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Mathematics in Literature

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Modernist Interrelations in Novels by
Thomas Pynchon, Hermann Broch, and Robert Musil

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Abstract

Mathematics in Literature – Modernist Interrelations in Novels by Thomas Pynchon, Hermann Broch, and Robert Musil

The focus of this thesis is on four novels' illustrations of the parallels and interrelations between the foundational crisis of mathematics and the political, linguistic, and epistemological crises around the turn to the twentieth century. While the latter crises with their climax in the First World War are commonly agreed to define modern culture and literature, this thesis concentrates on their relations with the 'modernist transformation' of mathematics as illustrated in Thomas Pynchon's *Against the Day* (2006) and *Gravity's Rainbow* (1973), Hermann Broch's *The Sleepwalkers* (1930-1932), and Robert Musil's *The Man without Qualities* (1930/32). In the revaluation of mathematics during its foundational crisis, the certainty and rationality of this most certain science is challenged, and the novels accordingly employ mathematics as an example for the dramatic transformation of the modern West, the wider loss of absolute truth, and the increasing scepticism towards Enlightenment values. Crisis, however, also implied some freedoms and opportunities for literature and criticism. When the developing modern notion of mathematics is defined by autonomy and independence from the natural world, it bears traits more commonly associated with literary fiction, and the novels examine the possible convergence of mathematics and literature in the freedom of imaginary existence. The novels thus highlight the unique position of the structural science mathematics in the relation of the (natural) sciences and the humanities and suggest it to escape or straddle the perceived divide between the disciplines. The examination and historicising of relations between fiction and mathematical conceptualisations of the world as introduced in the major works by Pynchon, Broch, and Musil thus also contributes to distinguishing the specific conditions of studying mathematics in fiction in the wider field of literature and science.

“I hereby declare that I am the sole author of this thesis; that the following thesis is entirely my own work; and that no part of this thesis has been submitted for another degree or qualification.”

Signed Edinburgh,

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To my Parents

Für meine Eltern

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All that Counts: Modern Mathematics and its Relation to Literature

'Mighty are numbers; joined with art, resistless'.[1] The quote from Euripides' play *Hecuba*[2] joins the two elements that are at the heart of the study 'Mathematics in Literature – Modernist Interrelations in Novels by Thomas Pynchon, Hermann Broch, and Robert Musil', and it expresses the pleasure resulting from the combination of mathematics and literature – domains that are often regarded 'as the opposite ends of a spectrum of disciplines' (Westfahl). The context of the quote reveals, however, that it neither refers to mathematics nor to literature, but is a threat that with cunning, Hecuba's numerous fellow Trojan women will help her 'master men' (Euripides 157) and avenge her son. In the figurative sense, the suggestion that number bears power also relates to the argument that is to follow: mathematics is generally regarded as 'among the most certain and true things we know' (Gray 'Anxiety' 27) and thus constitutes authoritative knowledge; yet, as the discussion of novels by Thomas Pynchon, Hermann Broch, and Robert Musil will illustrate, literature makes use of this privileged position of number and mathematics to further its own ends and in the course questions the established power structure of the disciplines.

The seemingly disparate domains of mathematics and literature can be looked at from different perspectives. This study is predominantly located on the side of literature – it examines mathematics *in* literature, and the main part is dedicated to detailed literary analyses of four novels' employments of mathematics: chapters on US-American author Thomas Pynchon's *Against the Day* (*AD*), published in 2006, and *Gravity's Rainbow (GR*), published in 1973, frame examinations of Hermann Broch's *The Sleepwalkers* (*SW*), originally published in German as three novels from 1930 to 1932 and later combined as *Die Schlafwandler*, and *The Man without Qualities* (*MwQ*), written by fellow Austrian author Robert Musil and published as *Der Mann ohne Eigenschaften* in 1930, 1932, and posthumously in 1978. The relation of mathematical texts to literary context or their employment of literary strategies and metaphors does not form part of the project, which in this respect differs from literature *and* science studies that, following Gillian Beer's seminal approach, investigate relations between literature and science from both sides. '[T]he traffic, then, was two-way' (Beer *Darwin's Plots* 5), Beer argues in *Darwin's Plots* (1983) and

[1] In the following I will quote from published English translations and occasionally amend a quote and give the original in a footnote. Texts not available in English will be given in my translation, with the original in a footnote.

[2] The quote circulates in this form that associates mathematics and art, particularly among mathematicians; see for example Robert Moritz's collection of mathematical quotations *Memorabilia Mathematica* (Moritz 246). However, a more common translation is: 'Numbers are a fearful thing, and joined to craft a desperate foe.' (Euripides 157)

demonstrates the fact when first examining Charles Darwin's *On the Origin of Species* in relation to literary culture and then turning to the 'opposite' of Victorian literature's integration of Darwin's theory. While this study is not aimed at an exploration of the two-way traffic between mathematics and literature specifically, it examines mathematics in relation to a broader cultural traffic in which mathematics and literature participate alongside other fields. Mathematics is thus not simply regarded as an influence on or source for the literary texts that form the focus of the study, but it is viewed in its historical, social and cultural contexts, and particularly in its interrelations with philosophy, linguistics, and politics.

Studies considering mathematics in its specific historical and cultural relations emerge in the mid-1970s. Before then, as Ivor Grattan-Guinness explains in his 1990 paper on the neglect of the mathematical field in the history of science, history of mathematics was predominantly written by mathematicians who gave 'an account of how a particular modern theory arose out of older theories instead of an account of those older theories in their own right. In other words, they confound the question, "How did we get here?", with the different question, "What happened in the past?"' ('Does History of Science' 157) Around the time when the history of mathematics becomes '"an independent *historical* discipline"' (conference announcement qtd. Corry 'Introduction' 2), the field of cultural science studies develops and, being based on 'the notion that scientific knowledge emerges from specific historical contexts and tak[ing] the historical embeddedness of science more seriously than some other forms of social studies of science' (McNeil 277), the discipline addresses the alignment of science with other cultural forms. Grattan-Guinness complains that 'History of Mathematics is among the least developed branches of History of Science' ('Does History of Science' 153), and mathematics is similarly underrepresented in cultural science studies; yet, over the last decades endeavours to put mathematics into context and explore its interconnections with the arts and humanities have increased.

In *A History of the Modern Fact* (1998) mathematics is considered in its wider contexts when Mary Poovey undertakes a historical analysis of how, in the late sixteenth to the first half of the nineteenth century, numbers and mathematics came to be accorded a special position among kinds of representation and were accepted as fact: 'one kind of representation – numbers – came to seem immune from theory or interpretation' (Poovey xii).[3] Joan Richards's *Mathematical Visions* (1988) is a detailed study of one

[3] Related projects exploring the preconditions that make knowledge possible are Ian Hacking's examination of styles of scientific reasoning (see for example 'Language, Truth, and Reason', '"Style" for Historians and Philosophers') and his studies *The Emergence of Probability Theory* (1975) and *The Taming of Chance* (1990); Lorraine Daston's *Classical Probability in the*

manifestation of the thus somewhat privileged field of mathematics: focusing on nineteenth-century English views of geometry, Richards examines changes in mathematics itself but also in terms of philosophy, institutions, and education. In this way, so Richards claims, her study 'portrays the mathematical visions of the Victorians' and 'explores for a particular time and place […] the ways in which mathematical ideas have been woven into the very fabric of Western culture' (Richards 11). The notion of interrelations of mathematics and Western culture is at the heart of the novels discussed in this study, though the focus is not on Victorian England as in Richards's book but on the early twentieth century. The novels' settings in German-speaking contexts – exclusively so in the works by the Austrian authors Broch and Musil, to a lesser but significant extent in both Pynchon's novels – accord with the central place Germany takes in the foundational crisis of mathematics, an event that dominates Western mathematics from the 1880s to about 1930. The process of modernisation that gives rise to the sense of crisis and leads to a profoundly changed modern mathematics begins in the last decades of the nineteenth century and involves 'deep change in all respects' (Corry 'How Useful' 1). The historian of mathematics Leo Corry summarises the developments in this 'special period' (ibid):

> new methodologies developed, new mathematical entities were investigated and concomitantly new sub-disciplines arose, the relationship between mathematics and its neighboring disciplines was transformed, the internal organization into sub-disciplines was completely reshaped, areas of research that were very important in the previous century receded into the background or were essentially forgotten, new philosophical conceptions were either implicitly espoused or explicitly discussed, etc. (ibid)

As part of the process of modernisation, so Corry shows in an overview of the history of the idea of proof, developments in geometry around 1900 help create 'an entirely new conception of mathematical proof' ('Development' 12). Interests of nineteenth-century geometers then largely cease to be of primary concern, and Richards consequently ends her book on the pursuit of geometry in Victorian England with the onset of modern mathematics: 'When they embraced the new point of view, mathematicians changed their subject so radically that to pursue its development past this point would require a second book.' (Richards 10)

In certain respects, Herbert Mehrtens's *Moderne Sprache Mathematik* (1990) and the work of Jeremy Gray, most of all *Plato's Ghost* (2008), are 'sequels' to Richards's book. Both historians of mathematics focus on mathematics in the early twentieth century,

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Enlightenment (1988); *Objectivity* (2007) by Daston and Peter Galison; *Wonders and the Order of Nature: 1150-1750* (1998) by Daston and Katharine Park; and Barbara Shapiro's *A Culture of Fact: England 1550-1700* (2000). Similar concerns also inform the work of Michel Foucault which examines the historical forces dictating the understanding of scientific truths.

particularly on its foundational crisis, and they address the interrelations of mathematics with the wider social and cultural matrix of the time.[4] Mehrtens and Gray are particularly concerned with the emergence of what they argue to be qualities that warrant viewing mathematics as part of a general modernist development. Mehrtens's work was the first to address the notion of modernism in mathematics, and in *Plato's Ghost* Gray specifically sets out to document 'the rise of what can be called mathematical modernism' (*Plato's Ghost* 452). Gray's aim to investigate a mathematical '"modernism" similar to the rise of modernism in cultural spheres such as painting, music, and literature' ('Modernism' 663) clearly shows that the term 'modernism' in historical analyses of mathematics was adopted from the domain of the arts,[5] but accounts of modernism in mathematics do not argue mathematics to be directly influenced by modernist developments in other areas. Gray explains: 'I do not claim that the modernization of mathematics was part of a broader cultural push, animated by concurrent changes in the arts. I do claim that the changes were similar in kind and were helped along by a growing diversity and specialization in all walks of cultural and intellectual life. But the mathematical ones described here and the better-known artistic ones happened independently.' (*Plato's Ghost* 14)

In his essay 'How Useful is the Term "Modernism" for Understanding the History of Early Twentieth-Century Mathematics?', which will be part of the forthcoming essay collection *Modernism in the Sciences*, Corry points out the need for more work in order to arrive at a fuller and more balanced picture of the interrelations of mathematics and modernist developments in other areas, while identifying Mehrtens's and Gray's work as an influential beginning of research around 'the possibility of understanding the rise and development of "modern mathematics" as a specific manifestation of the broader cultural trend "modernism"' ('How Useful' 2). Relations of mathematics and cultural developments can also be traced from the 'other' side, for which Linda Dalrymple Henderson's 1983 exploration of modern painters' ideas of the fourth dimension and non-Euclidean geometry is arguably the best-known example. Literature is a potentially particularly interesting and fruitful source for examining the possibility of viewing mathematics as part of a general cultural trend since it can add to the exploration in two ways: literary works can include mathematical topics and thus constitute cases of crossover between the different domains, and they can also directly introduce views as to interrelations between the modernisation of mathematics and developments in other fields. The chosen novels by

[4] Morris Kline's *Mathematics; The Loss of Certainty* (1982) is a more informal account of the foundational crisis and is focused on purely mathematical developments.

[5] William Everdell's *The First Moderns* (1997) is a non-academic account of the beginnings of modernism, which he traces in various disciplines, including mathematics.

Pynchon, Broch, and Musil precisely address both levels and are thus particularly suited for an exploration of interrelations between mathematics and other fields from the perspective of literature.

Two main aspects of the possibility to view the transformation of mathematics as comparable to modernist movements in the arts are, firstly, the break with former certainties and the sense of a foundational crisis of mathematics, and secondly, the emerging notion of mathematics' independence of physical reality (see 1.2 and 1.3). These elements are also of central importance to Pynchon's, Broch's, and Musil's work, making them exceedingly suited to explore modern mathematics' embeddedness in culture. Each of the novels sets mathematics' independence of reality and the related questions as to the truth and meaning of mathematics in relation to the notion of fiction, most significantly to its own fictionality, and the foundational crisis of mathematics is tied to the general crisis of the First World War in *Against the Day*, *The Sleepwalkers*, and *The Man without Qualities*, while *Gravity's Rainbow* introduces its competing mathematical concepts in the setting of the Second World War. Presenting the twentieth century as a time of major crisis and illustrating the nature and potential of fiction, the chosen novels thus reflect core concerns suggested to connect early twentieth-century mathematics and art in common modernist characteristics.

This study's combination of analyses of novels produced almost contemporaneously with the foundational crisis of mathematics on the one hand and Pynchon's postmodern reimagining of earlier periods on the other hand allows for a twofold perspective on novelistic illustrations of the interrelatedness of mathematics and other fields. The works by Broch and Musil are part of the modernist culture in which modern mathematics is suggested to participate, and they are, moreover, produced and situated in the German-speaking context in which much of proposed 'modernist transformation' (Gray *Plato's Ghost* 1) of mathematics took place. In contrast, Pynchon's *Against the Day* is set in the period of drastic change in early twentieth-century mathematics but was produced almost a hundred years later, that is, at a time when the historical and cultural study of mathematics and a proliferation of mathematical fiction document a revived interest in the relations of mathematics and literature. The three works thus mark decisive periods in the relationship of mathematics and literature. *Gravity's Rainbow* draws on mathematics and worldviews from a longer historical epoch, as the period around the Second World War is presented as a time of the culmination of concepts and thought structures having emerged in the seventeenth century. Spanning the epoch from the beginnings of the modern period and the scientific revolution in the seventeenth century to the twentieth-century crisis of modernity and its postmodern transformation, *Gravity's Rainbow* covers the rise, fall, and transformation of

the project of modernity and Enlightenment thinking from a postmodern position. It thus allows setting the changes in early twentieth-century notions of reason and its epitome mathematics into a wider historical perspective.

With its focus on literary fiction, this study examines a genre that can draw similarities between its imaginative nature and modern mathematics' independence of physical reality. It is also significant that each of the substantial novels or novel-cycles to be discussed can be characterised as an encyclopaedic work. Encyclopaedic novels address a 'full range of knowledge and beliefs' (Mendelson 1269) and search for 'a pattern that will explain, or at least enable man to order, the whole of life' (Pike 119). Pynchon's novels are named among the archetypal encyclopaedic novels (see Mendelson 1267), and *The Man without Qualities* and *The Sleepwalkers* also exhibit encyclopaedic features[6]: they 'attempt to render the full range of knowledge and beliefs of a national culture, while identifying the ideological perspectives from which that culture shapes and interprets its knowledge' (Mendelson 1269)[7]. Consistent with their encyclopaedic approach, the novels consider mathematics as part of the 'full range of knowledge and beliefs' in the early twentieth century and relate it to other fields. Thus, in the last part of Broch's novel trilogy *The Sleepwalkers*, an integrated essay introduces 'the research into first principles of modern mathematics' as 'the clearest example'[8] of a 'sweeping revolution in the style of thinking' (*SW* 481), and Musil's *The Man without Qualities* establishes mathematics as 'the new method of thought itself, the mind itself, the very wellspring of the times and the primal source of an incredible transformation' (*MwQ* 35). In *Against the Day*'s postmodern revisiting of the early twentieth century, Yashmeen alerts fellow mathematician Kit to connections between the foundational crisis of mathematics and the First World War: '"The political crisis in Europe maps into the crisis in mathematics. […] The connections lie there, Kit – hidden and poisonous."' (*AD* 668) These novels thus place mathematics at the core of the dramatic transformation of the Western world at the beginning of the twentieth century and employ it as a prime example in their encyclopaedic attempts to present the assumptions underlying twentieth-century Western culture. Interrelating mathematics and

[6] For a discussion of encyclopaedic characteristics in Musil see Pike 119-99 and Brecht's '"Die infinitesimale verstehende Auflockerung des Menschen". Robert Musils enzyklopädische Um- und Auswege'; also see discussions of the concept of the polyhistoric novel in Musil and Broch (Broch 'Kommentare', Kiss's 'Dialog der Meisterwerke oder Die ungleichen Zwillinge des polyhistorischen Romans', Steinecke's *Hermann Broch und der polyhistorische Roman*).

[7] A further encyclopaedic feature of *Against the Day*, *The Sleepwalkers*, *The Man without Qualities*, and *Gravity's Rainbow* is their setting in the immediate past that allows them to achieve 'the double function of prophecy and satire' (Mendelson 1270) by referring to events that are outside the novel's time frame but known to the reader. Each of the novels also features what Mendelson calls 'an encyclopedia of literary styles' (Mendelson 1271).

[8] 'am deutlichsten' (533).

contemporaneous developments, the novels thus give imaginative illustrations of the historical and cultural embeddedness of mathematics.

By examining encyclopaedic novels from and about periods of changing relations between mathematics and literature, this study adds to the understanding of the perception of mathematics and its cultural interconnections from the perspective of literature and thus relates to the recently growing interest in historical and cultural studies of mathematics and particularly to research regarding a mathematical modernism. However, the focus of the study is on literature and the illumination of major works by Pynchon, Broch, and Musil under the aspect of their employment of mathematics, and considering the wealth of material resulting from the unusually high extent to which the works are informed by mathematics and its interrelations with other fields, the literary analyses in the following chapters will employ extensive textual evidence from the primary material. The use of literary quotation will thus be evidential rather than appraisive or discursive. Firstly however, the introduction will provide the background for the analysis of the novels' employment of mathematics. It will sketch the history of mathematics, outline interrelations of mathematics with wider concerns in the late nineteenth and early twentieth centuries, and illustrate the reasons for the special place that mathematics holds in the relation of the sciences and the humanities.

1. The History of Mathematics

1.1 The Language of the Book of Nature

Due to its 'extraordinary precision, generality, and apparent absolute certainty' (Jacquette 13) mathematics inhabits a unique position among fields of knowledge. In 1902, the mathematician and philosopher Henri Poincaré summarised the traditional understanding of mathematics and its preponderance regarding questions of truth: 'Mathematical truths are derived from a few self-evident propositions, by a chain of flawless reasonings; they are imposed not only on us, but on Nature itself. By them the Creator is fettered […]. This, to the minds of most people […] is the origin of certainty in science.' (*Hypothesis* xxi) The view that mathematics forms the basis for any study of nature and is at the heart of knowledge goes back to the sixth century B. C. and the Pythagoreans' doctrine of a universe constructed in terms of whole numbers. The Pythagoreans believed in the mystical and symbolical qualities of number, whereas two thousand years later Galileo Galilei stressed the rational aspects of mathematics when declaring it the key to learning truths about reality: 'Philosophy is written in this grand book – I mean the universe – […] but it cannot be

understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics' (*Controversy* 183-84). With mathematical insights, Galilei asserts, mankind can reach the highest truth and participates in God's knowledge (see Galilei *Dialogue* 104). Given that from Ancient Greece onwards mathematics was regarded as essential to understand the world, many mathematicians and philosophers agreed with Plato who stressed mankind's duty to pursue this discipline: 'He is unworthy of the name of man who does not know that the diagonal of a square is incommensurable with its side.'

If mathematics is taken to be the language of the book of nature, it represents the physical world and derives its truth and meaning from this relation to reality. A consequence of such a link is the assumption that everything written in the language of mathematics stems from nature and therefore 'exists'. The sixteenth-century mathematician and astronomer Nicolaus Copernicus was among the first to argue for the equivalence of mathematical proof and reality while granting priority to mathematics: 'Copernicus only offered entirely abstract mathematical arguments. No matter how contrary to natural philosophy the motion of the earth may seem, Copernicus insisted, it must be true *because the mathematics demands it*. This was revolutionary' (Henry 17). Although Copernicus held mathematics to describe truths of reality, his heliocentric system was understood as a mathematical model only, mathematics being generally regarded as merely an auxiliary construction to gain knowledge about the world. Thanks to this misreading Copernicus remained unmolested by the Catholic Church, while when Galilei took up Copernicus's work and insisted on the physical reality of the mathematical description of the solar system, he was met with opposition and put under house arrest by the Inquisition. Questions regarding the truth of mathematics and its relation to nature thus had far-reaching consequences in the sixteenth and seventeenth centuries when mathematics began to challenge the explanatory system of Christianity and rival physical reality itself.

Galilei is a main protagonist in the scientific revolution and commonly regarded as the father of modern science since his programme of a detailed study of nature began to replace natural philosophy and its aim 'to describe and explain the entire system of the world' (Henry 4). The scientific revolution forms part of the Enlightenment movement and its valuation of reason, and mathematics holds a prominent position in the programme given that, as the philosopher Thomas Hobbes developed, reason is calculation. The importance of mathematics in the rational evaluation of the world is also reflected in the work of the central Enlightenment thinker Immanuel Kant. In *Critique of Pure Reason* (1781) Kant describes different categories of knowledge and classifies mathematics as synthetic judgment *a priori*.

Mathematics is independent of experience and therefore knowledge *a priori*; at the same time, it is synthetic as a calculation puts together different 'facts' and arrives at new knowledge: for example, the elements 5 and 7 add up to the new element 12 (see Kant 9-12). Classifying mathematics as synthetic judgement *a priori*, a category hitherto thought impossible, Kant took account of the mathematical 'truths' that were discovered in the scientific revolution and described nature so adequately. Taken to ultimately derive from knowledge *a priori*, any mathematical description of the world could be regarded as absolutely certain and true. The extreme consequences of believing in a mathematically described world were then formulated in 1814 by the mathematician Pierre-Simon Laplace who asserted that theoretically an intellect – later called 'Laplace's demon' – could know all determinants of the universe and express it in a single formula according to which past, present, and future could be calculated (see Laplace 4). A single mathematical formula would thus encompass the whole universe at all times, and mathematics as the description of all space and time would be the 'true' language of reality.

1.2 The Nineteenth Century: The Development of Modern Mathematics

The view of mathematics as a description of nature and the most certain science was dominant until the nineteenth century. Gray explains: 'Put simply, the prevailing view around 1800 among mathematicians was that mathematics was true. At its best it gave knowledge of the world' (*Plato's Ghost* 27). In the nineteenth century, however, newly discovered mathematical concepts raised awareness that not all of mathematics had counterparts in nature and that therefore the relation between mathematics and reality had to be rethought. Thus, in geometry, which since the third century B. C. had been based on five intuitively true axioms formulated by Euclid, mathematicians constructed new geometries in which Euclid's parallel postulate did not hold, that is, there is no pair of straight lines that are at constant distance from each other.[9] The mathematician Farkas Bolyai warned his son János about the consequences of developing a non-Euclidean geometry, and his dramatic language illustrates that the failure of the seemingly self-evident parallel axiom not only had consequences for mathematics but affected the sense of security at large: 'I have traversed this bottomless night, which extinguished all light and joy of my life. […] I turned back when I saw that no man can reach the bottom of this night. I turned back unconsoled, pitying

[9] Mathematical concepts not immediately relevant to the argument are explained in the glossary (see appendix, here entry 'non-Euclidean geometry'). The glossary also holds definitions of commonly used mathematical terms.

myself and all mankind.' (qtd. in Gray *János Bolyai* 51) Unabashed, János Bolyai published his findings of non-Euclidean geometry in 1832, and when in 1854 Bernhard Riemann showed that infinitely many geometries that are not Euclidean can be constructed, the overwhelming proof no longer allowed ignoring the fact that a fundamental premise of geometry, held to be true for over two thousand years, was not correct. As Poincaré pointed out in 1902, the discovery of non-Euclidean geometry triggered wider questions as to the meaning of geometry: 'If several geometries are possible, they say, is it certain that our geometry is the one that is true?' (*Hypothesis* 48) He concludes that Euclidean geometry cannot be said to be true but that its axioms '*are only definitions in disguise*' so that 'it can only be more convenient' (*Hypothesis* 50). The discovery of non-Euclidean geometry thus put into question the notion of mathematics as the language of nature which arrives at certain truths about the world.

Concepts perceived as worrying not only appeared in geometry; indeed, problems were more readily identified in algebra. In 1833, the mathematician Sir William Rowan Hamilton stated that '[n]o candid and intelligent person can doubt the truth of the chief properties of *Parallel Lines*, as set forth by EUCLID in his Elements', while in algebra 'it requires no peculiar scepticism to doubt, or even to disbelieve, the doctrine of Negatives and Imaginaries' (Hamilton 294). While the idea of debt renders negative quantities graspable, the counter-intuitive 'existence' of imaginary numbers meant that its wide acceptance did not take place until well into the nineteenth century. The imaginary number *i* is defined as the square root of minus one $\sqrt{-1}$, thus contradicting the rule in the commonly used system of real numbers that a square cannot be negative. If the imaginary number *i* is the square root of -1, then *i* squared equals -1. In mathematical notion: $i^2 = -1$. Yet, there are no negative squares in the real number system: $1^2 = 1$ and $(-1)^2 = 1$. Therefore, even though imaginary numbers proved useful in calculations, their existence was questioned. The seventeenth-century mathematician and philosopher Gottfried Wilhelm Leibniz illustrated the problem: 'I did not understand how … a quantity could be real, when imaginary or impossible numbers were used to express it.' (qtd. in Nahin 26) In calculations imaginary numbers are usually combined with real numbers, and the result is called a complex number: the real number *a* and the imaginary element *bi* make the complex number $a + bi$. Many nineteenth-century mathematicians essentially shared Leibniz's view of complex numbers as 'amphibian[s] between being and not-being' (qtd. in Rice 150), regarding their reality and existence as at least questionable. Even in the 1880s, 'the situation was such that one of the top mathematics students in England would recall […] that "it was an age when the use of $\sqrt{-1}$ was suspect at Cambridge"' (Nahin 83). Hamilton pointed out the consequences of the debated nature of

numbers: when working from the assumption that numbers are not true but 'that numbers, called *imaginary*, can be found or conceived or determined, […] [i]t must be hard to found a SCIENCE on such grounds as these' (Hamilton 294). In other words, if the essential nature of numbers is obscure, mathematics cannot be said to be reliable and certain.

Similarly to the discovery of non-Euclidean geometry, nineteenth-century developments around imaginary numbers worked towards a new understanding of mathematics. In 1843 Hamilton developed Quaternions, a mathematical concept that incorporates imaginary numbers and 'broke bonds set by centuries of mathematical thought' (Crowe 31) (also see chapter on Pynchon's *Against the Day*). Hamilton set out to extend complex numbers, which work in two dimensions, to a number system covering three dimensions, and his success demonstrated 'that it was possible consciously to construct new elements of algebra rather than finding them from elements of existing algebras' (Burton 637). Partly due to this possibility of conscious construction, Hamilton discerned a tendency in his contemporaries to no longer consider algebra 'a Science properly so called; strict, pure and independent; deduced by valid reasonings from its own intuitive principles' (Hamilton 295). Instead, he identified an increase in views which either 'regard Algebra as an *Art*, or as a *Language*: as a System of Rules, or else as a System of Expressions, but not as a System of *Truths*' (Hamilton 295). Reluctantly, Hamilton later admitted that these views were valuable, that is, 'that there is a sort of symbolical science, or *science of language*, which well deserves to be studied, abstraction being made for a while of *meaning*, or interpretation' (qtd. in Øhrstrøm 52). Thus, similarly to the situation in geometry where Poincaré argued that a geometry was not 'true' but only more or less 'convenient' (*Hypothesis* 50), mathematicians came to see algebra not as a system of truths but as consisting of diverse structures devised according to usefulness.

If algebra is understood not as a system of truths but as comprising diverse structures with different rules, the 'existence' of imaginary numbers ceases to be problematical. The explanation for the curious nature of $\sqrt{-1}$ then is that negative square roots are not part of and therefore do not 'exist' in the real number system but are defined and thus 'real' in the system of complex numbers. The changing sense of a number's reality can be illustrated more clearly by the case of irrational numbers which were discovered in the sixth century B. C. and scandalised the Pythagoreans since they are not part of the system of rational numbers: other than rational numbers, irrationals cannot be expressed by fractions or be written down since their decimals go on indefinitely without repeating themselves. The Pythagoreans therefore 'called these numbers *arrhetos*, unspeakable' (Koestler 215) and warned of the dangerous and even deadly consequences of talking about the 'unspeakable'

irrationals. From a contemporary viewpoint, accepting irrational numbers is comparatively unproblematic, since, for example, the irrational number √2 can be drawn as the diagonal of a square with side length 1, or π be described as the ratio of a circle's circumference to its diameter. Also, the system of real numbers comprises both rational and irrational numbers, so even if π is not part of and thus does not 'exist' in the rational number system, it is as 'real' as a rational number in the system of real numbers. The case of irrational numbers thus demonstrates that the understanding of a number's reality is changeable and that it can be said to be 'real' only in relation to a mathematical reference system while a match with physical reality is irrelevant. Yet, even though a number's 'existence' depends on the number system in use and, in effect, all numbers are equally real or unreal, the application of a number to the world can make it more easily graspable, and the fact that the relevance of imaginary numbers to the physical world is not intuitive made their acceptance more difficult.

Nineteenth-century discoveries of alternatives to the taken-for-granted geometry and algebra spread the view that mathematics was not the 'true' language of nature and that questions as to the existence of mathematics could not be answered by reference to physical reality. Instead of being defined in relation to nature, mathematical existence came to be seen as relying on coherence in the system of mathematics itself: 'In mathematics the word exist can only have one meaning; it signifies exemption from contradiction.' (Poincaré *Method* 151-52) Gray characterises the new understanding of mathematics: 'mathematicians fashioned for themselves a new image of the subject: autonomous, abstract, largely axiomatic, and unconstrained by applications even to physics' (*Plato's Ghost* 305). As a consequence of the detachment of mathematics from reality and the perceived possibility 'consciously to construct new elements' (Burton 637), early twentieth-century mathematicians, writers, and philosophers suggested mathematics to have a 'creative' potential and to share qualities with the sphere of art.

Before turning to possible convergences of mathematical and literary qualities in the early twentieth century, it will be useful to examine more closely the consequences of 'the discovery that mathematics is entirely independent of the physical world' (Stone 716) which the twentieth-century mathematician Marshall Stone claimed to mark 'one of the most significant intellectual advances in the history of mankind' (ibid). Namely, a question arises from the fact that mathematics is no longer assured by a relation to nature: what are the foundations of mathematics that guarantee its truth and meaning?

1.3 The Foundational Crisis of Mathematics

Set theory, decisively developed in 1874 by Georg Cantor, promised to be a foundational theory of mathematics; meaning that mathematics 'could be recast in the language of set theory and derived from its principles' (Giaquinto 136-37). Many colleagues agreed with the mathematician David Hilbert that this would set mathematics on secure grounds and prove the certainty it had always been believed to exemplify: 'No one shall drive us out of the paradise which Cantor has created for us.' ('Infinite' 141) Hilbert's talk at the International Conference of Mathematics in 1900 accordingly had a decidedly hopeful tone: 'We hear within us the perpetual call: There is the problem. Seek its solution. You can find it by pure reason, for in mathematics there is no *ignorabimus*.' ('Mathematical Problems' 445) In general, set theory as a foundational theory of mathematics gave rise to renewed belief in the power of mathematics.

Only a year after Hilbert's positive evaluation of the situation of mathematics, serious blows were dealt to set theory when the mathematician and philosopher Bertrand Russell discovered the paradox later named after him. In set theory, the question whether the 'set of all sets that are not members of themselves' is a member of itself reveals a paradox: if it is a member of itself then it is by definition not one of the sets that are not members of themselves; at the same time, if the 'set of all sets that are not members of themselves' is not a member of itself then it logically is to be counted towards the sets that are not members of themselves. This and further antinomies meant that Cantor's set theory could not solve the problem of the foundations of mathematics, and it thus had devastating effects on the mathematical community. Russell's colleague Alfred North Whitehead reacted by quoting '"never glad confident morning again"' (see Russell *Philosophical Development* 58), and Hilbert described the resulting situation of mathematics as 'intolerable': 'Just think, the definitions and deductive methods which everyone learns, teaches, and uses in mathematics, the paragon of truth and certitude, lead to absurdities! If mathematical thinking is defective, where are we to find truth and certitude?' ('Infinite' 141) Problems in the foundational theory of mathematics thus were taken to have consequences far beyond mathematics itself and to generally affect the possibility of certain knowledge.

Mathematicians generally believed that advances in mathematics created ever greater knowledge; Hermann Hankel even asserted that this feature distinguished mathematics from the other sciences: 'In Mathematics alone each generation builds a new story to an old structure.' (qtd. in Burton 33) Problems in its foundational theory then put into question the whole building of mathematics: 'the doubt arose if all these constructions

are built on solid foundations. The conclusion was drawn that a breath would bring them to the ground.' (Poincaré *Hypothesis* xxii) The feeling that the building of mathematics was threatened due to its uncertain foundations informs the period of the foundational crisis of mathematics, commonly said to last from the 1880s to about 1930.

The three schools of logicism, formalism, and intuitionism attempted to set mathematics on new foundations in the early twentieth century.[10] The changed relation of mathematics to the physical world informs all three approaches that thus reflect 'the appearance of mathematical modernity' (Mehrtens 327), as Mehrtens explains: 'the route of mathematical modernity leads to the renouncement of the representation of Something'[11] (Mehrtens 118). All three foundational schools of mathematics are modern in that they do not claim mathematics to represent nature, but Mehrtens and other historians of mathematics after him identify an antagonism between two orientations inside modern mathematics and argue that the conflict between the respectively called 'modern' and 'counter-modern' mathematics is at the core of the foundational crisis.[12] Logicism, founded by Gottlob Frege in 1884 and attempting to show that mathematics is part of logic, is counted towards the side of modern mathematics, but the contention mainly took place between David Hilbert as the representative of modern formalism and L. E. J. Brouwer as the founding father of counter-modern intuitionism. The main differences between formalism and intuitionism can partly be traced back to diverse reactions to the paradoxes discovered in Cantor's set theory. Hilbert hoped to rescue Cantor's foundational theory by proving its consistency and accepted the 'price of saying that the ordinary notions of meaning and truth [of mathematics] did not apply' (Bostock 198). By contrast, 'Brouwer insisted on genuine meaning and genuine truth value, and as a result was led to reject not only Cantor's theory but also many of the usual claims of traditional mathematics' (Bostock 198). The foundational crisis thus was not a purely mathematical crisis but rather concerned the philosophical understanding of the nature of mathematics: it was the 'shaking of the terms of truth, meaning, object, existence in mathematics'[13] (Mehrtens 8).

[10] See Snapper for a very readable description of the nature and respective failures of the three mathematical schools.

[11] 'den Auftritt der mathematischen Moderne'; 'Dagegen führt der Weg der mathematischen Moderne in den Verzicht auf die Repräsentation von Etwas.'

[12] The historian of mathematics Moritz Epple criticises Mehrtens's concentration on external historiography: 'His sources are mainly the programmatic declarations of the mathematicians involved and the documents of their institutional activities. Mehrtens […] makes no claims about the internal construction of modern mathematics.' (Epple 191) Epple then uses the example of abstract and concrete writing in mathematics to suggest the possibility of extending Mehrtens's conclusions of a division between modern and counter-modern mathematics to mathematical construction itself.

[13] 'die Erschütterung der Begriffe von Wahrheit, Sinn, Gegenstand, Existenz in der Mathematik'.

Intent on saving Cantor's set theory, formalists defined mathematical existence as absence of contradiction, and Hilbert described mathematics as working with symbols that 'have no significance in themselves' ('Infinite' 143) in the manner of 'a game played according to certain rules with meaningless marks on paper' (qtd. in Burton 621). Since according to the formalist view mathematics manipulates its symbols regardless of any consideration other than its consistency, it is 'absolutely free in its development and bound only to the requirement that its concepts permit no internal contradictions' (Dauben 61). The absence of external restrictions is also celebrated in Cantor's famous phrase 'the *essence* of *mathematics* is its *freedom*'[14] (Cantor 564). Free inside its own system and employing 'purely immanent concepts of existence and truth'[15] (Mehrtens 413), formalist mathematics claims no relation to any non-mathematical origin or meaning and is unresponsive to any demands for extra-mathematical truth or value: 'the discourse of mathematics has no "reason" apart from itself. "Truth" cannot be saved.'[16] (Mehrtens 520)

Counter-modern intuitionism asks precisely the questions that formalism excludes, namely: 'Where is the reference of mathematics to stable reality endowing it with value and meaning?'[17] (Mehrtens 436) The concern is evident in the case of Brouwer who demanded to pursue mathematics not for its own sake but in view of moral value: 'Let the motivation behind mathematics be the craving for the good' (qtd. in Dalen 82). The radical programme following from this consideration distrusts classical mathematics and sets out to construct mathematics from scratch, claiming that 'man builds up pure mathematics out of the basic intuition of the intellect' (Brouwer 'On the Foundations' 53). Intuitionism regards mathematics as a construct of the human mind, so that man, as the link between mathematics and the world, justifies the truth and meaning of mathematics. Since intuition is the '"prime cause" in which mathematics "originates" and from which it derives its truth and order'[18] (Mehrtens 9), Brouwer asserted that mathematics 'is independent of the so-called *logical laws* (laws of reasoning or of human thought)' ('On the Foundations' 72). Thus, while modern mathematics attempted to build mathematics on rational foundations independent of man, the counter-moderns 'were turning away from and even abandoning logic' (Kline *Mathematics* 230) and traced mathematics to a human origin which then allowed to advance

[14] 'das *Wesen* der *Mathematik* liegt gerade in ihrer *Freiheit*'.
[15] 'rein theorieimmanente Existenz- und Wahrheitsbegriffe'.
[16] 'der Diskurs der Mathematik keinen "Grund" hat außer sich selbst. Die "Wahrheit" ist nicht zu retten.'
[17] 'Wo also ist der Bezug der Mathematik zur festen Wirklichkeit, der ihr Wert und Sinn gibt?'
[18] '"Ur-Grund", in dem die Mathematik "wurzelt" und aus dem sie ihre Wahrheit und ihre Ordnung bezieht'.

their ultimate aim of 'a morally justified practice of mathematics'[19] (Mehrtens 189). Hilbert complained that the counter-modern disregard of reason, its being ruled by 'subjectivism […] which, as it seems to me, finds it [sic] apex in intuitionism' (qtd. in Dalen 578-79), 'seeks to break up and to disfigure mathematics' (qtd. in Wigner 225). On the other hand, counter-modern intuitionism objects to the abandonment of the notions of meaning and value in the formalist school. As Mehrtens puts it: 'The difference between modern and counter-modern mathematics boils down to the question: reality and eternal truth or creative freedom and freedom of contradiction?'[20] (Mehrtens 237)

In the 1920s when the conflict between modern formalism and counter-modern intuitionism came to a head, intuitionism gained philosophical support, but many mathematicians agreed with Hilbert's complaint after a lecture by Brouwer in 1924: 'With your methods most of the results of modern mathematics would have to be abandoned, and to me the important thing is not to get fewer results but to get more results.' (qtd. in Dalen 491) Thus, even though mathematicians admitted that intuitionism was a foundational theory of mathematics, the fact that it rejects classical theorems and introduces others that do not hold in classical mathematics led to its failure in praxis: 'the mathematical community has almost universally rejected intuitionism' (Snapper 211). The reasons for the non-acceptance of intuitionism thus were not scientific but pragmatic, mathematicians being unwilling to sacrifice a substantial part of well-working classical mathematics, and ultimately, '[t]hey are all emotional reasons, grounded in a deep sense as to what mathematics is all about' (Snapper 212).

If intuitionism failed the praxis test, Hilbert's formalist programme was proven to be impossible when in 1931 Kurt Gödel's incompleteness theorem demonstrated 'that formalization cannot be considered as a mathematical technique by means of which one can prove that mathematics is free of contradictions' (Snapper 214-15). The incompleteness theorem concerns axiomatised theories 'whose axioms are strong enough so that arithmetic can be done in terms of them' (Snapper 215), but transferring it to a non-technical context can illuminate its meaning. Reminiscent of the Russell paradox in set theory, the truth value of the sentence 'This sentence is unprovable.' is undecidable. If the sentence is taken to be true, it is unprovable, meaning that its correctness cannot be proven. If by contrast the sentence is taken to be false, then it should be provable, but it can only be proven unprovable and thus leads to a contradiction. Gödel's incompleteness theorem uses a comparable meta-language in mathematics to demonstrate that there are undecidable sentences in each

[19] 'eine moralisch begründete Praxis der Mathematik'.
[20] 'Der Unterschied zwischen Moderne und Gegenmoderne spitzt sich auf die Frage zu: Wirklichkeit und ewige Wahrheit oder Gestaltungsfreiheit und Widerspruchslosigkeit?'

axiomatic system of mathematics. It follows that any foundational theory of mathematics includes undecidable sentences and that, next to 'true' and 'false', the category 'undecidable' has to be added to the '"most certain of all the sciences"' (Carnap 31). Attempts to 'save' a foundational theory of mathematics from incompleteness have to fail: it is possible to devise a more comprehensive set of propositions which covers the undecidable sentence 'by adding on the undecidable sentence or its negation as a new axiom' (Kadvany 162), however, the newly designed system includes new undecidable sentences for which a bigger system needs to be designed which in turn includes undecidable sentences and so on ad infinitum. Years after the crisis, Russell described this infinite regression regarding the foundations of mathematics in more intuitive terms: 'Having constructed an elephant upon which the mathematical world could rest, I found the elephant tottering, and proceeded to construct a tortoise to keep the elephant from falling. But the tortoise was no more secure than the elephant' (*Portraits* 53). When Gödel's incompleteness theorem proved that formalism cannot demonstrate completeness and freedom of contradictions in mathematics – that any attempt at a comprehensive system only sets up another 'tortoise' and can never constitute firm ground – Hilbert's programme had failed. However, mathematicians preferred the more fruitful formalism to the restrictions of intuitionism, so Hilbert 'won the conflict in the social sense' even though he 'had lost it in the scientific sense' (Dalen 639). The crisis thus did not end with a solution to the foundational problems of mathematics or with a clear winner of the contention between the modern and the counter-modern position, but its questions and the diverse views ceased to be perceived as problematical.

The modern and counter-modern attempts to provide foundations for mathematics and their respective views on the role of reason and man have consequences for general epistemological questions. Not least, the crisis and ultimate failure of each school demotes mathematics as absolutely certain and objective knowledge. As the mathematician John von Neumann argued, the foundational crisis 'could serve as the best warning against presuming a given unchanging rigour in mathematics. […] I know how humiliatingly easily my views on the absolute truth of mathematics changed during these events, indeed, how they changed three times in a row!'[21] (Neumann 39)

[21] 'als die beste Warnung dienen könnte, eine unveränderliche Strenge in der Mathematik allzu sehr als gegeben anzusehen. […] ich weiß, wie erniedrigend leicht sich meine Ansichten über die absolute mathematische Wahrheit während dieser Ereignisse geändert haben, ja wie sie sich sogar dreimal hintereinander geändert haben!'

2. Interrelations – Mathematics: Modernity and Modernism

The foundational crisis of mathematics is contemporaneous with other crises in the late nineteenth and early twentieth centuries, most notably with the political upheaval around the First World War, increasing doubts as to the certainty of knowledge, and turn-of-the-century scepticism of language or 'Sprachkrise'. Aspects of the mathematical crisis find reverberations in the thoughts of philosophers such as Friedrich Nietzsche, Max Weber, Ernst Cassirer, Oswald Spengler, and Hans Vaihinger, and referring to these philosophers' thought, the following will exemplify how the foundational crisis of mathematics was seen to contribute and relate to a more general feeling of crisis and was perceived as interrelated with broader developments in politics, society, and culture in the decades around the turn of the twentieth century.

2.1 The Political Crisis

Awareness of questions regarding the nature of mathematics, its certainty and exactness grew in the nineteenth century and became urgent shortly after 1900, but '[t]he foundational crisis of mathematics was mainly an event taking place in Germany around 1920 to 1925. The questions about the justification, truth, and meaning of mathematics were closely interrelated with the period's social and political concerns.'[22] (Mehrtens 295) With hindsight, the mathematician Hermann Weyl, one of the main protagonists of the crisis in the 1920s, conceded that decisions between advocating a modern or counter-modern position in mathematics were not made on purely mathematical grounds: mathematicians 'are not indifferent to what their scientific endeavors mean in the context of man's whole caring and knowing, suffering and creative existence in the world' ('Mathematics and Logic' 13). Interrelations of mathematical and wider concerns of life are moreover suggested by the fact that the foundational conflict in the 1920s was not confined to the community of professional mathematicians but also took place among a non-specialist audience: 'The actual appearance of the great revolutionary in the lecture halls in Berlin caused a furore. […] The lecture hall was filled till the last seat – intuitionism and foundations became the talk of the town. Even the newspapers followed the events with interest. […] The lectures were attended by a mixed audience, consisting of students, professional mathematicians and interested laymen.'

[22] 'Die "Grundlagenkrise" der Mathematik war vor allem ein Ereignis, das etwa 1920 bis 1925 in Deutschland stattfand. Die Fragen nach Begründbarkeit, Wahrheit und Sinn der Mathematik waren eng verkoppelt mit den sozialen und politischen Fragen der Zeit.'

(Dalen 544-45) It thus seems that in the 1920s mathematicians and laypersons alike realised that with the foundations of the 'paragon of truth and certitude' (Hilbert 'Infinite' 141) more was at stake than mathematical questions alone.

Weyl's 1921 paper 'On the New Foundational Crisis of Mathematics' initiated the intensification of the crisis and provides a good example of the interconnections of mathematical and political concerns. In the paper, Weyl, a former student of Hilbert, sides with Brouwer's intuitionism and proclaims: 'Brouwer – that is the revolution!' ('New Foundational Crisis' 99) Hilbert, when launching his 'counter-revolution' (Dalen 484), continues the use of political terminology: 'Brouwer is not, as Weyl thinks the revolution, but only the repetition of an attempted coup (*Putsch*) by old means […] which now, where the power of the state is so well armed and strengthened by Frege, Dedekind and Cantor, is all the more from the beginning doomed to failure.' (qtd. in Dalen 486) After Hilbert's lecture, intuitionists began to call themselves 'Putschists', a further indication, so the philosopher of mathematics Dirk van Dalen argues, that mathematicians connected the crisis in their field to the pressing political situation in Germany: 'The German nation was thoroughly unstable and coups were part of the harsh reality. In 1920 Berlin had its "*Kapp Putsch*" and Munich had been the scene of a left-radical revolution in 1919, the same year that the Spartacist coup took place in Berlin.' (Dalen 486) The political instability in Germany raised the urgency to solve the foundational crisis of mathematics and gain certitude at least in this discipline at the heart of reason, and the interrelation makes understandable Hilbert's outcry in 1925: 'If mathematical thinking is defective, where are we to find truth and certitude?' ('Infinite' 141) Van Dalen goes so far as to conjecture that in a politically stable atmosphere, the mathematical conflict would not have escalated: 'without the First World War, there would not have been a conflict […] without the political complications there would not have been the fateful act' (Dalen II vii), namely Hilbert dismissing Brouwer from the editorial team of the journal *Mathematische Annalen*, thus forcing mathematicians to take sides in the conflict between formalism and intuitionism. In the same vein, Mehrtens explains the subsiding of the foundational crisis with the political stabilisation in Germany: 'Since the mid-1920s, the public, partly emotional debate around the crisis transformed into a specialist discourse among basic researchers. With the consolidation of the Weimar Republic this crisis similarly subsided. The question of meaning became public as a political concern and dissolved into private interpretation'[23]

[23] 'Die öffentliche, zum Teil leidenschaftlich geführte Debatte um die Krise verwandelte sich seit Mitte der zwanziger Jahre in einen Fachdiskurs unter Grundlagenforschern. Mit der Konsolidierung der Weimarer Republik ging auch diese Krise vorüber. Die Sinnfrage war als politische öffentlich geworden, löste sich in private Sinngebung auf'.

(Mehrtens 294). The interrelations of the mathematical and the political crises in 1920s Germany and the more politically stable situation of the Weimar Republic thus help explain why the foundational crisis of mathematics could abate without a solution or winner.

2.2 The Crisis of Modernity

a) Epistemological Crisis

The 'growing appreciation of error leading to a note of anxiety [in the mathematical community], hesitant at first but persistent by 1900' (Gray 'Anxiety' 23) ties in with the loss of certainty that characterises the fin de siècle and the time approaching the First World War. So if the mathematician Oskar Perron sums up the situation of mathematics in decidedly negative terms in 1911 – 'This complete reliability of mathematics is an illusion, it does not exist, at least not unconditionally' (qtd. in Gray 'Anxiety' 41) – in the non-mathematical sphere, the sense of crisis and the questioning of absolute reliability are arguably most prominent in the writings of Friedrich Nietzsche whose thought was even regarded as exemplary of the spirit of the First World War when the feeling of disintegration gave way to a crisis with immediately real consequences. Indeed, as the philosopher William Salter wrote in 1917: 'The present European War is […] even called "Nietzsche in Action," or the "Euro-Nietzschean (or Anglo-Nietzschean) War."' (Salter 357) Given that Nietzsche expressed prevailing ideas of the period, exemplarily examining aspects of his thought will allow establishing a more general picture of the time of the foundational crisis. Works of Max Weber, the 'foremost social theorist of the condition of modernity' (Whimster and Lash 1), and of the philosophers Henri Bergson and Ernst Cassirer will then work as further examples to illuminate the role attributed to mathematics in the wider feeling of crisis and help illustrate how doubts as to the certainty of the foundations of mathematics fed into the more general epistemological crisis propelled not least by the loss of a divine guarantee for truth.

A central concern in Nietzsche's work is the loss of certainty in the second half of the nineteenth century: 'Disintegration characterizes this time, and thus uncertainty: nothing stands firmly on its feet or on a hard faith in itself' (*Will to Power* 40). At the core of the disintegration is the decline of Christian faith: '"God is dead! God remains dead! And we have killed him!"' (*Gay Science* 120) The belief 'that God is truth' (ibid 201) then entails the abolition of truth since its foundation crumbles together with the faith in a divine origin, and given that Christian faith and the notion of truth determine what is considered morally good and valuable, the uncertainty spreads from these domains to almost any area of life. When

Nietzsche therefore proposed a '*revaluation of all values*' (*Twilight* 3) – 'the weight of all things must be determined anew' (*Gay Science* 152) – the nineteenth century is seen to experience a 'foundational crisis'.

Nietzsche diagnosed that the loss of Christian faith as the origin and guarantee of truth and value was coupled with the demand for certainty in other areas, with the greatest hopes being invested in the scientific domain: 'so many materialistic natural scientists rest content [… with] the faith in […] a "world of truth" that can be grasped entirely with the help of our four-cornered little human reason' (*Gay Science* 238). In the 'age of science' as the nineteenth century has been called (see David Knight's *The Age of Science*), science was more widely held to replace the Christian foundation of truth with rational, objective insight into reality: 'in the eyes of many the greatest achievement of science was to end religion's monopoly on "truth"' (Moore 2).[24] Among the sciences, mathematics with its associations of exactness and absolute certainty was deemed best suited for establishing firm grounds of truth. Nietzsche accordingly demanded to 'introduce the subtlety and rigour of mathematics into all sciences [and humanities][25]' (*Gay Science* 148) and proposed mathematics as a means to deal with the crisis of truth: 'Mathematics is […] the means to general and final knowledge of humanity.' (ibid) Mathematics is thus invested with hope to save certainty at a time when this most certain science enters a foundational crisis itself.

While a number of nineteenth-century scientists and philosophers hoped for certain knowledge through mathematics, the sociologist Max Weber used more critical terms to evaluate 'the rationalism and intellectualism of science' ('Science' 142) in the modern West. In 1918, Weber argued that scientific facts only partly compensate for the fragmentation brought about by the decline of faith: science does not lead to 'general knowledge of the conditions under which one lives' but provides a feeling of certainty by inspiring the 'belief that if one but wished one *could* learn it at any time. Hence, it means that principally there are no mysterious incalculable forces that come into play, but rather that one can, in principle, master all things by calculation.' ('Science' 139) Accordingly, in the age of science mankind no longer receives a stable system of truth centred by God but has to force the world into a meaningful order by calculation. The negative consequences of the

[24] In *Equations from God* Daniel J. Cohen investigates the relation of mathematics and religion in the nineteenth century in more detail and argues against assuming mathematics to have served to construct a completely scientific view. Instead, Cohen comes to the conclusion that in the first half of the nineteenth century mathematical logic was widely regarded as of divine purity and simplicity, while by the end of the century a more modest vision had established itself: 'Symbols and laws that so many intellectuals had once hailed as heavenly were recast by mathematicians as earthly creations.' (Cohen 13)

[25] The German term 'Wissenschaft' encompasses both the natural sciences and the humanities; it 'means any organized study or body of knowledge' (Williams x).

rationalisation and mastery by calculation described by Weber were taken to be most immediately visible in the First World War when scientific advances were employed to suppress people, and the belief in intellectual and technological progress gave way to aversion and fear. In two wartime papers, the French philosopher Henri Bergson associates the destructive force of rationalisation with Germany which is threatened to be taken over entirely by 'artificiality', rigidity, and mechanical 'precision': 'What would happen if the mechanical forces, which science had brought to a state of readiness for the service of man, should themselves take possession of man in order to make his nature material as their own?' (Bergson 35) This development in Germany is contrasted to French life-affirming naturalness: 'Whilst the one [force] is gradually spending itself, the other is continually remaking itself. […] Have no fear, our force will slay theirs.' (Bergson 47) Apart from pointing out threatening consequences of rationalisation, Bergson's papers provide an example of the feeling of immediate relevance of the rise of science, particularly in relation to the role of Germany in the First World War.

