a novel)*, p. 42.
[11] Franco Moretti, *Distant Reading* (London: Verso, 2013), p. 77.
[12] Franco Moretti, *Graphs, Maps, Trees: Abstract Models for Literary History* (London: Verso, 2007), p. 1.

and show how powerfully they contribute to the construction of meaning'.[13] Form, here, is that which repeats: that which can be counted.

Moretti was surprised by what he found when he began to measure literature. 'I assumed, like so many others, that the new approach would change the history, rather than the theory of literature', he said.[14] Quantitative reading often begins and ends with qualitative presuppositions: a set of categories or concepts are identified and translated into coding and indexing operations that can be used to test hypotheses on large datasets.[15] As such, computational methods and mediating devices like algorithms tend to embody the disciplinary knowledge structures they are embedded in. When Franco Moretti designed and deployed an algorithm to turn the literary-theoretical concept of 'character-space' into a series of operations to measure literary texts he did not, therefore, expect that the algorithm would threaten the underlying classificatory system of literary theory. Yet, set in motion, Moretti's algorithm seemed to him to be doing just that: reconfiguring the fundamental categories of literary studies. As texts were processed into networks of relational links between characters, established categories like 'protagonist' and 'minor character' gave way and a new set of categories emerged, classifying characters not by emphasis but by function (Moretti named these 'conflict', 'mediation' and 'obedience'). 'Measurement as a challenge to literary theory', Moretti remarked: 'This is not what I expected'.[16]

Mathematics has a new demotic. At the time of Bourbaki, 'algorithm' was a term employed in specialised fields: numerical analysis, philosophy of mathematics and the nascent computer science. Now, algorithms pervade daily experience: they are at least as interwoven with everyday life as arithmetic or geometry has ever been. Those algorithms make our world. The role of the algorithm in literature and literary studies can only grow: the simple algorithms that generate Moretti's statistical analyses are but a beginning.

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[13] Franco Moretti, 'Style, Inc.: Reflections on Seven Thousand Titles (British Novels, 1740-1850)', *Critical Inquiry*, 36.1 (2009), 134-158 (p. 156).
[14] Franco Moretti, '"Operationalizing": Or, the Function of Measurement in Literary Theory', *New Left Review*, 84 (2013), 103-119 (p. 113).
[15] Gregor Wiedemann gives a useful overview of various methods of computational text analysis and their discontents in 'Opening up to Big Data: Computer-Assisted Analysis of Textual Data in Social Sciences', *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 14.2 (2013).
[16] Moretti, '"Operationalizing"', p. 113.

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