Nietzsche and Weber, as well as the philosopher Ernst Cassirer, took into account that contemporaneously with the ascendency of science due to its promise to make accessible objective truths, there arises doubt of science being without presuppositions. All three thinkers argue that science does not lead to the stable grounds formerly provided by Christian faith but gives insufficient answers to demands for truth and certainty. Nietzsche holds that 'science, too, rests on a faith; there is simply no "presuppositionless" science. The question whether *truth* is necessary must get an answer in advance, the answer "yes"' (*Gay Science* 200). Similarly, Weber contends that science 'has seemed unable to answer with certainty the question of its own ultimate presuppositions' ('Religious Rejections' 355), and in *Substance and Function*, published in 1910, Cassirer points out that nineteenth-century research into logic 'compels renewed criticism of its presuppositions' (*Substance* 3) and that upon their reexamination '[t]he work of centuries in the formulation of fundamental doctrines seems more and more to crumble away' (ibid). Since 'the concept of number remains the first and truest expression of rational method in general' (*Substance* 27), the foundational crisis in mathematics has an impact on the understanding of reason and, so Cassirer argues, in its interrelation with logic it is central to the philosophical quest for the basis of knowledge: 'The new view that is developing in contemporary philosophy regarding the foundations of theoretical knowledge is manifested perhaps nowhere as clearly as in the transformation of the chief doctrines of formal logic. In logic alone, philosophical thought seemed to have gained a firm foundation' (*Substance* 3). Yet, this also implies that when mathematics is in a crisis, knowledge in general is put into question, and Cassirer even holds

that modern mathematics, which 'remains strictly within the field of its self-created structures, [… and] has in principle no concern with being' (*Substance* 112), is '[f]or the purposes of knowledge of nature, in the positivistic sense of the word, […] a constant danger' (*Substance* 116). Mathematics puts knowledge of nature at risk since it leads away from reality into its self-contained realm, threatening to 'let the empirical determinateness of being disappear into the freedom and caprice of thought' (ibid). And if mathematics as the foundation of knowledge does not allow for knowledge of reality but leads into the free fancy of self-referential mathematical thought, then any study based on it follows the same pattern. Set at the foundations of knowledge and failing to provide knowledge about nature, mathematics thus is at the core of a general epistemological crisis.

The – necessarily selective – thoughts by Nietzsche, Weber, Bergson, and Cassirer are examples that document the increasing importance of science, rationality, and mathematics which, while on the one hand promising to regain some of the certainty lost with the decline of Christian faith, come to be perceived as threatening to control nature and humanity. The revaluation of mathematics in the foundational crisis then challenges the picture of mathematical certainty and, complicating both the hopes for a mathematical footing of society and the fear of excessive rationalisation, decisively influences the role allocated to mathematics in reactions to the crisis of modernity.

b) Language and Literature

Nietzsche points out the interdependence of Christianity and language: 'I am afraid we are not getting rid of God because we still believe in grammar …' (*Twilight* 19). The connection is established in the Bible, which introduces God and language as a unity guaranteeing the signification of the immediately following creation of the universe and mankind: 'In the beginning was the Word, and the Word was with God, and the Word was God' (John 1:1). According to Nietzsche, the death of God and scepticism towards language then are interrelated, and when language is no longer believed to be anchored in God, the need to determine its basic principles becomes more pressing. The research into the foundations of language followed the trend of rationalisation and towards 'artificiality' and 'precision' as identified by Weber and Bergson; a development showing in the upsurge of rationally constructed languages: around 1900 'more plans were made for artificial languages than in any other time'[26] (Mehrtens 527). The attempts to establish the foundations of the language of mathematics can thus be seen as only one example of the

[26] 'um die Jahrhundertwende wurden so viele Pläne für künstliche Sprachen gemacht wie zu keiner anderen Zeit'.

rationalisation of language in general,[27] and if with the transformation of mathematics the readability of the book of nature was at stake, so research into the basic rules of everyday language entailed a reconsideration of the nature of language and its relation to reality and put into question the foundational elements of literature.

Hugo von Hofmannsthal's fictional 'Lord Chandos Letter' from 1902 famously expresses the growing unease regarding language: 'it gradually became impossible for me […] to use those words which all men use constantly and unhesitatingly. […] [T]hose abstractions which the tongue has to pronounce in making any judgement fell apart like rotten mushrooms in my mouth' (Hofmannsthal 9-10). The feeling of a loss of meaning as words are no longer felt to refer to real entities is reminiscent of the situation in mathematics where the increased awareness of constructs without counterparts in nature leads to 'anxiety' (Gray 'Anxiety' 23) and initiates modern mathematics' turn towards its own system. The lectures of the linguist Ferdinand de Saussure, published posthumously in 1916, develop a notion of language similarly dissociated from outward reference. Saussure's concept, which, so N. Katherine Halyes suggests in *The Cosmic Web*, is 'remarkably similar in spirit to those [proposals] occurring about the same time in physics and mathematics' (Hayles 22), introduces two aspects of a sign: the *signifiant* or sound structure, and the *signifié*, the mental concept this sound evokes. The referent does not figure in Saussure's concept, and as the relation to reality is not considered part of language, it does not occasion the meaning of a sign. Instead, its meaning depends on the relation to other signs in the system of language itself. Jacques Derrida builds on Saussure's system when arguing for a rupture in the interpretation of sign and of structure which 'presumably would have come about when the structurality of structure had to begin to be thought' (Derrida 'Structure' 91). Saussure's examination of the structure of language constitutes such a thinking of the structurality of the structure of language, but the foundational crisis of mathematics is an even clearer example: due to its independence from nature, which Derrida for example notes in his *Edmund Husserl's* Origin of Geometry*: An Introduction*, mathematics is not counted towards the natural sciences but considered a structural science (see 3.2), making the research into the fundamental laws of mathematics an investigation into the structurality of a structural science.

Derrida argues that the concept of centred structure is the 'concept of a play based on a fundamental ground, a play constituted on the basis of a fundamental immobility and a reassuring certitude' ('Structure' 90). When the structurality of structure begins to be

[27] Language is a central concern in Mehrtens's *Moderne Sprache Mathematik*; for an examination of language and speech in the discourse of mathematics see Mehrtens 402-522.

thought, the 'fundamental ground' guaranteeing certitude is put into question, namely, the centre of a structure is discovered to be a problematical concept: the centre 'which is by definition unique, constituted that very thing within a structure which while governing the structure, escapes structurality' (ibid). Since therefore 'the centre does not belong to the totality (is not part of the totality), the totality *has its centre elsewhere*. The centre is not the centre.' (ibid) The centre, at which are placed notions such as existence, truth, God, or man, is thus a questionable concept, and Derrida connects the emergence of doubt to the 'Nietzschean critique of metaphysics, the critique of the concepts of Being and truth, for which were substituted the concepts of play, interpretation, and sign (sign without present truth)' ('Structure' 91). As discussed above, similar developments occur when mathematics and language move away from notions of existence and truth and towards the conception of systems made up of signs that are independent of reality. In any structure, the absence of the 'fundamental ground' and certitude formerly supplied by the centre of a structure 'extends the domain and the play of signification infinitely' (ibid). Derrida diagnoses two reactions to the openness resulting from the loss of 'the central signified, the original or transcendental signified': the '*negative*, nostalgic' ('Structure' 102) side 'seeks to decipher, dreams of deciphering a truth or an origin which escapes play' (ibid), while 'Nietzschean *affirmation*, that is the joyous affirmation of the play of the world […], the affirmation of a world of signs without fault, without truth, and without origin' is no longer concerned with foundations and 'tries to pass beyond man and humanism, the name of man being the name of that being who […] has dreamed of full presence, the reassuring foundation, the origin and the end of play' (ibid). Indeed, mathematics roughly splits into these two interpretations when the structurality of this structural science is put under investigation: counter-modern intuitionism seeks an origin of mathematics and its truth in the intuition of man, while modern formalism affirms the freedom of engaging in 'a game played according to certain rules with meaningless marks on paper' (Hilbert qtd. in Burton 621). The self-referential turn thus opens up two fundamentally different paths, one preoccupied with regaining a central foundation, origin, and certitude, the other embracing the freedom of anarchism – anarchism being 'opposed to *archē*. Now, *archē*, in the first instance, means *beginning*, *origin*.' (Eltzbacher 183) (also see chapter on *Against the Day*).

The two paths resulting from examining the structurality of structure not only show in mathematics, thus affecting the notion of the language of the book of nature, but the diagnosed absence of a 'transcendental signified' (Derrida 'Structure' 91) and the epistemological questions highlighted in language scepticism also reverberate in the development of literature. Literature is a primary place to express scepticism of language

since its very medium is affected by it and its relation to reality questioned, and in *The Cosmic Web*, Hayles suggests that these concerns then also inform the development of literary form. She argues that nineteenth-century realist representation of reality is followed by a detachment of fiction from the outside world: 'meaning in a literary text was deemed to derive not from a mimetic relationship between the text and "real life," but from the internal relations of literary codes' (Hayles 23). Similarly to modern mathematics and language, fiction would thus create a self-contained realm apart from reality. In the outline given by Hayles, one branch of the novel in the early twentieth century then becomes anti-realistic and turns inward, 'assuming that literature, like language, is an internal system that has no necessary reference to anything outside itself' (Hayles 23). Alternatively, modern literature turns 'outward toward an apparently external referent', yet, the nature of reality is not represented as objective or 'as an object separate and distinct from its verbal expression. Rather, it is assumed to be continuous with the text, interpenetrating the signifiers that re-present it.' (ibid) According to the second view, fiction is not a completely separate domain but interacts with and makes accessible reality while always filtering and distorting it. For example, James Joyce's *Ulysses* exhibits characteristics of the outward turn when an external reality is implied to exist but the very diverse verbal expression, including passages in Old English, newspaper headlines, and stream-of-consciousness, draws attention to the fact that this reality is only perceptible through the text and is always distorted and changed by it. *Ulysses* also illustrates the inward turn when the episode 'Oxen of the Sun' is concerned mainly with the system of the English language and literature itself, tracing its development from Anglo-Saxon alliteration over the writings of Laurence Sterne and Charles Dickens to Dublin slang.

Hayles only suggests the possibility of writing the history of an inward and an outward turn of the modern novel, working with the premise that it 'would end by establishing: that well-known developments in the modern novel are part of a larger paradigm shift' (Hayles 24) which is also discernible in language scepticism and the foundational crisis of mathematics. It is not necessary in this case to just embrace Hayles's positing of a paradigm shift or 'profound transformation' (Hayles 15) in early twentieth-century thought, but based on a common concern with a language in crisis – literary and mathematical language respectively – the two-way response that Hayles identifies in regard to literature suggests a comparison with the history of mathematics, in particular the split into the schools of modern formalism and counter-modern intuitionism. The characteristics of inward-turning literature after the abandonment of realism resemble traits of modern mathematics: literature and the modern reaction to the foundational crisis of mathematics

respectively assume to be 'internal system[s]' without 'necessary reference to anything outside' (Hayles 23). By contrast, the outward turn presents the object as inextricably linked with the means of expression, so that reality is made accessible but not directly represented. This second response shares characteristics with the counter-modern orientation of mathematics, when intuitionists judge mathematical language to be an insufficient instrument to express the intuitive, pre-linguistic reality of mathematics: 'Such a linguistic accompaniment is not a representation of mathematics; still less is it mathematics itself.' (Heyting 42) Nevertheless, and complying with the outward turn of literature, intuitionism accepts mathematical language as a necessary evil to make graspable the reality of mathematics as experienced intuitively. The discussion of Broch's *The Sleepwalkers* will further examine parallels between modern and counter-modern mathematics and novelistic form, but a more general question following from the parallels between modern mathematics and the modern novel will be addressed next: if the developments of mathematics and literature around the turn of the century have common characteristics, can the two domains be said to converge in modernist responses to the crisis of modernity?

2.3 Modernism

When Robert Louis Stevenson challenged Henry James's claim in 'The Art of Fiction' (1884) that art competes with life, he illustrated his view with the example of mathematics which he compared to the creative arts: 'The arts, like arithmetic and geometry, turn away their eyes from the gross, coloured and mobile nature at our feet, and regard instead a certain figmentary abstraction. Geometry will tell us of a circle, a thing never seen in nature; asked about a green circle or an iron circle, it lays its hand upon its mouth. So with the arts.' (Stevenson 84) If a literary author compared art to the nature of mathematics,[28] so mathematicians detected literary features in their field. Referring to his discovery of non-Euclidean geometry, Bolyai wrote: 'I have created a new and different world out of nothing' (qtd. in Gray *János Bolyai* 52), thus declaring the creation of worlds for mathematics when in the common or 'naïve' understanding of mathematics and literature 'as the opposite ends of a spectrum of disciplines' (Westfahl) it is more likely located at the side of literature. The mathematician G. H. Hardy praised mathematics' '"[i]maginary" universes [which] are so much more beautiful than this stupidly constructed "real" one' (Hardy 135), while Poincaré less memorably conceded that 'mathematical reasoning has of itself a kind of creative virtue'

[28] Also see Musil's essay 'The Mathematical Man' and Yevgeny Zamyatin's 'On Literature, Revolution, Entropy, and Other Matters'.

(*Hypothesis* 3), and Weyl suggested that '"[m]athematizing" may well be a creative activity of man' (*Philosophy* 219). A convergence of literature and mathematics has thus been noted both from the side of the humanities and of mathematics, and exemplary instances of the two positions will be explored below.

a) Mathematics as Fiction – Philosophical Views

Cassirer's words about mathematics letting 'the empirical determinateness of being disappear into the freedom and caprice of thought' (*Substance* 116) evoke features of literary fiction. Nietzsche also associates the two domains when using mathematics as an example to argue that reality cannot be perceived directly but is always interpreted. According to his '"Perspectivism"' 'facts is precisely what there is not, only interpretations. [… The world] has no meaning behind it, but countless meanings.' (*Will to Power* 267) Consequently, '"[t]ruth" is […] not something there, that might be found or discovered – but something that must be created' (ibid 298). Even mathematics is caught up in this perspectivism and, instead of getting to the facts of reality directly, creates interpretations of reality: 'logic (like geometry and arithmetic) applies only to fictitious entities that we have created' (ibid 280). Mathematics is here not perceived as the language of the book of nature or as abstractions but as the language of 'fictitious entities', making mathematics a fiction: 'The arithmetic formulas, too, are only regulating fictions which we use to simplify and arrange real events to our proportion'[29] ('Posthumous'). Indeed, contrary to the hopes of its substituting the certainty no longer provided by Christian faith, Nietzsche claims mathematics not to be the 'paragon of truth and certitude' (Hilbert 'Infinite' 141) but to constitute one of our 'falsest judgements': 'our fundamental tendency is to assert that the falsest judgements (to which synthetic judgments *a priori* [e.g. mathematics] belong) are the most indispensable to us, that without granting as true the fictions of logic, […] without a continual falsification of the world by means of numbers, mankind could not live' (*Beyond Good and Evil* 35). Thus, according to Nietzsche, mathematics is not true but is claimed to be so because it is indispensable to life. It is consistent with Nietzsche's view of mathematics as a necessary fiction that the foundational crisis of mathematics subsides in the pragmatic practice of acknowledging the failure of the formalist programme while nevertheless holding on to its still useful tools.

[29] 'Die arithmetischen Formeln sind ebenfalls nur regulative Fiktionen, mit denen wir uns das wirkliche Geschehen […] vereinfachen und zurechtlegen.'

The German philosopher Oswald Spengler contributed to the philosophical responses to the crisis of mathematics with the highly controversial *The Decline of the West*, published in 1918 and 1922, which connects the foundational crisis with the wider sense of decline in the early twentieth century. Spengler argued that politics, philosophy, and mathematics, among other areas, are interrelated: 'Deep relations were revealed between political and mathematical aspects of the same Culture' (Spengler 47). Changes in any one area, Spengler contended, are always bound up with developments in other fields; for example: 'Every philosophy has hitherto grown up in conjunction with a mathematic *belonging* to it.' (Spengler 56) Mathematics thus develops in interrelation with philosophy and other fields, and while concepts such as irrational and imaginary numbers are regarded as 'impossible, futile and senseless' (Spengler 67) in certain periods, in other cultures or times the same 'mathematical […] way of thinking is right, convincing, a "necessity of thought"' (Spengler 67). Spengler concluded that '*[t]here is not, and cannot be, number as such*. There are several number-worlds as there are several Cultures.' (Spengler 59) Following from the idea that 'there are more mathematics than one' (ibid), any one instance of mathematics – any *mathematic* – cannot be said to be objective and absolute: mathematical '[t]ruths are truths only in relation to a particular mankind' (Spengler 46). Spengler explains this perspectivism of mathematics with its essentially belonging to the sphere of art: 'The mathematic, then, is an art. As such it has styles and style-periods.' (Spengler 62)

If Spengler's view of mathematics takes up Nietzsche's concept of perspectivism and claims that '"Mathematics" is an illusion' (Spengler 67), the third part of Cassirer's *The Philosophy of Symbolic Forms*, published in 1929, establishes mathematics as a symbolic form which represents 'ideal relations' (*Symbolic Forms* 380). Against the background of 'the conflict between "formalism" and "intuitionism" in its present acute form' (ibid 357), Cassirer then argued for considering mathematics in terms similar to language or art, which 'builds up a peculiar and independent, self-contained world of meaning according to an inherent formative law of its own' (ibid 383). Correspondingly, mathematics 'builds up this [physical] world according to its structure and so teaches us to understand it through the laws that prevail in it' (ibid 384). Although a 'characteristic process of detachment, of logical emancipation' (ibid 393) results from the introduction of ideal elements such as imaginary numbers, the 'trend of ideal formation' (ibid 383) does not inhibit the usefulness of mathematics. Rather, the 'unquestionable fruitfulness of the ideal elements' (ibid 391) enhances mathematics. With the notion of fruitful yet inexistent ideal formations in mathematics, Cassirer reflects Nietzsche's view of mathematics as a necessary fiction.

The German philosopher Hans Vaihinger notes the relation between ideals and fictions: 'all ideals, logically considered, are fictions' (Vaihinger 47). *The Philosophy of "As If"*, published in 1911, establishes the sense in which mathematics can be considered a theoretical fiction and introduces the situation in mathematics as a forerunner of a more general valuation of fictions. Vaihinger argued that mathematical elements, such as 'points without extension, lines without breadth, surfaces without depth', are 'contradictory fictions, mathematics being based upon an entirely imaginary foundation, indeed upon contradictions' (Vaihinger 51). The acknowledgement of the 'purely imaginative basis' (Vaihinger 57) of mathematics invites mathematicians to appreciate the continued value of 'contradictory' concepts such as '*negative* numbers, *fractions*, and *irrational* and *imaginary* numbers […] – they are fictional constructs possessing great value for the advancement of science' (Vaihinger 57), and, so Vaihinger contended, '[t]he imaginary (the absolute, ideal) is therefore justifiable in spite of its unreality' (Vaihinger 44). He further pointed out the particular importance of fictional elements in the mathematics of the early twentieth century: 'Modern mathematics is characterized specifically by the freedom with which it forms these fictional constructs.' (Vaihinger 148) As a domain of freedom, modern mathematics is then suggested as a model for other – and real – areas of life: '"Freedom is only an entity of thought", but mankind must retain this imaginary ideal, just as the mathematicians, for example, retain imaginary ideal points in spite of their inner contradiction.' (Vaihinger 44) Vaihinger thus voiced the hope that the development of modern mathematics, its freedom and fictionality, would provide an exemplar to areas of twentieth-century life that were increasingly losing freedom when becoming dominated by rationalisation and calculation.

Philosophers in the period of a revaluation of values proposed the 'modernist transformation' (Gray *Plato's Ghost* 1) of mathematics to serve as an example for the loss of absolute truth and the fruitfulness of fictional constructs. Pynchon, Broch, and Musil thus could build on philosophical views that argued for similarities between modern mathematics and fiction, and, as will be discussed in this study, their novels illustrate the interest in the suggested modernist convergence of mathematics and literary fiction. Pynchon's more recent novels fall into the period of revived interest in interrelations of mathematics and fiction and will allow comparing the contemporary responses to the period of drastic change in mathematics and its relation to literature with an imaginative engagement from a greater temporal distance.

b) Mathematics as Fiction – Mathematical Views

Corresponding to the interest of philosophers in the convergences between modern mathematics and fiction, mathematicians at the time of the foundational crisis were engaged in relating their research to philosophical questions and claimed similarities between mathematics and literature in their stead; Leopold Kronecker is even credited with the phrase: 'We mathematicians are the true poets, but we have to prove what our imagination creates.'[30] Yet, only in 1980 did philosophers of mathematics overcome what 'appear to be insuperable obstacles to the suggestion that mathematics may profitably be considered to be a kind of fiction' (Tharp 167) and formulated it into a theory.[31] Fictionalism, introduced in Hartry Field's *Science without Numbers*, maintains that mathematical theories are not true since the mathematical objects they seem to be about do not exist. Field compares the notion of truth of a mathematical theory to the truth of a statement about literary fiction which is true according to the conditions set out by the text but not true in reference to reality. For example, the statement 'Oliver Twist lived in London' is true when considered in reference to the fictional universe of Charles Dickens's *Oliver Twist*, but is not true in reality since Oliver Twist is a fictional character and never existed. Accordingly, the 'fictionalist can say that the sense in which "2+2=4" is true is pretty much the same as the sense in which "Oliver Twist lived in London" is true: the latter is true only in the sense that it is true *according to a certain well-known story*, and the former is true only in that it is true *according to standard mathematics*' (Field *Realism* 3). In other words, fictionalism claimed that a 'mathematical theory is like a work of fiction. We have to work within the constraints of the theory.' (Friend 134)

Field's fictionalism triggered a lot of response but was largely rejected. A recurring question regarding fictionalism, as well as modern mathematics in general, concerns the 'unreasonable effectiveness of mathematics' (Wigner 222), its surprising fruitfulness given its independence from nature. The objection is technically formulated in the Quine-Putnam indispensability argument, but a simpler version reads: '"Our mathematical theories are extremely useful in empirical science […] and the only way to account for this is to admit that our mathematical theories are true."' (Balaguer 133) The reasons why mathematics fits to the world continue to puzzle mathematicians and philosophers; however, there are other

[30] 'Wir Mathematiker sind die wahren Dichter, nur müssen wir das, was unsere Phantasie schafft, auch beweisen.'

[31] The mathematician Robert S. D. Thomas discusses some views of the large number of philosophers who observe some similarity between mathematics and fiction. In his two-part paper 'Mathematics and Fiction', Thomas proposes that Field's is not an acceptable notion of fiction to be compared with mathematics.

explanations than assuming its truth or considering the 'miracle of the appropriateness of the language of mathematics [… to be] a wonderful gift which we neither understand nor deserve' (Wigner 237). For example, the physicist and philosopher Gerhard Vollmer puts forward a combination of reasons: mathematics describes structures; nature is structured; mankind is adapted to the structured world through evolution and can recognise some of these structures; and finally, language, logic, and mathematics are tools to formulate structures that cannot be recognised directly, for example because they are too large or too small (see Vollmer 121-142).

Field's fictionalism on the mathematical side and Pynchon's postmodernist revisiting of a possible convergence of mathematical and fictional characteristics on the side of literature demonstrate that similar concerns animate thinkers in the late twentieth century as in its first decades. The French philosopher Alain Badiou similarly takes the example of mathematics to concerns of the postmodern era when arguing in the late 1980s that number is not 'an operational fiction' but: 'Number is *a form of Being*.' (*Number* 211) He holds that, since modern mathematics has no direct relation to reality and ultimately 'is' itself, '[i]n mathematics, being, thought, and consistency are one and the same thing' ('Platonism' 95). For Badiou, mathematics is thus not a fiction fruitfully employed to gain knowledge and therefore not a part of epistemological questions, but he makes '[t]he (philosophical) statement that mathematics *is* ontology – the science of being qua being' (*Being and Event* 4). With the assertion '"mathematics = ontology"' (ibid 6) Badiou transfers the modern interest in mathematics' epistemological role to the postmodern concern with ontology. Brian McHale introduces this shift in focus in relation to fiction when arguing that 'the dominant of modernist fiction is *epistemological*' (*Postmodernist Fiction* 9), whereas 'the dominant of postmodernist fiction is *ontological*' (ibid 10). Musil's *The Man without Qualities* and Broch's *The Sleepwalkers* are primarily concerned with ways of perceiving the world and therefore ask typical modernist questions such as 'What is there to be known?; Who knows it?; How do they know it, and with what degree of certainty?; […] What are the limits of the knowable?' (ibid 9) In contrast, as McHale points out when tracing the development in Pynchon's writing, *Gravity's Rainbow* is his first novel 'no longer constrained by the limits of modernism, [… but it] freely exploit[s] the artistic possibilities of the plurality of worlds, the transgression of boundaries between worlds' (ibid 24-25), foregrounding postmodernist questions such as: 'Which world is this? What is to be done in it? Which of my selves is to do it?' (Dick Higgins qtd. in ibid 10) *Against the Day* then even more clearly explores a plurality of worlds, not least since it incorporates traits of science fiction which 'is perhaps *the* ontological genre *par excellence*' (ibid 59): 'Science fiction, by

staging "close encounters" between different worlds, placing them in confrontation, foregrounds their respective structures and the disparities between them. It thus obeys the same underlying principles of ontological poetics as postmodernist fiction.' (ibid 60)

The fact that the interest of mathematicians, philosophers, and writers turns to the ontological dimension of the foundational changes in mathematics illustrates not only that the mathematical development continues to be of concern for thinkers in the late twentieth and twenty-first centuries, but that it is bound up with wider questions of living and existence, thus supporting the protagonist's conviction in *The Man without Qualities* that mathematics can directly pertain to life: 'If someone had asked him at any point while he was writing treatises on mathematical problems or mathematical logic […] what it was he hoped to achieve, he would have answered that there was only one question worth thinking about, the question of the right way to live.' (*MwQ* 275) For mathematicians, philosophers, and literary writers in the early and the later twentieth century, the fictional characteristics of modern mathematics in particular initiate the questioning of Enlightenment values and ontology but also raise the hope that responses to the crisis of modernity could be found in the (post)modernist creative domain.

3. The Relations of the Sciences and the Humanities

3.1 Disciplinary Boundaries and Communication with Laypersons

Philosophical and mathematical thinkers in the nineteenth and twentieth centuries suggested convergences of mathematics and fiction in modernist characteristics, but on the disciplinary level a split began to develop between the sciences and the humanities. Disciplines became specialised in the nineteenth century: science superseded its precursor natural philosophy, and the coinage of the word 'scientist' in 1833 signals the emergence of a professional scientific community. The sciences and humanities then increasingly formed into separate specialised domains, so that around 1860 'literature and science settled into considering one another as definitely different systems of knowledge, with no individual expected to master both' (Jenkins *Space* 233). In 1959, C. P. Snow's talk 'The Two Cultures' famously pointed out the resulting rift in knowledge. Snow diagnosed a division between literary intellectuals and scientists and lamented the fact that while scientists engaged with literature, literary intellectuals could not recite the most important scientific laws. He likely would also have agreed with the mathematician Norbert Wiener who wrote in 1956: 'the layman does not conceive it to be any part of his aesthetic and cultural duty to understand the least thing about mathematics' (Wiener 62). The relatively short history of

what can be termed 'science', the interrelated transformations in the sciences and the humanities at the beginning of the twentieth century, and literary testimonials of engagement with science such as those discussed in this study indicate that Snow's diagnosis of a split between the two cultures cannot be easily applied to the situation half a century before his talk. Similarly, the situation today is different from fifty years ago, but the fact that Snow is still cited frequently – and indeed serves as 'a straw man who has been so comprehensively pummelled that every last shred of his stuffing has vanished in the wind' (Sleigh 3) – is illustrative of the still common perception of an incompatibility of the sciences and humanities that has its beginnings in the disciplinary division in the nineteenth century.

In nineteenth-century Germany, demands to strengthen the position of the sciences in education won wide attention and demonstrate the beginning split between the natural sciences and the humanities on the Continent (see Albrecht 'Überall'). However, the different disciplinary structures in Britain and Germany reflect and influence the relation between the sciences and the humanities, and also inform the respective development of mathematics. José Ferreirós notes that the 'German scientific community seems to have been somewhat peculiar, within the context of the international panorama in the nineteenth-century' (Ferreirós 4), with German mathematics being characterised by 'the preference for a strictly theoretical orientation, the concentration on narrowly defined specialities or branches of mathematics, and in many cases a close attention to the philosophical presuppositions of the advocated theories' (Ferreirós 7). Particularly the University of Göttingen, the centre of mathematical research during the foundational crisis, profited from a 'close connection between the mathematicians and the philosophers, unmatched anywhere else' (Gray *Plato's Ghost* 209), which contributes to elucidating the fact that the core questions of the foundational crisis of mathematics concern the philosophical issues of the 'shaking of the terms of truth, meaning, object, existence in mathematics'[32] (Mehrtens 8).

The philosophical orientation of German mathematics interrelates with the primacy of abstract mathematics, while in Britain the movement of modern mathematics 'first needed to establish a recognizable group of pure mathematicians, something that had been long delayed by the successes of applied mathematics as a research subject in Cambridge and its visible technological triumphs' (Gray *Plato's Ghost* 5). The different orientations of Continental and British mathematics partly originated in the quarrel between Gottfried Wilhelm Leibniz and Isaac Newton who both claimed to have invented the calculus. The contention not only shook the mathematical community of the eighteenth

[32] 'die Erschütterung der Begriffe von Wahrheit, Sinn, Gegenstand, Existenz in der Mathematik'.

century but turned into a question of national pride, and while Leibniz's more intuitive notation was adopted throughout Europe, British mathematicians held true to Newton's system and consequently became mathematically isolated (see Rice 148). The reverse is true when after the First World War the predominance of mathematical talks and publications in German (along with French) came to an end, and the mutual boycott of German scientists and international science associations resulted in the isolation of German science.[33] The distinct characteristics of a German and British mathematical culture then subsided in the middle of the twentieth century.

The respective focus on applied and abstract mathematics and the different degrees of institutional proximity with philosophy also influenced the resources available to mathematically interested laypersons. 'By the end of the nineteenth century, the study of the history of mathematics was a significant part of German mathematical life' (Gray *Plato's Ghost* 366), and while in the US Florian Cajori wrote his successful *A History of Mathematics* which was published in 1894, in Britain, '[d]espite the reasonable importance of the country in the development of mathematics, the measure of historical writing is, and always has been, quite modest' (Grattan-Guinness 'The British Isles' 161). British empiricism encouraged 'an historiography which has always deemed the history of mathematics to be irrelevant to current knowledge and understanding, or at best a marginal activity' (ibid), so only when the British Society for the History of Science was founded after the Second World War, 'within its modest scale of activities the history of mathematics had some place' (ibid 176). The history of mathematics then developed more rapidly in the early 1970s when it also enjoyed renewed interest in other countries (see ibid 178) and fostered a genuinely *historical* focus.

The different disciplinary contexts and conditions of mathematics in nineteenth-century Britain and Germany – applied mathematics with strong ties to 'its visible technological triumphs' (Gray *Plato's Ghost* 5) on the one side, on the other abstract mathematics informed by closer exchange with philosophers and reaching out to laypersons – go some way to explain why British literature in the early twentieth century shows less awareness of mathematics and rather reflects on its applications in science and technology and on the resulting threats (for example H. G. Wells, E. M. Forster, D. H. Lawrence, Virginia Woolf, Aldous Huxley). In contrast, direct concern with mathematics is evident in Broch's *The Sleepwalkers* and Musil's *The Man without Qualities*, not least helped by the fact that both authors studied mathematics at university and thus were far

[33] See for example Roswitha Reinbothe's study of German as an international language in the sciences and the boycott after the First World War.

better informed than the average layperson of their time. Pynchon, who studied engineering physics, similarly has expert knowledge of mathematics but also easier access to non-specialist accounts of events in early twentieth-century mathematics.

3.2 The Missing Link: The Structural Science Mathematics

Mathematics is not a natural science but a structural science, and as such it has a special position in the relation of the sciences and the humanities. As the above examination of convergences between modern mathematics and literary fiction suggests, mathematics considered in its specificity complicates the strict division of the disciplines and can be regarded as a field escaping or straddling the divide.

The structural sciences include semiotics, chaos theory, information theory, and game theory, '[b]ut the archetype of the structural sciences is mathematics'[34] (Küppers *Nur Wissen* 315). The physicist and philosopher Bernd-Olaf Küppers identifies 'that an unmistakable characteristics of all structural sciences is the fact that their object is all of reality'[35] ('Strukturwissenschaften' 102). Concerned with 'the whole world'[36] (*Physik* 18), the structural sciences 'abstract from the qualitative characteristics of an object and substitute reality with mathematical terms, symbols and their transformations' [37] ('Strukturwissenschaften' 20). With their level of abstraction the structural sciences constitute what Weyl called 'a *logical mold ("Leerform") of possible sciences*' (*Philosophy* 25), and the fact that the abstract structures are applicable to any domain and thus 'create some kind of common basis of the two main currents of the sciences and the humanities'[38] (Küppers *Nur Wissen* 319) explains why the structural sciences seem 'best suited to build a bridge between the natural sciences and the humanities'[39] (*Physik* 104). Thus, although 'the convergence between the natural sciences and the humanities is not symmetrical'[40] (*Nur Wissen* 319-20) since the structural sciences play a significantly larger role in the natural sciences, the linking of the two cultures as demanded by Snow would not

[34] 'Die Urform aller Strukturwissenschaften ist jedoch die Mathematik.'
[35] 'daß ein unverwechselbares Kennzeichen aller Strukturwissenschaften darin besteht, daß ihr Gegenstandsbereich die gesamte Wirklichkeit ist'.
[36] 'die gesamte Welt'.
[37] 'von den qualitativen Eigenschaften eines Gegenstandes abstrahiert und die Wirklichkeit durch mathematische Begriffe, Symbole und deren Transformationen ersetzt'.
[38] 'so etwas wie das gemeinsame Fundament der beiden großen Wissenschaftsströmungen bilden'.
[39] 'am ehesten geeignet zu sein, zwischen den Natur- und und [sic] den Geisteswissenschaften eine Brücke zu schlagen'.
[40] 'verläuft die Annäherung zwischen Natur- und Geisteswissenschaft nicht symmetrisch'.

be a vision, but, as Küppers contends, 'it already has taken a concrete form in the development of the structural sciences'[41] (*Nur Wissen* 319).

Regarding the humanities Küppers only identifies characteristics of the structural sciences in structuralism and linguistics, but the abstract features of mathematics also extend to literature: 'The term "mathematics" […] was coined among the Pythagoreans where it described the ordered insight into numbers', and as 'the theory of order mathematics engages with everything in life, with all the sciences – and with art too'[42] (Menninger 8). If the structural sciences are concerned with 'the whole world' (Küppers *Physik* 18) and mathematics is the 'theory of order', in the domain of literature, encyclopaedic novels address a 'full range of knowledge and beliefs' (Mendelson 1269) and search for 'a pattern that will explain, or at least enable man to order, the whole of life' (Pike 119). As literary attempts to order the whole of life, it is not surprising that encyclopaedic novels should be concerned with mathematics, the 'theory of order'. The focus is particularly apt regarding the modernist encyclopaedic novel, which relates to the period of declining faith in Christianity's ability to order life and growing hope to regain certainty by means of mathematics. Not all encyclopaedic novels directly address mathematics of course, but the underlying similarities in outlook suggest fruitful possibilities of combination, and Pynchon, Broch, and Musil take advantage of these. So if mathematics connects concerns of the natural sciences and the humanities in the domain of abstract engagement with the world, novels with encyclopaedic characteristics such as *Gravity's Rainbow*, *The Sleepwalkers*, *The Man without Qualities*, and *Against the Day* suggest the possibility of linking mathematics and literature through the imaginary domain of fiction.

4. The Study of Mathematics and Literature

In the last decades, mathematics has forcefully entered popular culture, not least through a soaring number of novels, plays, films, and short stories with mathematical content – Alex Kasman's online database *Mathematical Fiction* gives an indication of the trend. In the wake of this development and the study of mathematics in relation to its historical, social, and cultural conditions, scholarly attention has also been directed to connections between mathematics and literature and has resulted in a number of collected works on the topic. In just the last year, four essay collections appeared in the area. *Mathematics in*

[41] 'sie hat in der Entwicklung der Strukturwissenschaften bereits konkrete Formen angenommen'.

[42] 'Das Wort "Mathematik" […] wurde in dem Kreis der Pythagoreer geprägt und bezeichnete dort geordnete Einsichten über Zahlen'; 'daß die Mathematik als Lehre von der Ordnung überall in unser Leben eingreift, in alle Wissenschaften – und auch in die Kunst'.

Popular Culture (2012), edited by Jessica and Elizabeth Sklar, combines essays on mathematical appearances in film, fiction, games, television, and other media. Contributions consider public perceptions of mathematics and mathematicians, explore the use of mathematical metaphors, and range from an examination of the commonly treated play *Arcadia* by Tom Stoppard to the more unusual case of analysing mathematics in role-playing games. Two recent essay collections are outputs of the research project 'Die Mathematik im Jenseits der Kulturwissenschaften; Zur literarischen und kulturellen Konstruktion des Mathematischen zwischen 1880 und 1950' at the University of Freiburg, led by Andrea Albrecht. The project reacts to the neglect of mathematics in cultural science studies and explores the role of mathematics by comparing and interpreting literary and cultural constructions of mathematics. Drawing on sources from literature, cultural science, the philosophy of mathematics, and texts by mathematicians, Albrecht's project aims to demonstrate that the changing relation between these fields is a constitutive element in cultural self-understanding in the period from 1880 to 1950. The publication in relation to the research project is *Fiktum versus Faktum? Nicht-mathematische Dialoge mit der Mathematik*, a collection of essays edited by Franziska Bomski and Stefan Suhr and published in Germany in 2011. The major part of the collection is dedicated to studies of literature and mathematics, while other contributions address mathematics in film and in philosophical texts. *Zahlen, Zeichen und Figuren* (2011), edited by Andrea Albrecht, Gesa von Essen, and Werner Frick, brings together essays on mathematics and music, the arts, and literature respectively. The section on mathematics and literature includes a paper by Leo Corry that is also available in English as 'Calculating the Limits of Poetic License: Fictional Narrative and the History of Mathematics'. With reference to Aristotle's distinction of fiction and history, Corry investigates the role of poetic licence and of suspension of disbelief in mathematics, the history of mathematics, and mathematical fiction. Thematically, Corry's essay relates to a growing theoretical interest in the interplay of mathematics and narrative, a concern that has led to the 2012 publication of *Circles Disturbed*. The essay collection, edited by Apostolos Doxiadis and Barry Mazur, combines contributions by mathematicians and literary scholars which discuss narratives of mathematics, the interplay of mathematics and narrative under structural and historical viewpoints, and the role of mathematics in the literary study of narrative. In relation to this study, Federica La Nave's examination of Rafael Bombelli's wrestle with the concept of imaginary numbers is particularly interesting, as is Uri Margolin's suggestion of classifying mathematics in narrative according to different categories: having a mathematician as character, using numbers or mathematical concepts as thematic or structuring devices,

employing concepts common to both mathematics and narrative, and the metanarrative use of mathematics in theories of narrative. In the most detailed section on concepts common to both mathematics and narrative, Margolin formulates the suggestive similarities between fiction and the modern notion of mathematics that the above discussion has shown to stimulate thought around the turn of the twentieth century:

> Both mathematical systems and literary narratives as symbolic systems belong in the realm of stipulation or free creation, free from the constraints of the empirical and material. Of both it can be said that they involve the creation of imaginary worlds, conjured into intersubjective being through signs (words, mathematical notation). Truth by correspondence to the actual world is not excluded, but is not criterial in either. (Margolin 488)

A notable, slightly earlier contribution to mathematics and literature studies is the 2009 special issue of *Configurations* on mathematics and the imagination. The essays come from both sides of the disciplinary divide and are concerned with questions of 'how/what mathematicians imagine when they do math, and how mathematics is imagined by mathematicians and nonmathematicians alike' (Saiber and Turner 12-13). *Journal of Romance Studies* has featured an issue on 'Literature and the Mathematical' in 2007, whose focus is '*literature's* relationship to mathematics' (Hanrahan 3). Barbara Fisher's *Noble Numbers, Subtle Words; The Art of Mathematics in the Science of Storytelling* (2007) likewise takes a literary perspective when Fisher examines mathematical elements as literary instruments in works by William Shakespeare, John Milton, Henry James, Jorge Luis Borges, and Toni Morrison. Finding several chapters on mathematics combined in one book of literary scholarship is still unusual,[43] but essays examining texts and topics treated by Fisher begin to be more in evidence in the 1960s, and their number has grown steadily in decades since. Apart from Pynchon, Broch, and Musil, authors and works frequently treated under the aspect of mathematics in English-speaking books and essays are William Shakespeare[44], Edwin A. Abbott's *Flatland*[45], James Joyce[46], Samuel Beckett[47], Jorge Luis

[43] An early book-length study is Scott Buchanan's *Poetry and Mathematics* from 1929. In the German-speaking context, the mathematician Knut Radbruch displays a relatively early interest in mathematical fiction and interrelations of mathematics and the humanities. In *Mathematik in den Geisteswissenschaften* (1989), Radbruch examines mathematics in relation to language, literature, religion, music, history, law, and philosophy. In the chapter on literature, he explores the use of mathematics in quantitative analyses of literary style and in the form of number symbolism before giving short overviews on mathematics in the work of Novalis, Broch, Musil, Hermann Hesse, and Max Frisch. A systematic account of mathematical traces in literature is given in *Mathematische Spuren in der Literatur* (1997), while a chapter in Radbruch's book towards a cultural philosophy of mathematics, *Bausteine zu einer Kulturphilosophie der Mathematik* (2009), addresses the topic of mathematical education in twentieth-century German literature.

[44] See for example: David Bady, 'The Sum of Something: Arithmetic in *The Merchant of Venice*'; Paula Blank, 'Shakespeare's Equalities: Checking the Math of *King Lear*'; Brian Rotman, *Signifying Nothing: The Semiotics of Zero* (78-86).

[45] See for example: Lila Marz Harper, '*Flatland* in Popular Culture'; Rosemary Jann, 'Abbott's

Borges[48], Tom Stoppard[49], and works by the group Oulipo[50] – a group of writers and mathematicians experimenting with constrained writing techniques, founded in 1960.[51] The novels by Pynchon, Broch, and Musil take a special position among literature with mathematical content: other than most mathematical fictions, which do not aim at presenting mathematics as part of a broader encyclopaedic endeavour and whose formal innovations are far more modest,[52] Pynchon's, Broch's, and Musil's works relate mathematics to its historical and cultural contexts and thus address concerns that also animate the relatively recent reorientation in scholarly examinations of mathematics.

Mathematics in literature has been noted for some time, and with the recent upsurge in mathematical fictions and the development towards more historical and cultural studies of mathematics, the field has been added to from both the side of literature and of mathematics

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"Flatland": Scientific Imagination and "Natural Christianity"'; Mark McGurl, 'Social Geometries: Taking Place in Henry James'; Chris Pak, 'Discovering a Higher Plane: Dimensionality and Enlightenment in *Flatland*'; Jonathan Smith, Lawrence I. Berkove, and Gerald A. Baker, 'A Grammar of Dissent: *Flatland*, Newman, and the Theology of Probability'.

[46] See for example: Reed Way Dasenbrock and Ray Mines, '"Quella vista nova": Dante, Mathematics and the Ending of *Ulysses*'; Michael Livingston, '"Dividends and Divisors Ever Diminishing": Joyce's Use of Mathematics in "Ithaca"'; Patrick A. McCarthy, 'Joyce's Unreliable Catechist: Mathematics and the Narration of "Ithaca"'; Jean-Michel Rabaté, 'Joyce, Husserl, Derrida: Calculating the Literary Infinite'; Thomas Jackson Rice, *Joyce, Chaos, and Complexity*.

[47] See for example: Hugh Culik, 'Mathematics as Metaphor: Samuel Beckett and the Esthetics of Incompleteness'; John Vignaux Smyth, 'A Glance at SunSet: Numerical Fundaments in Frege, Wittgenstein, Shakespeare, Beckett'; Brett Stevens, 'A Purgatorial Calculus: Beckett's Mathematics in "Quad"'; Céline Surprenant, 'An Occult Arithmetic: the "Proustian Equation" according to Beckett's *Proust*'.

[48] See for example: William G. Bloch, *The Unimaginable Mathematics of Borges' Library of Babel*; Guillermo Martinez, *Borges and Mathematics*; Floyd Merrell, 'Borges: Between Zero and Infinity' and *Unthinking Thinking: Jorge Luis Borges, Mathematics, and the New Physics*.

[49] See for example: Stephen D. Abbott, 'Turning Theorems into Plays'; Sharon Alker and Roberta Davidson, 'Smart Girls: The Uncanny Daughters of *Arcadia* and *Proof*'; Zekiye Antakyalioglu, 'Chaos Theory and Stoppard's *Arcadia*'; Robert L. Devaney, 'Chaos, Fractals, and Tom Stoppard's *Arcadia*'; David Guaspari, 'Stoppard's Arcadia'.

[50] See for example: Elvira Monika Laskowski-Caujolle, 'Jacques Roubaud: Literature, Mathematics, and the Quest for Truth'; François Le Lionnais, 'Raymond Queneau and the Amalgam of Mathematics and Literature'; Caroline Marie and Christelle Reggiani, 'Portrait of the Artist as a Mathematician'; Véronique Montémont, 'Roubaud's Number on Numbers'; Jacques Neefs, 'George Perec: Distributive Constraints, Textual Liberties'; Jacques Roubaud, 'Bourbaki and the Oulipo' and 'Mathematics in the Method of Raymond Queneau'; Colin Symes, 'Writing by Numbers: OuLiPo and the Creativity of Constraints'.

[51] Also see Brian Rotman's overview of mathematics in literature in *The Routledge Companion to Literature and Science* (2011).

[52] Michael Köhlmeier's *Abendland* (2007) is partly an exception. The novel, whose title gives rise to associations with Spengler's *Der Untergang des Abendlandes* (*The Decline of the West*), spans the twentieth century and relates major developments that are held together by the main protagonists – a mathematician and a writer. While comparable to the discussed novels in its ambition to chart a whole century, *Abendland* does not accord mathematics a position as prominent or as intricately interwoven with social, cultural, or political concerns. Also, Köhlmeier's novel is formally far less inventive. For a discussion of mathematics and the history of mathematics in Köhlmeier's novel see Albrecht's '"Spuren menschlicher Herkunft"'.

as well as by interdisciplinary projects. Yet, the relation between literature and the science furthest removed from nature and the human being is still among the least explored in the larger field of literature and science studies. In her essay 'George Eliot, Geometry and Gender', examining the gender coding tied to Euclidean geometry in Victorian culture, Alice Jenkins notes the lack of scholarship regarding literature and mathematics in the Victorian era: 'Very little attention indeed […] has been given by literary scholars to the workings of *mathematics* in Victorian culture. This is a problematic absence from both Victorian studies and literature and science studies.' ('George Eliot' 72) If anything, the convergence of mathematics and fiction suggested by turn-of-the-century mathematicians, philosophers, and literary writers raises the need for the study of literature and mathematics, and the important role of German-speaking mathematics in the early twentieth century encourages a transnational approach. As discussed in the panel 'Teaching Modern(ist) Literature and Science' at the 2012 conference of the British Society for Literature and Science, British literature and science studies are focused on Victorian literature while modernist literature is examined a lot less frequently (Plock, Whitworth et al.). German scholarship in the field is similarly centred on the nineteenth century (Klinkert 1), but not least due to the obvious importance of mathematics in the lives and works of the two major modernist writers Broch and Musil, the association of modernist literature and mathematics has a stronger tradition in the German-speaking context, even though, as Dale Adams notes, 'mathematics mainly appears in connection with the empirical sciences and is only occasionally considered as an independent discipline'[53] (Adams 30). As illustrated above, the distinct characteristics of mathematics gain importance at the beginning of the twentieth century, and since the specific nature of mathematics as a structural science comes into focus with its 'modernist transformation' (Gray *Plato's Ghost* 1), it is with mathematical modernism that the demand for a more specialised study of mathematics and fiction, rather than a mere subsumption under the heading of science and literature studies, becomes urgent.

The novels analysed in this study address parallels and interrelations between developments in mathematics and the wider worldview, mostly centred on the decades of the foundational crisis of mathematics and the contemporaneous crisis of the First World War. Pynchon's *Against the Day* explores the crises and their connections by presenting paths that were open around the turn of the century but not chosen by a world heading towards cataclysm. The account of various possibilities but informed by the knowledge of the actual development provides an ideal introduction to the period and the changing relations of

[53] 'In vielen Fällen erscheint die Mathematik jedoch vornehmlich in Verbindung mit den empirischen Wissenschaften, und wird dabei generell nur punktuell als eigenständige Disziplin berührt.'

mathematics, reality, and literature. The multiple alternatives in *Against the Day* are contrasted with Broch's account of the drastic changes in mathematics, philosophy, and life in *The Sleepwalkers,* which was written in the German-speaking context in which most of the crises took place. *The Sleepwalkers*, like *Against the Day* set in the 1880s to 1920s, thus complements Pynchon's more distanced view with an insider perspective on the cataclysmal period and attempts to explain the advent of the First World War by tracing changes in the common style of thinking, which are exemplified in mathematics. The analysis of views roughly contemporary with the crises is continued in the chapter on Musil's *The Man without Qualities* which traces the deepening conflict in the year before the outbreak of the war by focusing on the case of Austria and on a protagonist who embodies the conflict between rational and non-rational views, or, to quote from the novel, between 'mathematics and mysticism' (*MwQ* 837). Pynchon's *Gravity's Rainbow* again takes advantage of hindsight and illuminates the actual historical development about which Broch and Musil could only speculate. Employing mathematical concepts and relating them to worldviews from the seventeenth century to the Second World War, *Gravity's Rainbow* traces changes in mathematics and associated views from the Enlightenment to the postmodern period. The analysis thus allows for setting the earlier discussed works into the context of broader developments of mathematics and permits distinguishing the specific conditions in mathematics, history, and worldview that led to the crises in the twentieth century. By analysing novels written and set in the time of mathematical and general crises and illustrating their interrelations – particularly regarding possible convergences of modern mathematics and literary fiction – this study will not only illuminate major works by Pynchon, Broch, and Musil, but the examination and historicising of relations between fiction and mathematical conceptualisations of the world will also contribute to distinguishing the specific conditions of studying mathematics in fiction in the wider field of literature and science. Not least, exploring the novels' employment of mathematics, it will emerge that indeed, '[m]ighty are numbers; joined with art, resistless'.

Thomas Pynchon: Against the Day

Thomas Pynchon's novel *Against the Day* (2006) is set in the period between the 1893 Chicago World's Fair and the aftermath of the First World War in the early 1920s. Like a World's Fair itself, *Against the Day* takes stock of the world and its possible futures: it 'is a kind of inventory of the possibilities inherent in a particular moment in the history of the imagination. It is like a work of science fiction written in 1900.' (Menand) On closer examination, the statement only partly applies to *Against the Day* since, while science fiction creates a possible future of the world, the novel is clearly rooted in world history, exploring events such as the First World War, the decline of anarchism, and the foundational crisis in mathematics. On the other hand, *Against the Day* stresses the openness of fiction when introducing different plotlines which allow examining diverse paths the world could have taken, and in pointing out multiple possibilities open to the world at the turn of the century, the novel indeed works like science fiction.

From the elevated and far-sighted position of their airship *Inconvenience*, the Chums of Chance watch the crowd at the World's Fair; an event which displays the state of the present and advertises future possibilities. They 'saw that unshaped freedom being rationalized into movement only in straight lines and at right angles and a progressive reduction of choices, until the final turn through the final gate that led to the killing-floor' (11). This situation at the Fair illustrates the political development in the novel and also in historical reality, describing how the world deprives itself of open paths until almost all possibilities collapse, the final turn leading to the First World War. Hence, while the novel presents the turn of the century as a period of openness in which the world can take various paths to diverse futures, the optimistic outlook of the Columbian Exhibition is already impaired by the precognition of a reduction of the freedom of choice to the one-way street of mobilisation and the subsequent erasure of the known world in war. The Chums of Chance, who from above observe the world bringing about its own end, inhabit a universe of boys' books adventures, and theirs is the "most fictional" storyline in the novel: the conditions of the Chums' world differ from the earthly laws of other plotlines and even more from the reader's reality. Lew, inhabiting a set of more realistic conditions, asks: '"But you boys – you're not storybook characters." He had a thought. "Are you?" "No more than Wyatt Earp or Nellie Bly," Randolph supposed.' (41) Nelly Bly was the pen-name of the journalist Elizabeth Jane Cochrane, while Wyatt Earp is better known as a hero in serial novels and folk history than as the real person after which the figures were modelled. Neither of them is therefore unproblematically 'real', and Randolph's comparison does not deny the

Chums' higher degree of fictionality. It is thus from the elevated position of a more fictional existence which is yet related to the actual world that the course of the world can be perceived and the future be predicted.

Combining an informed historical position and exuberantly (science-) fictional outlooks on actual and possible versions of world history, *Against the Day* prominently transcends historical reality with its ascent to fictional realms while being nevertheless firmly rooted in historical actuality. With its combination of historical, science-fictional, and purely fictional elements, the novel's imaginative exploration of the period looks at the 1880s to 1920s both with the eyes of the contemporary and the historian, and *Against the Day* thus provides a particularly expedient introduction to the era and works as an ideal base for the analyses of Broch's *Sleepwalkers*-trilogy and Musil's *The Man Without Qualities* which are set in the same historical time span but examine it from a shorter temporal (as well as spatial) distance. *Against the Day*'s illustration of actual and possible developments in the early twentieth century then also illuminates the lost opportunities in the past of *Gravity's Rainbow* which is set in the Second World War as a time having to deal with the consequences of choices made in the first decades of the century.

1. Anarchism and Freedom: Politics, Fiction, and Mathematics

1.1 The Decline of Political Anarchism and its Transformation

In *Against the Day*, the turn-of-the-century feeling of potential change, open possibilities, and indeterminateness is illustrated by the still active hope of overthrowing repressive governments and capitalism, and introducing anarchy. Anarchism aims for a 'social state in which there is no governing person or body of persons, but each individual has absolute liberty (without implication of disorder)' (*OED* 'anarchy'). It 'is associated primarily with a rejection of representative democracy' (Cohn 21), questioning a government's ability to represent its people. In *Against the Day*, the increasingly influential governments do indeed not inspire trust, but, controlled by business magnates and capitalist corporations, they abuse their power. The state more and more perverts the principle of democratic representation and negates the interests of the people, reducing personal rights and freedom: if formerly, as the magician Luca explains, '"one man might have multiple identities, 'documents' might easily be forged or fictional"' (640-41), the possibility of redefining oneself is reduced by demands to be constantly and consistently identifiable. In contrast to the growing power of governments, anarchism propagates self-organisation among equals and the forming of self-sufficient groups whose members interact among

themselves rather than appeal to a higher representing level: 'Anarchism proposes a type of politics that allows individuals an unprecedented degree of social autonomy. They may, if they choose, form associations with other autonomous individuals, so long as no hierarchies are created within the associations, and, most important, no government controls the activities' (Weir 5). As this chapter will develop, in the course of *Against the Day* and in accordance with historical reality, political anarchism declines and is transformed to the more private principle of 'anarchistic' aid. At the same time, the imaginary domains of literary fiction and modern mathematics emerge as realms in which anarchism is still possible, thus supporting and developing further David Weir's thesis that 'anarchism succeeded culturally where it failed politically' (Weir 5).

Despite the still favourable prospects for anarchism at the end of the nineteenth century, in *Against the Day* the World's Fair already points to its incipient decline and the consequent decrease of personal freedom and overall loss of indeterminacy and openness: the Chums of Chance's observation at the fair predicts the reduction of choices until war is the only path left. In turn, the First World War bars any chance of reopening ways as it destroys political anarchism and its potential for freedom by promoting nationalism. In a conversation with Yashmeen, Ratty explains the mutual exclusiveness of anarchism and the nation state:

> Anarchism now is the idea that has seized hearts everywhere […]. If a nation wants to preserve itself, what other steps can it take, but mobilize and go to war? Central governments were never designed for peace. Their structure is line and staff, the same as an army. The *national idea* depends on war. A general European war […] would be just the ticket to wipe Anarchism off the political map. (1053)

The chance of freedom in anarchy is thus irrecoverably lost in wartime when central governments deprive public life of openness and furthermore restrict personal life to the point of deadlock: '"we observe that the more repressive the State is, the closer life under it resembles Death. If dying is deliverance into a condition of total non-freedom, then the State tends, in the limit, to Death."' (419) The post-war world then might be headed for the future from which the Trespassers seek refuge, namely, so one of them describes, '"a time of worldwide famine, exhausted fuel supplies, terminal poverty – the end of the capitalistic experiment"' (467). The Trespassers' world is made uninhabitable by capitalist developments, but in the present of *Against the Day* there is still hope that the world might chose a different path after the First World War and, instead of allowing the State to curtail freedom and act as a force of 'death', support anarchistic deeds which enhance freedom and life. An 'anarchistic' act is governed by no however widely defined capitalistic, national, or egoistical intentions; it represents no aim but is only the act itself. Accordingly, when Stray and others support people in distress, '"[e]verything's voluntary. Nobody makes a profit or

gets paid, not even credit or thank-yous."' (1121) The members of the loose grouping do not obey orders, Ratty explains, but '"work for one another"' (1047) and organise themselves '"[b]y knowing what has to be done. Which is usually obvious common sense."' (1047) And while the annihilation of anarchism in nationalism leads to the catastrophe of the First World War and maybe to the uninhabitable future of the Trespassers, with Stray's unconditional, 'anarchistic' aid there are 'very few limits on the good it became possible to do' (1097).

A common example of a small, self-organised group in which people are likely to unselfishly forgo profit in order to help others is the family. *Against the Day* presents the freedom inherent in such 'anarchistic' units accordingly and introduces the family's potential to enlarge life and achieve transcendence and a state of grace. Parents suspend their own desire in favour of their children's well-being, even up to total self-abandonment: Stray, 'sheltering Jesse with her body' (1142) when the militia threatens their family, cares more for her son than for herself. Self-abandonment is not restricted to the biological family, but by committing totally to another person's welfare, a family-tie of some sort is created. For example, when caring about injured Danilo, 'Cyprian had become Danilo's mother' (940-41); a fact showing itself in 'an often-absurd willingness to sacrifice all comfort until he was satisfied that Danilo would be safe for another spell' (941). Thus, Cyprian develops from being 'almost entirely fashioned of nothing but desire' (946) to disregarding his own desires in favour of fellow men. This paradoxically leads to the highest pleasure: 'This first encounter with release from desire brought Cyprian the unexpected delight of a first orgasm.' (941) By investing so strongly in another life, one becomes part of it, multiplying and opening up one's own existence in a way that is compared to the 'undeniable miracle' (406) of the birth of a child and the many possibilities the new life presents: 'It was a world entirely possible to withdraw from anglewise and soar high enough to see more, consider exits from, but nobody here in the smoke and breaking waves of desire wanted exit, the little world would certainly do, perhaps in a way that for some […] children, though also small, though comparably doomed, are forever more than enough' (947). Children, upon whom the most perfect selflessness is bestowed, also bring the gratification of 'a brief moment of certitude' (1066) in an unstable and chaotic world, with certitude having earlier been introduced as the understanding and acceptance 'that things were exactly what they were' (47) which leads to a feeling of 'grace' (46). Thus, although no reward is expected, overcoming the self in 'anarchistic' aid and committing fully to the family results in gratification and transcendence. *Against the Day* thus depicts the failure of anarchism in the collective political sense and illustrates its translation to the plane of local, individual, and

voluntary aid where it can enhance life and help re-appropriate the abundance of open paths of the pre-war years on a personal level.

The failing political anarchism is not only transferred to the level of personal relations, but *Against the Day* also illustrates Weir's thesis that in the early twentieth century anarchism found an alternative expression in culture: 'a great many anarchists, faced with their obvious isolation from politics at large, were driven toward culture as the only available means of disseminating their ideology' (Weir 4). In the novel, Fleetwood points out the prevalence of 'anarchistic' acts in literary fiction: '"I used to read Dickens as a child. The cruelty didn't surprise me, but I did wonder at the moments of uncompensated kindness, which I had never observed outside the pages of fiction."' (187) The higher likelihood of encountering anarchism in fiction is also illustrated by the Chums of Chance whose inhabiting more imaginary conditions allows them to draw different conclusions from the First World War. While the war results in the annihilation of anarchism in the earthly world, it makes the Chums understand the dangers of passing power to representatives instead of thinking and acting according to their own conscience, and they no longer feel bound to an order that conjured up such horror: 'Among distant sounds of repeated explosion could also be heard the strident massed buzzing of military aircraft. Below, across the embattled countryside, the first searchlights of evening were coming on. "We signed nothing that included any of this," Randolph reminded everyone.' (1153) The Chums then join their 'old friendly nemesis Captain Igor Padzhitnoff' (1148) and his team and become anarchists, '"declared enemies of whatever is in power now"' (1152). Ignoring national boundaries and politics altogether, they help 'whatever populations below were in need' (1151) and expect no recognition or reward for their 'supranational' (1217) commitment: 'Their motto was "There, but Invisible."' (1217)

The exemplary role of the Chums of Chance's anarchistic aid is highlighted when Yashmeen dreams of them as 'a small band of serious young people, dedicated to resisting death and tyranny, whom I understood at once to be the Compassionate' (842) whose work is 'the highest of callings. If there was any hope […] it was to persist in the hope of being brought in among them someday, to learn the Work, to transcend the World.' (842) The Chums are already on their way to transcendence, that is, they are engaged in 'transcending, surmounting, or rising above' (*OED* 'transcendence') the earthly conditions in their airship and approach a position 'above and independent of the universe' (*OED* 'transcendence'): '*Inconvenience*, once a vehicle of sky-pilgrimage, has transformed into its own destination' (1219). The ship becomes a self-sufficient, independent system, no longer related to the earthly world but forming a world of its own, while the crew still

compassionately and 'anarchistically' gives aid to the population below. The Chums' anarchistic existence is further enhanced when they all get married and expect children, and as a result of opening their lives to others *Inconvenience* becomes a place of freedom: 'any wish that can be made is at least addressed, if not always granted' (1219). The Chums have not yet achieved a perfect state as the universe would have to display some kind of anarchistic behaviour – 'good unsought and uncompensated would have evolved somehow' (1220) – but having agreed '"literally to transcend the old political space, the map-space of two dimensions, by climbing into the third"' (1218) and being on a journey into ever more imaginary domains, they 'know – Miles is certain – it is there […] They will put on smoked goggles for the glory of what is coming to part the sky. They fly toward grace.' (1220)

The Chums' flight in fictional realms and towards grace suggests that after its failure in the political domain, anarchism might succeed in fiction. *Against the Day* also locates an anarchistic potential in mathematics, thus not only showing mathematics in its traditional notion as a primary tool of reason due to which the 'unshaped freedom' before the First World War is 'rationalized […] until the final turn […] led to the killing-floor' (11), but introducing mathematics as an unexpected source of freedom and anarchy.

1.2 Mathematics and Politics

a) The Fall of the Governing System

The time spanned by the novel is not only a period of political upheaval and subsequent determining of a single set of conditions for the future, but *Against the Day* presents the significant political changes as contemporaneous with, mirroring, and mirrored by the foundational crisis of mathematics: '"The political crisis in Europe maps into the crisis in mathematics."' (668), Yashmeen explains to fellow mathematician Kit. Similarly to the situation of anarchism that seems promising at the time of the Columbian Exhibition and is defeated with the First World War, the World's Fair displays the then prevailing optimism about scientific advances while the destructive potential inherent in such discoveries is illustrated in the war. A Trespasser from the future complains: '"You have been so easy to fool – most of you anyway – you are such simpletons at the fair, gawking at your Wonders of Science, expecting as your entitlement all the Blessings of Progress"' (624). Scientific inventions such as Nikola Tesla's Magnifying Transmitter that promises 'free universal power for everybody' (176) even support an anarchistic future as they benefit everybody while not being governed by anyone. However, Tesla's scientific anarchism is defeated by

twentieth-century rationalisation and his capitalist adversaries, and the destructive consequences of scientific progress become apparent in the First World War towards which the diverse plotlines of the novel inexorably develop. The pre-war time is thus presented as a period of scientific discovery that bears the potential to reinforce anarchism but also makes possible the atrocities of the First World War. Not least these interrelations of scientific and political developments render necessary a detailed examination of *Against the Day*'s employment of mathematics so as to be able to appreciate the novel's account of the changing world around 1900.

Like the Pythagorean Brotherhood whose members 'believed that ultimately "all things are numbers"' (Koestler 215), the spiritual order T.W.I.T. (True Worshippers of the Ineffable Tetractys) in *Against the Day* base their faith on mathematics and thus provide explanations, stability, and sense for 'seekers of certitude, of whom there seemed an ever-increasing supply as the century had rushed to its end and through some unthinkable zero and on out the other side' (246-47). Yet, as Yashmeen points out, mathematics in the early twentieth century is, like politics, in a crisis – the foundational crisis of mathematics (see introductory chapter). In the novel, a psychiatrist in Göttingen notes how Georg Cantor's discovery of the 'actual existence' of infinity, that is, the idea that numbers can form a completed totality or 'set', and the then discovered paradoxes in set theory unsettle fundamental beliefs: '"Cantor, the *Beast of Halle*, who seeks to demolish the very foundations of mathematics, bring[s] these Göttingen people paranoid and screaming to my door"' (702). The maddening mathematical developments are simultaneous with the political problems culminating in the inapprehensible First World War, so Yashmeen points out: '"The political crisis in Europe maps into the crisis in mathematics. Weierstrass functions, Cantor's continuum, Russell's equally inexhaustible capacity for mischief – once, among nations, as in chess, suicide was illegal. Once, among mathematicians, 'the infinite' was all but a conjuror's convenience. The connections lie there […] hidden and poisonous."' (668) Comparable to the European nations that threaten their own existence by forcing conflict until war is almost inevitable and by continuing the fighting until on the verge of running out of soldiers, mathematics questions its own foundations until irresolvable antinomies lead to its downfall, destroying belief in a system that is traditionally viewed as 'among the most certain and true things we know' (Gray 'Anxiety' 27).

The concerns of the political and the mathematical crisis also connect in the question of anarchism. The development towards the cataclysmal First World War involves increased opposition to political anarchism and finally brings about its end, and the foundational research in mathematics plays out an aspect of anarchism when being informed by

scepticism towards its foundations: 'Anarchists […] shared a distaste for "first principles" or "foundations."' (Kadlec 8) While the foundational research aimed to set mathematics on new foundations and in this respect had no anarchistic agenda, an 'anarchistic' branch can be said to develop with the formalist school which established an autonomous understanding of mathematics and thus shares the anarchist rejection of a validating hierarchy and origin: apart from signifying opposition to a political leader or 'archon', anarchy 'means opposed to *archē*. Now, *archē*, in the first instance, means *beginning*, *origin*' (Eltzbacher 183). In contrast, the counter-modern approach determines intuition as the origin or *archē* of mathematics and establishes man as the guaranteeing authority. In the shape of a concern with the origin of mathematics, the question of anarchism thus forms part of the foundational conflict in early twentieth-century mathematics.

In *Against the Day*, '"[t]he political crisis in Europe maps into the crisis in mathematics"' (668), but mathematics and the political development do not necessarily influence each other. On the contrary, although national boundaries determine the affiliation to mathematical schools, mathematics is shown to transcend national disputes with a World Convention (590) where mathematics unites a 'band of varying ages and nationalities, whose only common language [… was] that of the Quaternions' (589). Yet, even though mathematical research is largely independent of national interests, applications can be put to political use and may even lead '"to some kind of human suffering"' (607). The destructive potential of supposedly innocent theoretical mathematics is demonstrated by the Quaternion Weapon or Q-Weapon: the dangerous power is inherent in the mathematical expression, the Quaternion, itself; it is hidden '"innocently," inside the *w* term' (609). The construction of a mathematical weapon in *Against the Day* contradicts the famous assertion of the mathematician G. H. Hardy that '[r]eal mathematics has no effects on war. No one has yet discovered any warlike purpose to be served by the theory of numbers' (Hardy 140). Indeed, in the novel, the aim of constructing new weapons rivals the drive for gaining mathematical knowledge: '"No one seems to know what these waves are, […] Quaternionists may have a chance someday of understanding them." "And arms dealers, don't forget," smiled Mulciber.' (625-26)

Apart from being associated with politics via its effects and possible applications, *Against the Day* shows that mathematics itself can be political. Not only does the rivalry between the mathematical schools of Quaternions and Vectors result in 'the transatlantic unpleasantness of the '90s known as the Quaternion Wars' (590), but mathematical concepts contradict the governing principles and 'anarchistically' unsettle the established worldview, introducing alternative spaces, opening up the common rules of calculation, and bringing

about shifts in worldview. Thus, Quaternions, introduced in 1843 by Sir William Rowan Hamilton, present an extension of the then known algebra and do not necessarily refer to a coordinate system whose origin – that is, the point where the axes intersect – determines a stable frame of reference. Quaternions thus 'broke bonds set by centuries of mathematical thought' (Crowe 31) and helped redefine the relation between mathematics and nature (see introductory chapter). While to follow and appreciate the argument *Against the Day* makes, it will be necessary to examine in more detail what a Quaternion is (see 1.2b), it is sufficient for the moment to note its novelty and the rivalry with the also newly introduced concept of Vectors. Both mathematical languages can be used to calculate similar problems, but they are associated with different political views in the novel and clash in the mathematical 'Quaternion Wars' (590). The Vectorists are described as '"Bolsheviks"' (599), not only because they are the majority but because they adhere to a centralised order by always referring to the origin of a coordinate system with the axes *x*, *y*, and *z*: they '"grimly pursued their aims, protected inside their belief that they are the inevitable future, the *xyz* people, the party of a single Established Coördinate System, present everywhere in the Universe, governing absolutely"' (599). Other than Vectors that are rendered easily graspable by a stable point of reference, Quaternions do not lead to one unified governing viewpoint. Instead, *Against the Day* introduces Quaternions as working in a way corresponding to anarchism which propagates self-organisation and the forming of self-sufficient groups whose members interact among themselves rather than appeal to a governing higher level. Accordingly, a Quaternionist complains: '"Of course we lost. Anarchists always lose out […]. We were only […] drifters who set up their working tents for as long as the problem might demand, then struck camp again and moved on, always ad hoc and local"' (599). The mathematical concept of Quaternions thus involves an anarchistic 'flavour', but in mathematics as in politics, a unified viewpoint defined by a governing frame of reference is more easily manageable, and the anarchist movement of Quaternionism is defeated.

The Quaternionists lose their 'war', but Quaternions are nevertheless indicative of a wider 'anarchistic' tendency in mathematics. The opening up of formerly governing views that is induced by Quaternions is intensified in the foundational crisis and the rethinking of mathematics' ability to represent reality and lead to authoritative truths about nature. In *Against the Day*, Quaternions thus exemplify the more widely spread element of anarchy and freedom that unexpectedly enters mathematics and establishes a contrast to the political developments in the period.

b) The Anarchy of Imaginary Existence

The comparison of the political and the mathematical crises in *Against the Day* already suggests that some kind of mathematical knowledge is needed to understand the unfolding of the novel. As the reader cannot be expected to be familiar with complex mathematical concepts, the novel provides explanations, for example to Pléiade's question: '"but what is a Quaternion?" Hilarity at the table was general and prolonged.' (604) After explaining that '"we're obliged to encounter it in more than one guise"' (605), a mathematician illustrates Quaternions' ability to calculate a vector's lengthening and rotation in space, '"among axes whose unit vector is not the familiar and comforting 'one' but the altogether disquieting *square root of minus one*. If *you* were a vector, mademoiselle, you would begin in the 'real' world, change your length, enter an 'imaginary' reference system, rotate up to three different ways, and return to 'reality' a new person. Or vector."' (605) Dr. Rao then puts the theory to practice by performing a Quaternion-Yoga-movement: he 'announced, "The 'Quadrantal Versor Asana,'" and commenced a routine which quickly became more contortionistic and now and then you'd say contrary-to-fact' (605). He then disappears and reappears in the adjoining room 'though, curiously, not quite the same person he had been before performing the Asana. Taller, for one thing.' (606) The following slightly more technical if less entertaining explanation of what a Quaternion is, will greatly contribute to the understanding of the novel and ultimately also bring us closer to *Against the Day*'s vision of the imaginative powers of literature.

A Quaternion equation reads: $a + bi + cj + dk$, with a, b, c, and d being variables that can take on any real number. They are scalars, that is, 'quantities which possess no direction but only magnitude. Such for example are time, temperature, volume' (Kelland and Tait 8). The variable a is not multiplied by any other number and is therefore called the scalar part of a Quaternion. The rest forms the so-called vector part: 'The simplest example of a vector quantity is a directed line, the whole conception involving both length and direction.' (Kelland and Tait 8) While the scalar part of a Quaternion is always purely real, the remaining vector part is imaginary, as i, j, and k are imaginary numbers: $i = j = k = \sqrt{-1}$, or in its most famous formulation: $i^2 = j^2 = k^2 = ijk = -1$. This definition contradicts the rule in the real number system that a square cannot be negative and seems to be assumed instead of 'found' by observation of nature. Given that Quaternions employ three imaginary numbers, the mathematician John Graves wrote to Hamilton that there was 'something in the system that gravels me. I have not yet any clear views as to the extent to which we are at liberty arbitrarily to create imaginaries, and to endow them with supernatural properties.' (qtd. in

Baez) Graves was not alone with his doubts, but the 'disquieting' (605) definition of imaginary numbers $i = \sqrt{-1}$ frequently led to claims that they did not exist. Imaginary numbers were therefore often perceived as an invention, a fiction that mathematicians assumed but which did not have a correlation in the real world.

The term 'imaginary numbers' was coined by René Descartes in the seventeenth century: 'the equation has neither a true nor a false root, but […] all the roots are imaginary' (Descartes 200). The problem of the existence of imaginary numbers persisted up to the nineteenth century when, for example, the mathematician Augustus De Morgan argued against using them: 'We have shown the symbol $\sqrt{-1}$ to be void of meaning, or rather self-contradictory and absurd.' (qtd. in Nahin 82) Similarly, the mathematician George Airy declared: 'I have not the smallest confidence in any result which is essentially obtained by the use of imaginary symbols.' (qtd. in Nahin 83); and the logician George Boole referred to $\sqrt{-1}$ as an 'uninterpretable symbol' (qtd. ibid).

The mathematician Carl Friedrich Gauss attributed the problematic ontological state of imaginary numbers not primarily to inherent characteristics but to the unfortunate labelling: calling the units 1, -1, and $\sqrt{-1}$ 'positive', 'negative', and 'imaginary' highlighted questions of existence. Instead, Gauss proposed the terms 'direct', 'inverse', and 'lateral' which did not come to general recognition. However, Gauss's term 'complex numbers' replaced Descartes's expression 'imaginary numbers', and he also substituted the constant reminder of 'inexistence' $\sqrt{-1}$ with the neutral sign i (see Kline *Mathematics* 158). Moreover, the geometrical representation of complex numbers $(a + ib)$ as points on a two-dimensional coordinate plan – with the x-axis showing the real part (a) and the y-axis the imaginary part (ib) – aided the imagination and somewhat reconciled mathematicians to imaginary numbers.

Hamilton rejected the widely accepted geometrical interpretation of complex numbers but argued for a purely algebraic account: he 'felt dissatisfied with any view which should not give to [imaginaries] from the outset a clear interpretation and *meaning*; and wished that this should be done, for square roots of negatives, without introducing considerations so *expressly geometrical*' (qtd. in Nahin 80; Nahin's modification of the quote). Hamilton therefore devised a new notation which replaced the complex number $a + ib$ with a couple (a, b): 'in the THEORY OF COUPLES, the same symbol $\sqrt{-1}$ is *significant*, and denotes a POSSIBLE EXTRACTION, or a REAL COUPLE, namely […] the *principal square-root of the couple* (-1, 0). In the latter theory, therefore, though not in the former, this sign $\sqrt{-1}$ may properly be employed' (Hamilton 417-18). Hamilton thus circumvented the dubious $\sqrt{-1}$. Resulting from his demand for interpretation and meaning,

Hamilton also 'felt that, just as geometry is the science of space […], algebra too should be the science of something on our physical existence. He decided the "something" must be time' (Nahin 80), arguing that seemingly symbolical and uninterpretable expressions 'may pass into the world of thoughts, and acquire reality and significance, if Algebra be viewed as not a mere Art or Language, but as the Science of Pure Time' (Hamilton 422).[1] His attribution of algebra to time never became widely accepted, but significantly for the context of *Against the Day*, in Hamilton's view the vector part of a Quaternion represented space and the scalar part time.

Hamilton initially argued that Quaternions represented reality better than any other mathematical system, and the mathematician P. G. Tait seconded that Quaternions eluded the artificiality of other mathematical systems but constituted an absolutely natural one: 'To me Quaternions are primarily a Mode of Representation […]. They *are*, virtually, the thing represented […]. Quaternions, in a word, *exist* in space, and we have only to recognize them' (qtd. in Crowe 213). The view that Quaternions represent elements of nature conflicts with the claim of their 'anarchistic' potential, given that anarchism precisely denies a governing system's ability of representation. And indeed, in light of the then following developments for which his Quaternions even helped pave the way, Hamilton had to contradict his own proposition. The uncertain ontological state of imaginary numbers drew attention to there being types of numbers that have no direct relation to reality, and '[t]he introduction and gradual acceptance of concepts that have no immediate counterparts in the real world certainly forced the recognition that mathematics is a human, somewhat arbitrary creation' (Kline *Mathematical Thought* 1032). Thus, for example, the introduction of Quaternions extended the number system and showed that 'there is not just the one algebra of real and complex numbers but many and diverse algebras' (ibid 791). If there are several algebras, not all of them can describe the real world, and consequently, the introduction of Quaternions challenged the notion of mathematics as the language of nature. Quaternions could accordingly no longer be said to represent space and time, and Hamilton himself ultimately admitted that 'there is a sort of symbolical science, or *science of language*, which well deserves to be studied, abstraction being made for a while of *meaning*, or interpretation; and *forms of expression* being treated as themselves the subject-matter to be studied' (qtd. in Øhrstrøm 52).

Against the Day traces the development of mathematics towards an increasingly non-referential notion and illustrates how Quaternions, which can no longer be thought of as

[1] For an account of Hamilton's life and work, also see Thomas Hankins's *Sir William Rowan Hamilton*, particularly the chapters '"Algebra as the Science of Pure Time"' (245-79) and 'Quaternions' (281-325).

representing time and space, lose the 'Quaternion Wars' and 'their great struggle for existence' (596): '"Face it. The *Kampf ums Dasein* is over, and we have lost." "Does that mean we only imagine now that we exist?" "Imaginary axes, imaginary existence."' (598-99) Thus, Quaternions develop from being seen as 'a Mode of Representation' (Tait qtd. in Crowe 213) and gaining their reality through a stable relation to the world – 'Quaternions, in a word, *exist* in space, and we have only to recognize them' (ibid) – to being seen as their own language and to exist in the world as an imaginary construct only. As developed in the nineteenth century, all of mathematics can be said to be of imaginary existence since its 'reality' is no longer guaranteed by a direct relation to nature (see introductory chapter), but Quaternions with their imaginary units draw attention to the problematic correlation with the world. Following the recognition that there are conflicting mathematical languages at least some of which have only an '"imaginary existence"' (599), mathematics in *Against the Day* disconcerts the 'seekers of certitude' (246). However, the changes in mathematics are not only considered in the negative light of a loss of certainty, but the imaginary elements of Quaternions are presented as enlarging the mathematical world: '"the discovery of Imaginary Numbers […] also provided a doubling of the mathematical Creation"' (149). The '"imaginary" mirror-world' (558) is free from representational claims but gives room to imaginativeness, a creative potential similar to fiction, and to the possibility of devising multiple worlds. With imaginary numbers and Quaternions, mathematics is thus shown to enter a new state of freedom, creating arbitrary structures and autonomous new 'worlds' instead of seeking to represent the given. Free from restrictions of reality, the newly developing mathematics governs itself and within its own limits of imaginary existence enjoys freedom from representation, or in the terms of *Against the Day*: anarchy.

2. Scientific Freedom

2.1 Escaping Reality through Mathematics

When in the course of the late nineteenth and early twentieth centuries mathematics was no longer expected to faithfully represent reality but came to be seen as an autonomous system, it increasingly allowed for freely constructing concepts and worlds that differ from the given. Venturing '"into the borderlands of the nonexistent"' (601) as Root complains, the contemporary '"foundations work, set theory, all abstract as possible,"' (601) not only reveal an intrinsic uncertainty and unknowability in mathematics but also open up imaginary spaces which hold potential for attaining personal freedom and leading multiple lives. Modern

mathematics thus allows for a similar realisation of anarchist objectives as proposed to be achievable by commitment to the family and the Chums of Chance's flight into more fictional realms. For example, Yashmeen learns that mathematics constitutes one of the 'routes of escape from a world whose terms she could not accept' (1057) and takes 'refuge more and more in the Zeta-function problem' (558) until this mathematical world dominates her life with its promise of mathematical knowledge and transcendence. While leaving the real world behind '"works for some people, […] [w]hen human tragedies happen, it always seems as if scientists and mathematicians can meet the situation more calmly than others"' (366), – a thought also voiced by Hardy: 'When the world is mad, a mathematician may find in mathematics an incomparable anodyne.' (Hardy 143) – Professor Vanderjuice rightly warns Kit that the demands of reality cannot be ignored for long: when '"escaping reality, […] sooner or later comes the payback"' (366). And indeed, Kit experiences the impossibility of evading reality through mathematics: 'Vectorism, in which Kit once thought he had glimpsed transcendence, a coexisting world of imaginaries, the "spirit realm" […] had not shown Kit, after all, a way to escape the world governed by real numbers. His father had been murdered by men whose allegiance […] was to that real axis and nothing beyond it.' (759) Escaping to a completely removed imaginary mathematical realm is thus impossible, but reality can at most be disregarded for a while. Moreover, developments in mathematics demolish the very foundations of this perfect parallel world, '"bringing these Göttingen people paranoid and screaming"' (702) to psychiatrists, seeking help and consolation in the real world. Revealing an equally disturbing condition of unknowability, uncertainty, and paradox in mathematics as in reality, trying to escape into mathematical realms is rendered futile.

2.2 Quaternions: The Imaginary Axis

With their three imaginary components, Quaternions are particularly potent to introduce fictionality, plurality, and freedom into mathematics. They were invented to extend complex numbers to describe points in space: if a complex number can be imagined as a point in a plane with the real part (a) showing its position on the x-axis and the imaginary part (ib) indicated on the y-axis, Quaternions can correspondingly be seen to designate points in space, '"plotting complex numbers along three axes instead of two"' (605) as Barry Nebulay explains in *Against the Day*. In the discovery of Quaternions Hamilton's decisive step was to go beyond the three axes of space and introduce a fourth element, as only this further dimension made possible the description of points in space. He explained that the

Quaternion 'may be said to be "time plus space", or "space plus time": and in this sense it has, or at least involves a reference to, four dimensions' (see Graves 635). Similarly to the case of imaginary numbers, the 'existence' of a fourth dimension was only beginning to be thought in the second quarter of the nineteenth century (Henderson 6) and was not received without scepticism. '"Four is the first step beyond the space we know"' (677) Yashmeen points out in *Against the Day*, and since human beings can only experience three dimensions, the existence of the fourth is uncertain: '"beyond the third […] do dimensions exist as something more than algebraists' whimsy?"' (677) Given that 'the first major discussion of *n*-dimensional geometry were published in the 1840s' (Henderson 3) and the existence of further dimensions was still controversial, Quaternions broke fairly new ground with their use of four dimensions in 1943.

The fourth dimension forms part of the '"'imaginary' reference system"' (605) with which Quaternions operate and which Dr. Rao uses when changing shape and appearing in an adjoining room. Characters experience it as set '"somewhere not *on* the surface of the Earth so much as–" "Perpendicular,"' (1163) that is, on the perpendicular *y*-axis that designates the imaginary value of a complex number. Like Dr. Rao, Yashmeen learns how to transcend the ordinary three axes of space. When vanishing from Kit's room she imagines '"*four axes*, all perpendicular to one another at the same point of origin, […] *i*, *j*, and *k*, the unit vectors of our given space, had each rotated an unknown number of degrees, about that unimaginable fourth axis"' (694). In Hamilton's terms, the imaginary axes of space rotate about the 'un-imaginable' – real – axis of time. Yashmeen then perceives '"some kind of *Schnitte* – one of those 'cuts' connecting the sheets of Riemann's multiply connected spaces – something that would allow access to a different … I don't know, 'set of conditions'? 'vector space'? Unreal, but not compellingly so"' (694). As the spiritual leader of the T.W.I.T. explains, these different and unreal sets of conditions belong to other worlds: '"Lateral world-sets, other parts of the Creation, lie all around us"' (248). The existence of other worlds set perpendicularly to the earthly world and sporting different conditions is most clearly illustrated by the Chums of Chance's upward travel into more fictional domains, which corresponds to the development of Quaternions: first employed in 'aerospace applications and flight simulators' (Mukundan 97), Quaternions are now predominantly used in computer graphics, games programming, and virtual reality systems. The Chums of Chance's advance on the perpendicular axis from their ascent over the World's Fair at the beginning of the novel to the creation of an autonomous domain above and different from earthly reality thus mirrors the development of Quaternions from advancing flight to furthering the creation of other worlds and spaces in virtual

realities. *Against the Day* thereby suggests that other, and maybe better, worlds can be reached by flights of fancy – by ascents to conditions with higher imaginary values, be they literary or mathematical.

Yashmeen profits from the freedom to move on imaginary axes, and her employment of mathematical concepts thus helps counteract the reduction of possible paths in the increasingly restrictive political conditions on earth. However, in her further research into worlds of higher dimensions, namely into the sphere of Riemann's zeta-function which takes 'account of the whole "imaginary" mirror-world' (558), Yashmeen also discovers a destructive potential in Quaternions. In his famous conjecture Bernhard Riemann hypothesised that the zeta-function's non-trivial zeros, which are made up of complex numbers, all have the real part ½. Yashmeen sees this perpendicular line through the real value ½ in Riemann's complex coordinate system as a '"spine of reality." Afterward she would remember she actually said "*Rückgrad von Wirklichkeit*."' (679) Complying with Yashmeen's imagery, one could say that the imaginary realm is held up by a spine that connects the different realities and also goes through the earthly world. The more the conditions differ from the earthly world, the higher the respective world is set on the perpendicular axis, but all worlds are linked by the common real part which thus is accorded special importance. Apart from granting Yashmeen freedom of movement, the spine of reality going through the real part ½ and connecting the lateral worlds is also exploited by the Quaternion weapon which uses the destructive potential held in the Quaternions' real unit: '"It's said the inventor of this weapon has found a way to get inside the scalar part of a Quaternion, where invisible powers may be had for the taking."' (626) The Quaternion weapon is therefore not strictly part of the world, but Umeki, who examines it thoroughly, takes it to reside in '"[s]omething like … a Riemann sphere. […] The realm of $x + iy$ – we are in it! whether we want to be or not."' (634) Rather than the more commonly problematic imaginary part, it is thus the real unit of a Quaternion that threatens the destruction of the known world and its seemingly self-evident conditions.

If the fourth dimension of the Quaternions, that is, the unimaginable axis beyond the three axes of space, can be employed to access multiple worlds as well as to build a weapon, the multidimensional Riemann sphere holds the potential both to increase individual freedom by allowing displacements in space and time and, in contrast, to end all freedom in the destruction of the world. The imaginary realm and its inherent freedom are thus not necessarily positive, but freedom also comprises the possibility to choose for the worse. Correspondingly, the imaginary domains into which the Chums of Chance ascend are not solely used for giving 'anarchistic' aid, but one of the boys points out: '"[t]here is,

unfortunately […] another school of thought which views the third dimension not as an avenue of transcendence but as a means for delivering explosives"' (1218). Thus, anarchism and the mathematics of Quaternions may be used for good and bad, but their potential impact on the world is unquestionable. The nineteenth-century mathematician Thomas Hill compared the possible effects of Quaternions to politics and stressed their positive potential, saying that in 'the Quaternions of Hamilton, there is as much real promise of benefit to mankind as in any event of Victoria's reign' (qtd. in Crowe v). *Against the Day* goes even further when suggesting that while political reign imposes restrictions, the greater benefit lies in the modern mathematics that, autonomous and 'anarchistically' free from claims for representation, makes accessible the freedom of imaginary domains.

2.3 Science and Time: Time-Travel

Hamilton's equation of a Quaternion's real part to time indicates that the controversy regarding Vectors and Quaternions not only concerned different mathematical notations but also entailed diverse views on the nature of space and time and their relation. Vectors do not include a temporal dimension, while Hamilton pointed out that in Quaternions '[t]he sciences of Space and Time […] became intimately intertwined and indissolubly connected with each other' (qtd. in Crowe 25). This observation could be taken to foreshadow Einstein's theory of relativity, 'but Hamilton drew from it a less fruitful conclusion: inasmuch as geometry is the science of space alone, algebra must be the science of pure time' (Kline *Mathematical Thought* 652-53). More precisely, Hamilton saw the temporal element as 'ORDER IN PROGRESSION' (Hamilton 297); a thought that Quaternions illustrate particularly clearly: unlike in the real number system where the order of multiplication has no effect (a*b = b*a), in the case of the non-commutative Quaternions it bears information: $i*j = -j*i$. Here, the time of calculating with an element in relation to the next element is crucial – time enters the picture and mathematics. In *Against the Day*, Kit warns a fellow mathematician: '"this function of time, you assume it's commutative, just glide on past it, when in fact–" "So?" "You can't make that assumption."' (676)

The Quaternion weapon draws destructive power from the Quaternions' algebraic, 'temporal' part, the '"Further Term, you see, transcending and conditioning **i, j,** and **k** – the dark visitor from the Exterior, the Destroyer, the fulfiller of the Trinity"' (626) which, so Dr. Rao explains in accordance with Hamilton's view, '"might be taken as due to Time, an intensified form of Time itself"' (626). A time-based weapon is inexorable, as time is the '"force no one knows how to defeat, resist, or reverse. It kills all forms of life sooner or

later."' (626) The enormous explosion of 'the Tunguska Event [might] have been caused by the discharge, planned or inadvertent, of a Q-weapon' (880). This explains the invisible source of the explosion, since it would be 'extra*temporal*' (878), displaced '*along the time axis*' (877): 'something which had not quite happened yet, so overflowing the tidy frames of reference available to Europe that it had only seemed to occur in the present, though really originating in the future' – the First World War 'collapsed into a single event' (895). With the war concentrated and displaced in time, 'a hitherto-unimagined quantity of energy had entered the equations of history. […] "it begins to look like a singularity"' (895). A mathematical singularity is a 'point at which a function takes an infinite value' (*OED* 'singularity), that is, the function is not defined and behaves anomalously. War could accordingly be termed a 'singularity' in history: order is suspended, and conditions are redefined (also see chapter on *Gravity's Rainbow*). After a singularity, the formerly continuously developing world can jump to a completely different state, as a Trespasser from the future tries to explain to his friend when standing at the future site of war in Flanders: '"This world you take to be 'the' world will die, and descend into Hell, and all history after that will belong properly to the history of Hell."' (622) Thus, the Quaternion weapon, in particular its dangerous real element which might be taken as '"an intensified form of Time itself"' (626), might have brought about the end of the known world in the First World War.

If time can be concentrated in a weapon to destroy Earth, hopes to manipulate time so as to defy this 'demiurge and servant of Death' (1062) are equally strong. The Trespasser who has returned to the time before the First World War understands: '"all investigations of Time, however sophisticated or abstract, have at their true base the human fear of mortality"' (622). Mathematics, and particularly Quaternions, seems to be a promising device to suspend time. While time '"moves on but one axis, […] past to future – the only turnings possible being turns of a hundred and eighty degrees"' (147), complex numbers (for which Quaternions are an extension) introduce an additional imaginary axis which allows turns through other angles, angles that require a complex number. And according to Dr. Rao, the expert on Quaternions in the novel, '"mappings in which a linear axis becomes curvilinear – functions of a complex variable such as $w=e^z$, where a straight line in the z-plane maps to a circle in the w-plane[2], […] do suggest the possibility of linear time becoming circular, and so achieving eternal return"' (147). Quaternions, and other functions employing imaginaries, can thus manipulate time, encouraging hope for immortality in a circular recurrence. The lateral worlds that mathematics creates and renders accessible are, accordingly, not only spatial dislocations but also temporally displaced, thus making

[2] All 'input' points of a function are said to lie on the z-plane, the 'output' points on the w-plane.

conceivable travel into the past and the future. Hence, with the mathematical concept of Quaternions it is potentially possible to command time and consequently to escape the restrictions of the given world and defy death, the '"condition of total non-freedom"' (419) that politics more and more approaches.

Ultimately, if interest in time-travel feeds on the fear of mortality, the real aim is for a timeless condition: '"is there such a thing as the *neutral hour*? one that goes neither forward nor back? is that too much to hope?"' (649) In *Against the Day*, several forms of timelessness are presented: at Candlebrow U. the Chums 'would find exactly the mixture of nostalgia and amnesia to provide them a reasonable counterfeit of the Timeless' (457); books may be '"[o]utside of time"' (149); and Cyprian reflects on a '"'convergence' to a kind of stillness, not merely in space but in Time as well"' (1076). Members of the T.W.I.T. aim at providing such a timeless state to the whole world, and they consequently track down persons who are responsible for unsettling events that cause or disrupt the flow of time. According to the leader of the T.W.I.T., the suspects '"are precisely the cadre of operatives who, working in secret, cause – or at least allow – History upon this island to happen"' (250). In working history, among it the First World War, the suspects commit a 'crime': '"it is more of an ongoing Transgression, accumulating as the days pass, the invasion of Time into a timeless world. Revealed to us, slowly, one hopes not terribly, in a bleak convergence … History, if you like."' (250) In causing history to happen and time to elapse, the workers of history are responsible for the loss of innocence and subsequent death: '"Suppose the Serpent in the Garden of Eden was never symbolic, but a real being in a real history of intrusion from somewhere else. Say from 'behind the sky.' Say we were perfect. We were law-abiding and clean. Then one day *they* arrived."' (250-51) The narrator even draws the reader of *Against the Day* into the 'crime': it is indeed '[w]e of the futurity' (793), and from another reality 'behind the sky', who, while reading, bring about the unfolding of the historical events that cause the upsetting of the novel's fictional universe. In a way, the reader travels back in time to the turn of the century when reading and, like the Trespassers whose passage from the future is 'enabled somehow by whatever was to happen here, in this part of West Flanders where they stood, by whatever terrible singularity in the smooth flow of Time had opened to them' (624), the reader introduces their calamitous history and reality into the fictional universe.

Generally, time-travel that actually happens in *Against the Day* is presented in negative terms: future energy from the First World War generates the explosion in the Tunguska, the Trespassers' displacement into the past is due to catastrophic disruptions of time, and history, a sequence of mainly fatal events, is a 'crime' brought from the future or

another dimension – maybe the reader's. Real freedom therefore does not lie in time-travel but in timelessness, a state outside of time and therefore without death. Quaternions cannot provide such a condition as they are themselves constructed of time and with the discharge of the Quaternion weapon become a part of history.

2.4 Bilocation and Double-Refraction

a) Multiple Personalities

Escaping to the perfect realm of mathematics, making use of Quaternions' imaginary qualities, and time-travel are ambiguous possibilities to change the world and escape from everyday restrictions. Other techniques introduced in *Against the World* provide more literal ways of enhancing life by doubling either personalities or worlds, thus increasing the freedom of life-choices. Bilocation is the ability to be in two places at once, to lead two separate lives in two bodies: '"Translation of the body, sort of lateral resurrection"' (485). One possibility to create a *Doppelgänger* is double-refraction as brought about by Iceland spar: 'Ordinary light, passing through this mineral, was divided into two separate rays, termed "ordinary" and "extraordinary"' (127). The extraordinary ray corresponds to the 'lateral resurrection', '"seeing not just the man but his ghost alongside him"' (423), Frank suggests. In the terminology that Gauss proposed, 'laterals' are imaginary numbers, and the extraordinary ray could accordingly be said to produce an imaginary double. The similar dates of discovery highlight the relationship between double-refraction and imaginary numbers: in *Against the Day*, Iceland spar is claimed to be '"the sub-structure of reality. The doubling of Creation, each image clear and believable. […] its curious advent into the world occurred within only a few years of the discovery of Imaginary Numbers, which also provided a doubling of the mathematical Creation"' (149). It is thus suggested that the extraordinary, imaginary doubles exist laterally to the 'ordinary' objects both in the domains of mathematics and of double-refraction.[3]

In theosophy, for example practiced by the T.W.I.T., the description '"lateral resurrection"' (485) is taken more literally when bilocation is argued to be the state of separation of a spiritual double from the earthly body: '"the etheric double," is a form of bodily envelope – the displacement or bilocation of which cannot be maintained for long periods, lest the physical body become mortified' (Milutis 47). The etheric double was thought to be connected to the Æther, a 'mysterious substratum that permeated the material

[3] Hanjo Berressem discusses a further mathematical model of 'the refraction of the world into a real and an imaginary field, [namely] the theory of eigenvalues and of eigenorganizations' (Berressem 364).

universe' (Bowler 87) and enabled the travel of light. In *Against the Day*, the simultaneous introduction of *Doppelgänger* personalities and the Michelson-Morley experiment draws attention to the connection between bilocation and the Æther, or rather, the nonexistence of the Æther: 'Professor Edward Morley and Charles "Blinky" Morgan were one and the same person! Separated by a couple-three letters in name as if alphabetically double-refracted, you could say.…' (68) And, so Merle thinks, if the criminal Blinky gets caught, 'there would also turn out to be no Æther. Not that one would cause the other, exactly, but that both would be different utterances of the same principle.' (68) One principle shared by magician Luca's production of bilocated people with a magical device called *La Doppiatrice* and the Michelson-Morley experiment, which disproved the Æther, is the splitting of light. In 1887, Albert Michelson and Edward Morley set out to measure light that travelled along with the motion of the Earth and light travelling against it. The experiment was based on the assumption that if the Æther existed the respective speeds of light would be different. The scientists tried to prove this by splitting a ray of light and sending the two rays into different directions. They were then reflected by mirrors and reunited. If the rays travelled at different speeds, they would be out of phase – coming back slightly displaced. Yet, the Michelson-Morley experiment showed that the rays were in phase and that therefore the Æther did not exist. Thus, while the splitting of a light beam disproves the scientific hypothesis of the Æther and undermines the theosophist belief in an etheric double, in *Against the Day* the same principle allows for the multiplication of personalities in Luca's magical *Doppiatrice*.

The Michelson-Morley experiment did not only disprove the Æther as a substance through which light waves propagated, but it had far-reaching implications for the general worldview. The Æther 'served as the vehicle and coordinating agent for all physical action' (Bowler 87), 'as a unifying principle for the whole universe' (Bowler 97), and providing a common point of reference, the Æther acts as the joining point of the axes of the universe's coordinate system, that is, as its origin: 'The ether, above all, is beginning itself, *arche*, or the source of all things. It is that vitalistic principle which holds the whole together.' (Milutis xiv) Given that belief in the Æther equals faith in a universal frame of reference, the possibility of its non-existence threatens the prospects of objective scientific observation and of interpretation in general: 'the ether is perhaps the original "transcendental signified,"' (Milutis xvi) the stable point of reference which locates and arrests representation. Its absence therefore upsets the order of representation, while 'the ethereal ur-medium holds out the fantasy (or dare we say "possibility") of return to something immediate that has been lost but is not irretrievable' (Milutis xv). The Æther promises immediate experience and accordingly freedom from representation; at the same time however, earthly phenomena

would represent etheric 'originals' in the same way as the material body is seen as the temporal double of an eternal etheric body or soul: 'It is this ethereal body that survives the death of the fleshly body' (Bowler 97). The discovery of the non-existence of the Æther therefore freed the Earth from claims of representing an ideal etheric world and from the government of a single stable frame of reference, while also destroying the 'vehicle by which the universe could once more be seen as a unified whole with a purposeful structure' (Bowler 89). A character in *Against the Day* accordingly asks: '"So with this Michelson-Morely result. We've all had a lot of faith invested. Now it looks like the Æther […] just doesn't exist. What do we do now?"' (69) With the disproval of the Æther, the imposition of an absolute, governing position in the universe appears to be unfunded by science, but the discovered independence from a coordinating origin and universal frame of reference instead supports an unsettling 'anarchistic' outlook on the world.

Against the Day translates the non-existence of the Æther and its implications to the level of the individual when double-refraction through Iceland Spar or *La Doppiatrice* splits a person into two, so that the doubled individual's reference frame is no longer unitary and universal: 'one' person has 'two' points of view, makes two different experiences and forms two different sets of values and opinions. Seen from the viewpoint of the double-refracted 'twin' the world appears different, it is 'doubled'. Similarly, a doubled viewpoint can be brought about when the world itself appears in a different light, when it is in upheaval. Thus, for example, the ships *Stupendica* and *Emperor Maximilian* merge at construction, causing the battle ship to become the *Stupendica*'s 'secret identity, latent in her present conformation, though invisible to the average passenger' (577). The 'unnaturally shaky quality of present-day "reality"' (580) leads to the ship picking up a message 'from somewhere else not quite "in" the world, more like from a continuum lateral to it …' (580). The message points to the beginning of the First World War, which in the ship's reality will not occur until several years later, and causes the ship's identities to separate: 'leaving its military double to wander the mists, the *Stupendica* continued its civilian journey' (586). This development prevents Kit, who is stuck in the *Emperor*'s engine room, from returning to his lodgings since '"there are no staterooms, it is no longer the *Stupendica* up there. That admirable vessel has sailed on to its destiny. Abovedecks now you will find only His Majesty's dreadnought, *Emperor Maximilian*."' (582) The uncertain conditions of reality and the breaking-in of a message from a world displaced on the imaginary lateral axis thus cause the world to become refracted, and at least parts of the drastically changing world leave the known conditions behind 'and perhaps its conventions about being in only one place at a time' (585).

While most people have something '"to keep them moving in the direction of their destiny"' (46) and to hold them together, others are more sensitive to the 'unnaturally shaky quality of present-day "reality"' (580) and '"keep bouncing free. Avoiding penance and thereby definition."' (46) Lew is so free and undefined in an upset world that he splits into two: 'somewhere else was the bilocational version of himself' (775). Bilocation is thus not only a device to increase life, but the freedom of self, the 'bouncing free', can also indicate or lead to a loss of oneself. Having abandoned revenge and taken up a life of leisure, Reef complains: '"I don't even know who I fuckin am anymore."' (757) And when voices repeatedly tell him to '"get back to yourself again"' (742) and to 'abandon this farcical existence, rededicate yourself to real-world issues' (901), Reef runs 'for his life, or anyhow the resumption of it' (901). Similarly, when Kit becomes estranged from his wife Dally, he feels no longer at the right place but believes that producing sounds in his throat 'would transport him to "where he should really be"' (1214). After a largely unconscious travel through real and imaginary realms that might be Shambhala, Kit arrives at his destiny and re-emerges into a reality that sees him and Dally as a happy couple once again: 'It was like the convergence of a complex function.' (1214) The Chums of Chance similarly use the power of an imaginary domain to regain their reality. Unsettled by the seduction of the Trespassers, the Chums 'chose lateral solutions, sidestepping the crisis by passing into metaphorical identities' (471). They become students of music, and unsure if they try 'to keep distracted from a reality too frightening' (476), are 'imperfect replicas of who they once were' (476), or even 'may only have once been readers of the Chums of Chance Series of boys' books, authorized somehow to serve as volunteer decoys' (476), the boys finally regain a life as Chums of Chance, possibly creating two sets of Chums, with one crew existing in another reality, 'a world scarcely different from the one they had left' (478). Problems in the real world can thus be solved by entering into lateral domains and making use of the advantages of imaginary worlds, but the real axis and the 'spine of reality' always have to be kept in view in order not to loose one's own identity and reality. The mathematician Jacques Hadamard described a similar problem-solving strategy in mathematics: 'the shortest and best way between two truths of the real domain often passes through the imaginary one' (Hadamard 123). The formulation is more commonly known as: 'The shortest path between two truths in the real domain passes through the complex domain.', as if acknowledging the necessary interconnection of the real and the imaginary. As Kit and the Chums of Chance learn, a passage through the complex domain – one that combines real and imaginary components – can lead to the recovery of a lost reality or to the discovery of new identities and worlds, while experiencing life from different perspectives

rather than entering an alternative reality can have the same effect: like a journey into a different world, the bilocated '"lateral resurrection[s]"' (485) destroy the stable frame of reference of a single life and increase the freedom to choose between different existences and worldviews. Lew accordingly leads several bilocated lives until the '[d]etours from what he still thought of as his official, supposed-to-be life' (1180) cease.

Mathematics and techniques of bilocation may allow passing over from reality to lateral imaginary existences while also showing the necessity to actively shape one's life and hold it on its path in order to regain reality and identity, yet, life can also be 'doubled' not by complicated scientific processes but by marriage. Diagnosed with an '"abnormal desire to be married"' (486), one of the Chums of Chance advocates the naturalness of doubling life through matrimony: '"Abnormal? What's abnormal in that? When have I ever kept it a secret that my governing desire in life is to be no longer one, but two, a two which is, moreover, one – that is, *denumerably* two, yet–"' (486). The magician Luca draws a further connection between his double-refracting device and a family: 'It was sort of like fathering a large number of real children' (642). And accordingly, after his death Webb lives on in his children as if being double-refracted; when Reef acts as a spiritual medium for his father, his brother holds: '"It was him, Reef. His voice, hell you even *looked* like him."' (756) Reef, who is 'Frank's wishful family look-alike' (732) and Kit's 'somehow aged or gravely assaulted double' (750), and his brothers pursue different approaches to life and almost appear as three versions of one person: '"It's like we specialized, Pa"' (356); '"Reef was always the reckless one, […] and Frank was the reasonable one" [… and] "I think you [Kit] were the religious one"' (751). Bilocation and double-refraction thus are possibilities of bringing about a multiplication of life which can be achieved by scientific techniques and making use of the imaginary domain of mathematics as well as by the family ties of a scientific layperson. Scientific concepts that are or may appear incredible, fictional, and arcane thus merely recreate a multiplying process natural in life.

b) Multiple Worlds

The existence of multiple personalities leads to one person's plural perceptions of reality, but *Against the Day* also exhibits different worlds, set inside and aside of the everyday world. In the more fictional universe that the Chums of Chance inhabit, crossings between worlds are common. The boys visit a people residing inside the Earth, fly to different planets, and even land on '"Antichthon," […] "The other Earth."' (1148): 'They were on the Counter-Earth, on it and of it, yet at the same time also on the Earth they had

never, it seemed, left.' (1148) Simultaneously being on the Earth and the Counter-Earth is possible given that another planet is always a 'reflection of our single Earth along a different Minkowskian space-time track. Travel to other worlds is therefore travel to alternate versions of the same Earth.' (1146) More precisely, travelling to other planets means visiting the Earth at a different point in time: 'if going up is like going north, with the common variable being cold, the analogous direction in Time, by the Second Law of Thermodynamics, ought to be from past to future, in the direction of increasing entropy' (1146). Stating that over time the temperature in a system becomes uniform, the Second Law of Thermodynamics implies that at some point in the future the temperature of the Earth will blend in with the colder universe. The naturally occurring decrease in temperature then also defines the irreversible direction of time: the so-called arrow of time points into the direction of a future final state of uniform coldness. In the context of *Against the Day*, travelling in the direction of lower temperature – associated with the north of a planet – consequently means travelling into the future. Perpendicularly displaced parallel worlds are thus future states of the Earth that the given world might or might not take but that were possible at one stage in its development.

The spiritual leader of the T.W.I.T. explains how the diverse worlds interconnect: '"Lateral world-sets, other parts of the Creation, lie all around us […] An unscheduled Explosion […] may easily open, now and then, passages to elsewhere.…"' (248) On a small scale this is how Lew '"found passage between the Worlds"' (248) – he dives into a detonation. On a larger scale, the massive explosion of the Tunguska Event as a possible condensation of the First World War, and the war itself, occasion the 'death' of the world and a passage to a different set of conditions: '"The world came to an end in 1914. [… We have] been in Hell ever since that terrible August."' (1211) While the war ends a world, the suspension of normal conditions caused by the Tunguska Event also reveals the spiritual realm of Shambhala: 'the sacred City had lain invisible […] until the Event over the Stony Tunguska, as if those precise light-frequencies which would allow human eyes to see the City had finally been released' (890). Thus, hope remains that a better spiritual reality might exist next to the one shaken by war, similarly to the case of Asia regarding which the Chums of Chance learn that it is riven by '"political struggle among the Powers of the Earth"' (280) but also exists as a realm '"by whose terms all such earthly struggle is illusion"' (280). The existence of '"worlds which are set to the side of the one we have taken, until now, to be the only world given us"' (280) also indicates that the world's path is not inevitable but that other possibilities always remain.

The time-span that *Against the Day* covers, 1893 to the early 1920s, is remarkable for its high rate of discoveries unsettling traditional knowledge and for the introduction of new technologies: 'In many ways the broad disposition of such massive technological systems [e.g. train and air travel, networked communication technologies, skyscrapers, automobiles] makes the first decade of the twentieth century one of the most radically transformative periods in the history of the West.' (Crawford 509) Science thus changes the world by introducing new information and opening up possibilities. Not least, the scientific invention of dynamite in 1867 made feasible the scheduling of explosions which, so the leader of the T.W.I.T. holds, '"may easily open, now and then, passages to elsewhere"' (248); a principle employed by the anarchist Webb who hopes to change the world's path by explosive means. Yet, Merle explains to Webb's son Frank that shaking up the world does not necessarily involve gunpowder. When showing Frank the process of double-refraction which can transform silver to gold and might thus '"*knock the Gold Standard right onto its glorified ass*"' (345) and destroy the world's capitalist order, Merle says: '"maybe what you think you're looking for isn't really what you're looking for. […] Just guessin', but it's also what your father Webb was looking for"' (345-46). Frank does not understand his meaning, so Merle tells the apparently unrelated story of the underground world of the tommyknockers. The existence of this invisible realm questions the taken-for-granted conditions above ground and facilitates imagining an alternative anarchistic world. Yet, many people are unable to perceive the hidden realm; for example, only seeing that Merle's is '"not a rational explanation"' (346), Doctor Turnstone suspects insanity rather than accepting that the tommyknockers are '"down there, all right"' (346). Sharing 'the everyday explanations owners and the like tended to favor. The belief, for instance, that tommyknockers are not little people in whimsical costumes but "only" pack rats' (347), Doctor Turnstone's preconceived worldview distorts reality, and he has to see the parallel world with his own eyes before he can break with his frame of reference and accept the tommyknockers for what they are. Given that '"there's at least one tommyknocker with a *hell* of a lot of dynamite stashed away"' (347), the largely misjudged underground population might prepare an explosive return to the everyday world, but in general, the common rational view and more unusual perspectives grow further apart. Whereas the number of traders who know 'the names and market prices' (78) of goods increase, their 'counterparts whom they most often never got even to meet, knew the magic uses' (78) but are suppressed in the process of rationalisation: 'They lived for different futures, but they were each other's unrecognized halves, and what fascination between them did come to pass was lit up, beyond question, with grace.' (78) A person also considering the non-rational

half, keeping their '"senses open, reject[ing] nothing"' (651), can experience whole worlds that the rulers of the rationalised world cannot control or even acknowledge. And with the acceptance of the possibility of other worlds, the potential for change presents itself: when transcending the conditions of the given and not taking the 'real' world for granted, alternatives can be thought and the world may be changed by active intervention – and even, by taking account of both halves of the world, be 'lit up […] with grace' (78).

2.5 The Language of Mathematics: Crisis of Representation

The rationalisation of the world results in a split into two halves that can no longer recognise each other, and if increasingly people do not acknowledge aspects for which there is '"not a rational explanation"' (346), language again and again fails to represent the concepts and entities that are difficult to grasp: '"He is unnameable."' (610); or: '"That creature, we did not have name for. Ever."' (139) The linguist Ferdinand de Saussure developed the notion that in general signs relate not to actual objects but to each other only (see introductory chapter), and *Against the Day* illustrates that if language is itself affected by the representational crisis, it no longer constitutes a reliable medium to demand and bring about change. Thus, the anarchist Webb reverts to an alternative way of voicing his discontent, namely to the more direct expression of explosives which can open up paths to other worlds. Frank understands 'that in each explosion, regardless of outcome, had spoken the voice Webb could not speak with in the daily world' (528), and like Webb who 'always expressed himself more by way of dynamite' (356), the Tunguska Event, that is, the representation of the unrepresentable war, also is an explosion – a sound structure or *signifiant*: 'the explosion arrived, the voice of a world announcing that it would never go back to what it had been' (878). As language fails, the remaining basic element of sound can only communicate the fact that the world is in a critical state.

Mathematics occupies a special place among languages as it exists almost solely in written form and is largely independent of national boundaries, forming a kind of universal language. The Chums of Chance notice the international nature of numbers when travelling to Italy: '"The Italian number that looks like a zero, is the same as our own American 'zero.' The one that looks like a one, is 'one.' The one that looks like a two–" "Enough, cretin!" snarled Darby, "we 'get the picture'!"' (273-74) The language of mathematics is further shown to constitute a universal system when mathematics transcends national disputes and unites a 'band of varying ages and nationalities, whose only common language [… was] that of the Quaternions' (589) and when Hermann Minkowski lectures in Yale without speaking

English: he 'gave the lecture in German but wrote down enough equations so people could follow it more or less' (515). Yet, however unifying mathematics might work, it is itself divided into diverse mathematical languages which are at odds with each other: 'Unlike the Yale math department, the one at Brown taught Quaternions, but despite the language difference, Kit found Root a cheerful fellow' (572-73). The language difference grows into 'the Quaternion Wars' (590) not primarily due to the dissimilar symbols or number systems used by Quaternions and Vectors, but the two mathematical languages entail diverse relations to nature and consequently support different interpretations of the world: '"Quaternions failed because they perverted what the Vectorists thought they know of God's intention – that space be simple, three-dimensional, and real, and if there must be a fourth term, an imaginary, that it be assigned to Time. But Quaternions came in and turned that all end for end […]. Of course the Vectorists went to war."' (599) In other words, the mathematical war arises from questions of representation. Attempts to link mathematical principles to the world thus result in contention, but in a similar move as when anarchism turns to establishing self-contained groupings in which political representation is abolished and language comes to be seen as self-referential, mathematics ceases to be perceived as necessarily related to nature. Even Hamilton and his supporters who had argued that Quaternions were, 'virtually, the thing represented' (Tait qtd. in Crowe 213) could not ignore the deepening crisis of representation and finally had to admit that mathematics should be studied as a '*science of language*' with '*forms of expression* being treated as themselves the subject-matter' (Hamilton qtd. in Øhrstrøm 52). When mathematics is no longer seen as a description of reality but as an autonomous system only referring to itself, any construction that complies with the rules inherent in the system is valid and 'real'. Mathematics can thus freely construct itself in its self-contained system – as Cantor famously phrased it: 'the *essence* of *mathematics* is its *freedom*'[4] (Cantor 564).

2.6 The Freedom of Mathematics

Against the Day suggests that mathematics' freedom from representation allows escaping the given reality and finding freedom in imaginary realms, in time-travel, bilocation, and double-refraction. Enabling access to lateral imaginary worlds, mathematics also points to different possible states of the given world and makes change more easily imaginable. The existence of lateral worlds, which differ from the earthly reality and therefore are perceived as '"[u]nreal, but not compellingly so"' (694), wins authority from a

[4] 'das *Wesen* der *Mathematik* liegt gerade in ihrer *Freiheit*'.

mathematical proof, and the possibility of reshaping the world is similarly supported by the most certain science: Kit 'was presented with a startling implication of Zermelo's Axiom of Choice. It was possible in theory, he was shown beyond a doubt, to take a sphere the size of a pea, cut it apart into several very precisely shaped pieces, and reassemble it into another sphere the size of the sun.' (1212) Kit remembers that the mathematician Ernst Zermelo, 'like Russell, had been preoccupied with the set of all sets that are not members of themselves' (1212) and discovered paradoxes not only in set theory but also regarding a journey to the pole which he deemed impossible 'because the amount of whisky needed was directly proportional to the tangent of the latitude. Polar latitude being 90°, this meant a value approaching infinity – Q.E.D.' (1212) While Zermelo's non-mathematical 'proof' makes Kit sceptical as to the implication of the Axiom of Choice, Professor Vanderjuice accepts what in mathematics is known as the Banach-Tarski paradox: 'One of the amazing results in the Banach-Tarski paper implies that a solid ball of any size can be cut up – in theory – into a finite number of pieces that can be reassembled to make a ball of any other seize. In other words, "a pea can be cut up to make the sun"!' (Burdman Feferman and Feferman 43) And 'unlike other paradoxes that entail actual contradictions, […] the Banach-Tarski Paradox is perfectly consistent with the generally accepted assumptions of modern mathematics – namely, the axioms for set theory' (ibid). Consequently, no mathematical paradox compromises Professor Vanderjuice's conclusion from Zermelo's Axiom of Choice in *Against the Day*: '"you see what this means don't you? […] the world we think we know can be dissected and reassembled into any number of worlds, each as real as 'this' one"' (1212). In other words, the different worlds that mathematics creates and explores are there, 'mathematically proven' so to speak, and it is a shortcoming of earthly reality that reassembling a pea cut to pieces is unlikely to arrive at a sun-sized sphere. As any given reality thus does not live up to its theoretical potential, an imaginary component has to provide room for what reality cannot generate. Modern mathematics, using its essential freedom to break open any governing worldview and construct alternative worlds all of which are equally 'real', then exhibits a potent 'anarchistic' ability.

Only few characters in *Against the Day* recognise the 'mathematically proven' existence of alternative worlds and manage to travel between realities, and the necessary complexity – combining real and imaginary components – of anarchism is shown when it is the Chums of Chance, living in a sphere that deviates most from '"[t]his world you take to be 'the' world"' (622) but still is contact with it, who have the far-sightedness to draw different conclusions from the crises on Earth and, pursuing anarchist ideals, approach grace. As the above discussion has shown and Sascha Pöhlmann also points out, the combination of

both real and imaginary elements is a central feature and appears in numerous guises in *Against the Day*:

> Ultimately, the ontological ambiguity of the Chums of Chance with regard to both their fictionality and the world they exist in works towards the same end as the motifs of Iceland spar, imaginary numbers, or bilocation in *Against the Day*: all these are ways of thinking about a complex universe that is always both real and imaginary, and in which the terms are constantly renegotiated, and neither of them can eradicate the other. (Pöhlmann 32)

The complex universe can be taken account of by systems that acknowledge the real value on the '"spine of reality"' (679) as well as the existence of alternative worlds set on the perpendicular axis. Providing a tool to create worlds and recreate what is taken to be 'the' world, mathematics incorporates plurality and freedom and attests to the anarchy of imaginary existence – a feature that is more commonly associated with literature. Thus, particularly with the illustration of the loss of its representational relation to reality, *Against the Day*'s presentation of mathematics becomes intertwined with the depiction and evaluation of fictional literature. The imaginative quality of mathematics and the consequent relation to literature should therefore be borne in mind during the following examination of the potential for freedom that is inherent in literary fiction. Moreover, the changing notion of mathematics and the thereby emerging relation between mathematics and fiction also informs the unfolding of the novel, and I shall therefore explore how *Against the Day* itself makes use of the freedom of imaginary domains and in doing so employs the consequences of the crisis in mathematics as an analogue for its own proceedings.

3. Freedom in Fiction

'If there is an inevitability to arrival by water […] as we watch the possibilities on shore being progressively narrowed at last to the destined quay or slip, there is no doubt a mirror-symmetry about departure, a *denial* of inevitability, an opening out from the point of embarkation, beginning the moment all lines are singled up' (920). Significantly, the novel *Against the Day* departs on its own course with the call: '"Now single up all lines!"' (3). The Chums of Chance's ascent into the unlimited sky severs the ties with the given world, and the novel similarly leaves the constrictions of historical reality behind and enjoys 'an unloosing of fate as the unknown and perhaps the uncreated begins to make its appearance ahead and astern, port and starboard, everywhere an expanding of possibility' (920). Reef experiences that fiction opens up new realms like a journey and provides alternatives to the everyday world from which the reader is setting off when he reads a Chums of Chance novel in prison: 'he enjoyed a sort of dual existence, both in Socorro and at the Pole' (241-42). The

planes of reality and fiction blur when Reef 'found himself looking at the sky, as if trying to locate somewhere in it the great airship. […] "They're watching us, all right."' (242) Reef's opening up to the Chums' existence shows that fiction can enhance a narrow rational worldview to seeing further possibilities, but while reading allows experiencing other worlds and travelling with the Chums in the more fictional domain of the heavens, the world becomes increasingly short-sighted and exclusive of what does not belong to the rational earthly reality: while at the Chicago World Fair people 'looked up at the airship in wonder' (11), in the course of the novel the balloon becomes 'more conjectural than literal' (287) until it is completely invisible (1217). Yet, similarly to mathematical worlds, which are joined by a 'spine of reality', literary fiction is never completely severed from reality. While the Chums of Chance in their boys' books universe resist the rationalisation of the earthly world, dwell 'thousands of feet in the air and far from any outpost of Reason' (138), and travel the heavens, they descend on the 'spine of reality' again and again – to protect Earth from the Trespassers, to help its population, and as stories that engage readers to the point where they might pass over into fiction: a surrogate Chums of Chance unit consists of boys who 'may have once been readers of the Chums of Chance Series of boys' books' (476) but then become a version of the Chums themselves and enter another, a fictional 'world scarcely different from the one they had left' (478). Crossing over to the fictional domain, the readers become indistinguishable from the 'original' Chums and attest to the permeable boundary between real and fictional existence.

Fiction permits readers to experience different lives and identities, releasing them into another existence, into fictional lateral worlds that do not represent the reader's reality but are worlds of their own. The process becomes clearer with the novel's example of photography which can work to recover life in a lateral, imaginary world. If '"[s]napping a photograph is like what the math professors call 'differentiating' an equation of motion – freezing that movement into the very small piece of time it takes the shutter to open and close"' (1165) then the picture depicts a given moment in the given world. The inventors Merle and Roswell reverse the procedure: they '"start with the still photo and *integrate* it, recover its complete primitive and release it back into action … even back to life…"' (1165). The integrated picture can thus show past, present, and future of the photographed object, and in this way, it time-travels. Even more, the photos also show alternative, 'fictional' versions of events: the objects may '"choose different paths than the originals"' (1180). The picture thus multiplies the depicted reality and creates worlds of its own, and in this respect Merle's and Roswell's photography resembles the scientific processes of bilocation and double-refraction: 'here seemed to be those old bilocational powers emerging now once

again, only different' (1180). Complying with the connection between bilocation and the most natural multiplying process, the inventors primarily employ the mathematical procedure of integration to 'anarchistically' recreate family bonds, recovering family members through space and time and from parallel worlds: 'there must now and then appear one compassionate time-machine story, time travel in the name of love, with no expectation of success, let alone reward' (1192). Merle watches his daughter Dally on another continent, and Lew sees his ex-wife again, but observing their loved ones in 'the mathematical mists' (1193) does not equal experiencing real life – the picture remains a scientific fiction: '"It looks like one of them wonders of science. […] I just wish it could be more, 's all."' (1193) The pictures themselves 'become real' however, when Merle releases them into their own world: 'photos trembled, stirred, began to move, […] pedestrians walked away out of the frame, […] resumed their lives, though clearly they had moved beyond the range of the lens' (1167). Walking out of the frame, the photographed objects leave the given world's frame of reference and resume life in their own world, benefitting from the anarchistic freedom granted by the mathematical procedure of integration.

If Merle's invention produces time-travel by showing a picture's past or future, the alternative worlds that the process also makes visible are results of 'defective' time-travels, that is, outcomes of failed hopes: '"What are any of these 'utopian dreams' of ours but defective forms of time-travel?"' (1058) Imaginary time-travel explores paths not taken by the given world, but envisaging the unconventional and non-existent can influence the way the actual future unfolds. Yashmeen claims: '"We can do whatever we can imagine. Are we not the world to come? Rules of proper conduct are for the dying, not for us."' (987) Imaginary worlds, dreams, and books such as the Chums of Chance novels thus facilitate crossings from one state of reality to another – regarding the world's future as well as mathematics, Hadamard's phrase proves correct: 'the shortest and best way between two truths of the real domain often passes through the imaginary one' (Hadamard 123). The potential of the imaginary domain is most manifest in the Chums' world, yet, like Kit who cannot 'escape the world governed by real numbers' (759) and Reef who is told to rededicate himself 'to real-world issues' (901), the Chums in their boys' books universe experience the danger of losing touch with earthly reality. 'Sworn by their Foundational Memorandum never to interfere in the affairs of the "groundhogs,"' the Chums are helpless when America 'passed so irrevocably into the control of the evil and moronic' (1148), and the balloon-boys are not even aware of the First World War, 'as if, long ago, having learned to fly, in soaring free from enfoldment by the indicative world below, they had paid with a waiver of allegiance to it and all that would occur down on the Surface' (1149). Only when Miles

remembers the warning from the Trespassers, it is 'as if some blindness had abruptly healed itself, allowing him at last to see the horror transpiring on the ground' (1150), and the Chums join Padzhitnoff's crew in their attempts to '"manage famine, disease, broken cities"' (1156). When the Chums then turn away from the monetary promises of America which is 'infected with light' (1160) so that capitalists can profit from working hours '"beyond the hours of daylight"' (1161), but together with their female counterparts sign up for the '"supranatural idea"' (1217), they can implement their more humane thinking on Earth, and only then, taking account of the imaginary and the real, they experience the 'brief moment of certitude' (1066) with the birth of their children and approach grace.

Against the Day suggests that, introducing alternatives to the given world and opening up the worldview, the imaginary domain of fiction is a precondition for change and part of any developing reality. Moreover, if freedom declines in respect of political anarchism, it continues to influence the world through the openness and potential for change inherent in mathematics and literature: denying direct representation and constituting free systems in themselves while still being connected to the world, mathematics and literature contest claims for the existence of any one governing system but imply that fiction and plurality are constitutive parts of whatever world there might be. Significantly however, change is shown to be possible only when also taking account of the 'spine of reality' that is part of and connects all worlds. *Against the Day* thus illustrates that a developing world is never purely real, nor purely imaginary, but always complex.

4. Essential Plurality – Arguing Against the Day

The '"ancient and abiding darkness which all hate, fear, and struggle against without cease"' (872) is commonly associated with irrationality, nothingness, and meaninglessness: the 'black-velvet absence of signs' (398). Light, on the other hand, is thought to dispel the 'irrational and pernicious' (872) with its presence, enlightening and giving interpretation and meaning. At least since the Age of Enlightenment, light is also linked to reason and the promotion of scientific methods, even up to the point that Theodor W. Adorno and Max Horkheimer explained in their 1947 *Dialectic of Enlightenment*: 'For the Enlightenment, whatever does not conform to the rule of computation and utility is suspect.' (Adorno and Horkheimer 6) In *Against the Day*, the two realms of darkness and light, first appearing to be literally as different as day and night, cannot be unambiguously assessed. For instance, a destructive quality of light turns it into a weapon: 'Phosgene', a gas used in the First World War, '"is really code for light. We learned it is light here which is really the destructive

agent."' (1070) Moreover, the Quaternion weapon, the Tunguska Event which might have been caused by it, and by implication the First World War bring about a 'heavenwide blast of light' (875). Instead of enlightenment, such excesses of light 'produce helplessness and fear' (1070) and a world in Hell (1211), ruled by '"Lucifer, son of the morning, bearer of light … Prince of Evil."' (1161) Pointing to the negative effects of light, *Against the Day* implies a criticism of the excessive 'rationalization and intellectualization' (Weber 'Science' 155) in the modern West; an aspect that is explicit in *Dialectic of Enlightenment*: 'the fully enlightened earth radiates disaster triumphant' (Adorno and Horkheimer 3). Given that extreme light in *Against the Day* is associated with rationalisation and the hell of the First World War, it 'must be received with judgment – too much, too constantly, would exhaust the soul' (1081): '"Nobody can withstand pure light, let alone see it."' (1079) Even the light of God has to be mediated, namely through the Shekhinah, the female aspect of God, which makes him visible by reflecting the light, while pure light indicates absence: '"When God hides his face, it is paraphrased as 'taking away' his Shekhinah."' (1079) Pure light is unbearable and even erases information: in French 'against the day' – *contre-jour* – is a term of photography and refers to conditions where the light source points directly to the camera. Silhouettes are thus sharply visible, whereas details remain dark and hidden. Correspondingly in *Against the Day*, 'God chose to hide within the light of day' (956) and Shambhala is 'cloaked in everyday light' (890). While pure light and presence thus deny perception and meaning, pure darkness similarly conveys no information. However, *Against the Day* also presents positive aspects of absent or obscured knowledge, for example when Jesse uses the cover of night to flee and the darkness allows a trooper capturing the teenager to let him go: '"Get your anarchist ass out of here, […] pray I don't see it in the daylight."' (1141)

The Chums of Chance realise that in their extremes, light and darkness are insupportable but that both are vital elements that have to be balanced. With this affirmation of the world's dual nature, the *Inconvenience* moves towards grace: 'As the sails of her destiny can be reefed against too much light, so they may also be spread to catch a favorable darkness.' (1219) Similarly, in the earthly world Cyprian's order demands that its members be aware of 'the unyielding doubleness of everything' and 'of the nearly unbearable conditions of cosmic struggle between darkness and light proceeding, inescapably, behind the presented world' (1074). The novel further raises awareness of the 'doubleness of everything' by highlighting double-refracted and bilocated persons, parallel worlds, '"anti-landmarks – for every beacon, an episode of intentional blindness"' (279), the 'Anti-Stone' (89) that brings death but at the same time freedom which is '"counter-Death"' (419);

a ‘counter-temple, dedicated to the current “Crisis” in European mathematics’ (711), ‘counter-light’ (653) which reveals a ‘counter-City’ (658) or ‘contra-Venezia’ (660); and a ‘Counter-Earth’ (1147). Thus, everything has its corresponding opposite, ‘like the dark conjugate of some daylit fiction’ (11). In mathematics two numbers p and q are conjugate if $^1/_p + {}^1/_q = 1$. Both $^1/_p$ (‘some daylit fiction’) and $^1/_q$ (‘the dark conjugate’) are fractions and together they make up 1, the whole. p and q can only be whole numbers if they take on the value 2, the double, and are thus equal and in balance. In all other cases they are not whole but decimal numbers or fractions. Also, it always takes both opposed elements to arrive at the whole 1 as p and q cannot be 0 (‘$^1/_0$’ is not defined). Furthermore, the components influence each other: if the value of p increases, the magnitude q has to decrease to preserve the balance. In a non-mathematical context, Kit similarly understands ‘that forms of life were a connected set – critters he was destined never to see existing so that those he did see would be just where they were, when he saw them’ (879). And several characters in *Against the Day* understand that finding a conjugate and with it the unity of the whole does not call for mathematical skills, but that conjugal supplementation of their own ‘fractional’ being achieves the same effect: ‘conjugate’ means ‘joined together, […] coupled’ and was also used in the sense of ‘united in marriage’ (*OED* ‘conjugate’).

Only with an awareness of the doubleness of everything, with seeing both aspects, ‘being two people’, can a person reach the mythical and utopian kingdom Shambhala. During his search for Shambhala, Auberon Halfcourt hears about a Tibetian text that illustrates the necessity of doubleness for arriving at his destination:

> Directions for journeying to Shambhala are addressed by the author to a Yogi, who is a sort of fictional character, though at the same time real – a figure in a vision, and also Rinpungpa himself. […] ‘Even if you forget everything else,’ Rinpungpa instructs the Yogi, ‘remember one thing – when you come to a fork in the road, take it.’ Easy for him to say, of course, being two people at once. (861)

In light of the more general concern with doublings of existence in the *Against the Day*, the story about the Yogi implies that incorporating another view by taking on a fictional existence is a precondition for self-reflection and insight and for reaching the mythical kingdom, as it opens up the preconceived worldview and introduces other possibilities into the taken-for-granted. The alternative spaces and worlds that the family, science, mathematics, and fiction reveal thus attest to an essential plurality of the world, a necessary coexistence of opposites. Most prominently, the ‘unyielding doubleness of everything’ (1074) contests the predominance of light, and *Against the Day* thus argues against the day and in favour of paying similar attention to the night which ‘prepare[s] them against the day’ (903) and renders it visible and bearable in the first place: in their extremes pure light and pure darkness, pure presence and pure absence, are equally void of meaning. Only

contrasting both qualities, darkness mediating light and vice versa, allows for perception and meaning, but nothing can be perceived outside a system of differences. The necessity of dissimilar elements in the perception of the world mirrors the development in mathematics and linguistics after their respective representational crisis: in the self-contained systems a *signifiant* only refers to other *signifiants*, creating autonomous systems of internal differences instead of referring to a present outside referent. Yet, there is more to *Against the Day* than the obvious polarity between light and dark, presence and absence first suggests. Even if everything has its corresponding opposite, the opposites of positive presence (+1) and negative absence (-1) are completed by the concept of the imaginary lateral ($\pm\sqrt{-1}$) and its imaginary existence. It does not alleviate the opposition of presence and absence, but enhances the one-dimensional number-ray of positive and negative numbers by the imaginary perpendicular axis. The domain of imaginary numbers thus corresponds to possibility, to imaginary or fictional versions of presence and absence. What is and what is not is completed by what could be, by lateral, fictional worlds.

Fiction reflects and mediates the full presence of present reality and the complete absence of the past and future with a vision of what could have been or come about. In this way, fiction acts as a Shekhinah, a mediating device that makes the insufferable light and presence of reality perceivable, bearable, and meaningful. A device to render the world liveable is particularly necessary in the early twentieth century when the world becomes increasingly incomprehensible, a development culminating in the general flight from the reality of the First World War. The impossibility or inadequacy of realist renderings of the world is suggested by a turn away from realism in early twentieth-century fiction, and *Against the Day* signals the departure from the confines of the real world with its very first sentence. The Chums' cry '"Now single up all lines!"' (3) prepares the reader to disconnect from the everyday world and climb into the vertical, to go up on the perpendicular imaginary axis. In other words, the balloon-boys' flight – and with it the novel's setting off – is marked as an ascent into the imaginary, into fictional realms. The result is a world 'at once dream-like and real' (40), that is, a novel set against nineteenth- and twentieth-century history but enhancing this 'real axis' with a fictional dimension, emphasising the freedom and plurality of imaginary existence. In the novel's subsequent intermingling and blurring of changing degrees of reality and fiction, the 'unnaturally shaky quality of present-day "reality"' (580) manifests itself, making it impossible to retrieve the reality of the historical period: 'We of the futurity' (793) do not get at the reality of the wartime directly but rely on textual renderings. Fiction thus mediates historical reality by displacing it on the imaginary axis and allows readers to experience the otherwise

irrecoverable past while at the same time counteracting twentieth-century rationalisation and the narrowing of choices by upholding 'anarchistic' plurality and freedom in the imaginary domain.

5. Narrative Anarchy: The Freedom of Imaginary Existence

The novel *Against the Day* comprises many worlds, but it is also a world itself. As such, it performatively creates of what it speaks: freedom in fiction. Setting several, sometimes contradicting, worlds next to and inside each other, *Against the Day* mirrors the 'lack of formal certainties in the world' (Schaub 3), but the novel's refracted form also exhibits the freedom and anarchism explored in its content. When different storylines conform to conventions of diverse genres and the novel's 'genre-poaching technique' (McHale 'Genre' 19) juxtaposes worlds that coexist according to their own respective rules, *Against the Day* prevents itself from becoming authoritative, from imposing 'daylit certainties' (928), and thus practices 'narrative anarchy'. Pynchon's novel thereby illustrates Weir's thesis that the stylistic fragmentation of the modernist novel is not only a 'register of an age in crisis' (Weir 169) but also a feature of the translation of anarchism from the political to the cultural domain. Indeed, the splitting of reality into multiple spheres is an attribute of anarchism: 'In theory, anarchist society is endlessly and actively fragmenting' (Weir 5). Seen from an anarchist perspective this 'fragmentation does not indicate the dissolution of society but its perfection, the realization of a utopian world divided into independent, autonomous units' (Weir 169). Modernist literature which 'is characterized by nothing so much as a tendency toward fragmentation and autonomy' (Weir 5) therefore suggests itself as a form to perpetuate the anarchist agenda when it fails politically; even more, so Weir argues, the characteristics of fragmentation and autonomy only consolidate in culture when their survival in the political domain is threatened: 'the failure of anarchism assured the success of modernism; that is, the politics of anarchism was transformed into the culture of modernism by a number of artists who gave aesthetic expression to political principles' (Weir 158). On the other hand, it could be argued that a unidirectional national politics allows to more easily accommodate uncertainty in other domains; an explanation employed by Dirk van Dalen in his account of the eventual acceptance of contradictory mathematical philosophies in the politically more stable Weimar Republic (see introductory chapter).

With the Chums of Chance's flight into a more fictional, self-governed domain of anarchy and grace, *Against the Day* illustrates the way in which 'modernist art is also the

aesthetic realization of anarchist politics' (Weir 169) and can be a place of moral value: 'Somewhere up in this sky was Miles's home, and all he knew of human virtue' (621). In the everyday world rushing toward hell and making lived virtue difficult, more literal forms of art constitute ways to perpetuate anarchism and value. The painter Tancredi who dies in the attempt to change the world for the better 'was a virtuous kid, like all these fucking artists' (836), and literary fiction introduces the idea '"of uncompensated kindness"' (187) that can only infrequently be observed on Earth. Moreover, the possibility of a functioning anarchistic society is explained in the terms of art when a character proposes that a band illustrates '"the most amazing social coherence, as if you all shared the same brain"' (417). When asked how to call this phenomenon, a member of the band replies: '"Jass"' (417), thus suggesting music as a realisation of anarchistic ideas. Jazz is further suggested to observe the inevitable doubleness of the everything when the novel's epigraph is by the jazz pianist and composer Thelonious Monk: 'It's always night, or we wouldn't need light.' Most significantly however, while on the level of content political anarchism is almost wiped out by the First World War, the coexistence of independent, autonomous, and 'conjugate' units is realised in the diverse storylines of *Against the Day*, so that the novel itself exhibits 'all the variety, multiplicity, and freedom of human expression that anarchism encouraged in the past' (Weir 259). As Graham Benton asserts, 'Pynchon's formal techniques – which favor heterogeneity over uniformity, spontaneity over conformity, and fragmentation over consolidation – align with an anarchist aesthetic that reflects a sustained skepticism toward all typologies and classifications of genre' (Benton 191). Yet, even though *Against the Day*'s 'anarchist aesthetic' supports the argument 'that much of modernist art is consistent with the politics of anarchism, and that this consistency extends into the form of the work itself' (Weir 160), Pynchon's decidedly post-modernist novel also requires adjustments to Weir's assertion. *Against the Day* goes a step further than practising anarchy by describing 'independent, autonomous units' (Weir 169) of 'the' world when the novel comprises multiple coexisting worlds. Thus, whereas the modernist fragmentation of style makes attaining a full and coherent understanding impossible but 'the ontological stability of external reality seems basic to Modernist fiction' (McHale 'Modernist Reading' 90), the universe of *Against the Day* itself disintegrates into independent, autonomous worlds of differing degrees of fictionality. Brian McHale takes such 'ontological doubt, uncertainty about what is (fictively) real and what fantastic' (ibid) to be characteristic of postmodernist fiction (see introductory chapter). Accordingly, the fragmented form of *Against the Day* illustrates the aesthetic realisation of the failed political programme of anarchism but also develops further the modernist transformation of anarchism by suggesting that the nature of

reality itself is anarchical. However, Pynchon's novel does point to a stable real element, namely the '"spine of reality"' (679) which is derived from Riemann's conjecture that the zeta-function's non-trivial zeros all have the real part ½. Drawing on the authority of mathematics, among other illustrations, *Against the Day* thus refuses to accept the confinement of anarchism to a purely imaginary existence, be it modernist or postmodernist. Instead, as Pöhlmann stresses, *Against the Day* is informed by decidedly real political concerns and thus 'positions itself far from the postmodern excesses of too easily conflating the real, the imaginary and the fictional, which ultimately deny any of them any power to change the other' (Pöhlmann 32-33). Due to the special importance accorded to the real element of any imaginary world, the novel leaves behind the indiscriminate plurality characteristic of postmodernist fiction, and therefore, so Pöhlmann claims, '[w]e may have to stop calling Thomas Pynchon a postmodern writer' (Pöhlmann 33).

Pointing to and itself making use of the lateral coexistence and crossovers of real and imaginary worlds, *Against the Day* performatively attains the freedom that political anarchism aims for but which is shown to be better realised by means of science, mathematics, family relations, and art. The novel thus most joyously celebrates the possibilities of fiction, which, although linked to the given world by the shared 'spine of reality', can be an end in itself, 'its own destination' where freedom reigns, and 'any wish that can be made is at least addressed, if not always granted' (1219). Nevertheless, with its complex content and form – being neither purely real nor purely imaginary – *Against the Day* also allows recovering the reality and the possibilities of a historical period upset by political, mathematical, and cultural crises, and it thus provides an almost ideal basis for the following analyses of Broch's and Musil's works, as well as working as a 'prequel' to Pynchon's earlier novel *Gravity's Rainbow* which is set in the Second World War.

Hermann Broch: The Sleepwalkers

The novel-trilogy *The Sleepwalkers* by the Austrian author Hermann Broch was published from 1930 to 1932[1]. The three parts are set in Germany and are clearly located in time as their titles already suggest: the trilogy comprises the parts *Pasenow or The Romantic – 1888*, *Esch or The Anarchist – 1903* and *Huguenau or The Realist – 1918* which closes its main plot with the German revolution at the end of the First World War but pursues one of its storylines to 1926 in the epilogue. The trilogy thus covers a time span comparable to Pynchon's *Against the Day*, discussed in the previous chapter. If *Against the Day* introduces mathematics as interrelated with the political crisis around the turn of the century, *The Sleepwalkers* uses the foundational crisis of mathematics as 'the clearest example'[2] (III 481) of the general development leading up to and culminating in the First World War. An obvious difference between the two works is the time of production: whereas Pynchon's novel was published almost a century after the crisis, Broch's work is produced far more closely to the cataclysmal time. 1930 is indeed commonly suggested as the endpoint of the foundational crisis of mathematics, so that *The Sleepwalkers* was written at the close of the period of mathematical uncertainty which it takes as exemplary of the wider upheaval. The time-frame and focus of *The Sleepwalkers* thus ideally accord with the compass of this project, but Broch, who received a 'comprehensive and well-founded mathematical education'[3] (Bendels 57) at the University of Vienna from 1925 to 1930, also shows his interest in science in several other theoretical and literary works.[4] Broch's direct work on mathematics was aimed at 'historically oriented, informed overviews on the one hand, and, on the other hand, engagement with epistemological questions around the foundational problems'[5] (Riemer 270). He is known to have written mathematical studies with which he aimed to participate in the debate around the foundational crisis of mathematics, but the unpublished documents were lost after their confiscation by the national socialists in 1938. Evaluating the available material, Carsten Könneker comes to the

[1] The pagination of the trilogy is continuous, but quotes will be identified as belonging to part I, II, or III.
[2] 'am deutlichsten' (533).
[3] 'umfassende und fundierte Ausbildung zum Mathematiker'.
[4] Literary works concerned with science but not examined here include the poem 'Mathematical Mystery', and the novels *The Unknown Quantity*, *The Death of Virgil*, and *The Guiltless*. Examinations of mathematics in Broch's nonfictional thought and in novels other than *The Sleepwalkers* for example in Adams, Albrecht and Blohmann, Bendels, Cliver, Könneker, and Radbruch *Mathematische Spuren* 156-164.
[5] 'um historisch orientierte, informierte Übersichtsstudien einerseits, und um die Auseinandersetzung mit der erkenntnistheoretischen Grundlagenproblematik andererseits'.

conclusion that Broch developed his own approach to the foundational crisis in which he combines aspects of the schools of logicism, formalism, and intuitionism and posits human intuition as the origin of all knowledge. Könneker notes a corresponding view on mathematics in Broch's creative writing, particularly in *The Unknown Quantity*, and Gwyneth Cliver in her doctoral dissertation similarly examines this novel by Broch, as well as his philosophical writing, to argue for Broch's emphasis on the irrational as a means to prevent a sceptically viewed hyperrationality. The following analysis will trace the illustration of mathematics through the three parts of the *The Sleepwalkers* and establish ways in which modern and counter-modern concerns inform the content and the form of the trilogy.

As sketched in the introductory chapter, the focus of the foundational crisis of mathematics lay less on purely mathematical problems, but the emerging uncertainty rather concerned 'the shaking of the terms of truth, meaning, object, existence in mathematics'[6] (Mehrtens 8), and *The Sleepwalkers* accordingly uses the foundational crisis as an example for examining the notions of truth, meaning, and existence more generally. Therefore, after first determining the role of mathematics as the trilogy's 'clearest example'[7] (III 481) of the overall crisis in the decades around the turn of the century, this chapter will examine the trilogy's presentation of analogous developments in the domains of reality and value. The then following analysis of links of the interrelated notions of mathematics, reality, and value with literature and the novel-trilogy itself will reveal central ideas in *The Sleepwalkers*'s evaluation of the period and its future, as well as illuminate the specific roles allocated to mathematics and literature in the comprehension and formation of reality.

1. Mathematics as the Clearest Example of the Common Style of Thinking

In contrast to Pynchon's *Against the Day* which illustrates potential paths as the world enters the twentieth century, *The Sleepwalkers* is not primarily concerned with past possibilities, but its 'great question' revolves around the conditions allowing for the advent of the First World War. In the essayistic chapters entitled 'Disintegration of Values', which are part of the third novel and formulate a theoretical framework of the trilogy, the concern is articulated most clearly:

> The great question remains: how can an individual whose ideas have been genuinely directed towards other aims understand and accommodate himself to the implications and the reality of dying? […] This age harboured somewhere a disinterested striving

[6] 'die Erschütterung der Begriffe von Wahrheit, Sinn, Gegenstand, Existenz in der Mathematik'.
[7] 'am deutlichsten' (533).

> for truth, a disinterested will towards art, and had after all a very definite social feeling; how could the men who created these values and shared in them "comprehend" the ideology of war, unresistingly accept and approve it? […] How could the ideology of war find any kind of response in these men, how could they ever come even to understand such an ideology and its field of reality […]? (III 374)

The text refers to the individual, values, and reality as domains in which attitudes must have changed to accommodate the idea of war. According to 'Disintegration of Values' and also evident in *The Sleepwalkers* as a whole, these fields and other manifestations of a period share a 'structure of thought' or 'style of thinking' (III 481) which forms them into a unity. The concept of a common style of thinking is introduced using the example of the Renaissance of which it is said that its phenomena 'must all possess a common root, and that root must have lain in the logical structure of thought itself, in that specific logic which penetrated and informed all the activities of the epoch' (ibid). The style of a period thus is 'something which uniformly permeates all the living expressions of the epoch' (III 397), so that a change in style similarly affects all areas across a period, and it is possible to follow the development in one area of thought and apply its structure to other fields by way of analogy. 'The Disintegration of Values' explicitly professes to do so when examining the 'sweeping revolution in the style of thinking' (III 481) through the example of 'the research into first principles of modern mathematics' (ibid). Mathematics is thus accorded a central place in the trilogy's depiction of changes in 'the logical structure of thought' (ibid) before and during the First World War and its concern with the question whether the discovered logic allows for a return to pre-war thinking.

'Disintegration of Values' describes the logic of the wartime period as profoundly different from earlier styles of thinking: it 'has lost something, has even quite deliberately abandoned something that it could not help abandoning, the lack of which distinguishes it fundamentally from previous styles: the characteristic use of ornament' (III 390). The ornament embodies the essence of a style of thinking and is the condensation of all its implementations: 'ornament, detached from all purposive activity, although produced by it, becomes the formula of style itself, and with that the formula of the entire epoch and its life' (III 398). The absence of an ornament in the wartime-style accordingly points towards the period's lack of essence: the areas of thought are no longer connected by a unifying element, but the style 'is no longer a style, [it] is merely a symptom' (III 391) of the world having lost its common point of reference. The notion of the lack of essence and organising principle is reminiscent of Jacques Derrida's description of the absence of 'the central signified, the original or transcendental signified' ('Structure' 91), which is discovered when examining the 'structurality of structure' ('Structure' 90). As a structural science, mathematics can exemplify structural developments, and also being closely related to the domain of logic, it

suggests itself for investigations into the drastic change in the 'logical structure of thought': 'We have before our own eyes the clearest example[8] of such a process in the research into first principles of modern mathematics' (III 481), it is accordingly claimed in 'Disintegration of Values'. In other words, *The Sleepwalkers* claims that by examining the changes in mathematics we can understand the development of the period in general.

2. The Development of Mathematics

The three novels, respectively set in 1888, 1903, and 1918, trace the development of mathematics into its foundational crisis and to the resulting transformations. The novels will not receive equal attention in the following analysis, since the third part of the trilogy is almost as long as the two previous novels taken together and mathematics plays virtually no role in *Pasenow*. In the context of the other novels, the absence of mathematics in the first part emerges as significant as it indicates the still unproblematic character of mathematical existence, truth, and meaning. *Esch* is the novel most concerned with mathematics on the level of plot, and mainly through the related field of accounting it presents the beginning questioning of fundamental concepts of mathematics. *Esch* also already hints at a splitting of mathematics during the foundational crisis and at the emerging notions of modern and counter-modern mathematics. The conflicting views are then specified and evaluated in the multiple storylines of *Huguenau*, most prominently in the integrated essay which also introduces the theory of analogous developments and of mathematics' constituting the clearest example of the period's changes. Having established the 'sweeping revolution in the style of thinking' (III 481) across the three novels with the help of the exemplary case of mathematics, it will then be possible to relate the transformations in mathematics to the development of the notions of reality and value. Interrelated with both the illustration of mathematics and understandings of reality and value is the novelistic form which develops from a 'harmless'[9] (Broch 'Kommentare' 724) realist style in *Pasenow* over the 'expressionistic prose' (Ziolkowski *Hermann Broch* 12) mirroring Esch's disorientation in a quickly changing world to *Huguenau*'s multiple storylines in dissimilar styles which depict the disintegration of the world in war on the narrative level. All three novels focus on the psychological dimension, which is stressed by the use of free indirect discourse; a turn inward that becomes significant when regarding the overall structure of the trilogy (see 5.1).

[8] 'am deutlichsten' (533).
[9] 'harmlose'.

2.1 *Esch*: Book-Keeping, Mathematics, and the Book of Nature

Esch evokes Galileo Galilei's view of the world as a book written in the language of mathematics when the eponymous character is a book-keeper convinced of the representational relation between the numbers and calculations in his books and reality: 'disorderly accounts meant a disorderly world' (II 216), Esch believes. Correct book-keeping is thus essential to ascertain the order of the world, but the system of accounting is in confusion even at the opening of the novel. While Esch considers himself to be a 'perfect book-keeper'[10] (II 170) and accuses his colleague of faulty work, he loses his job: 'they had fallen foul of him over an alleged mistake in the books' (II 161). Esch's 'perfect' book-keeping does not match with the received system, and he does not believe this to be a personal problem only; rather, the world has generally become too 'incomprehensible' (II 192) to be describable in books: the 'anarchical condition' (II 231) of the world where '[n]othing was clear and simple' (II 200) and 'no one seemed to know whether he was on the right or on the left, in the van or in the rear' (II 231) cannot be rendered in the ordered system of accounting.

Since the system of accounting and anarchical reality no longer comply with each other, Esch sets out to instil order in the world by balancing the entries in the book of nature according to the 'upright book-keeping of his soul' (II 236). Applying the rational rules of accounting to calculate the right and wrong in the world, he expects to arrive at right – correct as well as morally good – solutions to worldly problems. For instance, Esch is convinced that only if he reports his former colleague Nentwig's incorrect book-keeping to the police will his innocently imprisoned friend Martin be released: the police 'had seized an innocent man – perhaps because Esch himself had not handed Nentwig over to them' (II 204). A similarly irrational calculation induces Esch to save Ilona who is the assistant and lover of a knife-thrower and, so Esch feels, wrongly put into danger during the performances: 'a disorderly world meant that Ilona would go on being a target for knives' (II 216). He not only aims to free Ilona from the hazardous acts but also from any sexual contacts, even renouncing having a relationship with her himself. Yet, Esch is appalled when his sacrifice is not balanced by a corresponding gain: 'he was conscious of some discrepancy in his calculations. He had given up Ilona, yet he was supposed to look on while Erna turned away from him and set her cap at that idiot. It was against all the laws of book-keeping, which demanded that every debit entry should be balanced by a credit one.' (II 215) Esch finally accepts the loss of both Ilona and Erna, but he only does so in

[10] 'Perfekter Buchhalter' (193).

order to evade the yet bigger sacrifice of marriage, and due to this 'obscure miscalculation' (ibid) he feels his 'accounts' to be 'in a disorder which it would take the devil and all to clear up' (II 216). Esch thus experiences that the system of accounting is not easily applicable to the anarchical world and that the period's inherent uncertainty renders all attempts of traditional book-keeping futile: there always remains an ineradicable 'contradiction so colossal and so terrible that it cannot even be put down to a book-keeping error' (II 314). The 'smooth and flawless book-keeping' (II 217) that Esch encounters at work therefore falsifies the more complicated reality and, to him, conceals 'all manner of infamies' (ibid). Esch consequently leaves his post as an accountant and renounces the inadequate manner of keeping the books: 'He would have liked to go straight down to the counting-house and tell the blind fools there that they too should break out of their prison of hypocritical ciphers and columns and like him set themselves free' (ibid).

Having freed himself from the restricting perspective of book-keeping, Esch dreams about escaping to a place of order, justice, and value, and America promises to be such a perfect new world. However, Esch believes that he is not permitted to leave the anarchical conditions behind if the old accounts are not settled: '"First set the world right."' (II 214), he demands. In order to settle the scores so as to be able to leave for the new world of America, Esch has to rectify the error in the account of the world; yet, since the traditional system of book-keeping has failed him, an element outside of rational accounting has to achieve the balance: the 'glaring error in the books […] could only be put right by a wonderful new entry' (II 190). The ineradicable error in the book is always to one party's disadvantage, and Esch understands that willingly taking on the consequences of the error and thus ensuring the balance constitutes the 'wonderful new entry' and leads to the correct solution. When visiting his friend Martin who calmly bears his unjust imprisonment and whom Esch thinks of as a 'martyr' (II 234), Esch proclaims: '"that's the only thing left to do, to sacrifice oneself […]; a decent man must sacrifice himself or else there's no order in the world"' (II 290). Esch accordingly 'sacrifices' himself when he 'give[s] himself, not in marriage, certainly, but in personal service' (II 216) to the wrestling business that replaces the knife-throwing and in this way saves Ilona from the daggers. And when he also accepts the lack of a compensating 'credit entry' and toasts to Erna's engagement, 'the final line had been drawn under an account' (II 310). The non-rational and individual deed of sacrifice thus provides the 'wonderful new entry' that balances and closes the books that in an incomprehensible world can no longer be kept according to a purely rational system.

Esch renounces Erna, and when he in turn becomes engaged to be married, he no longer evades the biggest sacrifice but commits 'suicide' by submitting 'himself to that death which came from the dead' (II 315), namely from the old and infertile widow Mother Hentjen: 'if he resigned himself to Mother Hentjen and her body of death, [he] must by this unprecedented measure not only consummate Ilona's redemption, […] but by doing this he must also of necessity rescue Mother Hentjen from death, vivify again her loins' (II 315-16). The 'wonderful new entry' in this calculation is essential: 'the sacrifice had to be, had to grow even greater along with his devotion to this ageing woman, so that the world might be put in order and Ilona might be shielded from the daggers' (II 273). The final decision to sacrifice himself in marrying Mother Hentjen then balances the account: 'it was like a complicated book-keeping task which he had solved at last, indeed even more than a book-keeping task; it was the real task of love in all its absoluteness that he had taken upon him in submitting his earthly life to Mother Hentjen' (II 316). His life thus correctly balanced, Esch reaches some kind of order and stability, real love being 'the last attainable point on that coast beyond which lay the unattainable' (ibid), namely America. Given that the objective calculations in the traditional system of book-keeping have lost their security, Esch and his likes can no longer refer to general ordering systems but 'must build up a new order and justice for themselves' (II 295), and they thus can achieve order and certainty on the small scale of individual life only.

In a time when Christianity is in decline and the general worldview increasingly defined by reason, Esch 'combines Christian imagery and symbols […] with the logic of bookkeeping to shape his own religion' (Schlant *Hermann Broch* 46). Mathematical book-keeping enhanced by the 'wonderful new entry' of sacrifice replaces traditional faith, yet, Esch's realisation of the limits of exactitude that he can achieve and his megalomaniac inability to question his own power to bring order and meaning to the world lead to his distrusting even the validity of mathematics. The description of the general figure of the traveller on his way to the new world of America, who 'must build up a new order and justice' (II 294), also applies to Esch: the traveller 'believes no longer in the correctness of addition sums' (II 224-25) and even 'doubts that two and two make four' (II 295). In his effort to reach a future better order, the traveller mistrusts even the most basic mathematical truths; yet, similarly to Esch's book-keeping which is not rejected but transformed according to Esch's non-rational belief in sacrifice, mathematics is questioned but not abolished: 'they do not dare […] to invoke that terrible revolution of knowledge in which two and two will no longer be capable of addition' (II 295). Mathematics, once believed to be the language of the book of nature, is thus not invalidated, but it no longer uncomplicatedly constitutes truth

or the grounds for understanding and ordering the world. As becomes evident in the last part of the trilogy, similarly to Esch's adding a 'wonderful new entry' into book-keeping to ensure the system's usability in an anarchical world, the value of mathematics can only be saved by the introduction of a non-rational human element.

2.2 *Huguenau*: Book-Keeping – A World of its Own

In the fifteen years between the events depicted in *Esch* and the wartime setting in *Huguenau*, the development of accounting has reached its conclusion. Knowing 'that in the store, as in life, that perfect order can never be achieved which he maintains in his books' (III 368), the book-keeper no longer concerns himself with calculating numbers as representations of real counterparts but restricts his view to the system of book-keeping itself: if an 'error has occurred not in the books but in the stocktaking in the storeroom, then the head book-keeper simply shrugs his shoulders, and his lips wear a pitying or sarcastic smile, for the stocktaking lies outside his province' (III 368). Book-keeping has thus turned from being employed as a tool to understand and order the world to constituting a self-contained world and end in itself.[11]

The world of book-keeping holds particular appeal in its order and regularity, and its 'strict and extraordinarily exact system of rules' gives 'security to life': 'Supported firmly by such rules, he [the book-keeper] grows acclimatized to an all-powerful and yet modest world in which everything has its place' (III 367). The internal coherence of the book-keeper's world warrants 'the sureness of his smoothly proceeding calculations' (III 368) and thus assuages the desire for order and stability that the real world in the uncertain time of the First World War is less likely to satisfy. The book-keeper accordingly feels 'expected and yet enchanting surprise' (III 369) when, recalculating his columns, 'the miracle of calculation still exists like a sure rock in an incalculable world' (ibid). Moreover, the world of accounting appeals to the book-keeper because it has a meaning – all entries and calculations work together to the final result, the balance at the end of term: 'this intricate maze of established connections between account and account […] in which not a single knot is missing, is symbolized at last in a single figure' (III 368). The ordered world of book-keeping thus culminates in the unity of the final result that comprises all other figures and expresses the whole in a single number.

[11] Research in Victorian studies has addressed interrelations of literature and book-keeping and examined similarities between literary fiction and the 'paper fictions' of banknotes. See for example Tamara S. Wagner, *Financial Speculation in Victorian Fiction*, and the collections of essays *Victorian Literature and Finance*, edited by Francis O'Gorman.

The general type of the wartime accountant is presented as preferring the ordered and meaningful unity of book-keeping to the disconcerting wartime reality in which millions of people die for an incomprehensible cause. Even more, he considers the domain of accounting to be more 'real': 'a man who lives within a world of precisely adjusted relations will refuse to allow that there can be another world whose relations are incomprehensible and inscrutable to him' (III 369). The book-keeper therefore takes the world of accounting as a model according to which to disentangle the confused threads of the wartime world and order them rationally. The attempt to make reality comply to the domain of book keeping – the 'charg[ing] again and again for the honour of the accurate book-keeping that ought to be able to account for everything on earth' (III 370) – has no moral objective in the real world but only concerns the system of accounting itself: 'For ever the book-keeper will do battle for the right, since if a penny is out he will go over every item again should the integrity of his books require it, and without being actually a good man himself, he will rise as the advocate of oppressed justice as soon as he has recognized and registered the existence of injustice and wrong' (ibid). In 'a galling combat with a world of reality which to him is unreal' (III 369), the book-keeper thus tries to replace the chaotic wartime with the perfect world of accounting. In contrast to the notion of book-keeping in *Esch* where the books are expected and fail to mirror reality, the relation is reversed in *Huguenau* when the accountant aims at adjusting reality to the order of the books.

In the second novel, Esch feels the need to introduce a 'wonderful new entry' in order to make the books balance, and when in the third part Pasenow, who embodies traditional views (see 3.1a), advocates following the religious commandments and 'the categorical imperative of duty' (III 582), he echoes Esch's conviction that self-sacrifice is necessary to put the accounts in order. In this last part of the trilogy, Esch adopts Pasenow's traditional worldview, even converting to his Protestant faith, and assuming the posture of Christ at the cross, Esch 'felt strong, firm and robust, and as if it were an entry settling the world's account he repeated: "A man who sacrifices himself must be a decent chap"' (III 598). As in the second novel, accepting the necessity of self-sacrifice brings Esch some certainty: 'The world was divided into good and evil, debit and credit, black and white, and even if a book-keeping error should happen to creep in, then it must be expunged, and it would be expunged. Esch had grown calmer.' (III 430) The fact that Esch's belief in sacrifice complies with Pasenow's views indicates a turning back to a more traditional position, but nevertheless, since the books of accounting constitute a domain of their own, the understanding of book-keeping in *Huguenau* is fundamentally changed from its presentation in *Esch*.

2.3 'Disintegration of Values': The Foundational Crisis and Modern Mathematics

'Disintegration of Values' is an essay in ten parts that constitutes one of the multiple storylines of *Huguenau*. As one of the two strands whose episodes are held together with a title and that do not merge with other storylines, it occupies a prominent position in the novel, and the formal, rational diction and subject matter of the essay set it further apart from the clearly fictional chapters. However, the theoretical thoughts presented in the essay and topics developed in the remaining storylines and the previous parts of the trilogy are interrelated, and when the essay explicitly applies some of its ideas to the main plotline of *Huguenau*, it establishes itself as delivering the theoretical basis of the trilogy. Examining the topics introduced in 'Disintegration of Values' can therefore provide a key to understanding major concerns of *The Sleepwalkers*; most importantly for this project, the essay's theoretical discussion of developments in mathematics illuminates the presentation of book-keeping and mathematics on the level of plot.

The essay establishes a connection between accounting and mathematics when it refers to the '[t]he two great rational vehicles of understanding in the modern world, the language of science in mathematics and the language of money in book-keeping' (III 484). While the plot is focused on book-keeping, 'Disintegration of Values' concentrates on the development of mathematics in order to explore the changing 'logical structure of thought' (III 481), introducing it as the best example to trace the general structure of the time's 'complete revolution in thinking' (ibid). According to the essay, the style of thinking does not change due to the suddenly realised discrepancy between thought and reality, but reality adjusts to any view imposed by the style of thinking: 'reality submits to the erection of the most impossible theoretic structures, – and so long as the theory does not itself declare its bankruptcy it will be supported with confidence, and reality will take a subordinate role[12]' (III 482-83). If the style of thinking follows its own logic independent of outside reality, change solely occurs 'in thought's own province of logic' (III 482) and only subsequently entails a different view of reality. A revolutionary change in the structure of thinking takes place when the logic encounters inherent contradictions and has to dismiss itself: applying its logic to itself, a style of thinking founders on 'its own absolutism, its own antinomies of infinity, – its logic [… is] abrogated' (ibid); and 'no longer able to resolve the antinomies of infinity by the old methods, [… it] is compelled to revise its own basic principles' (III 481). The process of revolutionary changes in the style of thinking highlights the suitability of mathematics as a prime example of the development: when in the nineteenth century

[12] 'die Wirklichkeit ordnet sich ihr unter' (536).

mathematicians tried to mathematically prove the foundations of their field – to make its logic absolute, so to speak – the endeavour led to the foundational crisis and 'achieved a revolution of mathematical method' (III 481). Quite literally 'thought has reached its provisional limit of infinity' in nineteenth-century mathematics, given that, as put forward in 'Disintegration of Values', 'the research into first principles of modern mathematics […] start[ed] from the antinomies of infinity' (ibid). Infinity was traditionally treated as potential infinity, an entity that can potentially but not actually be determined; for example, when counting whole numbers there always is a number that can be added after the 'last' one – this constitutes a potential infinity since an end or actual state can never be reached. However, Georg Cantor argued for the existence of actual infinity, a counter-intuitive concept based on the idea that infinite entities could form a completed totality or, as Cantor called it, a 'set'. The status of infinity was thus in confusion, as pointed out in 'Disintegration of Values': 'questions about actual and potential infinity […] puzzle modern mathematics and provide its antinomies' (III 481). Cantor's set theory, working with the questionable concept of actual infinity, was thought to allow constructing a firm basis of mathematics, but when antinomies were discovered, the hope of finding a certain footing in set theory collapsed and mathematics entered its foundational crisis: 'no longer able to resolve the antinomies of infinity by the old methods, [… it] is compelled to revise its own basic principles' (III 481). Thus, in the terms of 'Disintegration of Values', mathematics constitutes a very good example of the revolution in the style of thinking when its foundational crisis is initiated by 'its own antinomies of infinity' (III 481).

When 'Disintegration of Values' describes the foundational crisis as 'a revolution of mathematical method whose extent cannot yet be estimated' (III 481), important features such as the self-referential turn have already been addressed using the example of book-keeping, so that the theoretical presentation of the foundational crisis of mathematics is more readily understandable. The essay introduces the modern notion of mathematics, which emerges in the foundational crisis, when it defines mathematics as a language independent of reality: mathematics 'arise[s] from that single and exclusive concentration on its own value-system, from that esotericism of expression'[13] (III 484). Mathematics thus is 'not a means to an end' (ibid), not a tool to describe reality, but it 'is' its own language: originating 'from the unambiguousness[14] of action, of that "action" which was thenceforth accounted the sole unambiguous language and the sole determining force' (III 484-85), mathematics constitutes a world which gains its truth and meaning from reference to itself and is independent of

[13] 'auf das eigene Wertgebiet und aus einer Esoterik des Ausdrucks' (538).
[14] 'Eindeutigkeit' (538).

application. Modern mathematics, exemplifying the 'severity and singleness of the language of things' (III 484), thus does not allow for communication about the world, but only referring to itself, it is a 'dumb language' (ibid). The description of the development of mathematics in 'Disintegration of Values' accords with the characteristics of self-containment and self-referentiality introduced in relation to the changing notion of book-keeping, and it also agrees with the accounts of the foundational crisis given by historians of mathematics (see introductory chapter).

2.4 'Disintegration of Values': Counter-Modern Mathematics

The essay employs religion as an example of developments towards absolutism and disintegration that then induce a counter-movement which regains some characteristics of the traditional belief: Protestantism caused a split of religion, and the resulting uncertainty of the time 'made possible the Counter-reformation [… which] took upon itself the gigantic task […] of attempting a new synthesis of the world and all its values' (III 486). When the schism is taken to stand at the 'mere beginnings of a movement that needed five hundred years for its full development' (ibid), the turn to the twentieth century emerges as the endpoint of disintegration, and mathematics and book-keeping transpire to be among the last areas to lose their unity. Analogously to the shift in Christianity, the confusion of disintegration in these rational domains is followed by a counter-movement working towards 'a new synthesis' (ibid), namely, Esch overcomes his doubts concerning accounting when developing a new concept in which the book-keeper guarantees the system's order and meaning in reality. The person of the book-keeper is essential to connect the otherwise independent worlds as only he can validate the books: 'when he has achieved his task, and ruled the last line beneath the account, he seals his labours with his signature' (III 368). With his personal investment the accountant makes book-keeping part of the world again, thus countering the self-containment of the books. Similarly to book-keeping which transforms into a system without direct relation to reality and is then reconnected to the world in a counter-movement, 'Disintegration of Values' argues that the questions raised by modern mathematics initiate a move into the opposite direction: 'research into mathematical first principles, pursuing the questions "what is number?" and "what is unity?" has reached a point at which it has found itself compelled to accept intuition as the only way out of its difficulties' (III 563-64). After the 'reformation' of the foundations of mathematics, the intuitionist counter-movement attempts a new synthesis of the mathematical world and its values by introducing human intuition as the origin of mathematics that relates it to the world via man. The historian of mathematics Herbert Mehrtens employs a term

corresponding to the religious example of *The Sleepwalkers* when he characterises the intuitionist reaction to modern mathematics' loss of truth and meaning as 'counter-modernism'[15] (also see introductory chapter).

Tracing the existence of mathematics back to intuition constitutes an extreme case of a general cognitive condition that 'Disintegration of Values' further elaborates on: 'the principle of "product of a product" provides intuition with its logical legitimation' (III 564). The 'product of a product' is an epistemological concept reminiscent of Friedrich Nietzsche's perspectivism, that is, the view that the world has no intrinsic meaning but takes on different meanings depending on the perspective from which it is observed. The essay in *The Sleepwalkers* explains that man cannot conceive the world directly but that it is multiply mediated: 'it is "a product of products," "a product of products of products," and so on in infinite iteration' (III 563). Actual reality thus is always several steps removed and all that can be grasped is the product produced by an individual: 'Every conceptually comprehensible unity in the world is "product of a product," every concept, every thing; and this methodological function of knowledge […] probably extends right into mathematics' (ibid). As a product of the perceiving Self, mathematics can be traced back to intuition: 'the infiltration of the Self into a hypostatized value-positing subject can be justifiably termed the methodological structure of the act of intuition' (III 564). If intuition is the origin of the 'product of products', a principle that also applies to mathematics, then all questions regarding mathematical existence, truth, and meaning can ultimately be answered in reference to intuition, and the introduction of intuition as 'the only way out' (III 563-64) of the foundational crisis is justified. Being 'compelled to accept intuition' (III 563) in order to hold on to the traditional notions of mathematical truth and meaning, mathematics as depicted in 'Disintegration of Values' mirrors the turn towards a unifying counter-movement in the religious domain.

Supporting the modern or the counter-modern notion of mathematics entails a decision as to the inclusion of a non-rational, intuitive element and the place of man in the system of mathematics, as well as regarding the value and meaning of mathematics in the world. The trilogy's presentation of the contrasted possibilities in mathematics is therefore significant for the appreciation of wider concerns in the novels and for the interpretation of *The Sleepwalkers* as a whole. Conversely, analysing the central topics of reality, value, and meaning in the trilogy will illuminate the stakes of deciding for either mathematical view and help evaluate the trilogy's ending which contrasts a time based on characteristics of modern mathematics with a vision of a counter-modern future.

[15] 'Gegenmoderne' ('counter-modernism') cf. 'Gegenreformation' ('counter-reformation').

3. Mathematics and Reality

3.1 Analogous Developments

As demonstrated above, *The Sleepwalkers*, using the case of book-keeping and mathematics, traces a development from stable traditional beliefs to their failing and to the subsequent formulations of a modern notion which assumes no truth, meaning, or existence outside itself and, on the other hand, a counter-modern view that puts man and intuition as the origin guaranteeing a relation to and value in the world. Having examined mathematics as 'the clearest example'[16] (III 481) of these changes in the style of thinking, the following will trace analogous developments in notions of reality and value. In *The Sleepwalkers*, the categories of reality and value are closely related. Since, as explained in 'Disintegration of Values', reality only exists as a 'product of products', it is always set by a 'value-positing subject' (III 561) and tied to either an individual or to 'fictive centres of value' (ibid) that act as points of reference. Without such a reference centre that creates a comprehensive worldview by undertaking 'reality-formations' (ibid), reality cannot be perceived: 'An event without a value-positing centre dissolves into nebulosity' (ibid). In other words, only value renders reality graspable and 'real': 'life can be comprehended only in the category of value' (ibid). Changes in the notion of reality and the proposed analogy to the transformations in mathematics therefore have to be examined in relation to the development of value-systems. Moreover, since the view of reality being based on a value-positing subject is already related to counter-modern mathematics guaranteed by intuition and man but is opposed to the modern idea which allows for no value outside mathematics itself, the analysis of the development of value-systems and the realities they engender will clarify the wider implications of supporting the one or the other mathematical orientation in the foundational crisis. Not least, another level of the antagonism will be revealed when analysing the narrative technique in the trilogy, since the principles of reality and reality-formation also concern the 'reality' of *The Sleepwalkers* itself.

a) *Pasenow*: Romanticism, Traditional Value-Systems, and Ordered Reality

The seventy year-old father of the main protagonist Pasenow is the first character introduced in *Pasenow or the Romantic – 1888*, so that the trilogy spans exactly a hundred years from his birth in 1818 to the final book of the trilogy set in 1918. Herr von Pasenow does indeed seem to be part of a different century as he is still deeply ingrained in the traditional value-systems. The security of his worldview is expressed in his focused walk and

[16] 'am deutlichsten' (533).

determined use of the walking-stick; yet, the meaning of his determination has already become questionable in 1888: 'it was horrible, too, to realize that the three-legged purposiveness of the man's walk must be as deceptive as its undeviating rapidity: that it was directed towards nothing at all!' (I 10) His son, the eponymous Joachim von Pasenow, is indeed afraid that the traditional values of religious and military duty lose their meaning and do not lead to any final aim or purpose. He thus questions the meaning of life and reality as hitherto understood.

Pasenow tries to reestablish the original meaning of the now empty traditional values in order to then base his life on the regained value-system and infuse it with order, reality, and purpose. Saying the Lord's Prayer he is 'careful not to utter a single word emptily, but to grasp the meaning of each' (I 46) and is promptly rewarded with the meaningful reality this creates: 'the words "uplifted and strengthened" came into his mind, and they did not seem empty to him, but full of new and encouraging meaning' (ibid). Moreover, the rediscovered Christian values propose a direction and purpose in his life: he knows that to find salvation, he has to follow 'the straight path of duty, although he might be consumed in following it' (I 141). Acting according to conventional values, Pasenow 'dutifully' abandons his unconventional love Ruzena, a Catholic Bohemian prostitute, and marries a virtuous neighbour of the same class and Protestant faith. The marriage to Elisabeth firmly settles him in the certain reality of traditional values: '"with her by my side I hope to find a way into the open"', he explains, while otherwise '"I should feel that I was irretrievably floundering again in all the awful complications of the past months"' (I 133-34). Having decided to comply with the traditional value-system, it completely determines Pasenow's further private life which thus unfolds in an orderly fashion along conventional lines and is so predictable that the novel can end: 'How this came about need not be told here.[17] Besides, after the material for character construction already provided, the reader can imagine it for himself.' (I 158) In parallel to Broch's statement about the foreseeable development of a minor character, it could be said that Pasenow's 'fate is […] calculated with almost mathematical exactitude'[18] (*Briefe* 89), and the conventional literary form of this first part of the trilogy is so reliable that the expected ending does not even need to be developed.

The value-system of the military which defines Pasenow's behaviour in the public domain most clearly demonstrates how conventions influence the perception of reality and provide a feeling of order and certainty: it is 'the uniform's true function to manifest and ordain order in the world, to arrest the confusion and flux' (I 21). Thus, Pasenow can shake

[17] 'muß nicht mehr erzählt werden' (149).
[18] 'das Schicksal […] ist ja schon […] mit ziemlicher mathematischer Exaktheit errechnet'.

off doubts by ascertaining the values his uniform represents: 'he thrust them aside and with a jerk resumed his stiff, official bearing' (I 23). Moreover, events difficult to grasp in their reality become understandable according to military values, for example when Pasenow visits the coffin of his brother who has died in a duel of honour, and the touch of the Iron Cross hanging on the wall dispels his feelings of unreality and disintegration:

> this refound fragment of actuality transformed death in a novel and almost exciting way into a matter of drapery, accommodating almost cheerfully the fact that Helmuth in his coffin, decked with all his flowers, had been introduced into this room like a new piece of furniture, thus once more reducing the incomprehensible so radically to the comprehensible, the certain and assured, that the experience […] passed over into a soothing feeling of quiet confidence (I 42).

The framework of the military value-system thus organises a world of inexplicable events into a comprehensive and certain reality, man finds 'a better organization of life' (I 21) in the uniform, and Pasenow experiences 'security and peace' (I 24) when 'the uncertainty of life, yes, life itself, recedes to a distance' (I 21). From the stable and removed view-point granted by the uniform, man is able to evaluate reality from the outside: 'he is no longer tied to things, and as they scarcely concern him any longer he is able to divide them into the good and the bad' (ibid). The uniform thus arrests the chaos of reality and constitutes a point of reference that allows assessing the world from a secure, 'objective' stand. As the uniform determines Pasenow's view of reality and grants a sense of community with his '"Comrades in the King's uniform"' (I 23), it becomes indistinguishable from his person: 'no one, and least of all Joachim von Pasenow, will be able to specify then where the frontier between his self and his uniform lies' (I 24). Taken up in the worldview that the military values dictate, Pasenow is thus 'cut off from the world' (ibid) and completely dependent on the reality that his uniform provides: 'he could no longer live without it' (ibid).

In this first part of the trilogy, Pasenow demonstrates that although the validity of traditional values is in decline, general value-systems can still be appropriated on an individual basis. The values of religion and the uniform orient and indeed merge with Pasenow's life, determine his reality and enable a sense of community with members of the same value-system. Yet, they can only hide but not dispel the underlying uncertainty; a fact Pasenow notices when contemplating that underclothes are not part of the uniform: 'it was uncanny to think that every soldier carried about with him under his tunic the anarchical passions common to all men. Perhaps the world would have gone off the rails altogether had not someone at the last moment invented stiff shirt-fronts for the civilians, thus transforming the shirt into a white board and making it quite unrecognizable as underclothing.' (I 23) A mere change of style can thus reveal the chaos of the world, and with fashion having altered fifteen years later the 'anarchical passions' indeed come to the fore in *Esch or The Anarchist*.

b) *Esch*: Anarchy and the Disintegration of Values and Reality

In *Esch*, the value-systems of religion and the military have lost their validity: Esch is not concerned with notions of duty or honour and 'didn't give a damn for the parsons and morality'[19] (II 171). He therefore lacks a stable point of reference from which to evaluate good and bad, but a focus on reason replaces the traditional value-systems. However, as developed above, in the course of the novel Esch 'recognized that it was mere chance if the addition of the columns balanced' (II 339) as the rational system of book-keeping no longer fits the anarchical world, and calculation fails to provide life with a final aim or meaning: he even muses that 'where the kingdom of salvation was concerned everything was uncertain, every hour uncertain, every number and every addition'[20] (II 320).

Mother Hentjen, Esch's future wife, similarly experiences the impossibility of understanding the world in an anarchical time when even the most objective value-systems fail: 'The world was so unfamiliar that it was impossible to grasp it, and nothing now connected her with it' (II 250). But when 'Esch set the accounts against each other, made his calculations, and the sum gave the clear answer: he must induce Mother Hentjen to yoke herself like him to the task' (II 331), at least a limited sense of community and shared reality can develop. Mother Hentjen ends her independent life as a widow and Esch accepts that 'whoever sacrificed himself must give up his liberty first of all' (II 332) and that therefore 'it was all up with America. […] He was imprisoned. The torch of liberty was quenched.' (II 331-32) The orphan Esch and Mother Hentjen, who cannot bear children, thus draw closer to each other, complement their respective lonelinesses in marriage, and 'went hand in hand, although each walked a different and endless road' (II 340). Sacrificing his freedom, Esch is furthermore rewarded by feeling 'more at home in the earthly world than formerly' (II 340), while at the same time he can 'contemplate the earthly as from a higher coign of vantage, as from an airy castle rising from the plain, shut off from the world and yet open like a mirror to it' (II 339). A more removed viewpoint and experiencing reality as certain thus condition each other, but while Pasenow's retreat into a world determined by Christian and military values assures a reality shared with many others, Esch can only regain it on an individual level. The changed situation at the beginning of the twentieth century thus emphasises the irresolvable failing of more general ordering systems, above all of the rational domains of book-keeping and mathematics which now have to be validated by the non-rational element of individual sacrifice.

[19] 'die Pfaffen und die Moral' (193).
[20] 'jede Zahl und Addition' (539).

c) *Huguenau*: Modern Practicality and Absence of Values

The disintegration of a universal value-system and shared reality is far advanced at the end of the First World War, and the absence of a unified world is mirrored by the disintegration of the novel *Huguenau* into several storylines that are only partly linked and stylistically diverse. The main storyline continues the free indirect discourse used in the previous novels and predominantly employs Pasenow, Esch, and Huguenau as internal focalizers. The episodes around the war hospital consist mainly of direct speech and thus convey an exterior view, while the chapters attributed to Hanna Wendling are almost entirely taken up by the omniscient narrator's presentation of Hanna's inner life. The 'Story of the Salvation Army Girl in Berlin' is the only first-person narration and the most lyrical strand; it is thus contrasted to the rational diction of the essay 'Disintegration of Values'. The stylistic variety is further enhanced by poems, a dramatic interlude, a fragmented newspaper article, and a business contract; the diverse styles thus act as an immediate indication of the disintegrated reality – the endpoint of the development depicted in *Pasenow* and *Esch*.

Huguenau personifies the general attitude of his time when he leaves any value-system and community behind and works towards his own advantage in a practical, matter-of-fact manner. With his desertion from the front, he breaks with all governing values right at the opening of the novel: 'he crawled out of the trench and shook himself free of human obligations' (III 350), thus marking the beginning of an existence 'liberated from values' (III 629). Although his life is not ruled by values, Huguenau is not completely separated from value-systems but uses the reality created by them to further his plans: 'he was faced with the task of setting up his own little world of reality on the outposts of that greater order and of adapting the one to the other' (III 418). Thus, Huguenau occasionally finds it of avail to adopt a value-system, for example complying with the rules of commerce to settle transactions or converting to the Protestant faith in order to marry into a wealthy family. Huguenau's essential independence from any value-system becomes evident however when in the chaos of the German revolution he can kill Esch without fearing disadvantages: 'His murder of Esch, moreover, while it hardly came within the province of his duty as a business man, was not an infringement of the business code.' (III 629) As it complies with his egoistical philosophy, Huguenau does not consider the murder a wrong or problematic deed: 'he had no need to reflect upon it, nor did he do so. Had he done so, however, he might simply have said that his procedure had been quite reasonable' (III 625). Huguenau's practical, matter-of-fact attitude is thus solely focused on himself and his own advantage and not consistently tied to any value-system.

When it is profitable for Huguenau to revert back to the commercial system after the war, the murder of Esch which does not fit the logic of commerce becomes unreal: the war events 'faded into a mere silhouette, into the delicate half-tones of the French banknotes that Huguenau the business man had been handling ever since' (III 632-33). In the end, only 'a single entry of 8000 francs' (ibid) remains as the 'final balance' of the wartime. Yet, if 'none of our actions remains alive except those that consort with our reigning system of values' (III 637) and Huguenau's egoistical perspective remains stable, then there still is 'a firm line of demarcation between what was reasonable and what was unreasonable, between reality and unreality' (III 625) for Huguenau: focused on himself, Huguenau constitutes his own point of reference and from it creates his own reality. In a society of Huguenaus then, reality is split into a multitude of personal realities that temporarily adapt to and adopt any partial order advantageous to the individual but in their egoistical focus do not lend themselves to create a common value-system. The essay 'Disintegration of Values' provides the theoretical explanation of the dissociation of worldviews when it defines the world as a 'product of the intelligible Self' (III 563) and as based on intuition: if reality is ultimately located in the individual and overarching value-systems disintegrate, it disperses into a multitude of disconnected individual worldviews. When the unity and certainty of a former common reality, be it based on traditional values or rational book-keeping, is lost completely in the disintegration of wartime, the last part of *The Sleepwalkers* illustrates the situation described by Nietzsche: 'Disintegration characterizes this time, and thus uncertainty: nothing stands firmly on its feet or on a hard faith in itself' (*Will to Power* 40).

Several other storylines in *Huguenau* draw out the implications of the disintegration of value-systems and reality. Hanna Wendling experiences the loss of a common reality and withdraws into her own world which is not only distanced from that of others but similarly recedes from the objective, 'real' reality that is no longer accessible by a common worldview. When Hanna Wendling's situation is described, it is stated more generally that 'the more lonely he [man] becomes, the more disintegrated and isolated will things seem to him' (III 400). And with order, the world loses meaning, so Hanna experiences: 'the curse of the fortuitous and the accidental had spread itself over things and the relations between things' (III 399). Hanna understands that the war, too, is a 'disintegration of the world' (III 539) and a result of isolation which affects the connection to reality: 'loneliness was the root of the disease!' (III 538) The First World War is thus presented as a conflict between the incompatible realities of isolated people; a diagnosis echoing notions of a '"Euro-Nietzschean (or Anglo-Nietzschean) War"' (Salter 357) (see introductory chapter).

In one of the episodes set around the war hospital, the soldier Jaretzki shares Hanna's view of loneliness as a fundamental reason of the First World War: '"the war can't stop because every man out there has found himself alone […] and every man who is all alone must kill some other man"' (III 508). As the enthusiasm in war that temporarily provided '"a real sense of fellowship"' (III 566) fades, Jaretzki substitutes the drunkenness from patriotism with the effects of alcohol in order to fight the chaos of the world and his loneliness. His doctor proposes the alternative relief that helped Esch in 1903: '"if you must have intoxication and fellowship, there's a simple enough remedy: fall in love"' (ibid). But Jaretzki reveals the inapplicability of this cure: not only can love not be prescribed, but also man is profoundly altered by the experience of war and now incapable of love. Jaretzki himself literally disintegrates when his arm has to be amputated: '"there's a good bit of me missing"' (III 388), he answers when asked if he is recovering. The artificial arm designed to make him whole again only turns him into '"a newly-born machine"' (III 565) that is unable to love and find fellowship: the prosthesis lacks '"a special joint for cuddling"' (III 566). The disintegration of man thus renders community impossible, and the recourse to the certain reality of love is no longer feasible in a world fallen to pieces.

Doctor Flurschütz diagnoses the underlying emotional and mental problems of the time when he sends Jaretzki to an institution for nervous cases and explains: '"Jaretzki is a dead soul, […] that's what they all are"' (III 586). He proposes the same cure for Jaretzki's dead soul as for his lifeless arm: '"if our souls are dead there's nothing for it but the surgical knife"' (ibid). He further predicts that the future will remove the soul by forgetting: '"people will do nothing but try to forget, only to forget"' (ibid). And indeed, Huguenau fulfils the prognosis when he forgets almost all the wartime events, and lacking any values he also proves correct Sister Mathilde's response to Flurschütz's prediction: "But that would be dreadful, to live without ideals!" (ibid) Huguenau's leaving behind the past and any ideals is a precondition of survival, as otherwise '"one should by rights be going off one's head"' (III 395) by the incomprehensibility of war, and, like Jaretzki who is sent to an institution, be forced to have reality shut out in another way. The changed wartime world thus makes life according to tradition impossible, but people have to embrace the absence of values and a common reality like Huguenau, perish from loneliness like Hanna, or go off their head like Jaretzki.

The fact that the pre-war reality and value-systems cannot survive is best illustrated in relation to the fate of Pasenow and Esch, the representatives of past worldviews. In the last part of the trilogy, Pasenow is completely defined by the traditional values he has chosen: he is no longer referred to by his first name as in *Pasenow* but always by his military

rank and last name or simply named 'the Major', thus perfecting the conflation of uniform and personality. However, the war erodes the military value-system to which he has submitted when instead of being the 'crown […or] the fulfilment of a life in uniform' (III 422), the First World War is responsible for the 'unchivalrous' gas weapon, contradictory orders, and 'the growing and general disorder' (III 573) that the uniform is meant to quench. Negating the values which determine Pasenow's acts, the war means the end of his life: the 'war had […] invisibly and yet more palpably shaken the foundations of that life, had worn threadbare the ties of morality holding it together' (III 422). Without the guidance of values, Pasenow is incapable of action; he is unable to arrest the deserter Huguenau but equally cannot take the consequences of failing to perform his duty: since he insists on handing his post over 'in a regular manner' (III 585) but 'chaos was spreading over his thoughts and over the world' (III 582) and makes ordering his affairs impossible, Pasenow simply stays in office. When the revolution overthrows the military order completely, Pasenow is unable to care for himself in a world that his traditional worldview can no longer make sense of, and he consequently loses his wits in an accident and becomes a 'living and motionless puppet' (III 618). Huguenau then takes advantage of his helpless state to secure his own escape, so Pasenow, together with his traditional value-systems and reality, is overcome by the First World War, appropriated by the new powers, and finally only serves to advance the survivors to their egoistical ends.

Similarly to the failing of Pasenow's traditional value-systems, Esch's belief in self-sacrifice is proved wrong by the reality of Huguenau's generation. When during the revolution the inmates of the local prison break free, they do not follow Esch's belief that '"of our own free will we must accept our imprisonment"' (III 530) and that, as Esch has come to accept in the second part of the trilogy, 'whoever sacrificed himself must give up his liberty first of all' (II 332). Nor does the prisoners' behaviour comply with the story that Esch reads from the Bible and advocates as model behaviour, but instead of following Apostle Paul's example of staying in prison and pacifying the distressed guard with the words '"Do thyself no harm: for we are all here."' (III 530), the fugitives aim to kill Pasenow whom they hold responsible for their imprisonment. Esch saves the injured Major from the mob, but he fails nevertheless, as Pasenow, having lost his value-system, reality, and wits, is unable to live independently and falls into the hands of Huguenau. Esch's world of perfect order and balanced accounts guaranteed by sacrifice thus loses the struggle against the actual world, and he is consequently killed by Huguenau, the personified embracing of disintegrated reality. With Pasenow and Esch as the remainders of old reality overcome, the

traditional way of ascertaining reality through value-systems or rational book-keeping is replaced by Huguenau's turn towards completely egoistical interests.

Huguenau's focus on himself and his own interests can be described as constituting a separate, self-referential reality and thus bears traits of the development of modern mathematics towards an independent world of its own. And similarly to the questions as to mathematical reality and meaning that were asked in the foundational crisis but remained unanswered by the modern notion of mathematics, the meaning of reality and reality itself become doubtful in disintegrated wartime: 'Can this age be said still to have reality? Does it possess any real value in which the meaning of its existence is preserved?' (III 559) As will be expanded in the following, 'Disintegration of Values' and 'Story of the Salvation Army Girl' examine this question of the reality of reality and, comparable to the counter-modern move in mathematics, introduce the concept of intuition in order to counter the absence of meaning and value.

d) *Huguenau*: Counter-Movement and Intuition

'Story of the Salvation Army Girl', told from the perspective of Dr. Bertrand Müller, and the theoretical essay 'Disintegration of Values' are linked when Müller is suggested to be the author of the essay. He states to be working on 'my thesis on the disintegration of values' (III 439), and later two consecutive chapters begin almost identically: the beginning of chapter thirteen of 'Story of the Salvation Army Girl' – 'Can this age, this disintegrating life, be said still to have reality?' (III 557) – is echoed by the next chapter, which is a part of 'Disintegration of Values': 'Can this age be said still to have reality?' (III 559) While identical phrases appear in almost all of the storylines and across the novels, the close proximity and prominent place of the repetition strengthens the suggestion that Müller composes the essay.

In 'Story of the Salvation Army Girl', Müller doubts the reality of a world falling apart in wartime: 'on all sides I encounter unreality' (III 557). He comes to renounce all rational examination of the world, and having stopped thinking, his questioning reality is finally answered by a 'physical feeling' (III 575) which gives him 'the certitude of living in a sort of second-grade reality, giving rise to a kind of unreal reality, of real unreality' (ibid). The physical feeling, a phenomenon closer to intuition than to reason, thus allows Müller to perceive the inevitable mediation of reality, that is, the second-grade reality of a 'product of products'. The essay then further develops the hope that springs from connecting to reality through a physical feeling: if all perception of reality goes back to intuition, this constitutes a

common base and reference point of worldviews and ensures their translatability and ultimate unity. In the words of the novel, intuition 'provides in the unity of thought a common denominator for all human speech, a warrant for the unity of mankind and of […] humanity' (III 564). By placing intuition at the origin of the questioned reality, 'Story of the Salvation Army Girl' and the essay 'Disintegration of Values' mirror the counter-modern solution to the foundational crisis of mathematics.

Similarly to the situation of mathematics whose relation to reality before the crisis cannot be reestablished, Müller, despite his physical feeling and the theory of unifying intuition, does not reconnect with the world but withdraws into his own reality. Himself suffering from poor health, he claims in his essay: 'Who can be more light-hearted than an invalid? […] he can remain wrapped in the cocoon of his own thoughts, – wrapped in the autonomy of his own knowledge he is free to think deductively, to think theologically. Who can be happier than the man who is at freedom to think out his religion!' (III 623) Mirroring his image of the withdrawn invalid, Müller no longer tries to understand the world but ends 'Story of the Salvation Army Girl' in the muteness that characterises the time of failed community and communication: 'I had talked too much in any case and let the matter drop there.' (III 624) Müller's decision to fall silent is only followed by two more chapters in the trilogy: a poem and the epilogue as the last part of 'Disintegration of Values'. Since the essay develops Müller's worldview and 'private theology' (III 631), he does indeed 'think out his religion' (III 623) and withdraw into his own autonomous thinking and reality. He thus fails to take the path out of disintegration that he both physically feels and devises in the essay, and the notion of all-pervading intuition that connects the world and counters disintegration remains an abstract model. The fact that theoretically derived solutions are not necessarily applicable to the world is also suggested earlier in the novel when the ninth part of the theoretical essay concludes with the hopeful picture of the 'continuing unity of the world, a unity of man[21], illuminating all things, still surviving and imperishable through all eternities of space and time' (III 565), but the next chapter at least questions the unity of man when it begins: 'Dr Flurschütz was helping Jaretzki to fit on his artificial arm.' (III 565) Thus, similarly to the two mathematical notions emerging from the foundational crisis, the notion of reality in *Huguenau* is divided into a modern praxis of dealing with disintegration and self-containment and a competing counter-modern but solely theoretical solution based on intuition.

[21] 'Einheit des Menschen' (624).

3.2 Interrelations: Modern Unreality versus Counter-Modern Hope

The Sleepwalkers establishes developments in the domains of mathematics and reality as analogous: not only does the essay introduce the idea theoretically, but on the level of plot characters' attitudes towards realities determined by value correspond to diverse views of mathematical existence, truth, and meaning. Roughly speaking, Pasenow's belief in value-systems that order and make sense of the world is related to the view that the universe can be understood through mathematics as the language of the book of nature; Esch's conviction that man and the non-rational element of sacrifice can mediate between reality and the disconnected world of book-keeping complies with the counter-modern introduction of intuition as the link between mathematics and the world; and Huguenau's concentration on himself as his own 'value-system' corresponds to the self-containment and self-referentiality of modern mathematics that does not lend itself to create outside value. The epilogue as the last part of the essay pursues the development of the world after the complete annihilation of the old order in the German revolution and presents two scenarios: a world stagnated in the unreality of countless egoistical realities, and a hopeful vision based on the theory of underlying and unifying intuition. In the two possible futures of reality, value, and community, the interrelation and mutual influence of notions of mathematics and reality show most clearly: the more persuasive mathematical orientation strengthens the corresponding view of reality, while reciprocally, the more convincing vision of the future development of the world has implications as to which mathematical view is considered correct.

As the last part of 'Disintegration of Values', the epilogue follows the fate of Huguenau after the German revolution and to at least 1926, while also pursuing its theoretical contemplations. After the war, Huguenau stands in the unreality between 'what has been and what is not yet' (III 640), and rational ways to understand the world fail due to the all-pervading irrational chaos: 'no vision of the world can any longer be reduced to a sum in rational addition' (III 641). Yet, while Huguenau senses the irrational, 'he could not account for [it] at all' (ibid) and is thus unable to grasp the world. He only finds happily 'back to sober reality' (III 643) when his uneasiness 'discharge[s] itself in boxing his child on the ear for no reason at all' (ibid), meaning that the lacking relation to the world still expresses itself in violence. The related 'almost insane indifference to the suffering of others' (III 645) during wartime marks the absolute absence of values and of the reality they engender: 'the Philistinism of a value-system whose field is restricted to the individual and his irrational impulses, that last product of every disintegration of values, remains the point

of absolute degeneracy; the point, so to speak, of an invariant absolute zero' (ibid). Huguenau's time is thus unrelated to any notion of value and therefore completely 'unreal'.

Comparably to the development of mathematics and book-keeping where the counter-modern view emerges from the dissatisfying absence of a modern answer to the question 'Where is the reference of mathematics to stable reality endowing it with value and meaning?'[22] (Mehrtens 436), the complete disintegration of Huguenau's time is taken to constitute a necessary state before renewal: 'the transition from any value-system to a new one must pass through that zero-point of atomic dissolution' (III 645). The zero-point is a mathematical image and is defined as the origin of a coordinate system, that is, the zero-point is the intersection of the axes that bear the 'scales of value' (ibid). As such, it is the point to which all values in a coordinate system refer, and hence, the 'invariant absolute zero […] is common to all scales of value and all value-systems' (ibid). Every value-system includes the point of the complete absence of values, and a disintegrating system has to go back to this common zero-point before a new order can be established. Since the 'value-system whose field is restricted to the individual and his irrational impulses […] remains the point of absolute degeneracy' (ibid), the common zero-point and origin of all value-systems is precisely the individual and irrational: 'Every system of values springs from irrational impulses' (III 626). The central irrational component also prevents logic from turning towards itself: if there always is an 'irreducible residue of the irrational' (ibid) the rational system can never completely encompass itself, and in this way, the irrational origin 'preserves the rational itself from a literally suicidal autonomy' (ibid). For instance, the turn towards irrational intuition keeps rational mathematics from falling prey to the problems of self-referentiality when, finding an origin and guarantor in intuition, mathematics does not need to prove itself mathematically and thus evades its antinomies and becoming 'autonomous [… and] thus radically evil' (III 627). In other words, intuition as a non-rational component is always outside rational orders such as mathematics or value-systems and can act as an origin that prevents the 'suicidal autonomy' (III 626) of self-referentiality.

If the origin of any value-system is found in intuition, it is from this irrational base that a positive future may emerge: 'from our dim inklings and feelings of[23] truth there will spring up the high-day and holiday assurance with which we shall know that every man has the divine spark in his soul and that our oneness cannot be forfeited' (III 648). Having identified intuition as the origin of all value-systems on which the possibility of communication and community relies, the trilogy can end with the common voice 'that binds

[22] 'Wo also ist der Bezug der Mathematik zur festen Wirklichkeit, der ihr Wert und Sinn gibt?'
[23] 'Herausfühlen' (715).

our loneliness to all other lonelinesses' (ibid). And as any value-system springs from the irrational impulse to curtail egoistical advantage in favour of adhering to the rules of the system, the final sentence of the trilogy echoes Esch's reading and draws hope from Apostle Paul's determination to voluntarily forego selfish aims and accept imprisonment: '"Do thyself no harm! for we are all here!"' (ibid) While Huguenau's generation remains in the unreality of a world fallen apart, the epilogue thus develops the theoretical possibility of a renewal of community, communication, and value from the zero-point of disintegration. By initiating a move towards the irrational and placing intuition as the origin of a newly unified world, the hopeful vision adopts the strategy taken by counter-modern mathematics to solve the problems raised in the foundational crisis.

Erich Herd holds that 'the positive ending of the *Sleepwalkers* does not develop directly from the trilogy; it ultimately destroys the choreographic symmetry and does not offer more than "a warm and human pat on the shoulder"[24] of the reader who has witnessed the development of the disintegration'[25] (Herd 75). The opinion is shared by Jürgen Heizmann and others: 'Despite the reconciliatory conclusion, the impression of disparity and dissolution is scarcely relieved.' (Heizmann 188) Indeed, in view of its presentation and the interrelations with the development of mathematics, the concluding vision of once again achievable unity, community, and value remains unconvincing. Put forward in the theoretical diction of the essay, the positive vision is subverted by the contrary developments on the level of plot where the generation of the zero-point does not turn to a new value-system but stagnates in the unreality of disintegration: Huguenau is increasingly separated from his fellow men, Müller withdraws into his own thoughts, and the essay states that a condition 'where all that has been sundered is again joined into one' is '[u]nattainable for any man' (III 645). Moreover, both historians of mathematics and *The Sleepwalkers* introduce the counter-modern movement as only a reaction to the modern view: 'Counter-modernism only emerges with modernism'[26] (Mehrtens 512) Mehrtens argues, and in the trilogy, mathematics is described to be 'compelled to accept intuition as the only way out of its difficulties' (III 563-64) and a book-keeping system based on intuition does not appear before the failing of the self-contained system which is unrelated to reality and therefore unable to provide meaning in the world.[27] Modern mathematics is thus rejected as it does not

[24] See Broch *Briefe* 172: 'ein warmes und menschliches Klopfen auf die Schulter'.
[25] 'der positive Schluß der *Schlafwandler* wächst nicht unmittelbar aus der Trilogie heraus; er zerstört letztlich die choreographische Symmetrie und bietet nicht viel mehr als "ein warmes und menschliches Klopfen auf die Schulter" des Lesers, der die Entwicklung des Zerfalls miterlebt hat.'
[26] 'Mit der Moderne entsteht erst die Gegenmoderne'.
[27] Also compare Broch's argument in his essay 'Die sogenannten philosophischen Grundfragen einer empirischen Wissenschaft': 'in the end, intuition is the only resort for a logical intellect to take on

provide a 'way out' (III 564) of the difficulties posed by the foundational crisis, and the counter-modern solution appears to be chosen as a stopgap or due to wishful thinking rather than by virtue of its persuasive power or mathematical credibility. The presentation of different concepts of reality in *The Sleepwalkers* corresponds to this evaluation of mathematics and book-keeping: the value-based realities of Pasenow and Esch fulfil the need of giving the world order and meaning, but it is the modern notion of disintegrated, unconnected egoistical systems that asserts itself. The interrelated illustration of the mathematical notions and concepts of reality thus act together to the effect of revealing a counter-modern reestablishment of unity and value to derive from the wish to solve the crisis but to be improbable. Hence, the unreality of the unsolved crisis is countered by an impractical and therefore equally unreal hopeful vision.

The interrelations of mathematics with, respectively, the depiction of future unreality and the vision of a hopeful future illustrate that the understanding of mathematics in *The Sleepwalkers* is part of the wider expression of the time, influencing and being influenced by the mindset, aims, and beliefs of the period. *The Sleepwalkers* thus implies that while mathematics might constitute a world of its own, it is nevertheless set in the earthly world and its understanding is bound up with wider notions of reality, value, and meaning. As the mathematician Hermann Weyl put it: mathematicians 'are not indifferent to what their scientific endeavors mean in the context of man's whole caring and knowing, suffering and creative existence in the world' ('Mathematics and Logic' 13). The preference of the rather unconvincing counter-modern notion can thus be explained by its wider significance for concepts of truth and meaning as well as by its supporting the vision of a value-based world. Contrary to the theory put forward in 'Disintegration of Values', *The Sleepwalkers* thus does not present mathematics as developing according to its own logic but as part of a wider worldview that it affects but by which it is also changed. In the following I will argue that the modern and counter-modern positions are not mutually exclusive and that in *The Sleepwalkers* both views entail positive aspects: the gains of holding the unpersuasive and impractical counter-modern view are acknowledged, as is the potential inherent in the modern creation of possibilities apart from reality. Moreover, considering the trilogy in its entirety, it will be examined which of the two possible concepts informs *The Sleepwalkers* itself.

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the mystery of the comprehension of the irreducible residue' ('Die sogenannten' 143) ['es bleibt für einen logischen Verstand letzten Endes dann doch nur die Intuition übrig, die das Rätsel der Erfassung der unreduziblen Reste zu übernehmen hat'].

4. Modern Mathematics as Model: Framework for the Future

The combined evidence of the unpersuasive introduction of counter-modern mathematics and the structural ambivalence of the final vision in the theoretical part of the epilogue which is undermined by characters failing to arrive at a positive ending and is further exposed as implausible when the author of the essay by no means reaches this hopeful state, suggests that the implementation of the vision is at least questionable. However, even though the perfect state might be unattainable, it does not necessarily follow that envisioning it is a futile activity. On the contrary, by theoretically deriving the conditions for a value-based future, *The Sleepwalkers* both demonstrates a strategy to counter disintegration and plays out an aspect of the more credible notion of modern mathematics. The potential inherent in constructing a framework of possibility is introduced in relation to the character Gödicke, a bricklayer turned soldier who dies in the First World War, is resurrected, and is then concerned with recreating his life and identity. Gödicke personifies the state of the world, which is annihilated in its traditional notion in the First World War and whose reality and unity are in question; he thus constitutes a model of dealing with the general disintegration and for a possible 'resurrection' of reality. Not least, Gödicke's disintegration also is an analogy of the fragmented novel *Huguenau* itself.

Gödicke dies on the battlefield, and while '[h]e could not be said to have revived under artificial respiration' (III 350) which is administered amateurishly, he nevertheless rises from the dead. Gödicke's major injuries are not bodily, but he suffers from the condition diagnosed by doctor Flurschütz as the affliction of wartime: he '"is a dead soul"' (III 586). Gödicke's soul 'has been torn and pulverized into atoms' (III 351) and in order to regain life, he has to reassemble the pieces: 'his soul collected itself […] with agony around the core of his ego' (III 351-52). However, comparable to disintegrated wartime reality, 'in Gödicke's soul there existed several autonomous and integral separate existences, to each of which one might have ventured to give the title of Gödicke' (III 408). While the coexistence of multiple past Gödickes is unproblematic, he is unable to make a 'connection between the earlier biography and himself' (III 407), and together with the relation to his pre-war self, Gödicke 'had lost his own identity' (ibid). Therefore, like a 'newly born child' (III 351), he has to create himself anew.

Due to the loss of his past as the 'foundation' of his life, the bricklayer Gödicke feels himself unable to build a new 'house of his soul' (III 382); he cannot think about assembling 'the tiles and bricks for the house itself' (ibid). Instead, he is 'concerned with the mere scaffolding' (ibid): 'Ludwig Gödicke the bricklayer had, so to speak, built a scaffolding for

the house of his soul, and as he hobbled about on his sticks he felt himself to be merely a scaffolding with supports and stresses on all sides' (ibid). Gödicke thus only erects the supporting framework, the form and possibility of a future 'house of his soul', while the actual content of his life remains impossible to build. The substance of his past even threatens to destabilise the newly erected framework: when his former life returns as an 'intruder' (III 437) in the form of a postcard from his wife, the past recurs as 'bricks' of content that are 'piled with furious haste on the scaffolding, so that they towered in great heaps and could not be worked off. The scaffolding must collapse if one did not at once put the winch and the concrete-mixing machine out of action to stop the whole business.' (III 438) Since he cannot integrate the past, Gödicke blocks it out, together with any input from outside reality: 'the man Gödicke must see nothing, hear nothing, eat nothing' (ibid). Isolated from the world, uninhibited by any real content but concentrating solely on himself and the construction of the framework, Gödicke feels that 'his powers were increased, and that those growing[28] powers must raise the scaffolding to ever higher and airier heights' (ibid). Developing independently from the world, the scaffolding is described to exist 'in itself and by itself' (III 382), but even though it is a self-contained structure, the framework nevertheless fulfils a 'real purpose, since invisibly in the centre of the scaffolding, and yet also in every single supporting beam, the ego of Ludwig Gödicke was precariously suspended and had to be preserved from dizziness' (ibid). Gödicke thus becomes the self-contained scaffolding itself.

Gödicke's concentrating on building and being a self-contained framework that defines and supports possible content but ultimately is its own aim bears features of modern mathematics and the formalists' belief that mathematics is pure form and 'means itself'[29] (Mehrtens 12). Since modern mathematics is not concerned with application to the world but with 'language in its formality', 'the description of something turns into the writing of the possibilities of regular description'[30] (Mehrtens 93) and mathematics can be said to be a structure of 'pure possibility'[31] (Mehrtens 457). In an essay from 1934, Broch accordingly explains that mathematics 'includes every conceivable logical structure that could exist […], or more correctly, every new discovery in mathematics expands its range but defines a new possible logical structure for the real world as well' ('The Spirit' 45). Gödicke's scaffolding for future content thus resembles aspects of mathematics as a language of possibility and

[28] 'die wachsenden Kräfte' (487).
[29] 'bedeutet sich selbst'.
[30] 'die Sprache in ihrer Formalität'; 'So wird aus der Beschreibung von etwas die Er-schreibung der Möglichkeiten regelgerechter Beschreibung.'
[31] 'reinen Möglichkeitsform'.

implies the potential of modern mathematics to create possibilities for future application. In a similar way as the dissociation from reality liberates modern mathematics and widens its possibilities, Gödicke's scaffolding can grow to 'ever higher and airier heights' (III 438) precisely by disregarding the outside world, and when he accepts the complete and irreversible separation from his old life as a bricklayer, 'the earthly part of his life had become more solid, and yet it seemed to be growing loftier and airier, without losing any of its stability' (III 486). Gödicke therefore no longer has to withdraw from the world in 'defence of his ego' (III 487), but although life condenses round him, it does not turn into content: 'everything that came would simply serve to build the scaffolding yet higher' (ibid). Given that his essential independence from the world is guaranteed by his death, Gödicke can take up 'a fitting and as it were a post-mortem position' (ibid), and considering it to be 'a kind of corroboration of his new-won life' (ibid) when his friend believes that the disintegration of wartime must finally lead to the salvation of the soul, Gödicke takes up the role of a model for the regeneration of dead souls: he introduces himself as '"Ludwig Gödicke, arisen from the dead"' (III 488) and is accepted by Esch's Bible group as 'a holy man' (III 533). When his friend declares Gödicke to be a man who '"feels changes beforehand … he knows lots of things beforehand"' (III 596), he is further established as related to the future development of the world.

Gödicke is further suggested as an example of regeneration when Esch first generally muses: 'The truth that comes to you in dreams walks on crutches […] the whole world goes on crutches … a hobbling monstrosity…' (III 498-99), and later addresses Gödicke in corresponding terms: '"you and your crutches, you monstrosity[32]"' (III 533). Moreover, Esch voices the need 'for the son who shall build the house anew … only then will the mists thin away and the new life will come' (III 500), and when he later reiterates the view when doubting Gödicke's holiness, he only draws the more attention to the bricklayer's building a new life:

> Esch made a gesture of sweeping denial:
> 'No one is holy … there's no one holy but the son who will build the house.'
> 'I build all kinds of houses,' roared Gödicke the bricklayer, 'all kinds of houses have I built … higher and higher…' and he spat contemptuously.
> 'Skyscrapers in America, I suppose,' sneered Esch.
> 'He can build skyscrapers too,' wept Samwald the watchmaker.
> 'Scraper yourself … scraping down walls is all he's fit for.'
> 'From the earth beneath to the very skies. …'
> Gödicke had raised his arms in the air with his two sticks; he looked menacing and powerful, '…arisen from the dead!' (III 534)

[32] 'Mißgeburt' (589) cf. 'Mißgeburt' (553).

The juxtaposition of Esch's and Gödicke's speeches connects the bricklayer Gödicke to Esch's hope for divine provision of a new life and for the perfect new world of America that Esch tried to reach in the second part of the trilogy. Gödicke claims to already have reached a new life himself when building himself up from the fragmented self to which the war has reduced him, and he figuratively constructs a building into the skies when he comes to take up a position further and further above the reality of wartime and feels that eventually his building would become so high that the surroundings 'would never reach the height where he stood' (III 438). With the height of the scaffolding Gödicke's ability of foresight grows, and he comments on the events of the German revolution from the elevated viewpoint of his construction and moreover 'standing on the hillside, which he had chosen as a coign of vantage' (III 607): '"The Judgment Day … […] you must go to hell if you don't rise from the dead … the devil will get you all …"' (III 608) In the revolution the old world order is overthrown and the former reality annihilated, and while the survivor Huguenau only manages to exist in his own egoistical reality, Gödicke, who has already risen from the dead, might achieve reintegration into the world. Whereas in the beginning of rebuilding himself 'the man Gödicke must see nothing, hear nothing, eat nothing' (III 438), after his prophecy regarding the 'Judgment Day' of the German revolution, Gödicke obeys the call '"Ludwig, it's the dinner-hour, come down from the scaffolding."' (III 608) Abandoning the self-contained framework for the intake of nourishment from the outside world, he might begin to build the content of the 'house of his soul' (III 382), so that the concentration on the scaffolding as a self-contained creation of possibilities and the temporary suppression of content would not create the bleak picture of a value-free egoistical reality but promise renewal.

The epilogue introduces the possibility that a guide might attain regeneration and set an example for the world, and if Gödicke is not named, he is clearly evoked in the figure of 'the Leader who will build the house anew that the dead may come to life again, and who himself has risen again from the multitude of the dead' (III 647). Gödicke's example of death and rebirth also instils the 'death' of the world in the First World War with some meaning as it might lead to regeneration; he thus resembles 'the Healer who by his own actions will give a meaning to the incomprehensible events of the age, so that Time can begin anew' (ibid). However, Gödicke and the Leader cannot complete the path they point out; they only reach a higher coign of vantage but never arrive at the heights of the promised land. The world thus cannot follow any leader to renewal, but Gödicke's example nevertheless inspires hope in Esch's Bible group, and the epilogue states in more general terms: 'the mere hope of wisdom from a Leader is wisdom for us, the mere divination of

grace is grace, and […] our goal remains approachable[33], our hope that a Messiah will lead us to it remains imperishable, and the renascence of values is fated to recur' (III 648). It is thus the promise of renewal, the possibility of regeneration rather than revival itself that is suggested to conquer disintegration.

Gödicke creates the possibility for future content by constructing scaffolding and thus maintains the possibility and hope for the 'renascence of values' (III 648). In a comparable way, *The Sleepwalkers*, particularly in the essay and the epilogue, creates a framework of theoretical possibilities and fans the hope for a better world by envisioning it. As Leo Kreutzer puts it, Gödicke's rebuilding himself 'can be seen as a self-interpretation and self-justification of the trilogy'[34] (Kreutzer 191). In light of these findings, views that '[d]espite the reconciliatory conclusion, the impression of disparity and dissolution is scarcely relieved' (Heizmann 188) can be explained and refined: even if the trilogy's counter-modern ending of regaining unity and value through intuition remains unconvincing, drawing out the framework of its possibility and examining its conditions in the theoretical form of the essay corresponds to building a framework which sustains the possibility of future content and can thus advance the world on its way to an unattainable vision.

5. Interrelations in *The Sleepwalkers*: Mathematics, Reality, and Literature

5.1 Literature and the 'Style of Thinking'

The Sleepwalkers presents developments in mathematics, reality, and value as analogous and interrelated, and it also addresses the simultaneous changes occurring in literature. The trilogy introduces a connection between developments in mathematics and literature in a broad sense when in the third novel Esch keeps book of the world not in the guise of an accountant but as editor of a newspaper. Similarly to his initial understanding of book-keeping, Esch expects newspapers to report real events of the world in order to render it understandable, and as editor he leads a 'fight for precise evidence of the world's doings, and against the false or falsified book-keeping entries which people tried to fob off on him' (III 370-71). Yet, for newspapers 'any methodical keeping of the books becomes a sheer impossibility' (III 369) in the 'inaccuracy of a war' (III 370), and analogous to the development of book-keeping and mathematics, the newspaper turns from a means of describing reality to creating its own: 'only by referring to the Censor's office can one establish what is to pass for truth and what must remain in the realm of untruth, and each

[33] 'annäherbar' (715).
[34] 'kann als Selbstauslegung und -rechtfertigung der Trilogie angesehen werden'.

nation lives enclosed in its own patriotic reality' (III 369). Neither of the 'two unrealities' (III 370), namely the perfect realm of book-keeping and the patriotic version created by the Censor's office and repeated in the newspapers, thus adequately renders the chaotic given world.

The essay 'Disintegration of Values' explicitly mentions art as an example of the wartime style and its 'ruthless logic directed on the object and on the object alone' (III 446): next to 'war is war [… and] business is business', '*l'art pour l'art*' (III 446) is an example of 'the style of thinking that characterizes our age' (ibid). Literature is thus argued to participate in the self-referential turn of the period, and accordingly, its connection to and value in the world becomes questionable: Pasenow doubts any impact of his leading article, 'gratifying as it might be to believe that his words had had an effect' (III 476), and the reader is bound to agree since only fragments of the article appear in the novel and his argument necessarily remains sketchy. Moreover, Bertrand Müller despairs of the usefulness of words in general when ending his narration in silence: 'I had talked too much in any case and let the matter drop there.' (III 624) The domains of literature and language are thus described as developing according to the changes in the general style of thinking of the period, tending towards self-referentiality, turning away from value, and threatening to fail when completely unable to connect to reality. Yet, even though literature and language are presented as participating in the overall disintegration, they are also at the core of the vision of regeneration when a 'voice' (III 648) announces hope at the end of the trilogy. As Michael Kessler explains: 'A positive conclusion, being refused by reality from the one side […] thus celebrates resurrection in language itself.' (Kessler 73-74) Moreover, the Biblical language that permeates the novels and ends the trilogy invokes the promises of the Holy Scripture, and it is suggested that only the fragmentary nature of Pasenow's article impairs its impact when Esch, who reads the article in whole, is affected by its views and grows 'calmer' (III 430). If literature and language are part of the overall disintegration of the period, they are thus also presented as ways to pronounce hope and create relief.

Even a cursory examination reveals that the changes in the notions of mathematics, reality, and literature are reflected in the form of the trilogy: the narration in the first novel which 'is as harmless as possible, is consistently paced and has an almost entirely naturalistic colouring'[35] (Broch 'Kommentare' 724)[36] is replaced by 'hectic expressionistic

[35] 'möglichst harmlose Erzählung von gleichmäßigem Tempogefälle und fast ungebrochener naturalistischer Färbung'.

[36] A closer examination of the style in *Pasenow* reveals that the naturalism is already undermined. Ziolkowski points out: 'Only careful attention to Broch's use of point of view reveals that the narrator has carefully excluded himself from the story; every incident is consistently related in its

prose' (Ziolkowski *Hermann Broch* 12) in *Esch* and ends in the disintegrated storylines and dissimilar styles of *Huguenau*. The form thus corresponds to the 'sweeping revolution in the style of thinking' (III 481) around the turn to the twentieth century, and analysing the overall structure of the trilogy can provide additional indications as to whether a modern or counter-modern outcome of the revolution is granted preference. Given that the essay 'Disintegration of Values' shows knowledge of the main plot,[37] which in turn includes characters from the previous novels, when first-person narrator Bertrand Müller is suggested to be the author of the essay, it 'becomes clear that Bertrand Müller has to be pictured as the narrating I of the whole trilogy'[38] (Lützeler 74). Readers consequently do not get directly at the 'reality' presented by the novels, but it is mediated through Müller's consciousness, meaning that the trilogy is 'a product of the intelligible Self' (III 563), a fictional reality pervaded and created by the 'value-subject' (III 564) Bertrand Müller. Theodore Ziolkowski explains: 'What we have taken to be absolute reality is revealed as a relative system dependent upon this novel's "intelligible Self," Bertrand Müller.' ('Relativity' 376) Through the stepwise disclosure of Müller's function in the trilogy, *The Sleepwalkers* performs the theory of a necessarily mediated reality, and by introducing Müller as the 'value-subject into everything, into every concept however abstract' (III 564), his consciousness underlies and 'reanimates' (ibid) the whole world of the trilogy. *The Sleepwalkers* thus emerges as a 'conceptually comprehensive unity' (III 563) originating in Müller's thought, and in this way the counter-modern hope for unity guaranteed by man is realised regarding the trilogy as a whole.

By revealing that the world of the trilogy is mediated by Müller and cannot be accessed directly by the reader, *The Sleepwalkers* performs the counter-modern outward turn that N. Katherine Hayles suggests to constitute one of the two possible directions taken by the modern novel: in the outward turn 'toward an apparently external referent', reality is not represented directly, 'it is no longer simply external and objective, nor is it represented as an object separate and distinct from its verbal expression' (Hayles 23). The mechanism

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filtration through various shifting focuses. "Reality" turns out to be anything but the stable world of traditional realism, and its breakdown is anticipated stylistically.' (*Hermann Broch* 12)

[37] In the fourth part of 'Disintegration of Values', the question: 'in how far is the style of an age incarnated in the average man, in a business man, for example, of the type of Wilhelm Huguenau?' (III 414) makes a connection between the theoretical considerations of the essay and the main plotline. The two strands are then more consistently interwoven in the epilogue.

[38] Es 'wird deutlich, daß Bertrand Müller als das Erzähl-Ich der ganzen Trilogie vorzustellen ist'. The thesis that Bertrand Müller is the author-narrator of the entire trilogy is not unchallenged. For example, Ernestine Schlant holds that it is 'a conjecture for which there is no basis in the text' (*Hermann Broch* 170), and Martens formulates with caution: 'the theoretical essay and maybe the whole book is attributed to a character in the last part of the trilogy' (Martens 239-40) [Es wird 'der theoretische Essay und vielleicht sogar das ganze Buch im letzten Teil der Trilogie einer der Figuren zugeschrieben']. Yet, since the essay explicitly refers to Huguenau (see previous fn), the author of the essay is clearly shown to be aware of the trilogy at large.

underlying the discovery in *The Sleepwalkers* that what has been experienced as an objective fictional world for the most part of the trilogy has to be thought of as filtered through Müller, is made explicit in the essay 'Disintegration of Values' where it is identified as central to the transformation of logic or the 'style of thinking' (III 481) in the early twentieth century: 'methodologically regarded, to define a thing as the "product of a product" is nothing else than to introduce the ideal observer into the field of observation, as has been already done long since by the empirical sciences (by physics, for example, in the Theory of Relativity)' (III 563). Again, the trilogy and its style are suggested to be part of a more general 'revolution in the style of thinking' (III 481).

The analogy between the concept that 'the world is a product of the intelligible Self' (III 563) and modern physics' taking into account that the observer always shapes the object of observation is only addressed in passing in *The Sleepwalkers*, but Ziolkowski notes a preoccupation with the theory of relativity in Broch's letters and particularly in his essay 'James Joyce and the Present Age' (1936).[39] In the essay, Broch explicitly connects the discovery in physics to literature and, so Ziolkowski argues, refers to their interrelation in *The Sleepwalkers* even though the topic of the essay is Joyce's *Ulysses*: 'the whole passage makes more sense if it is read as a commentary on and as a theoretical justification of Broch's own novel, *The Sleepwalkers*' ('Relativity' 371). As Broch frequently compared his work to Joyce's and was at pains to demonstrate their common objectives, this seems plausible. In the essay, Broch holds that it 'can give no offence to the theory of relativity if we draw a parallel with literature' ('James Joyce' 88), and he argues that modern physics implies that

> it is not permissible simply to place the object under observation and do nothing other than describe it; but that representation of the subject, in other words "the narrator as idea", and not the least the language with which he describes the representational object, belong to it in the role of representational media. What he [Joyce but also applying to Broch] seeks to create is a unity of representational object and representational means (ibid 89).

While the author-narrator Müller cannot simply be equated with the 'narrator as idea',[40] he is both part of the 'representational object' and the 'representational means' of *The Sleepwalkers* and is an important component in demonstrating the impossibility of separating

[39] Also see Schlant 'Hermann Broch and Modern Physics'.

[40] Ziolkowski asserts that Müller works as the "narrator as idea" and that when his role is revealed, the fictional reality is reshaped 'in such a manner as to reflect the way in which men experience the world in the age of relativity' ('Relativity' 376). Schlant expresses the conflicting view, arguing that if Müller is seen as the author of the entire novel, 'the innovative function of the "narrator as idea" is lost' (*Hermann Broch* 170). Instead, she holds that 'the "narrator as idea" is present in any device which draws attention to the fact that the novel is a deliberate, "scientific" construct, expressing not only narrative content but cognizance of stylistic and technical limitations as well as those of perspective' (*Hermann Broch* 51). Also see Kreutzer 18-28, Lützeler 73-82, and Reinhardt 29-38.

the subject and the object of observation. The explicit reference to the recognition of the principle of 'product of a product' in the sciences connects the core concern identified in the essayistic chapters of the trilogy to developments in early twentieth-century science, and together with Broch's essayistic arguing for the relevance of scientific knowledge for the conception of literature, the suggestion in *The Sleepwalkers* that what has been experienced as novelistic reality is 'observed' and presented by one of its characters takes a principle exemplified by physics into the domain of literature and the novel trilogy itself.

5.2 The Specific Roles of Mathematics and Literature

The Sleepwalkers draws parallels between the development of literature and science, both in its content and through its form, but the presentation of the conceptual revolution also illuminates the specific roles allocated to literature and mathematics in the comprehension and formation of reality. In *The Cosmic Web*, Hayles introduces the field concept which she holds to become a dominant view in diverse disciplines in the early twentieth century and one aspect of which is the presentation of reality as a field of which the observer is always part. As Hayles develops, the particular potential of literature shows in its illustration of what the developments towards a field concept 'imply not only about the nature of the world, but about how one interacts with the world' (Hayles 31); an obviously important aspect given that according to the field concept there is no observing reality without interacting with it. *The Sleepwalkers* puts forward a comparable notion of a common development of diverse fields towards acknowledging the principle of 'product of a product', and performatively the trilogy demonstrates that literature lends itself to address the 'human meaning' (Hayles 59) and the position of man in the period's newly developed style of thinking. In contrast, mathematics can be employed as an example, even 'the clearest example'[41] (III 481), of the 'sweeping revolution in the style of thinking' (III 481), but, so Mehrtens points out: 'In the language of mathematics the mathematician cannot talk about himself'[42] (Mehrtens 482). In his commentary to *The Sleepwalkers* and his theoretical work Broch similarly argues that mathematics is an 'absolutely correct means of communication' ('Kommentare' 729) but 'is largely detached from the mathematician; he cannot interpret subjectively with it, […] it is a precise, mute, de-subjectified language'[43] ('The Spirit' 181).

[41] 'am deutlichsten' (533).
[42] 'In der Sprache Mathematik kann der Mathematiker sich selbst nicht zur Sprache bringen.'
[43] 'absolut korrektes Verständigungsmittel'; 'die Mathematik ist vom Mathematiker weitgehend losgelöst, er kann mit ihr nicht subjektiv interpretieren, […] sie ist eine präzise, stumme, entsubjektivierte Sprache.'

Since the increasingly mathematised sciences cannot address the irrational course of the world, Broch contents that '[f]rom the word's perspective: the sciences have become mute too'[44] ('Kommentare' 729). He holds that due to this development in the nineteenth and twentieth centuries, literature has to cover the areas no longer encompassed by science: 'because of a self-restriction of the scientific, the irrational elements of life are now turned back to the irrational expression of literature'[45] ('Kommentare' 731). Yet, although 'literature has to be concerned with those human problems […] that are discarded by science'[46] ('Kommentare' 719), it cannot ignore science which plays an important role in twentieth century society; on the contrary, so Broch claims, '[l]iterature has to submit to the spirit of the epoch, to its scientificity, […] and it does so by becoming polyhistoric'[47] ('mythische Erbschaft' 209).

The polyhistoric novel as envisioned by Broch is a synthesis of science and the irrational of life and takes account of the significance of science while also striving for 'the totality of world comprehension' ('James Joyce' 101) and satisfying 'man's desire for the totality of the worldview'[48] ('Kommentare' 732).[49] Broch's concept of the polyhistoric novel is thus related to the encyclopaedic novel which addresses a 'full range of knowledge and beliefs' (Mendelson 1269) and searches for 'a pattern that will explain, or at least enable man to order, the whole of life' (Pike 119). As *The Sleepwalkers* develops, knowledge of the world and any totality of the world is always bound up with the observer, so that a novel adequate to the period would not only need to be a polyhistoric work but also an '"*epistemological novel*"'[50] (*Briefe* 93).[51] Broch explained that the epistemological novel would go back 'to fundamental epistemological assumptions and to the true logic and plausibility of values'[52] (ibid), doing so by not only depicting the plot and the characters' thoughts, but introducing 'the epistemological level which is the true level of the author, namely the one where he translates the dark and universal logic of experience into the

[44] 'Vom Wort aus gesehen: sind auch die Wissenschaften stumm geworden.'
[45] 'infolge einer Selbstbescheidung des Wissenschaftlichen [… werden jetzt] die irrationalen Bestandteile des Lebens wieder an den irrationalen Ausdruck des Dichterischen zurückgewiesen.'
[46] 'die Literatur [hat] mit jenen menschlichen Problemen sich zu befassen […], die einesteils von der Wissenschaft ausgeschieden werden'.
[47] 'die Dichtung [… muß sich] dem Geist der Epoche, muß sich seiner Wissenschaftlichkeit unterordnen, […] und sie besorgt dies, indem sie polyhistorisch wird'.
[48] 'Wunsch des Menschen nach der Totalität des Weltbildes'.
[49] For example discussed in Mandelkow 156-71; Ritzer 182-83; Steinecke.
[50] '"*erkenntnistheoretische Roman*"'.
[51] For Broch's concept of the epistemological novel see for example Kreutzer and Reinhardt 56-61.
[52] 'erkenntnistheoretische Grundhaltungen und auf die eigentliche Wertlogik und Wertplausibilität'.

rational logic of rational understanding. It is the level of commentary, so to speak.'[53] ('Bemerkungen' 299) Broch admitted that the intended epistemological novel was only hinted at in *The Sleepwalkers* (see *Briefe* 92-93), but concerns with the underlying ideas are evident: apart from the 'polyhistoric' inclusion of concepts from science and various other disciplines, the last novel uses the essay as a 'level of commentary' for the epistemological discussion of the concept of the 'product of products', and the overall structure of the trilogy points to the potential of literature to acknowledge the role of the observer in what is perceived as reality. *The Sleepwalkers* thus might not be the epistemological novel envisioned by Broch, but by examining 'how one interacts with the world' (Hayles 31) it addresses modern epistemological questions and the 'human meaning' (Hayles 59) of the field concept.

Literature might be a more adequate form than mathematics to express the human meaning of man's interaction with the field of reality, but the question arises how it can depict such a complex field: 'can a holistic field be represented in a linear flow of words?' (Hayles 27) When Bertrand Müller is disclosed as the observing and narrating instance in *The Sleepwalkers*, it becomes clear that the trilogy does not claim to directly present a fictional reality, that it does not capture 'the elusive whole, but the observer who would speak that whole' (Hayles 21). The trilogy illustrates the epistemological consequences of the inclusion of the observer in the field of observation by relating the notions of certainty and insight to a position removed from the world: life 'recedes to a distance' (I 21) for Pasenow when he is in uniform and thus 'no longer tied to things, and […] able to divide them into the good and the bad' (ibid); Esch, when accepting the essential anarchy of the world, can 'contemplate the earthly as from a higher coign of vantage […], shut off from the world and yet open like a mirror to it' (II 339); and the more Gödicke separates himself from the world, the higher his scaffolding and more far-reaching his insights become. None of the characters arrives at a secure viewpoint at the outside, they all remain part of the world they want to observe and can thus only achieve limited certainty and insight, and the revelation of Müller's involvement in the world of the trilogy suggests that the same limitation applies to *The Sleepwalkers* as a whole. However, by presenting Müller as the origin of the trilogy that thus becomes a 'conceptually comprehensive unity' (III 563), *The Sleepwalkers* points towards the 'holistic field' without actually representing it in its 'linear flow of words'. In other words, the world is discovered not to be describable in book-keeping entries, but the activity of keeping book is part of the world, of the 'grand book' that

[53] 'die erkenntnistheoretische Ebene, welche die eigentliche Ebene des Autors ist, nämlich jene, auf welcher er die dunkle und allgemeine Logik des Erlebnisses in die rationale Logik rationalen Verstehens umsetzt. Es ist sozusagen die Ebene des Kommentars.'

is the 'universe' (Galilei *Controversy* 183): Müller's struggle to depict and understand reality is part of the book *The Sleepwalkers* itself. The reader, connected to the novels by reading them but not part of the fictional universe, inhabits a position further removed from the trilogy's reality and is therefore granted greater insight: the underlying unity of the novels, guaranteed by the value-subject and fictional author Müller, can be detected, but the trilogy's question as to the structure and value of historical reality remains unanswerable. Thus, while in the 'sweeping revolution in the style of thinking' (III 481) at the beginning of the twentieth century accounting for the book of the world in the language of mathematics fails, literature becomes not a tool to understand the book itself but to illustrate how we read it.

Robert Musil: The Man without Qualities

1. Mathematics and Mysticism: Europe in the Early Twentieth Century

The novel *The Man without Qualities* by the Austrian author Robert Musil was designed as two books consisting of two parts each, but when Musil died in 1942 the project remained unfinished. Both parts of book 1, 'A Sort of Introduction' and 'Pseudoreality Prevails', were published in 1930, and 38 chapters of 'Into the Millennium [The Criminals]', the first part of book 2, appeared in 1932. A further twenty chapters were submitted to the printer but withdrawn in 1938; next to these so-called galley chapters, there exists a fair copy of six chapters of a revised version as well as additional versions and chapters of this continuation of the first part of book 2. There are also copious notes for further chapters and the envisioned last part 'A Sort of Ending', a selection of which was published together with the galley chapters and revised versions in 1978.[1]

Similarly to Pynchon's *Against the Day* and Broch's *Sleepwalkers*-trilogy, Musil sets his work against the historical and mathematical developments of the 1880s to 1920s and beyond: 'I want to develop an image of the world, the real background, in order to be able to unfold my unreality before it. I observe life since 1880' (*Diaries* 262). Other than the earlier discussed works however, the actual plot of *The Man without Qualities* spans only one year, approaching the outbreak of the First World War in August 1914. The plot never arrives at the war, but the imminent catastrophe overshadows the unfolding of the novel; Musil explained: 'That war came, that war had to come, is the sum of all the conflicting currents and movements that I show' (qtd. in Fanta 280). The spirit of the time is thus condensed into one year, and similarly, the setting in the state Kakania, an abbreviation for the imperial and royal – k.(aiserlich) & k.(öniglich) – monarchy of the Austro-Hungarian Empire, illustrates a wider situation: 'this grotesque Austria is nothing but a particularly clear-cut case of the modern world' (Musil *Diaries* 209). In a further step of condensation, mathematics is established as 'the new method of thought itself, the mind itself, the very wellspring of the times and the primal source of an incredible transformation' (35). As in Broch's *The Sleepwalkers* then, *The Man without Qualities* places mathematics at the core of the dramatic transformation of the Western world at the beginning of the twentieth century.

Not least due to the fact that the protagonist in *The Man without Qualities* is a mathematician and Musil himself studied mathematics, the importance of mathematics in the

[1] In the following, quotes from the parts not published in Musil's lifetime are marked 'galley', 'drafts', or 'notes'. Citations from the fair copy, which is not included in the translation by Wilkins and Pike, are my translations and the original is given in a footnote.

novel has frequently been noted. However, as Dale Adams points out, mathematics is mostly employed as an example of rationality or addressed in connection with the natural sciences, whereas its specific role in the novel is examined a lot less frequently (see Adams 40-49). Two early studies analysing the employment of mathematics in *The Man without Qualities* in more detail are Gerolf Jäßl's examination of the polarity between mathematics and mysticism, and Jürgen Kaizik's study of mathematics in Musil's work as an example of the role of rationalism in art. More recently, Christian Kassung and Claus Hoheisel have provided commentaries to the novel that do not, or not primarily, engage in literary interpretation but explain the scientific concepts informing the novel. I'm inclined to agree with Thomas Klinkert who holds: 'However disproportionate the gain for interpretation sometimes is to the effort in this approach – it is impressive to see the detailed and differentiated way in which contemporary scientific knowledge informs Musil's novel.'[2] (Klinkert 273) Kassung's and Hoheisel's works are also subject to Andreas Johann's more general complaint that the importance of contemporary knowledge in *The Man without Qualities* is commonly noted but that 'the scholarly examination of the most banal of all questions, namely what Musil does with that knowledge, is still in its infancy. This is particularly true for the field of the sciences.'[3] (Johann 160) Gwyneth Cliver's 2008 dissertation sheds more light on how Musil employs mathematics to illustrate the interconnectedness of the rational and the irrational rather than setting the domains into a binary opposition, and Adams's 2011 examination of mathematics in Musil's fictional and nonfictional work also goes some way in closing the perceived gap in scholarship. Yet, Adams's focus is precisely 'not to provide a new interpretation of the work, but it is hoped to show that the epistemological and poetological principles that have been developed in connection with mathematics are manifest in the respective work'[4] (Adams 32). In contrast, the focus of this chapter is on a literary analysis of the novel and its employment of mathematics that aims to also point out consequences for the interpretation of *The Man without Qualities*.

[2] 'Sosehr der interpretatorische Ertrag dieses Verfahrens bisweilen in einem Missverhältnis zu dem betriebenen Aufwand steht, so eindrucksvoll ist es doch auf der anderen Seite zu erkennen, in welch detaillierter und differenzierter Weise aktuelles naturwissenschaftliches Wissen in Musils Roman eingegangen ist.'

[3] 'Dennoch steckt die wissenschaftliche Aufarbeitung der banalsten aller Fragen, nämlich derjenigen, was Musil mit diesem Wissen eigentlich tut, noch immer in den Kinderschuhen. Dies gilt vor allem für den Bereich der Naturwissenschaften.'

[4] 'Das Ziel ist nicht eine neue Interpretation der Werke anzubieten, sondern es wird der Nachweis angestrebt, dass die vorher in Verbindung mit der Mathematik erarbeiteten epistemologischen und poetologischen Prinzipien sich in dem jeweiligen Werk manifestieren.'

When in *The Man without Qualities* mathematics is taken to be the new method of thought and a source of transformation, the research into its own foundations emerges as a model for considering developments in culture at large. The mathematician Ulrich, the eponymous man without qualities, undertakes the corresponding 'task of rethinking the cultural axioms that Musil himself saw undergirding modernity' (Thiher 232), but in a time when, as the narrator describes, '"What people are" evidently keeps changing as rapidly as "What people are wearing,"' (494) anybody not going along with the development 'would look silly, like a person caught between the opposing poles[5] of an electric therapy machine, wildly twitching and jerking' (494). The poles between which Ulrich oscillates are those of '"mathematics and mysticism"' (837), also variously called violence and love, precision and soul, single-mindedness and metaphor (see 647), and held by Musil to constitute the defining elements of the twentieth century: 'rationality and mysticism are the poles of the time' (*Diaries* 216). While the relationship and a possible fusion of the poles has commonly been interpreted in the stable terms of thesis, antithesis, and synthesis, I shall argue that the novel establishes an opposition between mathematics and mysticism but reveals it to be a false antagonism used to simplify life by providing a clear-cut distinction. In the novel, this strategy is most clearly illustrated in relation to law which is based on the belief that 'between two contraries there is no third or middle state' (261), while cases are more accurately examined taking into consideration nature's 'peculiar preference': '*Natura non fecit saltus*, she makes no jumps but prefers gradual transitions' (261). This chapter accordingly demonstrates that mathematics in *The Man without Qualities* not only exemplifies the side of rationality, but that by exploring aspects of mathematics, the binary opposition is transformed into the notion of a circle where the poles of mathematics and mysticism take diametrically opposed positions but are connected by transitional states on the circumference.

Arguing for a transformation of the antagonism of mathematics and mysticism into a relation described by a circle, I will develop and modify a thought by Cliver: 'The positivist faith in mathematics, logic and rationality dwindles, and what at first looked like a linear progression from the irrational to the rational begins to appear more as a circle, eternally connected' ('Maddening Mathematics' 83). In her paper and her dissertation on mathematics in texts by Broch and Musil, Cliver argues that '[t]he rational and the irrational intertwine and mingle – indeed, comprise one another' (*Musil, Broch* 104) and that the interweaving is shown through the concern with mathematics and madness. Cliver concludes that in Musil's novels, 'an overzealous exploration of rational mathematics ironically leads to a flirtation

[5] 'Pole' (454).

with irrational thought and, if not checked, mental illness' ('Maddening Mathematics' 75), a risk from which only Ulrich is exempt. I will argue that it is not primarily the characters' direct engagement with mathematics that relates it to the irrational, but that mathematics itself is shown to encompass an irrational, mystical element. *The Man without Qualities* thus takes up a notion of mathematics that, together with the contrasted understanding of mathematics as the symbolic extreme within the domain of reason, plays out a central conflict of the foundational crisis of mathematics and also elaborates on the antagonism of rationality and its various Others in the critical pre-war period at large.

1.1 Mathematics in a Time without Qualities

Mathematics at the beginning of the twentieth century is preoccupied with the foundational concerns caused by and in turn causing the questioning of notions of truth, meaning, and existence. Kakania in 1913 is described to undergo a comparable development: 'the soil can no longer be worked with the old tools' (531), and the generally felt need to end the uncertainty caused by the inability to make sense of the world in the terms of traditional categories renders necessary an alteration of 'the basic forms and foundations of a moral order that over two thousand years has adjusted only piecemeal to evolving tastes' (272). Only sure that it is not the country it used to be, Kakania is in a foundational crisis, and the citizens are urged to take up the task of determining its essential character when the year 1918 is declared '"as a jubilee year for our Emperor of Peace"' (79) in order to anticipate the celebration of the German Emperor's thirty years of reign earlier in the same year. The Parallel Campaign is established to organise the jubilee year and 'reveal the innermost being of Austrian culture' (109), to free a 'unifying power' (190) and ensure that the '"splendorous rally of the Austrian spirit" would prove a "milestone" for the whole world and enable it to find its own true being again' (89). Kakanians thus plan to define their country's essential character and fundamental value and '"to set the world an example of unification, of a shared idea"' (621). The futility of the Parallel Campaign is immediately obvious to the reader, given that the Austrian Emperor died in 1916, and the year 1918 was hardly a year of celebration, much less of any 'Emperor of Peace'. Moreover, *The Man without Qualities* itself does not work as 'an example of unification' as it remains unfinished.

Diotima, the main organiser of the Parallel Campaign, believes that its central idea 'must come out of the total community' (190) but quickly realises the heterogeneity of the period: there are 'organizations and counterorganizations of every kind' (375), the 'times rejoice in a number of great ideas, and by a special kindness of fate each idea is paired with

its opposite' (405), so that '[e]very time Diotima had almost opted in favor of some idea, she could not help noticing that its opposite was equally great and equally worthy of realization' (247). The lack of a central organising idea is also illustrated when Ulrich's friend Clarisse, peering through her wedding ring, ponders: '"if we could be cut open our entire life might look like a ring, just something that goes around something. […] There's nothing inside, and yet it looks as though that were precisely what matters most."' (401) The Parallel Campaign thus has the difficult task of defining the unifying idea of a period without centre, content, or unambiguous qualities. On a personal level, Ulrich is faced with a similar problem: as '"a man without qualities"' (62) he suffers from the overwhelming choice entailed by seeing 'in himself all the abilities and qualities favored by his time' while having 'lost the capacity to apply them' (44). Thus, corresponding to the Parallel Campaign's search for the period's true being and unifying idea, Ulrich seeks to determine his character and the content that '"matters most"' (401) to him: '"there's a whole circle of questions here, which has a large circumference and no center, and all these questions are: 'How should I live?'"' (972)

Ulrich has made three attempts to satisfy his inborn wish to become a great man before he resolves 'to take a year's leave of absence from his life in order to seek an appropriate application for his abilities' (44). The three chosen careers in the military, engineering, and mathematics all fail, but they illustrate what Ulrich considers worth devoting himself to and how he hopes to employ mathematics in his search for a valuable life. Ulrich abandons his military career as soon as it turns out not to be a way of becoming a hero on the 'stage of world-shaking adventures' (32), and he is similarly disillusioned with civil engineers whose 'feelings have not yet learned to make use of their intellect' (33). As engineers are unlikely to help Ulrich adjust the world to the level of contemporary scientific knowledge – 'any suggestion that they might apply their daring ideas to themselves instead of to their machines would have taken them aback' (34-35) – Ulrich turns to his third and 'most important' (35) attempt at becoming a great man: mathematics.

Ulrich welcomes the 'hard, courageous, flexible, razor-cold, razor-keen logic of mathematics' (36), qualities that put it at the peak of rationality. Ulrich then hopes to employ this 'new method of thought' (35) to change people's behaviour and promote a way of living better suited to the advanced scientific knowledge of the time. He feels: 'they have no idea how one can already think[6]; if they could be taught to think in a new way, they would change their lives' (37). Thus 'in love with science not so much on scientific as on human grounds' (37), Ulrich pursues mathematics in view of fundamental moral questions: 'If

[6] 'wie man schon denken kann' (41).

someone had asked him at any point while he was writing treatises on mathematical problems or mathematical logic […] what it was he hoped to achieve, he would have answered that there was only one question worth thinking about, the question of the right way to live.' (275) However, Ulrich experiences a similar disillusion in mathematics as in engineering when he learns that mathematicians are not concerned with meaningful application of their professional thinking to life, but, being addicted to 'some strange pale drug that filled their world with visions of numbers and abstract relations' (44), do not look outside the field of mathematics. Struck by the failure of this most promising attempt to change the way of living, Ulrich embarks on his sabbatical, but the model of mathematics still plays a decisive role in Ulrich's search for the right way to live, not only as one of the poles between which life oscillates, but the 'new method of thought' and 'primal source of an incredible transformation' (35) also informs Ulrich's most fruitful strategy of dealing with the period's foundational crisis.

1.2 Mysticism in a Time without Qualities

As a mathematician Ulrich is immediately associated with one of the opposed poles of '"mathematics and mysticism"' (837) and indeed predominantly examines life according to rational criteria in book 1, but in book 2, he reorients his focus in favour of the pole of mysticism. Moosbrugger, a murderer who waits for the authorities to agree whether to sentence him to death or declare him insane, embodies the consequences of being removed from the sphere of mathematics and close to the pole of mysticism. Moosbrugger's diminished responsibility constitutes a problem for legal categories which are established on the belief that 'between two contraries there is no third or middle state' (261), and his case induces a reexamination of the interrelated notions of reason and responsibility: '"as the intellect and reasoning power develops, the will comes to dominate desires or instincts […]. Any willed act is accordingly always the result of prior thought and not purely instinctive."' (343), so Ulrich's father – a lawyer – claims. The legal term 'accountability'[7] is associated with mathematics, or as Cliver puts it: 'the concept of sanity grows directly out of at least arithmetical, if not mathematical, capacity' ('Maddening Mathematics' 84). The shared relation of law and mathematics to reason is strengthened when counting plays a role in evaluating the extent of Moosbrugger's accountability: while persons clearly irresponsible of their actions are thought to have no grasp of mathematics and 'when asked to multiply 7

[7] 'Zurechnungsfähigkeit' (243).

times 7 stick out their tongue' (263), Moosbrugger's mathematical abilities cannot be dismissed as easily. Asked to add fourteen to fourteen, he replies:

> 'Oh, about twenty-eight to forty.' This 'about' gave them trouble, which made Moosbrugger grin. It was really simple. He knew perfectly well that you get twenty-eight when you go on from fourteen to another fourteen; but who says you have to stop there? Moosbrugger's gaze would always range a little farther ahead, like that of a man who has reached the top of a ridge outlined against the sky and finds that behind it there are other, similar ridges. (259)

Moosbrugger's idiosyncratic calculation clearly differs from the traditional rules of mathematics, but it is not entirely wrong. Moreover, his inability to stop at a 'right' answer points to the problems encountered in early twentieth-century mathematics when attempts to determine the 'correct' basis of mathematics give rise to ever further problems. The association of Moosbrugger's calculation with an unending succession of obstacles thus implies that, since in the foundational crisis the grounds of mathematics itself are found to be elusive, mathematics is no longer an entirely reliable means of determining reason. Indeed, as the law of excluded middle is a logical concept accepted in formalist mathematics but contested by intuitionists, Moosbrugger's case is mirrored in the foundational crisis of mathematics: if law assumes that 'between two contraries there is no third or middle state' (261) so formalist mathematics works from the premise that either a proposition is true or its negation is true, whereas intuitionists, who do not accept the law of excluded middle as an axiom, take a stance comparable to Moosbrugger's psychologists who argue that there are states in between absolute accountability and absolute unaccountability. Since Moosbrugger's condition of diminished responsibility can only be judged when the grounds on which to determine reason and responsibility are agreed upon, his case depends not only on a revision of middle states in law but also on the foundational research in mathematics which thus becomes a vital task for the general evaluation of humanity.

Ulrich suspends his personality in order to find a way of living better suited to the changed conditions in a world without defined qualities, content, or centre. Moosbrugger reacts differently to the uncertainty of the time and 'the dissolution of the anthropocentric point of view, which for such a long time considered man to be at the center of the universe but which has been fading away for centuries, has finally arrived at the "I" itself' (159), when he forces the world into simplicity by killing the Other that he does not understand, namely women: taking a prostitute to be his 'accursed second self' (74) he stabs her 'until he had completely separated her from himself' (74). After the killing, having re-unified himself into an unambiguous identity, Moosbrugger enters a near-mystical state and is in harmony with the world and himself: his 'experience and conviction were that no thing could be

singled out by itself, because things hang together' (259) so that 'he thought both inside and outside' (258) and 'these periods were all meaning' (257).

Ulrich's friend Clarisse serves as another example of the dangers of orienting life towards the pole of mysticism and concentrating on the individual self while leaving behind the general rational order exemplified by mathematics. Clarisse insists on expressing her inner life and soul regardless of social conventions, but when the extreme consequences of her request to live wholly according to oneself are exemplified by Moosbrugger who constitutes one of the 'cases of chemically pure souls actually committing crimes' (198), the gruesome implications of a self-centred mystical position induce Clarisse's husband Walter to reject a focus on one pole of life only: '"Everything that tries to overstep the limits set for us is dishonest! Mysticism is just as dishonest as the conceit that nature can be reduced to a mathematical formula!"' (992) Walter thus voices an issue similarly discovered by Diotima and Ulrich: in a time without qualities, each characteristic is necessarily paired with its opposite and no quality alone can do justice to the world.

1.3 Synthesis of the Poles of Mathematics and Mysticism

A dramatic change of orientation from the pole of mathematics to the pole of mysticism is said to take place in Kakania in the decades around 1900. Born in 1880 or 1881 Ulrich has experienced the '"growing rationality"' (235) and fast progress in the sciences that characterise 'the mood and the tendency of a period – a number of years, hardly of decades – of which Ulrich was just old enough to have known something. At that time people were thinking – "people" is a deliberately vague way of putting it, as no one could say who and how many thought that way; let us say it was in the air – that perhaps life could be lived with precision.' (265) The professed vagueness also extends to the question why the period of precision ends, but it is only said that a counter-movement towards uncertainty occurs in the beginning of the twentieth century, its supporters holding 'that pure knowledge tore apart every sublime achievement of mankind' (268) and 'screaming to have their sores rubbed with soul' (269). By 1913, the time of the novel's setting, the reaction against reason has taken over to such an extent that 'in the opinion of nonmathematicians' (36) almost all problems are explicable by the fact that the time's '"spirit of cold calculation and brute force has lost touch with the soul"' (621). Set at the far end of damaging rationality, mathematics in particular is blamed for the ills of the period: 'those who must know something about the soul (considering that as clergymen, historians, and artists they draw a good income from it) all testify that the soul has been destroyed by mathematics and that mathematics is the source

of an evil intelligence that while making man the lord of the earth has also made him the slave of his machines' (36) According to these views, the soul is the very antithesis of mathematics: 'It is simply that which sneaks off at the mention of algebraic series.' (106) Opposed to the soul as the seat of virtuous emotions, mathematics is also farthest removed from value: '"they could make of murder the noble virtue of bravery, but it seems doubtful to me that something of the sort can be done with calculating[8]: there is no real goodness, no dignity, no depth of feeling in it"' (592). In conclusion, the nonmathematicians hold that 'mathematics […] was also the primordial mother of the spirit that eventually gave rise to poison gas and warplanes' (37), which suggests that if Moosbrugger as one of the 'chemically pure souls' (198) embodies the negative implications of the sphere of reason's Others, so an excess of mathematics might have similar consequences. The tone of exaggeration in the descriptions of the non-mathematicians' views clearly indicates criticism of such unsophisticated advocates of the soul, but at the same time, the mathematician Ulrich is portrayed as not embracing purely mathematical views either: seeing that either mathematics or the soul alone results in violence, Ulrich asks for 'bringing together again what had fallen apart' (648) in a synthesis of mathematics and mysticism.

Ulrich is suited to the task of bringing together the contradictory tendencies of the period – '"let's call it a kind of synthesis"' (510), he proposes – not least because he combines aspects of both mathematics and mysticism: while as a mathematician he is particularly prone to losing his soul, his adversary Arnheim attests him to have 'reserves of soul as yet untapped' (598). Indeed, Ulrich feels himself to be the personified antagonism of the two poles between which life unfolds: 'his life, if it had any meaning at all, demonstrated the presence of the two fundamental spheres of human existence in their separateness and in their way of working against each other' (648). The dissociation of the foundational elements of life renders the question '""How should I live?"" (972) impossible to answer: '"Maybe our morality is already splitting into these two components. I might also say into mathematics and mysticism."' (837), Ulrich suggests. The idea is given additional weight when Ulrich is described as not having been 'so openly excited about anything in years. The "maybe"s in his speech did not trouble him; they seemed only natural.' (837) Divided into separate and opposed categories, morality cannot take account of the whole of life, and Ulrich's 'state of moral arrest that had oppressed him for a long time […] might simply be the result of his failure to bring these two tracks together' (647). Choosing either one of the 'two kinds of outlook' (268) does not constitute an appropriate answer to the question of the right way to live: single-minded mathematics 'is satisfied to be precise' and mysticism

[8] 'Rechnen' (542).

'always looks at the whole picture and derives its insights from so-called great and eternal truths', so that 'a pessimist could say that the results in the first case are worth nothing and in the second case are not true' (268). As Ulrich is just old enough to have witnessed, the 'pendulum of evolution' swings 'between these two poles of Neither and Nor' (268), but only a synthesis of the poles could take account of both fundamental spheres and determine a valuable orientation in life.

Given the growing disintegration, the pre-war period might be the last opportunity to mend the century-old split between mathematics and mysticism that is suggested to begin in the scientific revolution with its figurehead, 'the great Galileo Galilei, always the first to be mentioned in this connection' (326). As Allen Thiher notices, it 'sometimes appears, indeed, that Ulrich actually wants to leave the modern world to go back to the scientific revolution of the seventeenth century and to reunite the irreconcilable epistemologies that emerged then' (Thiher 232). The feeling of 'homesickness, a longing to be stopped, to cease evolving, to stay put, to return to the point before the thrown switch put us on the wrong track' (28) can thus be related to the wish for a view of the whole not yet divided into mathematics and mysticism.[9] Yet, even in the time of a diametrical opposition of mathematics and the soul, the realm of reason always implies that there are domains it cannot comprehend. The area where actions seem to be 'always reasonable' (196) resembles 'a semicircle before one, but the ends of this semicircle are joined by a string' (196), and although the half where everything seems 'understandable and self-contained' (196) is wholly enclosed, it does not give the impression of being complete but is always 'accompanied by an obscure feeling that it is only half the story' (196). The incomprehensible, ungraspable then constitutes the 'half that is always missing even when everything is a whole, this is what eventually makes one perceive what one calls the soul' (196). The semicircle of reason thus always implies the half of the soul, and in order to take account of the whole world, Ulrich approaches the synthesis of the poles of mathematics and mysticism from a rational perspective.

The '"World Secretariat for Precision and Soul"' (651) is Ulrich's attempt to achieve a synthesis of the two spheres through a rational institution of order, but since the pole of mysticism is opposed to the violent appropriation of reason, it cannot be ruled by precision, and although Ulrich again and again returns to his suggestion of bringing about a fusion by

[9] The idea of returning to the origin of the divide between scientific and non-scientific worldviews is also present in Pynchon's *Gravity's Rainbow* which asks whether events in the seventeenth century could 'have been the fork in the road America never took, the singular point she jumped the wrong way from' (*GR* 658). Responsible for 'put[ting] us on the wrong track' (28) of separating the essential domains of life are the Elect, among them Pointsman whose very name suggests his responsibility for switching the tracks of history.

rational means, he insists to have made the proposition only '"in fun, for while we created science a long time ago for truth, asking for something similar to cope with everything else would still appear so foolish today as to be embarrassing"' (805-6). Approaching the synthesis from the point of mysticism allows Ulrich to experience both halves of the world in what he calls the Other Condition. In contrast to Moosbrugger who enters a near-mystical state by killing the disconcerting female Other, Ulrich forms a unity with his sister Agathe who, as a female version of himself, makes him whole. The fusion with the female sphere constitutes one of the 'ecstatic moments in which a split has not yet occurred' (931), and as morality is not yet separated into the halves of mathematics and mysticism, the Other Condition is 'the only state in which there exists a morality without interruption' (898). However, the synthesis cannot serve as a model for the world at large, since it entails withdrawing from reality into an Other Condition.

Ulrich's attempts at a synthesis either from the side of ordering reason or by the means of mysticism fail. Yet, another way of taking account of both the halves of mathematics and mysticism emerges in *The Man without Qualities* when the poles are not taken as endpoints of a one-dimensional opposition but as the poles of the world or as opposite positions on a circle: the poles are still contrasted but also connected by the circumference, that is, by the '"whole circle of questions"' (972) itself. The poles of mathematics and mysticism thus need not be forced into a synthesis at the empty centre of the circle, but they are joined through an infinite number of intermediate positions on the circumference, enabling not a fusion but a transition between the poles, thus also respecting nature's 'peculiar preference' of 'gradual transitions' (261). The circular connection of the poles appears in the novel when mathematics is not only presented as constituting the pole of rationality but also participates in at least two states of transition: in the more mystical exploration of book 2, the idea of mathematical exactitude is combined with the non-rational and mystical elements emerging with the counter-movement in the foundational crisis of mathematics, while the corresponding transition from mysticism to mathematics is marked by statistics when a large number of random individual cases combines into the regularity of a general mathematical law. Given that mathematics features both as the pole of reason and in the transitional states on the circumference connecting the polar halves of life, the impossible synthesis of the poles is replaced with the more appropriate method of answering the circle of questions with a circle of answers.

2. Mathematics and Morality: Mathematics as a Model for Living

Musil studied mathematics and physics[10], and both his fictional and non-fictional writings document his engagement with contemporary scientific discussions and the wider influence of the drastic changes in scientific knowledge: 'the most basic principles of mathematics are logically unsecured; the laws of physics have only an approximate validity, and the constellations move in a system of coordinates that nowhere has a locus' (Musil *Precision and Soul* 63). With its humorous and exaggerated tone, Musil's essay 'The Mathematical Man' (MM) from 1913 paints a very clear picture of the impact of mathematics on other domains of life:

> We may say that we live almost entirely from the results of mathematics […]. With the exception of a few handmade pieces of furniture, of clothing, shoes, and children, everything comes to us through the intervention of mathematical calculations. [… Life] is not only dependent on mathematics for its comprehensibility, but has effectively come into being through it and depends on it for its existence (MM 41).

Due to the vital role of mathematics, the questioning of its foundations has immense effects on life at large:

> the pioneers of mathematics formulated usable notions of certain principles that yielded conclusions, methods of calculation, and results, and these were applied by the physicists to obtain new results; and finally came the technicians, who often took only the results and added new calculations to them, and thus the machines arose. And suddenly, after everything had been brought into the most beautiful kind of existence, the mathematicians […] came upon something wrong in the fundamentals of the whole thing that absolutely could not be put right. They actually looked all the way to the bottom and found that the whole building was standing in midair. But the machines worked! We must assume 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. (MM 41-42)

The crisis in mathematics undermines life, but Musil also proposes the new method of thought emerging in the foundational crisis as a model to cope with the unprecedented situation: 'all intellectual daring today lies in the natural sciences. We shall not learn from Goethe, Hebbel, or Hölderlin, but from Mach, Lorentz, Einstein, Minkowski, from Couturat, Russell, Peano …' (*Precision and Soul* 13) In *The Man without Qualities*, the idea that 'mathematics, the mother of natural science and grandmother of technology' (37) can lead to a new mode of living underlies its description as 'the very wellspring of the times and the primal source of an incredible transformation' (35), and its transformative potential is explicitly set in relation to human existence: 'If we translate "scientific outlook" into "view of life," "hypothesis" into "attempt," and "truth" into "action," then there would be no

[10] Evaluations of Musil's expert scientific knowledge for example in: Adams; J. Kraus; Albrecht 'Mathematische' 226 and 235; Hoheisel 449.

notable scientist or mathematician whose life's work, in courage and revolutionary impact, did not far outmatch the greatest deeds in history.' (37) The following will examine the presentation of mathematics in the novel, its interrelation with wider concerns of the time, and the changing relation to the pole of mysticism that is brought about in light of the drastic developments of mathematics in the foundational crisis.

2.1 The Pole of Mathematics: Modern Mathematics

As a mathematician Ulrich is, so Thomas Sebastian claims, 'so well informed that the reader is forced to take several crash courses in scientific theory to appreciate the author's relentless appropriation of scientific ideas' (Sebastian 64). Sebastian's example, namely 'Ulrich's familiarity with "the law of the large numbers" [which] demonstrates the author's declared intent to make him "a man equipped with the most advanced knowledge of his time"' (Sebastian 64) is rather unhappily chosen, considering that the law of large numbers was described by Siméon Poisson in 1835, thus hardly constituting an instance of the most advanced knowledge in 1913. Yet, it is evident that Ulrich's mathematical knowledge is indeed up to date when he is concerned with contemporary questions regarding the foundations of mathematics: 'He was one of those mathematicians called logicians, for whom nothing was ever "correct" and who were working out a new foundational theory[11].' (939) Ulrich's mathematical orientation suggests that it is not a specific mathematical law but rather the philosophy of mathematics that is at the core of Musil's appropriation of scientific ideas, and this indirect employment makes a crash course in scientific theory even more necessary. Based on the overview given in the introductory chapter of what the historian of science Herbert Mehrtens calls modern and counter-modern approaches to rebuilding the mathematical foundations, the respective tendencies and their implications in *The Man without Qualities* will be examined and set in relation to Ulrich's main reason for doing mathematics: 'while he was writing treatises on mathematical problems or mathematical logic, […] there was only one question worth thinking about, the question of the right way to live.' (275)

a) Modern Mathematics and Reality

Logicism, the school Ulrich follows to develop a foundational theory for mathematics, emerges out of the nineteenth-century thought 'that perhaps life could be lived

[11] 'Fundamentallehre' (865).

with precision' (265) and that mathematics could be established as an 'always reasonable' and 'self-contained' (196) domain by setting it on purely logical foundations. In the novel, logicism is placed at the end of a development begun by Galilei whose 'superficial' (326) description of surface phenomena supersedes finding the explanation of events in the essence of nature. Since Galilei's method of inquiry no longer refers to the inner quality of nature, it entails a loss of essence out of which arises 'our era's moral decay' (326). In the twentieth century, mathematics is no longer taken to be the prime tool for the 'superficial' investigation of nature, but mathematics has lost this direct relation with reality and turned towards itself. The description of mathematicians in *The Man without Qualities* accordingly emphasises the self-containment of mathematics: being 'security chiefs of logic' and 'addicts of some strange pale drug that filled their world with visions of numbers and abstract relations' (44), mathematicians resemble 'racing cyclists pedaling away for dear life, blind to everything in the world except the back wheel of the rider ahead of them' (37). The fact that Ulrich retires from the outside world when doing his mathematical work further highlights the artificiality of mathematics: 'He had drawn the curtains and was working in the subdued light like an acrobat in a dimly lit circus arena rehearsing dangerous new somersaults for a panel of experts before the public has been let in.' (115) Removed from nature into an artistic sphere, Ulrich works on new moves that have to be approved by the mathematical community before being released for application in the world.

When Ulrich decides to take a holiday from life 'since the possession of qualities assumes a certain pleasure in their reality' (13) but he has 'lost the capacity to apply them' (44), he plans to remove himself from the world. His turn away from reality, reverting to the realm of his own thoughts and arguing that concerning reality, '"[a]ll one can do is refuse intellectual participation in it"' (296), mirrors the turn of mathematics towards itself and has the result that Ulrich's 'connections to the world had become pale, shadowy, and negative' (285-86). However, an encounter between Ulrich and the fellow scientist Dr. Strastil shows that Ulrich is also critical of relinquishing the possibility of having an impact on the world. Strastil is on her way to a holiday in the mountains, and her life is suggested to have no more direct relation to physical reality than mathematics when she reacts indignantly to Ulrich's question as to 'what she needed nature for. […] She could lie on the mountain meadow for three whole days without stirring' (940). That Strastil does not feel any inclination to interact with or act upon nature suggests that the self-containment of mathematics also translates into her private life, while Ulrich's reply that a farmer would be bored by merely laying on the grounds he usually ploughs, illustrates his belief that nature has to be worked on in order to bear fruit.

The two scientists illustrate further aspects of the modern notion of mathematics when their wording alludes to concerns raised in the foundational crisis. Strastil 'doubted that he was feeling on a sufficiently elementary level' (940), thus pointing to the necessity of considering the very basis of questions, and she demonstrates her interest in core topics of the foundational crisis when referring to the categories of possibility, correctness, and truth: '"Do *you* think Kneppler's deduction is possible?"' (939) She then explains her standpoint: '"I don't think Kneppler's deduction is mistaken, it's just that it's wrong"' (939). Hoheisel maintains that Musil here criticises the scientific discourse, particularly by making fun of the 'one-dimensionality of the scientific approach'[12] (Hoheisel 385). While Strastil, the scientist with 'an exceptionally developed capacity for abstract thought and a notably retarded understanding of the soul' (941), is obviously ridiculed, on a different level, her distinction between 'mistaken' and 'wrong' deductions indicates the serious matter of the precision of mathematics and its problematical transfer to everyday language: 'She might have said with the same firmness that she did consider the deduction mistaken but nevertheless not essentially wrong. She knew what she meant, but in ordinary language, where the terms are undefined, one cannot express oneself unequivocally.' (939-40) Strastil holds that the definition of terms enables unambiguous expression in mathematics, but her struggle with the wording reveals that mathematics cannot be translated into the 'holiday language' (940) and context of everyday life, particularly regarding the category of truth. Furthermore, the fact that Strastil asks for Ulrich's opinion on the possibility of Kneppler's deduction suggests that mathematics is not a field of indisputable statements, but that the evaluation of deductions can differ according to personal conviction. Indeed, the mathematical community at the beginning of the twentieth century is divided into the schools of logicism, formalism, and intuitionism, so that the decision whether a deduction is proclaimed right or wrong can depend on a mathematician's adherence to a particular school, and it makes a difference whether there is a mistake in Kneppler's deduction or Strastil disagrees with his fundamental understanding of what mathematics is.

Ulrich's response to Strastil's problem indicates a further complication of the matter: he only shrugs, being 'one of those mathematicians called logicians, for whom nothing was ever "correct" and who were working out a new foundational theory[13]' (939) and moreover are 'not entirely satisfied with the logic of the logicians either. Had he continued his work, he would have gone right back to Aristotle' (939). His dissatisfaction with the logic of the logicians is a sign of the logical paradoxes that had been discovered by the turn of the

[12] 'Eindimensionalität der naturwissenschaftlichen Arbeitsweise'.
[13] 'Fundamentallehre' (865).

century and jeopardised the project of setting mathematics on a logical basis, but Ulrich's shrug also indicates that, strictly speaking, judging a deduction is impossible as long as there is no generally agreed foundational theory. The short exchange between Ulrich and Strastil thus evokes central questions of the foundational crisis by highlighting inner-mathematical exactitude and the three foundational schools' contradicting claims to correctness and truth. The fact that mathematicians can have disparate opinions or none at all regarding the possibility of a deduction furthermore highlights questions as to the possibility of mathematical truth in general.

b) Modern Mathematics and Possibility

Ulrich cannot realise any quality but potentially possesses all qualities; he can therefore be described as a man of possibility and fittingly cultivates a 'sense of possibility' (10): 'Whoever has it does not say, for instance: Here this or that has happened, will happen, must happen; but he invents: Here this or that might, could, or ought to happen.' (11) In his youth Ulrich puts forward the idea that God 'probably preferred to speak of His world in the subjunctive of possibility […], for God creates the world and thinks while He is at it that it could just as well be done differently' (14). According to this view, the book of nature is not written in the unambiguous language of Galilei's representational mathematics, but in a language able to describe many possible states. The modern notion of mathematics is suggested to be such a language of possibilities, for example by David Hilbert who claimed in 1900: 'The mathematician will have also to take account not only of those theories coming near to reality, but also […] of all logically possible theories.' ('Mathematical Problems' 454) Bertrand Russell similarly asserted 'that mathematics is concerned not with (physical) existence, but only with the *possibility* of existence' (Benacerraf and Putnam 6).

Mehrtens explicitly refers to the sense of possibility in *The Man without Qualities* (Mehrtens 403) and characterises modern mathematics in young Ulrich's terms: 'The language of mathematics is quasi set in the subjunctive'[14] (Mehrtens 57). The thought that mathematics describes possibilities other than the one actualised in reality becomes common with the growing awareness in the nineteenth century that concepts such as imaginary numbers, non-Euclidean geometry, and higher dimensionalities might not have counterparts in nature but are nevertheless fruitfully employed in calculations (see introductory chapter). Musil takes up the case of imaginary numbers in his first novel *The Confusions of Young*

[14] 'Die Sprache der Mathematik steht gleichsam im Konjunktiv'.

Törless (1906) where Törless holds that √-1 '"doesn't exist […] there can't be such a thing as a real number that's the square root of something negative"' (*Törless* 81). His teacher more accurately explains that such concepts are not mathematical impossibilities but '"purely mathematical logical necessities […] mathematics is a whole world in itself"' (*Törless* 86). However, Törless is more interested in the way imaginary numbers enhance the possibilities of mathematics by solving problems in the imaginary domain and leading to a result once again expressed in real numbers: '"in that kind of calculation you have very solid figures at the beginning, which can represent metres or weights or something similarly tangible, and which are at least real numbers. And there are real numbers at the end of the calculation as well. But they're connected to one another by something that doesn't exist.' (*Törless* 82) In Törless's terms, mathematics makes use of possibilities outside the real domain but nevertheless leads back to it, '"like a bridge consisting only of the first and last pillars, and yet you walk over it as securely as though it was all there"' (ibid). A similar thought informs 'The Mathematical Man' and its emphasis on the self-containment of mathematics as well as on its potential to explore and enhance possibilities: 'one may call mathematics an ideal intellectual apparatus whose task and accomplishment are to anticipate in principle every possible case' (MM 40). Across Musil's writing then, not being directly connected to reality means having no definitive qualities but possessing possibilities, and regarding *The Man without Qualities*, Ulrich as the man without qualities is associated with the 'sense of possibility' (10) which is also expressed in modern mathematics, the new method of thought.

If mathematics is concerned with possibilities, then, so L. E. J. Brouwer explained, reality holds no special position in its system: 'Next to the really observed sequences with their determined parameter values, sequences with other parameter values are postulated as *possibilities*; the fact that only the observed values of the parameters occurred in reality is considered *accidental*.' ('On the Foundations' 54) In *The Man without Qualities*, the modern mathematician Ulrich similarly concludes the accidental nature of reality: '"everything that happens happens for no good or sufficient reason"' (140). This attitude explains why the man of possibility attaches 'no more importance to what is than to what is not' (11). The subjunctive of possibility as the language of the book of nature in the twentieth century thus questions the supremacy of physical reality and opens up a vast domain of alternative structures. The possibilities explored by a man or a language of possibility do not represent reality, but they are nevertheless related to it and not inferior to merely accidentally actualised reality. Rather, possibilities always bear the potential of being realised: a 'possible experience or truth is not the same as an actual experience or truth minus its "reality value"

but has […] something quite divine about it, […] a readiness to build and a conscious utopianism that does not shrink from reality but sees it as a project, something yet to be invented' (11). Seeing possibilities as potential realities, a man with a sense of possibility gives 'the new possibilities their meaning, their direction, and he awakens them' (12), thus taking the first step towards actualising them. The sense of possibility thus is presented as a major force in bringing about better states of reality: 'Utopias are much the same as possibilities; that a possibility is not a reality means nothing more than that the circumstances in which it is for the moment entangled prevent it from being realized – otherwise it would be only an impossibility.' (265) Exploring the possibility of utopia, the man of possibility is more concerned with and more effective in bringing about the right way to live than a man of reality who works in the confines of the imperfect actual circumstances. The limitations of acting only in view of reality are pointed out by Count Leinsdorf: '"*realpolitik* means *not* doing the very thing you would love to do […] politics must be guided not by the power of an idea"' (376). In contrast, not restricting oneself to existing structures can advance an ideal: 'morality was neither conformism nor philosophic wisdom, but living the infinite fullness of possibilities' (1116), and '[o]ut of all that "could be" there suddenly crystallizes, to the stunned amazement of everyone concerned, the "it is"' (559). The sense of possibility possessed by the man without qualities and inherent in modern mathematics thus might not have a direct effect on the world, but Musil's novel proposes that using the freedom to posit alternatives to accidental reality, it can induce change and keep in view the possibility of utopia.

c) Mathematical Precision: Ending the Dilettantism of Being Human

In Ulrich's view, the freedom of mathematics to explore possibilities correlates with its precision: since the scientific revolution, '"the world has known truth in thinking and accordingly, to a certain degree, rational freedom of thought"' (1116). In contrast, man's feeling has '"neither the strict discipline of truth nor any freedom of movement"' (1116) but is pressed into inflexible and arbitrary moralities that force the '"order and integrity of the emotional life"' (1116) and destroy the authenticity of the soul. Ulrich reasons that if truth in thinking entails its freedom, then achieving a similar precision in the domain of feeling should allow emotions the freedom to adjust to the conditions changed so drastically by scientific advance: 'science has developed a concept of hard, sober intelligence that makes the old metaphysical and moral ideas of the human race simply intolerable' (43). Seeing that 'we carry on our human business in a most irrational manner when we do not use those

methods by which the exact sciences have forged ahead in such exemplary fashion' (264), Ulrich examines the possibility of transferring the precision and consequent freedom of science to living and thus end the '"unpleasant feeling of dilettantism"' (231) that being human has about it.

The first chapter of the novel presents a common way of applying scientific precision to emotional questions, which does not lead to a more liberated way of feeling but streamlines and stifles it. When after a traffic accident the arrival of the ambulance allows the bystanders to abandon their half-hearted attempts to help and proves the organised rescue service to work well, the onlookers 'dispersed almost as if justified in feeling that they had just witnessed something entirely lawful and orderly' (5), and relieved from the need to feel unsettled or touched, a lady's 'queasy feeling in the pit of her stomach, which she credited to compassion' (5), is appeased. A technical assessment of the accident has a similar effect on the lady temporarily afflicted by compassion: learning that the breaking distance of the truck is too long, she can 'put this ghastly incident into perspective by reducing it to a technicality of no direct personal concern to her' (5). Moreover, when the lady's companion quotes accident statistics, the incident becomes a necessary part of a general picture, and this 'dispersonification by statistics'[15] (Adams 117) implies that the lady is 'on the unjustified assumption that she had experienced something unusual' (5). The professional response and the technical and statistical explanations thus transform a calamity asking for compassion into complacency seeing the accident's 'entirely lawful and orderly' (5) place in an organised system. In this case, the use of science does not heighten the truth and freedom of feeling but eradicates emotion in favour of knowledge and order.

The chapter following the citizens' reactions to the traffic accident features the man without qualities who does not replace feeling with scientific precision but employs it to examine the nature of being human. Observing passers-by from his window, he tries to calculate the 'leaps of attention, flexings of eye muscles, fluctuations of the psyche, […] all the efforts it takes for a man just to hold himself upright within the flow of traffic' (7). Ulrich estimates that summed up, such values common to everyday life would create 'far more energy into the world than do rare heroic feats' (7), and in the light of this everyday heroism he concludes the futility of his inborn wish to become an important man: '"No matter what you do, […] within this mare's nest of forces at work, it doesn't make the slightest difference!"' (7) With his precise examination of life, Ulrich thus arrives at a new evaluation of moral questions and his ambitions, and concludes the absolute freedom of feeling and action. Yet, he also realises that a 'utopia of exact living' (263) leads to

[15] 'Entpersonifizierung durch die Statistik'.

favouring the objective criteria according to which the deeds of a sportsperson or a '"racehorse of genius"' (41) can be measured over the imprecise values of real 'genius and human greatness' (42). Reducing the notion of humanity and value to measurable entities runs counter to a liberation of feeling, and Ulrich consequently comes to oppose '"precision of feeling"' (627) and the professionalisation of life: '"I don't believe in the Devil, but if I did I should think of him as the trainer who drives Heaven to break its own records."' (539)

Instead of merely transferring mathematical precision to the domain of feeling, Ulrich wants the domains outside of reason to 'take flight' (897) from the level that knowledge has reached: 'The art of transcending knowledge must again be practiced.' (897) In an essay, Musil emphasised the superiority of using science rather than imitating it: there is a difference 'whether one […] as a half-scientific person whose imagination is gripped by the pleasures of science writes a pseudoscientific novel […], or whether one really goes all the way to the end of the trampoline of science and only then jumps' (*Precision and Soul* 67). While Musil here establishes the need for an informed use of science in relation to writing, the failing of the 'utopia of exact living' (263) in *The Man without Qualities* similarly shows that superficially transferring scientific precision to the realm of feelings is not fruitful, but that using it to explore life can lead to new insights. As a logician 'working out a new foundational theory[16]' (939) Ulrich has in-depth knowledge of the current development of mathematics and is in a good position to exploit science as a springboard towards answering 'the question of the right way to live' (275); in book 2, it bounces him into other directions than expected.

2.2 Transition from Mathematics to Mysticism: Counter-modern Mathematics

The last chapter of book 1 'The turning point' indicates a change in Ulrich's life, punctuated by his father's death. Ulrich is relieved of the ties with traditional morality that his father represents, and he also closes the chapter of rational research regarding the question of the right way to live when, shortly after the funeral at the beginning of book 2, he finishes 'his interrupted mathematical investigation' (782) which '"may well be the last piece of work that reaches back to that time"' (783). In fact, rational investigation is implied to destroy the old order embodied by Ulrich's father and to leave the remnants in a mess: when according to his father's last wish, the body is put 'at the disposal of science; after which anatomical intervention it was only natural to assume that the old gentleman had been hurriedly sewn up again' (772), the unity of the world of the father is literally destroyed by

[16] 'Fundamentallehre' (865).

science, and the community of mourners at the funeral is not held together by an intact entity, but 'at the center of this great, beautiful, solemn pageantry, was an untidily recobbled object' (772). The situation also illustrates the state of the modern world which has lost the moral order formerly guaranteed by God the Father and substitutes the empty place at the centre with a multitude of contradictory ideas that do not properly fit together. The concurrence of the funeral and the completion of Ulrich's last mathematical problem furthermore invites a comparison with the situation of mathematics where research has destroyed the body of orthodox beliefs and left it in pieces fought over by logicism, formalism, and intuitionism. When intuition plays an important role in the solution of Ulrich's last mathematical problem, the transition from his logicist orientation to a counter-modern strategy locating truth, meaning, and value in an inner origin associated with the pole of mysticism also signals the move from his rational investigation of the right way to live in book 1 to pursuing more mystical ways in book 2.

a) Intuition

Working on his last mathematical problem, Ulrich is

> helped in this unexpected solution by one of those random ideas of which one might say, not that they turn up only when one has stopped expecting them, but rather that the startling way they flash into the mind is like another sudden recognition – that of the beloved who had always been just another girl among one's friends until the moment when the lover is suddenly amazed that he could ever have put her on the same level as the rest (782).

Ulrich thus experiences the situation that 'one's ideas seem to have come of their own accord instead of waiting for their creator. This disconcerted feeling is nowadays called intuition' (116). The example of the suddenly recognised love for a friend indicates that in Ulrich's distinction between the poles of life, the intuitive idea is related to the realm of mysticism and love. The solution of the mathematical problem is therefore not entirely part of the semicircle of reason, but such intuitive answers are 'prompted by some stimulus outside the scope of everyday scientific activity' (748) and are 'never purely intellectual, but involve an element of passion as well' (782). Although not originating in the domain of precision and truth, intuitive understanding 'was well grounded and its deductions were highly probable[17]' (748), and defined as 'the affinity and coherence of the things themselves, meeting inside a head' (116), the conclusions intuition arrives at are no less true than rational deductions. Intuition can even be more accurate: 'there are so many problems where one's

[17] 'von großer Wahrscheinlichkeit' (688).

rheumatism happens to be a surer guide than science' (591). Arnheim gives the example of playing billiards to illustrate that intuition can answer problems that are practically irresolvable by precise means: taking account of all the determining forces results in incalculable complexity, even a layperson '"must be enough of a mathematician to see that it would take a life-time to plan a single carom shot in that fashion; we are abandoned by reason[18]!"' (622). In contrast, dismissing reason from the outset and hardly thinking about playing the ball, the task almost solves itself. Arnheim argues for the general applicability of the rule derived from billiards: '"politics, honor, war, art, all the crucial processes of life, take place beyond the scope of the conscious mind. Man's greatness is rooted in the irrational."' (622) In the course of the novel Arnheim's arguing for the precedence of the irrational and the soul is counteracted by the revelation of his exceedingly rational preparations to profit in the case of war, and he is frequently contradicted by Ulrich's arguments as to the value of reason. When completing his mathematical problem however, Ulrich experiences that intuition may take precedence over reason even in mathematics.

The implications of relating mathematics to intuition on a basic level are profound, as the history of intuitionism and its role in the foundational crisis reveal. While logicism and formalism only refer to rational means to secure the foundations of mathematics, intuitionism reacts against the implications of a purely logical or formal basis: the father of intuitionism claims that 'mathematics is independent of the so-called *logical laws* (laws of reasoning or of human thought)' (Brouwer 'On the Foundations' 72). The foundational dispute between modern and counter-modern mathematics thus also revolves around the question 'whether mathematics could be regarded as rational' (Gray *Plato's Ghost* 407), and modern and counter-modern views of mathematics are further contrasted regarding the place allocated to man, a consequence of their definition of mathematical truth and existence: in modern terms, mathematical existence is defined as absence of contradiction, while the counter-modern view emphasises 'the *individual consciousness* as the source and seat of all knowledge' (Stigt 4) (also see introductory chapter). [19]

Comparable to the opposition of views in the foundational crisis of mathematics, in *The Man without Qualities*, the focus on man's soul and the absolute individuality of insanity that is set at the pole of mysticism is contrasted to mathematical abstractness and generality: '"to be wholly objective […] is almost the same as being impersonal"' (518),

[18] '"der Verstand läßt uns einfach im Stich!"' (570).

[19] For a discussion of the influence of modern and counter-modern mathematics on Musil's *The Confusions of Young Törless*, see Justice Kraus. Kraus sets the presentation of mathematics in *Törless* in relation to Cantor's notion of infinity, Hilbert's role in the self-referential turn in mathematics, and Brouwer's critique of language.

Ulrich explains. A childhood memory shared by Agathe and Ulrich points to the opposition of general mathematics and a concrete individual: when a house is being built in the garden, the young siblings plan to smuggle slips of paper with beautiful verses into the walls, but as they do not come up with a poem 'Agathe copied a sentence out of her arithmetic book, and Ulrich wrote: "I am …" and added his name' (768). Apart from highlighting the opposed qualities of impersonal mathematics and an individual name, the contributions also exemplify the division of mathematicians at the beginning of the century: forced to act when 'the walls were already rising out of the foundations'[20] (767), Agathe throws an arithmetical sentence into the building pit and thus helps construct a building on mathematical grounds, while when slipping 'Ulrich's name into the wall' (768) the individual itself is involved in the building of mathematics. Shortly after this childhood memory, Ulrich solves his mathematical problem with the help of intuition, and he also draws closer to the pole of mysticism when beginning to examine the general question of how to live through the personal relation to his sister.

The different evaluations of the place of reason and the human being in mathematics have implications for the notions of truth and value and thereby affect Ulrich's investigations into the right way to live. In modern mathematics, existence is defined as absence of contradiction, and having thus 'stripped mathematics of any meaning at all' (Breger 253) it has no intrinsic value. Counter-modern intuitionism is related to reality via the human intuition which guarantees its meaning and value in the world: mathematics originates from 'exceptional, gifted minds; but the minds and their talent are nature, and therefore their products, the language of mathematics, have a scientific explanation and justifiable value'[21] (Mehrtens 285). Moreover, being related to and having value in the world, counter-modern mathematics includes a moral aspect. The focus is evident in Brouwer's intention to call his PhD dissertation 'The Value of Mathematics' before settling on the actual title 'On the Foundations of Mathematics', and in his demand to pursue mathematics not for its own sake but in view of moral value: 'Let the motivation behind mathematics be the craving for the good' (Brouwer qtd. in Dalen 82). The counter-modern strategy of relating mathematics to reality via intuition originating in the human mind thus guarantees the meaning and value that is lost in the modern notion of mathematics.

[20] The German term 'Baugrube' (707) ('building pit') does not directly allude to the foundational crisis but nevertheless refers to the basis of the enterprise.

[21] 'den besonderen, begabten Köpfen; die Köpfe und ihre Begabung aber sind Natur, und darum haben auch ihre Produkte, die Sprache Mathematik, eine naturwissenschaftliche Erklärung und einen begründbaren Wert'.

In *The Man without Qualities*, Ulrich shares the intuitionist concern with value; his mathematical work is ultimately directed at 'the question of the right way to live' (275). He consequently toys with the idea of transferring the intuitive insight from mathematics to life at large: 'He glimpsed the possibility of applying the idea that had solved his problem to other, far more complex problems' (782). Yet, he quickly dismisses intuition as a comprehensive means of explanation: 'Whether one called it divine illumination or, in the modern fashion, merely intuition, he considered it the main hindrance to real understanding.' (831) Seeing that purely intuitive ideas 'that would not stand up under careful investigation' (831) are only an excuse for 'all those who could not justify what they did by logic' (595), Ulrich once again arrives at the conclusion that a synthesis of the two poles of life is needed. Significantly however, Ulrich's experience of non-rational solutions in the domain of reason reveals that the opposition between the poles is not absolute but that the intuitionist notion of mathematics inhabits a transitional position between the understanding of mathematics as the impersonal acme of reason and the individuality and subjectivity of the pole of mysticism.

b) Mysticism

Relating mathematics and mysticism is not uncommon as belief in holy or unlucky numbers shows, but in the course of collecting suggestions for the jubilee year, Ulrich comes across a particularly curious instance of number mysticism in a proposal to issue an order 'favoring four-stroke letter series in shop signs' which would 'turn out to be a blessing for all mankind' (378), given the great satisfaction when 'the number of straight strokes in the big block letters of the shop signs' (377) divided by the number of letters comes out right. While at first sight merely ridiculous, the proposition 'can be attributed to a boom for inventors of languages and writings around 1900'[22] (Stockhammer 266), and in the light of the wish to determine the basic rules of language and construct a universal system, the research into the foundations of mathematics turns out to be only one example of a wider move towards rationalising language. Moreover, the link with language highlights the mystical implications of intuitionist mathematics and strengthens the idea of a transition between the poles of mathematics and mysticism in *The Man without Qualities*.

Brouwer 'connects his discipline with mysticism'[23] (Mehrtens 558), and as a strong character unerringly pursuing his individual views and antipode to Hilbert's belief in reason,

[22] 'lässt sich auf eine Hochkonjunktur der Sprachen- und Schriftenerfinder um 1900 zurückführen'.
[23] 'seine Disziplin der Mystik verbindet'.

he was considered by some in the mathematical community to stray too far on the side of mysticism and even insanity. Brouwer, 'the radical of counter-modernism, posited the wisdom of the mystic against the alleged truth of science'[24] (Mehrtens 167), and while a mathematician arguing against the truth of science might have been perceived as not quite reasonable in the first place, the 'mysterious revolutionary' (Dalen II vii) was also famously eccentric. Albert Einstein even described Brouwer as 'somewhat mad' (qtd. in Dalen 619) and wrote: 'I consider him, with all due respect for his mind, a psychopath' (qtd. in Dalen 604). The drastic formulation is at least partly due to the fact that the addressee was Hilbert who was gravely ill and very upset about Brouwer's backlash after having him dismissed from the editorial board of *Mathematische Annalen* 'given the incompatibility of our views on fundamental matters' (Hilbert qtd. in Dalen 601). Yet, questioning reason, dismissing science in favour of mysticism, and living his views regardless of social conventions are characteristics that associate Brouwer with the non-rational, or, in the terms of *The Man without Qualities*, with the pole of mysticism and the soul.

Not only can Brouwer be seen as related to the pole of mysticism identified in *The Man without Qualities*, but he described mathematics itself as a near-mystical realm characterised by unity: 'it develops from a single aprioristic basic intuition, which may be called *invariance in change* as well as *unity in multitude*' ('On the Foundations' 97). Further tightening the relation to the non-rational domain, Brouwer explained that 'mathematical understanding is something like "yes" or "no" just like sleeping is something like "yes" or "no"' (qtd. in Dalen 83) and that '[m]athematics justifies itself, needs no deeper grounds than moral mysticism' (qtd. in Dalen 84). Moreover, while modern mathematicians set about the rigorisation of mathematics as a formal or logical language, Brouwer considered language to be only an insufficient instrument to express the reality of the mystical state and argued that mathematical intuition connected with 'the prelinguistic truth of nature'[25] (Mehrtens 285). According to Brouwer, when mathematical intuition enters time in the form of counting and is formalised into a mathematical language, the mathematician is already removed from the true mathematics which requires 'the mystic's passively being one with the world. When one turns into two, there begins the I, mathematics, the horror of interference with the world.'[26] (Mehrtens 261) Mathematical language is a step removed from its pure mystical state

[24] 'der Radikale der Gegenmoderne, setzte die Weisheit des Mystikers gegen die vorgebliche Wahrheit der Wissenschaft'.
[25] 'die vorsprachliche Wahrheit der Natur'.
[26] 'das passive Einssein des Mystikers mit der Welt. Wo aus Eins Zwei wird, beginnt das Ich, die Mathematik, der Schrecken des Eingriffs in die Welt.'

experienced by intuition, and therefore, getting rid of mathematics equals going back to mystical unity; Brouwer therefore claimed: 'One could see as the goal of one's life: Abolition and delivery from all mathematics.' (qtd. in Dalen 83) More generally, Brouwer believed all expressions of reason to be deplorable deviances from a mystical ur-state of bliss and real knowledge to be achievable only by renouncing reason: 'For those who relinquish the intellect, however, the world is anything but subtle or complex: it is immediately clear' ('Life, Art and Mysticism' 8). Ultimately then, Brouwer saw intuitionist mathematics as closest to but also as the first removal from a state of pre-linguistic mystical understanding.

In *The Man without Qualities*, research into language not only shows in the curious instance of number mysticism, but mirroring the case of mathematics where research into its own language results in the discovery of logical paradoxes and the foundational crisis, characters' growing awareness of words invokes a crisis of language. Significantly, the characters most acutely aware of problems in language are also most closely related to the pole of prelinguistic mysticism. In a letter to Ulrich, Clarisse's words disintegrate into meaningless components: 'My dar*ling* – my duck*ling* – my *ling!* Do you know what a *ling* is? I can't work it out.' (773), and she concludes: '"One can *never* express things. Least of all in a letter."' (777) Clarisse's experience of the deficiencies of language illustrates how the precise examination of the building blocks of language, performed by Ferdinand de Saussure for everyday language and at the centre of the foundational crisis for mathematics, provokes loss of meaning and threatens the possibility of communication while heightening the desire for unity in a prelinguistic mystical state.

Moosbrugger is also unable to put his experiences into words: all the 'words he did have were: hm-hm, uh-uh' (428). He does not engage in the rational dissection of language that reveals its meaninglessness, but, in contrast, is overwhelmed by the significance and power of words:

> It had happened that he said to a girl, "Your sweet rose lips," but suddenly the words gave way at their seams and something upsetting happened: her face went gray, like earth veiled in a mist, there was a rose sticking out of it on a long stem, and the temptation to take a knife and cut it off, or punch it back into the face, was overwhelming. Of course, Moosbrugger did not always go for his knife; he only did that when he couldn't get rid of the temptation any other way. Usually he used all his enormous strength to hold the world together. (259)

The quote illustrates how ambiguous language aggravates the incomprehensibility of the world and runs counter to Moosbrugger's need for unity, and only murder allows him to enter a near-mystical state where there is no disconcerting distance between language and the world as it is 'all meaning' (257). Thus, while Clarisse's breakdown of language into its

basic units reveals its arbitrariness and inherent meaninglessness in a similar way as does modern mathematics for its field, Moosbrugger's reaction of seeking refuge from the ambiguous nature of language in the perfect meaning in mysticism mirrors the intuitionist belief of mathematical meaning being set in a prelinguistic realm and impaired as soon as it enters formalisation. The relation between mathematics and the insanity of the two characters therefore goes deeper than allowed for by Cliver's statement that in the novel 'the engagement with mathematics seems to adversely affect the sanity of Musil's characters and in fact displaces the very distinction between the rational and the irrational' ('Maddening Mathematics' 75-76). Clarisse and Moosbrugger are not overexposed to mathematics, but it is their engagement with the fundamental question of the meaning of language, mirroring the foundational research in mathematics, that encourages their escapes into the unambiguousness of their own minds and the perfect meaning in mysticism. Since not only do number mysticism and overzealous exploration of language result in 'a flirtation with irrational thought' (Cliver 'Maddening Mathematics' 75), but non-rational and quasi-mystical elements emerge in mathematics itself, it moves away from the pole of pure reason and crosses over into the realm of mysticism. Having explored the crossover from the pole of mathematics as the acme of reason towards the pole of mysticism, the corresponding transition from the individuality of mysticism to general mathematics will be examined next.

2.3 Transition from Mysticism to Mathematics: The Order of the Average

Directly after finding an intuitive solution to his last mathematical problem, Ulrich reminds himself that mathematical progress does not rely on the inner qualities of an individual: '"what it finally amounts to is something remarkably impersonal […] everything serves an evolution that is both unfathomable and inescapable"' (784). Having accepted that mathematics remains impersonal despite the intuitive part in his final mathematical exercise and does therefore not lend itself to making a personal impact on the world, Ulrich plunges himself into the city crowd where he comes to feel that individual achievement is not only insignificant in science but that in general 'it is not oneself that matters but only this mass' (785). Individual characteristics dissolve in the face of the multitude which can display completely different qualities: 'Water, for instance, is less of a pleasure in excessive than in small doses, by exactly the difference between drowning and drinking' (321-22). Ulrich reasons that the period would itself be among the 'many things in the world […] that taken singly mean something quite different to people from what they mean in the mass' (321) if supposing that '"every one of them is stupid, but all of them together are

pregnant with the future"' (534). Arguing that a world bent on scientific truth is opposed to personality and that individuality is losing '"the longtime war against individuality"' (624), he discerns a development towards a focus on the general outcome, and given the fact that personal destiny '"is being displaced by collective processes that can finally be expressed in statistical terms"' (785), a general meaning might emerge from statistical description.

The so-called law of large numbers states that a general order emerges from many individual cases, since with a large number of incidents random factors balance. As Ulrich puts it in *The Man without Qualities*: '"one person may commit suicide for this reason and another for that reason, but when a great number is involved, then the accidental and the personal elements cancel each other out"' (532). Most values group around the highly probable average while extreme occurrences are unlikely, so that, Ulrich explains, the resulting normal distribution is vital for '"any possibility of leading an ordered life […]. If there were no such laws of averages, we might have a year with nothing at all happening, followed by one in which you could count on nothing for certain"' (533). At the same time, a general statistical order denies the individuality of feeling: 'these most personal sentiments could in fact be charted in sweeping statistical curves representing their mass distribution throughout the city' (564). Ulrich stands for this development when responding to the talk of love 'with the statistical curve that indicates the automatic rise and fall in the annual birthrate' (302), while Agathe suggests that impersonal statistical order might replace love as a means of transcendence: '"wouldn't it be lovely to be dissolved by statistics? […] It's been such a long time since love could do it!"' (785) Walking among the crowd, Ulrich indeed feels that being included in an impersonal mass can 'produce a physical well-being and irresponsibility amounting to folly' (786) and that '"when the false significance we attach to personality has gone, we may enter upon a new kind of significance"' (624). As Gerhard Meisel establishes, in the fair copy, which gives a revised version of the galley chapters, '[t]he category "probability" […] evolves as a central key concept'[27] (Meisel 247). Ulrich considers the advance of the 'average person' (fair copy 1206) which, since 'the average always is also something probable' (ibid 1208), means that 'gradually "probable man" and "probably life" would emerge in place of "true" man and life'[28] (ibid 1209). Considering the traffic accident at the beginning of the novel where the bystanders come to think of the victim not in terms of his true life or death but regarding its statistical probability and thus replace their compassion with the pleasure of seeing the accident's part in the overall

[27] 'Die Kategorie "Wahrscheinlichkeit" […] gerät […] zum zentralen Schlüsselbegriff'.

[28] 'Durchschnittsmenschen'; 'das Durchschnittliche ist immer auch etwas Wahrscheinliches'; 'nach und nach der "wahrscheinliche Mensch" und das "wahrscheinliche Leben" anstelle des "wahren" Menschen und Lebens emporzukommen begännen'.

statistical order, it remains doubtful whether the significance of statistics is a satisfactory alternative to dissolving in love.

Given that '"the moral sphere works more or less like the physical, as suggested by the kinetic theory of gases: everything whirling around at random' (535), morality is governed by the law of large numbers, and statistics could disclose the significance of its overall order. Since '"[c]onventional morality is a perfectly valid average and collective value"' (624), Ulrich wonders whether the average, and accordingly moral meaning, is grounded in '"laws of the collective phenomenon"' (532) or if it is '"simply by some irony of nature that […] the ultimate meaning turns out to be something arrived at by taking the average of what is basically meaningless"' (532-33). In other words, the average is either a meaningful characteristic of the whole or the most ordinary of all random happenings. In the fair copy, Ulrich examines the idea of the world developing according to 'a history of the average'[29] (fair copy 1206) and concludes that, since the average world is also the most probable world, its path 'would not turn out much differently if everything was left to chance in the first place'[30] (fair copy 1207). Indeed, if the average is the aim, then the randomness of history is the best way to achieve it; the world would have '"reached an aim in the peculiar manner of not having any"' (ibid 1208) and leading a good life would mean '"just following chance"'[31] (ibid 1208). Having reached this point, Ulrich is not in the mood of pursuing his thoughts further and doubts the fundamental thesis that it is possible to transfer the 'concept of probability to historical and spiritual events and to compare two areas that are so different'[32] (ibid 1209). His reluctance to accept the conclusion that '"our personal, individual share in all this makes no difference […we do] not affect this average term, which is all that God and the world care about"' (535) and his persistent concern with the question of the right way to live point to the different conditions on the general and the individual level; yet, the planes respectively associated with mathematics and mysticism are not separated but, so Ulrich argues, '"[e]verything partakes of the universal and also has something special all its own"' (624). The law of large numbers thus does not achieve a synthesis between the two aspects since considering the significance of statistics means disregarding the meaning of the individual, but it connects the levels, marking the transition between random single cases and a general statistical order in which the individual is mystically dissolved. The turn from the mathematical pole towards

[29] 'eine Geschichte des Durchschnitts'.
[30] 'nicht viel anders ausfiele, als er ist, wenn alles gleich nur dem Zufall überlassen bliebe'.
[31] '"erreichte auf die seltsame Art dadurch ein Ziel, daß sie keines hat"'; '"einfach dem Zufall zu folgen"'.
[32] 'Begriffe der Wahrscheinlichkeit auf geschichtliche und geistige Ereignisse zu übertragen und zwei so verschiedene Geschichtskreise einander gegenüberzustellen'.

mysticism, which is performed by the intuitionist understanding of man as the origin of mathematics, is thus mirrored by a transition from the level of individual parts to a mathematically describable whole.

The average of a large number of individual moralities in a period is itself an individual instance of the world across time, but the average of this whole cannot be determined since the development of the world is not complete. Each period in world history therefore presents 'unsatisfactory and, in themselves, false answers', and 'there might emerge the right and whole solution only when mankind had learned to put all the pieces together' (388). However, many '"partial answer[s]"' (64) taken together at least make a more general truth, and Ulrich consequently examines the possibility of studying not the whole described by statistics but, starting from the individual partial answers, tackling the problem of the question of the right way to live in the manner of 'mathematical problems that do not admit of a general solution but do allow for particular solutions, which one could combine to come nearer to a general solution' (388). A period therefore cannot be evaluated or directed towards the final general value but any solution is partial and worthy only in relation to a later revealed whole whose meaning, that is, the average, changes with the inclusion of every new period. A mathematical example clarifies the idea that '"the same act may be either good or bad, depending on circumstances"' (812) or on the next step in the development: if a negative number is multiplied by another negative number, it turns into a positive value; in this respect, '"[t]here's a plus in every minus. […] Some good in every bad."' (798) Ulrich devises the '"morality of the 'next step'"' (804) based on the idea that any moral judgement is always suspended: '"It's never what one does that counts, but only what one does next!"' (798) The problematic nature of such a form of preliminary and relative morality is immediately clear, as Ulrich points out: '"But then what matters after the next step? Evidently the one that follows after *that*. And after the *n*th step, the *n*-plus-one step!"' (799) The infinite succession does not allow for a definitive value-judgement or for working towards a better state of the world, so combining particular solutions 'to come nearer to a general solution' (388) cannot arrive at a synthesis of the individual and the general any more than following the mathematical model of statistics.

The failure to find meaning in the order of the average shows that the transitional state connecting individual cases and a general statistical order does not constitute a successful synthesis of the poles; moreover, since the binary opposition of mathematics and mysticism is broken down, a potential synthesis has to take account not only of the poles but also of the crossovers between them. In the novel, the method of exploring diverse positions on the '"circle of questions […] which has a large circumference and no center, and all these

questions are: 'How should I live?'" (972) is introduced under the name of 'essayism', and it also is the form in which science and literature, as well as mathematics and mysticism, meet.

3. Essayism: Between Science and Literature

An essay is a literary form that does not attempt to provide a full picture of an issue but examines it under specific aspects: 'A composition of moderate length on any particular subject, […] a composition more or less elaborate in style, though limited in range.' (*OED* 'essay') Ulrich's idea of essayism as a strategy of living proposes to examine the circle of questions in a similar manner: 'It was more or less in the way an essay […] explores a thing from many sides without wholly encompassing it […] that he believed he could most rightly survey and handle the world and his own life.' (270) It is specifically the 'literary model' (273) that informs the notion of essayism as a form of living, but the 'translation of "essay" as "attempt"' [33] (273) or 'trial, testing, proof; experiment' (*OED* 'essay') invokes scientific methods and the examination of possibilities in mathematics. As frequently discussed, *The Man without Qualities* itself displays characteristics of essayism when Ulrich examines aspects of life and morality from scientific and mystical perspectives and his views are further explored through reflections in other characters: 'Possibilities, perspectives, alternatives structure the narrative' (Peters 17) to the point that '[a]t times the novel ceases to be a narrative to become something like an encyclopedia that includes a series of essays' (Thiher 265). The presentation of 'Ulrich's puzzling attempt to shape his life according to the literary logic of essayism' (McBride 128) thus not only describes his way of surveying and managing life but also illustrates the structure of the novel itself.[34]

Combining scientific and literary qualities, the essay addresses the domain 'between religion and knowledge, between example and doctrine, between *amor intellectualis* and poetry' (273) or, in more general terms, it is 'a combination of exact and inexact, of precision and passion' (272). The very beginning of *The Man without Qualities* establishes this combination of scientific precision and a subjective, anthropocentric stance as the frame in which much of the novel unfolds. The first eleven lines of the novel are taken up by a meteorological description of the weather: 'A barometric low hung over the Atlantic. It

[33] 'Versuch' (253) means both 'attempt' and '(scientific) experiment'.
[34] Also see Walter Moser's 'The Factual in Fiction' and 'Zwischen Wissenschaft und Literatur. Zu Robert Musils Essayismus'; and Marie-Louise Roth's 'Essay und Essayismus bei Robert Musil'.

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 functioning as they should. The air temperature was appropriate relative to the annual mean temperature […]' (3). The technical account is then rephrased in one sentence in everyday language: 'In a word that characterizes the facts fairly accurately, even if it is a bit old-fashioned: It was a fine day in August 1913.' (3) As has frequently been pointed out, the scientific and the commonplace formulations refer to the same phenomenon so that the diverse styles of description introduce a competition between the two spheres while of course uniting them in the literary text itself.

In his non-fictional work, Musil further describes the essay's state in-between disciplines: 'It takes its form and method from science, its matter from art. […] [I]t proceeds from facts, like the natural sciences […]. Except that these facts are not generally observable, and also their connections are in many cases only a singularity. […] But the essay does present evidence, and investigates.' (*Precision and Soul* 49) That the essay 'proceeds from facts' meets Ulrich's concern for reality that becomes particularly clear in the galley chapters where he demands 'some kind of distinction between "reality" and "full reality," or the distinction between "reality for someone" and "real reality,"' (galley 1303) and stresses the fruitful focus of the natural sciences which '"placed the question of what is real ahead of the question of what is logical […] nature appears to have been waiting for just such a lack of philosophy in order to let itself be discovered"' (galley 1244). But even in book 1, Ulrich contemplates 'with revulsion' (649) that purely logical thinking resembles 'piling one ladder upon another, so that the topmost rungs teetered far above the level of natural life' (648-49), thus sharing a thought formulated in one of Musil's essays: 'If I want to have a worldview, then I must view the world. That is, I must establish the facts.' (*Precision and Soul* 155) The scientific qualities of essayism ensure this relation to the facts of reality. However, in order to determine the right way to live, Ulrich demands '"to experiment consciously"'[35] (693), and a world resembling 'a vast experimental station for trying out the best ways of being a man' (160) lacks this directing consciousness. Ulrich diagnoses: '"Today we live […] without any method of conscious, inductive thinking; we simply go on trying this and that like a band of monkeys."' (694) Since 'a conscious human essayism would face the task of transforming the world's haphazard awareness into a will' (271), undirected scientific experimentation is not a model for Ulrich's idea of essayism.

[35] '"das Bewusstsein des Versuchs"' (636).

While the scientific component of the essay ensures precision and the relation to reality, the exploration of subjective views and diverse possibilities is part of its literary side. The essay is 'the unique and unalterable form assumed by a man's inner life in a decisive thought' (273), and therefore always tied to a person and their subjectivity, essayism provides 'no total solution, but only a series of particular ones' (Musil *Precision and Soul* 49). Introducing a succession of partial answers and thus constantly being in 'intellectual movement'[36] (Musil 'Franz Blei' 1025) and open to development, essayism acknowledges 'that there is no such thing as "objective judgment," only a "living one"' (*Diaries* 426), and able to adapt to constantly changing life, it answers the demand 'for a new morality capable of fitting more closely the mobility of facts' (272) that is particularly urgent in a time of drastic change. Yet, a number of essays is not only a succession of unique expressions and partial answers, but taking together views from different perspectives, essayism can approach, if never reach, a general view. Thus, a subjective, particular essay is no more separated from reality than any personal feeling is from its surroundings: 'personal happiness […] is self-contained only as a stone is in a wall, or a drop of water in a river, which are permeated by the forces and tensions of the whole' (571). Essayism thus examines an issue with scientific precision and thereby arrives at an ordered and meaningful interpretation of it, while also addressing the whole of reality. A note to the novel shows that Musil considered *The Man without Qualities* in these essayistic terms: 'Quite presumptuously: I ask to be read twice, in parts and as a whole' (notes 1766). The succession of partial answers in the novel is thus suggested to create meaning on another level, and while reading *The Man without Qualities* in whole is not possible since it has remained a fragment, considering this fact together with the series of 'essays', essayism appears as a constitutive technique of the whole fragmentary novel and vindicates the incompleteness of each partial answer.

The literary component of the essay sets a sense of possibility against the scientific sense of reality when exploring individual cases and imagining possible developments of the current state, so that essayism has 'a readiness to build and a conscious utopianism that does not shrink from reality but sees it as a project, something yet to be invented' (11). However, the inventive and fictional nature of essayism that helps the creation of possibilities has to be combined with the relation to reality guaranteed by science in order to ensure essayism's potential impact on the world. Therefore, literature alone is not an adequate means of answering the question as to the right way to live, and similarly to the presentation of mathematics as the apex of reason but also as related to mysticism by the transitional

[36] 'geistiger Bewegung'.

positions of intuitionism and the law of large numbers, literature is portrayed as not having definitive qualities, but it assumes diverse states on the circle connecting the poles of mathematics and mysticism (see 3.1). The changeableness of literature is highlighted in the very first sentences of *The Man of Qualities* where scientific and everyday diction are contrasted, and the sense of possibility permeates the novel even down to the level of grammatical structure when the subjunctive of possibility is the dominant mood: 'Like the individual sentences and the chapters, the whole novel is ruled by the principle of the subjunctive of possibility.'[37] (Schöne 203) Thus, both the content and the form of the novel show that literature, similar to mathematics, is too variable to serve as a model for the right way to live, but that only a combination of scientific and literary qualities – of fact and fiction, the general and individual, the poles of mathematics and mysticism – can take account of the fundamental elements of life and explore the circle of questions.

3.1 Literature: Poles and Transition

Maybe least surprisingly, literature in *The Man without Qualities* is described as a means to express individuality and can take on aspects of the pole of mysticism: Arnheim holds that art '"should first reflect the unity of existence and its inner order"' (211), and the poet is presented as 'the voice of the inner life, […] or all mankind' who feels himself to be the medium of 'the mysterious whole' and to participate in a 'great irrational power' (323). Explaining that he stopped writing poems because of '"a growing aversion to the disorderly and bohemian romanticism of that sort of emotional excess"' (1042), Ulrich takes a critical perspective regarding the individual and mystical nature of literature, and a similarly sceptical evaluation is given in 'The Mathematical Man': 'whenever one reads two German novels in a row, one must solve an integral equation to grow lean again' (MM 42).

The contrast between the individuality of literature and the pole of rationality is strengthened when Clarisse encounters an insane painter and realises that '"even academic art […] has a sister in Bedlam"' (1068). Literature in particular is related to Moosbrugger's insanity through the figure of the philosopher Dr. Meingast who is claimed to be able to '"live by ideas"' (851). Thus constituting an unambiguous whole and inspiring others through his writing, Meingast is held to be a saviour: '"Salvation, after all, means the same thing as making one whole,"' so that '"[s]aviors may be wrong, but they make us whole again"'[38] (852). Meingast is associated with Moosbrugger who attains the mystical feeling of

[37] 'Wie der einzelne Satz, wie das Kapitel, so wird der ganze Roman vom Prinzip des Conjunctivus potentialis regiert.'
[38] In German the word for saviour is 'Heilbringer', 'heil' meaning both 'salvation' and 'whole'.

unity through murder, when he, Clarisse, and others observe an exhibitionist from Meingast's writing room. The 'afflicted man' (859) is 'filled with the utter ruthlessness of a killer' (856), but the sexual offence is also related to art: the change in the exhibitionist's mental state reminds Ulrich 'of a singer who has just finished eating and drinking and then steps up to the piano […] and, opening his mouth to sing, is partly someone else and partly not' (855). Meingast is explicitly connected to the exhibitionist when Clarisse calls the man outside a '"swine"' (857) and Meingast is reminded of his own behaviour: 'he had often heard her use such terms, provoked by his free-and-easy ways with her' (857) in her youth. Due to the association with Moosbrugger via the sexual offender, Meingast becomes a questionable representative of the 'great irrational power' that writers have access to, and his working for 'the mysterious whole' (323) is suggested to result in killing the Other that threatens to destabilise his unambiguous worldview. The capability of literature to get closer to the '"unity of existence and its inner order"' (211) thus also makes it vulnerable to the disorder and insanity of the pole of mysticism.

Despite its closeness to mysticism, writing can also be adapted to the scientific progress and rationalisation of the turn of the century, thus approaching the pole of mathematics. For example, Arnheim holds that due to the increased importance of the factual, the age of great individual writers draws to an end and that the '"poet and philosopher of the future will emerge out of journalism"' (704). Others thinks that writing a '"Thirty-five Mile" poem' (436) would be an appropriate response to the technical advance illustrated by the flight over the English Channel at thirty-five miles per hour and would allow them 'to chuck all the rest of our moth-eaten literature into the garbage' (436). Moreover, the inventor of the shorthand system Oehl proposes to rationalise the nature of writing itself and thus initiate an improvement in thinking, morality, and aesthetics: shorthand saves mental effort, it is 'crucial' from the 'moral standpoint' since longhand 'encouraged tendencies to imprecision, arbitrariness, and wastefulness', and finally, 'there was the aesthetic side of it. Wasn't prolixity rightly considered an ugly quality?' (379) Rationalised writing, adapted to the changed conditions of living in terms of its content or its form, no longer expresses disorderly '"emotional excess"' (1042) or a mystical unity but exhibits qualities from the pole of mathematics.

Writing, like mathematics, not only takes on features of the poles of life but is a medium which also marks the transition between the general order associated with mathematics and the individual views related to mysticism. The '"thread of the story," which is, it seems, the thread of life itself' (709) is a primary means to bring the chaos of reality into a 'unidimensional order, as a mathematician would say' (708-9): 'Most people relate to

themselves as storytellers. […] [T]hey love the orderly sequence of facts because it has the look of necessity, and the impression that their life has a "course" is somehow their refuge from chaos.' (709) The contradictory pre-war society 'has already ceased to be narrative' (709), while the thread of the story still orders the individual domain; only Ulrich 'had lost this elementary, narrative mode of thought' (709). The possibility of narrative thus marks the transition between a state of general order and many individual orders, and analogous to counter-modern mathematics which establishes individual intuition as a guarantor for meaningful mathematics after the loss of certainty on a general level, when the overall narrative order of reality is lost, it is up to the individual to create a meaningful story and life.

Lastly, writing also provides a means and example for the turn from the individual to the general. In Ulrich's eyes, literature should be used to generalise and distance oneself from life; he asks to consider 'our experiences less as something personal and real and more as something general and abstract, or with the detachment with which we look at a painting or listen to a song' (396). Living life in a manner 'more or less as they read' (399), people would have the open mind necessary to live 'poetically creative and morally experimental on a grand scale' (396). Yet, living ideas results in an inability to interact with reality: the exhibitionist is unable to talk to the girl he observes, but '[h]is imagination, ready to conjure up any possibility[39] that could even be suggested by a woman, became fearful and awkward when confronted with the natural possibility of admiring this defenseless little creature' (860); and more drastically, the suggestion that '"our existence should consist wholly of literature"' (397) implies that 'reality ought to be done away with' (396). Modelling life on literature thus does achieve a distance from individual life, but the detachment detrimentally affects the relation to reality.

General Stumm also feels the negative consequences of using literature to generalise life when visiting the library to gain an overview on culture and distil '"the finest idea in the world"' (501). The librarian does not read individual books but focuses on the '"general overview"' (568-69) provided by the '""bibliography of bibliographies""' (502): '""if you want to know how I know about every book here, I can tell you: Because I never read any of them""' (503). He thus attains a '"reliable *intellectual* order"' (505), but the abstract bibliography of bibliographies also prompts Stumm's insight into 'the paradox of excessive order' (569). He understands that absolute order makes development impossible: '"the perfect civilian state of order […] is death by freezing, it's rigor mortis, a moonscape, a geometric plague!"' (505) In a way reminiscent of the law of large numbers

[39] 'jede Möglichkeit (791).

that renders general statements possible but ultimately only points to the meaningless average, bringing the vast number of books into a graspable abstract order results in a dead excess of intellectual order: 'what is gained in order is lost in information'[40] (Meisel 226).

In *The Man without Qualities*, writing is presented not as a domain with unambiguous qualities but as taking on various positions on the circle connecting the poles of mathematics and mysticism. The variable form of literature thus cannot generally be said to achieve a synthesis of the fundamental elements of life, but only a literary genre that combines the individual and the general, the mathematical and the mystical, can perform a successful fusion.

3.2 Between Fiction and Reality: Mathematics, Accountability and Practical Fiction

Remembering one of their few shared childhood experiences, Ulrich and Agathe plan to 'write wonderful poems' (767) but unable to do so, they put an arithmetical sentence and Ulrich's name on two slips of paper. The idea of composing a literary piece thus splits into a general mathematical part and an individual component, but the possibility of combining both aspects in literature is nevertheless implied. The essay is suggested as the literary form in which a synthesis can be achieved, as an essayist is neither a scholar 'who wants the truth' in the general domain nor a writer 'who wants to give free play to his subjectivity' but a man 'who wants something in between' (274). Itself set between truth and subjectivity, the essay is then also a fitting form for examining morality which similarly takes an intermediate position: 'Examples of what lies in between can be found in every moral precept, such as the well-known and simple: Thou shalt not kill. One sees right off that that is neither a fact nor a subjective experience.' (274) While in reality killing is mostly disapproved of and sometimes, for example in war, accepted, 'in a very large number of cases of a third kind, involving imagination, desires, drama, or the enjoyment of a news story, we vacillate erratically between aversion and attraction' (274). Analysing how mathematics and law make use of this third domain outside the polarity of the either-or will show that in *The Man without Qualities* and other works by Musil the fictive affects the possibilities of essayism and, through it, can be used to shape reality towards a moral aim. Moreover, identifying a fictional component in the major ordering systems of reason and accountability, a crossover appears between literature and mathematics.

[40] 'was an Ordnung gewonnen wird, geht an Information verloren'.

a) Fiction and Mathematics

The essay, according to the notion developed in *The Man without Qualities*, examines an issue from different perspectives, but set between subjectivism and truth, its truth-value cannot be judged: 'Terms like true and false, wise and unwise, are equally inapplicable, and yet the essay is subject to laws that are no less strict for appearing to be delicate and ineffable.' (273) The characterisation equally applies to modern mathematics which, although following strict rules, 'isn't the sort of thing that can be appropriately evaluated in terms of truth and falsehood' (Field *Science* viii) either, since it does not refer to reality; indeed, the narrator in *The Man without Qualities* states that 'mathematics sometimes resorts to the absurd in order to arrive at the truth' (826). Musil's literary exploration of the role of absurd or imaginary elements in moral belief systems but also in rational mathematics reflects the contemporary concern with fictional elements in mathematics, voiced in the mathematical community at the time of the foundational crisis as well as in non-mathematical circles. On the mathematical side, Georg Cantor put freedom at the heart of mathematics, Henri Poincaré stated that 'mathematical reasoning has of itself a kind of creative virtue' (*Hypothesis* 3), and the physicist and philosopher Ernst Mach, about whose work Musil wrote his doctoral thesis, explained that concerning the mathematical concept of the continuum '[t]here can be no objection to such a system, considered as a fiction merely' (Mach 73) so that '[w]here experience raises no protest, we may hold fast to the convenient fiction of a continuum, which is in no wise injurious' (Mach 78).[41] In the non-mathematical sphere around 1900, Friedrich Nietzsche, whose name and thoughts are mentioned frequently in *The Man without Qualities*, Ernst Cassirer, Oswald Spengler, and Hans Vaihinger engaged with the idea of employing mathematics as a means to turn incomprehensible reality into understandable fictions (see introductory chapter).

In *The Man without Qualities*, the principle '"*Credo ut intelligam*"' (575) – 'I believe so that I may understand' – underlies the consideration that any order 'always rests in part on a voluntary faith in it' (575). This is true not only of the religious system in the light of which the Benedictine monk Anselm of Canterbury coined the phrase, but also applies to mathematics; Ulrich directly relates the two domains when comparing belief in the explanatory stories of the bible to the strategy of 'an arithmetician who, with the system of

[41] For a summary and evaluation of Musil's dissertation see Imai and Thiher 17-49. Thiher focuses on Musil's criticsm of Mach and concludes that 'Musil's reaction to Mach, in his dissertation and at times in his creative work, presents a role reversal of what one might expect from writer and scientist: the writer defends the truth of reality against the scientific epistemologist for whom the knowledge of laws or recurring functions is essentially a fiction created by autonomous scientists.' (Thiher 46)

his feelings spread out before him, concludes, from the fact that none of them could be justified, that he would have to introduce a fantastic hypothesis' (949). Through fantastic hypotheses, a fictive component becomes part of religion and mathematics, allowing them to better explain the world and get closer to truth, but the unreal, 'absurd' (826) element in mathematics also affects the world more directly: scientists divide up 'the world into atoms, laws, hypotheses, and curious mathematical symbols, and the technicians use all these fictions to build up a world of new things' (553). The physical world of things is thus taken to be based on the fictions of mathematics, and with a slight change in the wording, a statement from 'The Mathematical Man' illustrates the implications for life: 'our existence is a pale ghost; we live it, but actually only on the basis of a fiction [original: an error] without which it would not have arisen' (MM 42). The voluntary faith in a system and its fictive element is compared to a production credit, allowing real transactions to be performed with nonexistent capital; '"*Credo ut intelligam*"' (575) is translated accordingly into: '"O Lord, please grant my spirit a production credit!"' (575) In the beginning of the twentieth century when the foundations of mathematics are questioned and the mathematical fictions used 'to build up a world of new things' (553) are therefore in crisis, the credit is withdrawn from the world of things, contributing to the wider loss of belief: 'Kakania was the first country in our present historical phase from which God withdrew His credit: the love of life, faith in itself, and the ability of all civilized nations to disseminate the useful illusion that they have a mission to fulfill.' (575) The 'mysterious malady' (54) of the pre-war period stagnated in chaos can therefore be diagnosed to be caused by the loss of its production credit: 'So what has been lost? Something imponderable. An omen. An illusion.' (56) In Musil's first novel, Törless can still end in trusting the imaginary domain to work as an 'inexistent' bridge between the pillars of two real states: metaphors carry over meaning, fictional literature helps overcome the confusions of youth, and in mathematics '"you land safely in the end"' (*Törless* 82) when imaginary numbers lead back to the domain of real numbers. In contrast, in the credit crunch of belief in pre-war Kakania, the imaginary component is doubted and systems no longer work but the fundamental domains of mathematics, language, and the meaning of life are in crisis.

b) Fiction, Accountability, and Practicality

Having established that the most rational of the sciences 'resorts to the absurd in order to arrive at the truth' (826), a similar need for fantastical components becomes more easily justifiable in other domains of life. In *The Man without Qualities*, any moral order is

revealed to employ an imaginary element: men 'must believe that they are something more than they are in order to be capable of being what they are' (576), and man follows moralities 'not because they are sometimes true but because he needs to believe; because he has to keep his feelings in order' (1126). By regulating emotions, moralities render man capable of acting, so the imaginary element makes possible rather than impairs a system's effect on reality. Ulrich argues: '"there has never been such a thing as the true faith, the true morality, and the true philosophy. But the wars, the viciousness, and the hatred unleashed in their name have transformed the world in a fruitful way"' (141). The idea that fiction enables action is also central to Vaihinger's work: '*The Ideal is a practical fiction*' (Vaihinger 48) that can be employed 'as if' it existed and thus make life practicable, while '[w]ithout the imaginary factor neither science nor life in their highest form are possible' (Vaihinger 44). Vaihinger here identifies the importance of fiction for science in order to render its use more respectable in other areas, and he highlights the pioneering role of mathematics: 'The fictive judgment has in its essentials only developed in modern times, partly in connection with the progress of mathematics, mechanics and jurisprudence' (Vaihinger 95). Law as the most rationalised moral order then is a clear example that 'just as science, and especially mathematics, leads to the imaginary, so life leads us to the impossible' (Vaihinger 44), as for example evident when criminals are judged according to the ideal of responsibility even though 'absolute freewill and responsibility are impossible' (Vaihinger 44). Thus, according to Vaihinger as well as to *The Man without Qualities*, mathematics is only a particularly clear case of the general fact that systems are not practicable without making use of imaginary concepts.

In *The Man without Qualities*, mathematics and law are connected in their shared concern with reason. Moosbrugger's idiosyncratic calculation illustrates his state of diminished responsibility, and his case also highlights the impracticality of entirely factual assessments when the scientific enquiry of psychiatrists takes account of nature's 'peculiar preference' for 'gradual transitions' (261) but as they are 'absolutely precise: they did not dare say more than that Moosbrugger's clinical picture did not exactly correspond to any hitherto observed syndrome' (267). In contrast, juridical precision is not concerned with the individual case and 'not at all with the facts but only with the imaginary concept of cumulative law' (267), and disregarding Moosbrugger's actual mental state so as to satisfy the premise that 'between two contraries there is no third or middle state' (261) law renders possible a verdict based on the fiction of absolute responsibility. Ulrich is convinced that practicality will ultimately decide Moosbrugger's fate: 'the state would eventually kill Moosbrugger because in the present state of incompleteness this was simply the

cleanest, cheapest, and safest solution' (264). Thus, man dispenses with scientific precision and the reality of facts in favour of the feasibility granted by fiction even in matters of life and death.

Having lost a unifying fiction, the period at the beginning of the century disintegrates into many partial and contradictory ideas, and Ulrich predicts that leaving the time's '"too many possibilities of feeling"' (1127) unordered will result in the reduction of possibilities to the one-way street of nationalism: '"it's the Millennial War of Beliefs[42]. […] So the War Ministry can sit back and serenely await the next mass catastrophe."' (1127) With the war, '"the moral imagination has taken its revenge"' (1125) for the fact that, although 'every event that moves mankind arises from the imagination, only the purely rational problems have achieved an objective order' (1126). Indeed, 'when God cut off Kakania's credit' (576) and man misses 'something imaginary' (576) that has up to then secured life's foundations, it is proposed that 'a good Kakanian could have joyfully answered the question of what he was by saying: "Nothing,"' (577) while the moral imagination takes its revenge when the open possibilities of feeling and living are not taken as the freedom to make 'of a Kakanian everything he had never yet been' (577). Instead, seeing that the disintegration of practical fictions and loss of imaginary values renders the period impracticable, people in Kakania gladly take nationalism 'as a way of understanding the incomprehensible fact that there are seven days in the week. There are so many inexplicable things in life, but one loses sight of them when singing the national anthem.' (577) The loss of practical fictions other than nationalism thus has dire consequences when reality ends in the First World War.

Ulrich considers the possibility of preventing a war of beliefs by treating 'the moral imagination, or, more simply, feeling' (1126) in a scientific way: '"Today we are facing too many possibilities of feeling, too many possible ways of living. But isn't it like the kind of problem our intellect deals with whenever it is confronted with a vast number of facts and a history of the relevant theories?"' (1127) The '"quest for feeling"' (1128) could thus be advanced by a method analogous to the '"open-ended but precise procedure"' (1127) employed by reason to deal with the overwhelming number of possibilities in the 'quest for truth' (1128), and this rational method of handling possibilities might provide an alternative to the path leading into the First World War. The indefinite but precise scientific ordering of facts, never arriving at a final order but ensuring the veracity and practicality of reason, and the essential freedom of mathematics to endlessly explore its possibilities thus inspire Ulrich's idea of a morality that welcomes the absence of defining qualities as freedom: 'For

[42] 'Glaubenskrieg' (1038).

him morality was […] living the infinite fullness of possibilities' (1116). Since considering possibilities means imagining states apart from reality, a corresponding definition is: 'Morality is imagination' (1117). However, the moral imagination does not encompass any fiction: 'Imagination is not arbitrary' (1117); rather, it cannot be left to develop randomly but should emulate the order of reason. Taking morality to be a precise development of possibilities that is free to evolve but also open to conscious direction, the problem of a proliferation of possibilities after the loss of the unifying production credit is not neglected but handled in a similar way as '"our intellect deals with […] a vast number of facts"' (1127). If, however, imagination, and consequently morality, is left to develop arbitrarily, it expands in all directions and the 'various opinions lash out at each other since they have no way of communicating' (1117) until again finding unity in nationalism. The First World War then is implied to be a time which closes options and in which any morality, that is, 'living the infinite fullness of possibilities' (1116), is almost impossible. As Martin Swales puts it in an adaptation of the poet Karl Kraus' words: 'Possibility expired when that world awoke.'[43] (Swales 10)

The Man without Qualities explains the First World War as a result of the period's failure to follow Ulrich's suggestion to answer the loss of foundations and imaginary credit according to the model of the intellect and examine the question of the right way to live in an '"open-ended but precise procedure"' (1127). As is developed in more detail in the essay 'The Mathematical Man' and will be examined in the next section, mathematics as the language of possibility and new method of thought promises to show a route away from the restriction of possibilities in the First World War. Essayism, a never complete method reaching 'the strictest form attainable in an area where one can*not* work precisely' (Musil *Precision and Soul* 48), mirrors qualities of modern mathematics and is suggested in *The Man without Qualities* to be a form which allows handling the fundamental crisis of European culture in a similarly fruitful way as mathematicians respond to the crisis of mathematics.

[43] 'Die Möglichkeit entschlief als jene Welt erwachte.' Karl Kraus's last poem is a reaction to the takeover of the Nazi Party and ends in the line: 'The word expired when that world awoke.' (Kraus 259) Also compare with *Against the Day*'s illustration of a narrowing of choices in the pre-war West.

3.3 A Crisis Marked 'Fi'

The Parallel Campaign develops quickly even without an actual aim, that is, without its fundamental idea that is supposed to express the essence of the epoch. The 'swelling tide of written communication' is a measurable indication of the Campaign's progress: '"With reference to our mem. no. so-and-so, ref. to no. such-and-such/XYZ, no. this-and-that"; all these numbers grew larger with each communication. This in itself was already a sign of healthy growth.' (241) The numbered documents are not evaluated in relation to a central idea but refer to each other, and as a consequence of this self-referential turn, the system becomes an end in itself: 'The apparatus was set up, and because it was there it had to function, and once it was functioning, it began to accelerate [… and took] a very impressive and remarkable course of its own.' (241-42) Satisfied with the well-working machinery, Count Leinsdorf happily ignores the fact that he cannot be sure to see progress into the right direction as the Campaign is precisely unable to decide on its central idea and aim: 'he felt that the Parallel Campaign was on a good and proper way, and the true way would be found sooner or later'[44] (242). Similarly to the endless deferral defining the morality of the next step, the value of propositions cannot be judged until the essential aim of the campaign is settled on: '"we can't say yes and we can't say no as long as we have no really firm idea what our central goal is"' (242). Suggestions are therefore marked '"Fi"', that is: '"Filed for later decision,"' (242) and predictably, amassing vast amounts of files and dissolving into ever new levels of organisation, the Parallel Campaign loses sight of its original purpose. Also, the diverse and contradictory time makes a concrete realisation of the Parallel Campaign's project impossible: '"Who can take it upon himself, today, even to think of putting great political ideas into practice? […] The function of diplomacy is to keep what we have."' (649) While the impossibility of combining the period's ideas from the polar domains of mathematics and mysticism does not inhibit and even perpetuates the Parallel Campaign, the theoretically enabling uncertainty leaves worrying pragmatic gaps and disables from purposive action. In the final analysis, as Arnheim points out in the novel and the readers' more informed position allows them to see: '"Keeping what we have leads to war"' (649).

Arnheim observes the danger of not acting on the disintegration of the period, but his own embodiment of the unity of the rational and the non-rational is suggested to be only a pretence of the impossible synthesis: Ulrich claims Arnheim to be '"a phenomenon like a rainbow with a foot you can take hold of and actually feel"' (203). Arnheim realises the

[44] 'er hatte das Gefühl, daß die Parallelaktion auf einem guten und ordentlichen Wege sei, und der wahre Weg werde sich schon finden' (225).

integration of polar opposites in the sense that he '"talks about love and economics, chemistry and trips in kayaks; […] in short, what the rest of us are separately, he is rolled into one"' (203). Being a successful industrialist and heir of 'the mightiest mogul of "Iron Germany,"' (98) Arnheim says to have left his native Prussia in order 'to recuperate a little, under the baroque spell of the Old Austrian culture, from the calculations, materialism, and bleak rationalism' (112), and thus merging 'soul and economics' (111) he is praised as able to lead the period into a once again unified future. On closer inspection, Arnheim's existence does not warrant the hope 'that he combined these normally opposite poles in his own person' (111), given that his 'excursions into scientific areas for support of his general views did not […] always satisfy the strictest criteria' (204) and he fails to realise his soul's wish to marry Diotima since he feels economically obliged 'to marry a prominent American widow at the very least' (547). Moreover, following the belief that '[m]oral wealth is closely related to the financial kind' (552), Arnheim joins the Parallel Campaign at least partly so as to establish business contacts to be prepared for the possibility of a war, and ultimately, so Ulrich concludes in a conversation with General Stumm, '"his munitions works will supply you with the cannons you want!"' (841) As Arnheim's actions reveal, he does not initiate change in order to advance a synthesis in life but goes along with the general development of the period to foster his own interests and 'was convinced that it was a sign of greatness in a man not to be overly critical of his times. The best rider on the best horse who is fighting it will not take his hurdles as smoothly as the horseman who manages to move as one with his mount.' (471) Thus, Arnheim might embody and argue for unity on the abstract level, but the merging of 'soul and economics' (111) 'founders on his pragmatism' (Bangerter 13) and his actions in effect assist war and thereby further disintegration.

The Parallel Campaign thrives on the contradictory ideas that are proposed as its possible aim, and Ulrich more generally wonders if it matters whether aspiring '"to integrity deserves a lot of credit"' or one should accept that '"[t]here's no longer a whole man confronting a whole world, only a human something moving about in a general culture-medium"': 'Ulrich thought privately that it would be just as easy to agree as to argue.' (234) The thought that arguing might be unnecessary similarly seems to strike the mathematical community after 30 years of strife, and the unspectacular close of the period of upheaval in 'the new method of thought' (35) illustrates aspects of the tactics of filing and of essayism. In the foundational crisis, 'Fi' is discovered to not only be 'one of the basic formulas of the building of our life[45]' (243) but also of the foundationless building of mathematics: strictly speaking, mathematical propositions cannot be proven true but only be marked 'Fi' until

[45] 'Lebensgebäude' (226).

evaluated in relation to a certain base of mathematical truth and existence, which, however, was hotly debated in the foundational crisis. Towards the end of the crisis, most mathematicians had adopted Hilbert's formalism in practice, and even the fact that Gödel's incompleteness theorem proved the impossibility of basing mathematics on formalist foundations did not alter this development. Effectively, so historians of mathematics agree, the mathematical community had already ceased the fighting: 'In talks and essays from 1928 to 1930 the tone is of an obituary of the crisis; saying that a "synthesis" had been reached, that the controversy corresponded to the different orientations of mathematical branches, that the foundational questions were questions of liking.'[46] (Mehrtens 295) Thus, the absence of agreed foundations was no longer considered a general problem, and the mathematical conflict ceased to be considered as a conflict (also see introductory chapter).

The crisis in mathematics not only lost its criticality, but it was even reevaluated in a positive light; in 1928 Hilbert was able to say: 'For the mathematical sciences the most recent decades were a period of greatest flourishing.' ('Problems' 227) From a later vantage point Mehrtens similarly assesses: 'Regarding questions as to the grounds of certain knowledge, this episode was not a crisis at all but an extraordinarily fruitful phase'[47] (Mehrtens 298). Thus, although the opposition of modern and counter-modern views remained unresolved, the foundational crisis of mathematics ended in an acknowledgement of its ultimate productiveness. Considering that the attitude to '"just go along"' (234) with the crisis works in the case of mathematics, Ulrich's move from advocating '"precision of feeling"' to 'taking the opposite view' (627), favouring agreement over argument and '"letting things happen"' (627), does not necessarily signal capitulation but might stem from the insight that uncertainty and conflict can be fruitful. Moreover, due to the stakes of admitting the failure to identify the essential idea and a 'unifying power' (190) of Kakania, Count Leinsdorf praises the technique of filing when it averts an impasse in the Campaign's meetings: a member '"has come up with a really saving idea; we've decided to continue this evening's meeting another time"' (1130). As the Count's comment closes book 2 of *The Man without Qualities*, '"Fi" is also acknowledged to be one of the 'basic formulas' (243) of the novel fragment itself.

In 'The Mathematical Man', modern mathematics and the reaction to its foundational crisis are explicitly proposed as a model for literature to deal with the wider

[46] 'In Reden und Aufsätzen der Jahre 1928 bis 1930 dann findet man den Ton eines Nachrufs auf die Krise: eine "Synthese" sei erreicht, die Kontroverse entspreche der Orientierung von Teilgebieten der Mathematik, die Grundlagenfragen seien Fragen des Geschmacks.'

[47] 'Für das Fragen nach der Begründung der Erkenntnisgewißheit war diese Episode alles andere als eine Krise, sondern eine außerordentlich fruchtbare Phase'.

cultural crisis at the beginning of the twentieth century, and the explanation in the essay also illustrates Ulrich's general tactics of investigation in *The Man without Qualities*. Musil's essay describes how life is 'not only dependent on mathematics for its comprehensibility, but has effectively come into being through it and depends on it for its existence' (MM 41), so when the foundations of mathematics are found to be 'standing in midair', the consequences for reality are immense: we live life 'only on the basis of an error without which it would not have arisen' (MM 42). As Andrea Albrecht points out, the essay is characterised by 'ambivalences and ambiguities' ('Mathematische' 220) and held in 'ironical-humorous suspense'[48] ('Mathematische' 222), but the speaker also voices the hope that the serious concern 'shines through the playfulness I have been directing at the nature of mathematics' (MM 42). The then following proposition that literature should mirror the response of mathematics to the foundational crisis in order to help overcome 'our age's lack of culture' (MM 42) therefore should not be dismissed lightly: 'in their field they [mathematicians] do 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.' (MM 42) In particular, people react to the cultural crisis by abandoning reason, but it is suggested that they should instead counter the revelation of the pale ghostliness of existence in the manner of the mathematician who 'endures this intellectual scandal in exemplary fashion, that is with confidence and pride in the devilish riskiness of his intellect' (MM 42). Holding on to reason and drawing confidence from the example of modern mathematics which, according to Musil's essay, shows that 'a groundless, that is, totally contingent system can still be completely operational' (McBride 54) and that its 'fictive, speculative quality constitutes a risky but at the same time attractive potential'[49] (Albrecht 'Mathematische' 239), literature, a field naturally displaying these qualities, could similarly make use of intellectual investigation and its fictional potential to help deal fruitfully with the loss of the cultural foundations. In *The Man without Qualities*, essayism, set in between science and literature and truth and subjectivity, is proposed as such a literary answer that holds on to the potential and 'devilish riskiness of [… the] intellect' (MM 42) and employs modern mathematics 'as the maybe most important method of description'[50] (Kaizik 29). In this way, *The Man without Qualities* deals with the cultural crisis in a manner comparable to the mathematicians' reaction to the crisis in their field.

[48] 'Ambivalenzen und Ambiguitäten'; 'ironisch-humoristischen Schwebe'.
[49] 'fiktiven, spekulativen Gehalt der Mathematik ein zwar riskantes, aber zugleich attraktives Potential ausmacht'.
[50] 'als vielleicht wichtigste Methode der Beschreibung'.

4. *The Man without Qualities*: Running in Circles

Essayism, the constitutive form of *The Man without Qualities* and a method of examining the question of the right way to live, only provides partial answers, but the mathematician Ulrich occasionally holds the view that incompleteness and living in the midst of contradictions need not be inhibiting. He argues that at least '"our ignorance is manifestly of a very rich and varied sort"' (527) and asks Walter 'why he needed to make sense of it. It seemed to be doing nicely without that' (232). An overall order might not be necessary and the individual orientation between the poles of mathematics and mysticism a matter of personal preference, as already manifest in other provinces of life: '"I prefer scientific tennis to the intuitive kind"' (458). Deciding on the general foundations of life thus would not matter much regarding the practical details where personal choice prevails, and Ulrich suggests that instead of lamenting the loss of stable foundations one could as well '"just go along"' (234).

The advice to just go along resembles Count Leinsdorf's acceptance of any strategy that keeps the Campaign working, but Ulrich does not resort to complacent inaction and still believes in the value of continued preoccupation with the '"whole circle of questions […]: 'How should I live?'"' (972) The narrator in *The Man without Qualities* even argues that the open-endedness of the examination is preferable, since 'a thing wholly encompassed suddenly loses its scope and melts down to a concept' (270). The German word for 'scope' – 'Umfang' (250) – also signifies a circle's circumference and thus relates the strategy of complete explanation to the diminishing of the circle of examination to a central belief. In contrast, essayism, only giving partial answers, maintains the scope of the object of investigation. In a draft to the novel, the openness of essayism is not only valued over limiting comprehensive systems but also over the unity and completion in the synthesis of mysticism: 'all perfected beauty […] is nothing more than the final piece in a circle; an arc is completed, one sees it but would like to know the circle' (drafts 1461). Thus, the rounded feeling in the Other Conditions which is 'motionless at the core' (942) is ultimately unfulfilling, but if aching for the circle of questions as soon as it is answered, the right way to live needs the motion of development and might, like beauty, be 'something that secretly negates, something incomplete and incompletable, a happiness without purpose, without sense' (drafts 1461).

Essayism reflects the incompletable and the negation of the absolute by considering positions on the circle from the pole of mathematics over intermediate states to the pole of mysticism and back to the beginning where a new turn of the cycle begins. By exploring the

circumference in a dynamic succession of piecemeal states, essayism does not provide a complete view of the whole but might nevertheless give an impression of it by connecting the diametrically opposed poles and the halves of existence on its way of running the circle of life. The whole of life then also is the domain where the fundamental elements of existence meet: the 'intermediate zone between reason and soul is for Musil a fundamental phenomenon of life itself, it does not need to be theoretically developed and artistically synthesised, but it is already present in life'[51] (Jäßl 221-22), so Jäßl argues in his examination of mathematics and mysticism in Ulrich's worldview. More specifically, as Kaizik concludes in his study of mathematics in Musil as an example of rationalism in art, reason and mysticism are 'ways of being, linked through man'[52] (Kaizik 2), so the two disparate fundamental elements whose synthesis signifies a moral state are combined in a counter-modern move, locating their fusion in the human being. Man's activity of asking the circle of questions and constantly exploring different partial answers and positions on the circumference is itself the connection between the poles of life, and examining the world from pole to pole, essayism is the proposed method to combine the spheres of life while also establishing the facts and helping to replace worldviews with views of the world. The whole fragmentary novel thus leads to a similar insight as Törless arrives at in Musil's earlier novel: '"things are things and will remain so for ever; and no doubt I will see them now one way, now another. Now with the eyes of reason, now with those other eyes … And I will no longer try to compare the two …'" (*Törless* 157) The reader of *The Man without Qualities* could conclude accordingly, resolving to no longer try to bring the two poles into a stable synthesis but being content to consider an unending succession of partial answers from all angles of the world.

The Man without Qualities finally allows the reader to draw a similar conclusion regarding the novel as a whole as mathematicians reach in the foundational crisis: when the novel's incompleteness is proven by its thinning out into fragments and any hope of finding consistent meaning is destroyed, it does not matter much, since it has long before become clear that none of Ulrich's attempts regarding the right way to live is correct but that this fundamental question is unanswerable. Moreover, the crisis and ultimate absence of the foundations of life is fruitful: not only do Ulrich's diverse suggestions give rise to the prolific one thousand pages of the originally published novel as well as to 6.000 pages of notes and sketches, – making understandable the description of *The Man without Qualities* as

[51] 'diese Mittelzone zwischen Ratio und Seele, ist aber für Musil ein Grundphänomen des Lebens selbst, es muß nicht erst theoretisch erschlossen und künstlerisch synthetisiert werden, sondern ist bereits im Leben vorhanden'.
[52] 'durch den Menschen zusammenhängende Seinsweisen'.

a 'torture machine' inviting to commit 'suicide by reading'[53] (Peyret 31) – but also, the fragmentary nature of the novel 'makes demands on the reader to continue to think'[54] (Hüppauf 131) about the still open questions. The acknowledgement of scientific and literary, general and individual, factual and fictional aspects, as well as of the freedom resulting from the incompleteness of the novel and the 'filing' of possible ways to live thus inspire the appreciation of the fruitful responding to irresolvable questions which is demanded in 'The Mathematical Man' and exemplified by modern mathematics.

Finally, when considering the essayistic novel according to Musil's request to be read 'in parts and as a whole' (notes 1766), one is not only presented with views of the world, but since all positions, even diametrically opposed mathematics and mysticism, are connected by the circumference of the questions of life, by the globe of the earth itself, there is a feeling, so Ulrich muses, that '"each one of us is also a particle and an offspring of this world, not at all as detached from the others and as independent as he imagines"' (747). This feeling is derived through the partly scientific, partly literary form of essayism, and there is 'nothing objectionable […] for a man of mathematical-scientific bent and precise feelings' if 'at times an intimation of oneness and love arises from the world, almost a certainty that the normal exigencies of life keep us from seeing more than half of the great pattern of the interrelationships of being' (747). The 'semicircle' of the 'understandable and self-contained' is always 'accompanied by an obscure feeling that it is only half the story' (196), and since 'the ends of this semicircle are joined by a string, and the plane of this string goes right through the middle of the world' (196), the semicircle is always connected to reality. The concern with opposites and the imagery of a half that intimates a whole will be explored further in the next chapter on Pynchon's *Gravity's Rainbow* whose two-part title already indicates a connection of scientific and literary fields.

[53] 'Foltermaschine'; 'Selbstmord beim Lesen'.
[54] 'stellt den Anspruch an den Leser, den Anspruch weiterzudenken'.

Thomas Pynchon: Gravity's Rainbow

1. Change, Prediction, and Fiction – Mathematics in *Gravity's Rainbow*

Thomas Pynchon's novel *Gravity's Rainbow*, published in 1973, is mainly set in the year between September 1944 and 1945, but the time around the end of the Second World War is presented as only the culmination of concepts and thought structures having emerged three centuries earlier. For example, the war in the novel is characterised by the use of rockets, a newly introduced weapon, but the scientific concepts underlying the description and control of their path were already developed in the seventeenth century. Moreover, the influence of seventeenth-century scientific discoveries on the general perception of the world was immense, the most prominent example being the publication of Isaac Newton's *Principia Mathematica* in 1687 which, according to the mathematician Alexis Clairaut's assessment in 1745, 'spread the light of mathematics on a science which up to then had remained in the darkness of conjectures and hypotheses'[1] (Clairaut 329). Putting the scientific exploration of the world on a logical basis comprehensible by reason, Newton's *Principia* can be taken to mark the beginning of Enlightenment – the notion of 'Newton as an icon of Enlightenment' (Shank 11) is famously phrased in Alexander Pope's epitaph: 'Nature and Nature's laws lay hid in night: / God said, Let Newton be! and all was light.' (Pope 122)

The novel's title 'Gravity's Rainbow' most prominently refers to the shape of a rocket's flight under the influence of gravity and thus alludes to the setting in the Second World War, but it also implies the seventeenth century and the beginning of Enlightenment by pointing to the formulation of the law of universal gravitation in Newton's *Principia*. The discovery of the universal character of gravitation, meaning that it has the same effects on all bodies, had far-reaching consequences: 'By introducing the concept of universal gravitation Newton swept aside the separation of celestial and terrestrial motions which had been assumed for the previous two thousand years' (Gondhalekar viii). The fact 'that the heavens and Earth were not governed by different laws' (Darling 90) also meant that the order presumed to rule the heavens should similarly be found on earth, so the discovery of the law of universal gravitation spurred scientific investigations into the regularity of nature. As further laws and regularities were discovered, the universe became increasingly seen as ruled by causality and determinism, concepts that also implied the possibility of predicting the world's future development with the means of science. The arguably most famous

[1] Newton 'a répandu la lumière des Mathématiques sur une science qui jusqu'alors avait été dans les ténèbres des conjectures & des hypothèses'.

representative of causality and determinism is the mathematician Pierre-Simon Laplace who held that '[w]e ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow' (Laplace 4), and that therefore, man's 'discoveries in mechanics and geometry, added to that of universal gravity, have enabled it to comprehend in the same analytical expressions the past and future states of the system of the world' (ibid). Thus, Newton's law of universal gravitation played a decisive role in the advent of a mechanistic and deterministic worldview, the belief in the possibility of describing the world through mathematics, and the consequent hope of the predictability of the future.

The novel's present at the end of the Second World War is not only shaped by the philosophical results of seventeenth century scientific discoveries and their tangible manifestation in the form of the Rocket, but it is also influenced by other decisions made in this time of change. William Slothrop, who 'in 1634 or -5' (657) begins preaching, is sensitive to the changing views that inspire and are further advanced by Newton: 'It was a little early for Isaac Newton, but feelings about action and reaction were in the air.' (657) Newton formulates the third law of motion stating that an action always occurs together with a simultaneous reaction of opposite direction, but William draws a different conclusion from the idea that forces always arise in pairs: in his tract '*On Preterition*', he argues holiness for 'the Preterite, the many God passes over when he chooses a few for salvation' (658), as they are a kind of 'reaction', the necessary counterpart without whom 'there'd be no elect' (658). While Newton's discovery becomes widely influential, William's corresponding realisation that '[e]verything in the Creation has its equal and opposite counterpart' (658) is suppressed; the scientific advance does not translate to the everyday world.

When the narrator wonders if William and his non-scientific formulation of the relation between action and reaction could 'have been the fork in the road America never took, the singular point she jumped the wrong way from?' (658), another scientific concept emerging in the seventeenth century is raised: the term 'singular point' relates the moment of choosing the course of the world to the calculus, a mathematical concept that can be used to describe motion and change: 'Calculus allowed a mathematical description of continuous change' (Gondhalekar 86). Newton was one of the inventors of the calculus, the other being the German philosopher and mathematician Gottfried Wilhelm Leibniz who developed it independently around the same time (also see 3.1). Newton's influence is also present in the other main mathematical theory employed in *Gravity's Rainbow*: the invention of probability theory, another product of the seventeenth century which allows projecting developments into the future, only became possible because of the belief in a determined and calculable

future based on Newton's law of universal gravitation. In view of the significance and immense consequences of seventeenth-century science and mathematics, I disagree with John Stark's opinion in his discussion of science in *Gravity's Rainbow* that 'Pynchon refers most often to scientific information that was discovered or became important during World War II' (Stark 46). Instead, it is the aim of this chapter to investigate the central role of the calculus and probability theory as the mathematics of change and prediction and to explore their role in the world's choosing the wrong path in the seventeenth century.

Under the influence of gravity, a rocket describes a parabolic path, a route similar to the shape of a rainbow whose ends seem to touch the ground. The image of the Rocket is not only closely related to the title of the novel but also comprehends the most important mathematical concepts and associates them with past, present, and future, so that the analysis of mathematics in *Gravity's Rainbow* will advantageously follow the different stages in the rocket's 'life': '"between the two points, in the five minutes, *it* lives an entire life"' (249), Katje claims. During the ascent, the future path of the Rocket is determined; it constitutes the past conditions according to which its present position and future course can be predicted. The associated mathematical concept is the calculus with which the changing parameters and their relation can be described and calculated (see section 2). A defining point on the Rocket's path is the 'Brennschlusspunkt', meaning the point of 'fuel cutoff, end of burning' (7). This infinitely small moment determining the end of ascent and beginning of descent is related to the 'right here, right now' (see 101, 430, 558) of the present and can be expressed with the methods of the infinitesimal calculus which is used to determine quantities approaching zero (see section 3). Finally, seen from the perspective of the victims, the descent of the Rocket poses the question of its future – its point of impact – and opens up the mathematical field of probability theory (see section 4). While the mathematical concepts are related to the three stages of the Rocket's life, its existence does not end with the 'death' in explosion, but Rocket 00000 is partly reassembled and 'reborn' in its dark counterpart 00001. This last stage of the Rocket's circular existence encapsulates the novel's concern with mutually defining opposites forming into a whole, and it will allow examining the 'opposites' which together constitute the whole *Gravity's Rainbow* (see section 5).

2. Ascent – Past – Calculus

The ascent of the Rocket is regulated by the launching side, using controlling devices such as air rudders, gyro and yaw control, or fuel supply – elements that provide the Rocket with ways to withstand outside forces such as air resistance and gravity. Its resulting path is describable in mathematical terms: 'So was the Rocket's terrible passage reduced,

literally, to bourgeois terms, terms of an equation such as that elegant blend of philosophy and hardware, abstract change and hinged pivots of real metals which describes motion under the aspect of yaw control: $\theta \frac{d^2\phi}{dt^2} + \delta * \frac{d\phi}{dt} + \frac{\partial L}{\partial \alpha}(s_1 - s_2)\alpha = -\frac{\partial R}{\partial \beta} s_2 \beta$' (284). For the majority of readers, the equation expressing the forces on the rocket is inscrutable. But even to the most informed reader, the secret of calculating the Rocket's path is not given away; attempts to understand the equation necessarily fail: the equation might look like a calculation used to determine the flight of a rocket, however, as the literary scholar Lance Schachterle and the physicist P. K. Aravind explain, in their combination and context 'most of the symbols in Pynchon's equation [are] obscure […]. This equation, then, is not a genuine mathematical expression in this context. It may appear authoritative to the layperson, but it is unlikely to fool a rocket scientist.' (Schachterle and Aravind 162) Schachterle and Aravind assert that a reader trying to penetrate through the blinding scientificity of the equation by consulting the textbook on rocket weapons from which Slothrop learns about the Rocket and which Pynchon probably used himself (namely the textbook by Kooy and Uytenbogaart) would not find even a similar formula. Thus, in their combination and in the context of 'motion under the aspect of yaw control' (284), the commonly used mathematical symbols in the formula make no sense to the physicist, and as the supposedly exact and informative equation only helps obscure the Rocket's path and the controlling forces, the possibility that a mysterious power directs the Rocket cannot be ruled out.

Indeed, characters in *Gravity's Rainbow* assume special factors to play a part in the equation. One hypothesis is that 'They', the Elect that wield power and are favoured in the world, are responsible for the exact flight of the rockets, as They do not suffer from the explosions, but the victims are mainly the powerless Preterite: '"east, east, and south of the river too, where all the bugs live, that's who's getting it *thick*-est"' (205), a character notices. Not only the Rocket, but also the Preterite themselves might be controlled by the inscrutable power of the Elect: after death souls feel themselves 'Rocketlike, […] under a Control they cannot quite name …' (285). Other characters are not aware of the possible control by the Elect, but, noting that the chart of rocket hits in London and the map marking Slothrop's sexual encounters match, assume Slothrop to influence the points of impact. For example, Edwin Treacle holds that Slothrop directs the rockets through 'psychokinesis. Slothrop is, with the force of his mind, *causing* the rockets to drop where they do.' (100) While it may seem odd to consider unscientific elements to play a part in the path of the Rocket, the unquestioning acceptance of the authority of science is shown to be similarly displaced:

blinded by the trustworthily complicated mathematical symbols, the reader's belief in the correctness of the equation of motion under the aspect of yaw control is no more informed than the characters' assumptions of less conventional guidance factors.

2.1 Functions, Correspondence, and Cause and Effect

Most employees in the institution PISCES take the stars on Slothrop's map to indicate a sexual encounter in the indicated part of the city. Following this assumption, Slothrop's map is organised by a function, that is, a rule that relates to each element *x* exactly one element *y*: each sexual adventure is assigned a star in the corresponding position on the map, illustrating why a 'function is also called a *map* or *mapping*' (Stewart and Tall 86). People at PISCES then notice another function, namely between rocket hits and the stars on Slothrop's map: 'The two patterns also happen to be identical. They match up square for square.' (100-1) Following the widespread view that '[o]ne of the most important problems in many sciences, as well as in mathematics, is to determine when certain variables are functions of others and then to express these functional relations as precisely as possible' (Cooley et al. 253), employees at PISCES figure out that a rocket hits a quadrant two to ten days after Slothrop adorns the corresponding part of his map with a star. Few people follow Treacle's view that Slothrop consciously directs the rockets, but most explain the observed pattern and functional relation by regarding the Rocket as a trigger for Slothrop's erections and his subsequent sexual encounters. In this case, Slothrop's erection would be provoked by the Rocket days before it is launched, but the scientists at PISCES accept the reversal of cause and effect and use the functional relation as a basis to predict the locations of future rocket hits.

When explaining the matching of the two maps with a causal relation between Slothrop's sexual encounters and the rocket hits, the scientists fall prey to the fallacy *cum hoc ergo propter hoc* ('with this, therefore because of this'), the erroneous taking of a contemporaneous occurrence as a relation of cause and effect. The textbook *Introduction to Mathematics* by Cooley et al. explains that functions correlate quantities but do not make any statement as to the nature of the relation. The book uses the example of two columns, one giving the value of Siamese imports from the United States in each year of a period of time, and the other showing the number of marriages in New York City in the same years: 'Thus to each amount of imports in the table there is made to correspond a definite number of marriages, and vice versa. The correspondence is therefore a functional relation' (Cooley et al. 263). While the obvious arbitrariness of the relation between the two columns might

lead a person to 'object to calling this correspondence a functional relation because he may not see how the amount of imports could have had any effect on the number of marriages' (Cooley et al. 263), mathematicians are not concerned with such considerations: 'the definition of a functional relation does not require that one variable should be the *cause* of the other. It only requires that to each value of one variable there shall correspond a value of the other variable.' (ibid) The warning not to deduce causal linkages from mere functional relations could equally well be addressed to the people working at PISCES, and the assurance that the correspondence between Siamese imports and New Yorker marriages is 'a functional relation of no practical value. No one would think of basing any predictions on it.' (ibid) is certainly not correct in the paranoid universe of *Gravity's Rainbow*.[2] Rather, the fact that characters do base predictions on the specious correspondence of stars and rocket hits points to the need of finding explanations and causal relations which, strengthening the notion of a causal and deterministic universe, then allow for predicting the future and for thus reducing uncertainty.

Among the strongest advocates of a causal relation between Slothrop's sexual encounters and the rocket hits is Edward Pointsman. He not only assumes that the functional relation is based on cause and effect, but with his work on conditioning, he forcefully turns the one into the other. In Ivan Pavlov's famous experiment, food, the sight of which causes a dog to salivate, is presented together with a ringing bell. The food and the bell have no causal connection but only occur simultaneously; they thus resemble the relationship described by a mathematical function. With a certain amount of repetition, however, the correspondence between the bell and the dog's salivation turns into a causal relation: the dog starts to salivate when hearing the bell, even when the food as the initial causal stimulus is absent. Thus, the correspondence of the ringing and the dog's salivation has become a causal relation: the ringing of the bell *causes* the dog to salivate. True to his Pavlovian training, Pointsman pursues the theory that Slothrop was conditioned to respond to the Rocket with an erection, meaning that the rocket hits and Slothrop's sexual encounters would be bound together by cause and effect. He even sacrifices logical order and argues for Slothrop's reaction before the stimulating explosion takes place in order to retain the explanatory power of the causal relation: 'But the stimulus, somehow, *must* be the rocket' (101).

[2] Even concerning reality, the mathematics textbook rather overestimates the hold of rationality: during the 2010 Football World Cup, Paul the Psychic Octopus was said to 'predict' the outcome of Germany's matches by taking food from the container with the flag of the winning team. Paul was right on each occasion, and the correspondence between his preferred food container and the victorious team can be described as a functional relation. Not only was this obviously arbitrary relation taken to predict the result of the matches, but threats to cook Paul for dinner if he did not pick the 'right' team attest to the even less rational idea that the octopus could actually influence the outcome.

The consequences of Pointsman's adherence to explaining the correspondence between rocket hits and Slothrop's sexual encounters by conditioning are far-reaching: if there is a stimulus 'then the rockets follow from it, 100% of the time. No exceptions. When we find it, we'll have shown again the stone determinacy of everything, of every soul.' (101) With his hope in a deterministic world, Pointsman follows his master Pavlov who, so Pointsman explains, '"believed that the ideal, the end we all struggle toward in science, is the true mechanical explanation. […] No effect without cause, and a clear train of linkages."' (104) In such a causal and deterministic universe, once having understood the stimuli that determine effects, one could influence them, and Pointsman accordingly concludes the necessity of controlling Slothrop and his erections: '"he is, physiologically, historically, a monster. *We must never lose control*."' (171) A worldview based on causality and determinacy thus ensures Their power, as Joseph Slade points out in his study on science and technology in *Gravity's Rainbow*: '"Their" authority stems from classical physics, which *does* rest on cause and effect relationships between forces and objects' (Slade 197). Even more, the logical conclusion of such a view is to employ conditioning as a tool to establish causal structures by turning mere correspondences into causal relations.

2.2 The Fictionality of Kute Korrespondences

If the controlling Elect can turn correspondences into causal relations, '[t]he rest of us […] must go on blundering inside our front-brain faith in Kute Korrespondences, […] – kicking endlessly among the plastic trivia, finding in each Deeper Significance and trying to string them all together like terms of a power series hoping to zero in on the tremendous and secret Function' (699). Examining correspondences is hoped to lead to a function that could then be used to calculate the future; yet, as a basic mathematical understanding reveals, predictions based on the Kute Korrespondences described by functions are not reliable. Pointsman's desperate attempt to provide a causal explanation to the congruence of the maps and his adherence to a causal explanation despite initial reservations and logical problems indicate the allure and the dominant position that causal explanations hold, and suggest that the immediate resort to cause and effect could itself be seen as conditioned: the sight of a correspondence triggers the assumption of a causal relation, or in the words of Bernard Duyfhuizen: 'Pointsman's reflex response to his colleague's death and toward Slothrop has been conditioned by the map' (Duyfhuizen 16). However, despite the stimulating correspondence and the supposed causal explanation, in the course of the novel Pointsman learns that the observed matching is not answerable by Slothrop's conditioning, that indeed,

not only is there no causal relation between rocket hits and Slothrop's sexual encounters but they might not even be connected through a Kute Korrespondence.

After the war, Pointsman initiates an investigation into 'a random sample of Slothropian sex adventures' (321) and learns that the data shows '"a number of cases where the names on Slothrop's map do not appear to have counterparts in the body of fact"' (323). Many of the girls supposedly correlated to the stars cannot be found: '"No Jenny. No Sally W. No Cybele. No Angela. No Catherine. No Lucy. No Gretchen."' (323). Mathematical functions are explicitly mentioned in this context: 'These are mostly all first names, you see, the, the Xs without the Ys so to speak' (324). Duyfhuizen collects the clues that indicate the problematic nature of Slothrop's map, most importantly Slothrop's remembering 'the gentlemanly reflex that made him edit, switch names, insert fantasies into the yarns he spun for Tantivy' (360). The stars thus do not indicate real meetings but relate to the stories Slothrop tells his friend, and instead of denoting a relation between rocket hits and Slothrop's real sex life, the congruence of the maps shows a correspondence of rocket hits and fiction. In other words: the reader has to 'realize the map's fictional quality' (Duyfhuizen 20). If Slothrop's map does not match real encounters, then the proposed causal relation between his sexual adventures and the rocket hits is groundless: the relation is not causal, it does not even rest upon Kute Korrespondences, but it is based on fiction.

The impulse to account for the world in terms of cause and effect not only conditions Pointsman's responses in the novel but also defined scientific research until relatively recently, indicating the fast hold that the 'conditioning' of Enlightenment thinking and causality have maintained since the seventeenth century. In her history of probability and statistics, *Classical Probability in the Enlightenment*, Lorraine Daston contends: 'Until the nineteenth century, no mathematician, scientist, or philosopher appears to have contemplated the possibility of genuinely random phenomena except to dismiss the idea as nonsensical: causeless events were unthinkable.' (*Classical Probability* 10) And as characters in the novel disregard the fictional quality of Slothrop's map in order to maintain a causal relation, so, as the next point will develop, the science employed in *Gravity's Rainbow*, too, is partly built on fictional premises so as to ensure the explanatory and predictive power of causality.

2.3 Gravity

a) The Gravity of Control

The correspondence between his stories and the points of impact is not the only factor that ties Slothrop to the flight of the Rocket, but he is also directly related with the

mathematics describing and determining its flight. His forefather Constant Slothrop is born in 1737, the year the mathematician Leonhard Euler adopted the mathematical constant π (see Eves 99), thus popularising its use. Constant's death in 1766, making his son Variable the head of the Slothrop family, coincides with Euler's introduction of the 'calculus of variations'.[3] In this way, the seventeenth-century discovery of the calculus, the mathematical method to describe motion and change and to thus control the flight of the Rocket, also illustrates the development of the Slothrops.[4]

If Slothrop's existence and the mathematical methods underlying the shape of the Rocket's life are interwoven, the formula of the forces determining the flight can also offer valuable clues as to the powers that control Slothrop. The equation of motion under the aspect of yaw control which 'exemplifies one of the more advanced constructs of the calculus with widespread application' (Schachterle and Aravind 161) expresses how the flight of the rocket 'will change over time as a result of the forces acting on it' (ibid), and comparably, Slothrop feels that his supposedly freely unfolding life is controlled by the Elect. The image of life being ruled by probability is accordingly replaced by a comparison with a game of chance that only seems to be free but is manipulated: 'all in his life of what has looked free or random, is discovered to've been under some Control, all the time, the same as a fixed roulette wheel' (249). Just as the forces affecting the Rocket are definitive and pinned down in an equation but left obscure to even the most informed reader, so the aims and power of the Elect as the controlling force in Slothrop's life remain unknown, and all Slothrop realises is that his life follows a predetermined formula according to Their plans: '"This is some kind of a plot, right?" […] "*Everything* is some kind of a plot, man"' (714).

The active control over the Rocket only lasts to fuel cutoff, the Brennschlusspunkt: 'All the rest will happen according to the laws of ballistics. The Rocket is helpless in it. Something else has taken over. Something beyond what was designed in.' (265) The force taking over is gravity, the ubiquitous attraction that the forces of flight can only temporarily oppose: each 'ascent will be betrayed to Gravity' (900). Achtfaden complains about this inescapable force: 'Does no one recognize what enslavement gravity is[?]' (540) If gravity

[3] Lance Ozier disregards the reference to the calculus and therefore concludes that 'Pynchon misses an easy trick […] in his choice of names for Tyrone Slothrop's ancestors. While perhaps dismaying that Variable Slothrop is not quite the man his father, Constant, was, from a mathematical point of view the father should be Variable and the son Constant, because the mathematical "derivative" of a first-power variable (such as *x* or *t*) is a constant, namely *one*.' ('Antipointsman/Antimexico' fn89) Yet, as the historical references point to a parallel development of the Slothrop family and the calculus, the choice of names is meaningful and unlikely to be a mere oversight.

[4] Isaiah Slothrop's death in 1812 further ties the Slothrop family to mathematics as it is the year that Laplace published his work on probability theory, making non-mathematical prophets like the biblical Isaiah redundant.

leads the Rocket to its destruction in explosion, similarly, all human life is 'at the mercy of a Gravity' (699) and a flight from this controlling force. Franz Pökler realises this when he loves his wife Leni for her apparent ability to 'carry him on her back, away to a place where Destiny couldn't reach. As if it were gravity. […] "Your wings … oh, Leni, your wings …"' (192-93). Yet, when Leni cannot also carry Pökler, his only chance to escape gravity lies with his work on the rocket: 'Let him look for flight out at the Raketenflugplatz' (193). Slothrop seems to escape the grave reality of war in a flight to the stars marking the imagined meetings with girls, but he too, is forced back into reality by Them and directed towards other destinies. Ultimately, all human or rocket flight has to end, as gravity takes over and leads life's course towards the ground and the grave. In the life of the Rocket, only the ascent is controlled by the firing side, while it is then taken over by gravity, and similarly, while the Elect control the life of the Preterite, sooner or later a universal force takes over and leads to death: '"They can't keep us from dying"' (864), Enzian points out. Thus, with the calculus and gravity, two scientific concepts formulated in the seventeenth century determine the shape of the Rocket's path as well as Slothrop's life: in the case of the Rocket, the calculus is used to determine the ascent and expresses the past conditions that regulate the 'now' of the Brennschluss, while gravity is responsible for its ultimate fall. Comparably, Slothrop's family is tied up with the development of the calculus, and obscure forces determine the 'equation' of his life. Sooner or later, however, the universal force that leads towards burial in the ground takes over. In other words, the calculus as the mathematics of change and motion is associated with continually developing life, while the force of gravity with its universal control resembles the doom of death.

b) Gravity Out of Control

Following the realisation that an apparently causal relation might turn out to be a mere Kute Korrespondence, the notion of control as the cause of events cannot be upheld without question. Profiting from the knowledge of the afterlife, a medium expresses the danger of seeking reasons and explanations: '"The illusion of control. That A could do B. But that was false. Completely. No one can *do*. Things only happen"' (36). Most significantly, the universal controlling force gravity, responsible for the Rocket's descent and metaphorically for the end of life is, on closer inspection, not a force unproblematically in control; indeed, it is not a force at all.

Two main protagonists in the early quarrel over the force of gravity were Newton and Leibniz. Their names are more familiarly linked through the infamous quarrel over the

question who first invented the calculus (see 3.1), but their antagonism also exemplifies the diverse viewpoints regarding the newly discovered law of gravitation. In *Gravity's Rainbow*, Newton is introduced in relation to the third law of motion as exemplary of the thinking in terms of 'action and reaction' (657), thus alluding to the calculability of a mechanistic universe. In contrast, Leibniz's name appears regarding the terminology used in the calculus (358) and its concepts (483) and is thus related to the acausal connections described by mathematics. Their stances regarding the status of gravity accord with this rough attribution to a worldview respectively based on causality and on correspondence.

In Newton's theory, 'gravity was a force whose reality was proved beyond doubt by phenomena' (Alexander xix). Gravity and the effects it caused could only be accounted for and understood properly if it had a determined origin – 'as a real force it must have a cause' (ibid) – but Newton was precisely unable to clarify this point: 'the cause of gravity is what I do not pretend to know' (Newton qtd. in ibid). Since the cause of gravity remained obscure, Leibniz dismissed Newton's theory of 'the *gravity* of things as due to a *gravitational* force' (Ross 41) and held that 'gravity in Newtonian physics is either an occult quality or a perpetual miracle' (Alexander xviii). Against Newton's theory of a universally controlling force, Leibniz set a concept comparable to the Kute Korrespondences in *Gravity's Rainbow*. '[A]ctively rejecting any law of gravity' (Hacking *Emergence* 184) and the concept of causation, Leibniz speaks of a '*constant and regulated relation*' (qtd. in ibid) between events: 'the states of substances are harmonized by God so that they give the appearance of causal interaction' (Jolley 49). Leibniz's view thus is close to the notion of a function, which describes a regulated and constant correlation without implying causality and a determining force. Leibniz rejected Newton's view mainly due to its philosophical and ethical implications: while causal relations strengthen the mechanistic worldview and threaten human freedom and self-determination, the acausal concept of 'a constant and regulated relation' leaves room for free will, and Leibniz could accordingly argue that 'God and human beings are free in a way that allows them to be morally responsible for their actions' (Jolley 125).

Perplexity regarding the law of universal gravitation was not confined to its beginnings, but the ignorance as to the cause and exact working of gravity persisted: until the beginning of the twentieth century, '*gravity* was no more than an empty name for a phenomenon they [scientists] didn't really understand' (Darling 141). And when Newton's inability to give the cause of gravity finally became explainable, Leibniz's scepticism was affirmed. In his study of early ideas about probability *The Emergence of Probability*, the philosopher of science Ian Hacking declares: 'Newton, the chief glory of physics, has not

come up with the goods. Where we had longed for causes and rational demonstration, we found only constant conjunction and lawlike regularity.' (*Emergence* 182) *Gravity's Rainbow* presents more recent changes in the scientific understanding when Lyle Bland eludes the grip of gravity. Realising that the old magic in Masonic rituals has escaped the 'grim rationalizing of the World' (696), Bland uses them to defy gravity: 'Lyle Bland rose up out of his body, about a foot, face-up' (697). In his experiments, Bland gains deeper knowledge of gravity than '[t]he rest of us, not chosen for enlightenment, left on the outside of Earth, at the mercy of a Gravity we have only begun to learn how to detect and measure' (699), and finds 'that Gravity, taken so for granted, is really something eerie, Messianic, extrasensory in Earth's mindbody' (698). Bland thus does not fall prey to the seventeenth-century scientific rationalising personified by Newton but realises what Leibniz calls the 'occult' quality (*Philosophical* 167) of gravity. And by accepting its mysterious nature, Bland arrives at a deeper and, from a contemporary view, more accurate understanding of gravity: perfecting his voyaging outside gravity, Bland feels that '[t]he Bland who came back to rejoin the inert white container he'd seen belly-up on the sofa, thousands of years beneath him, had changed forever' (697). This experience of travelling in space and time when overcoming gravity – leaving his body 'thousands of years beneath him' – points towards a scientific discovery of the early twentieth century that revolutionised the perception of gravity: Albert Einstein's theory of relativity. Einstein's theory is also implicit in a way of overriding gravity by less magical means which is presented later in the novel: 'A wine rush: a wine rush is defying gravity, finding yourself on the elevator ceiling as it rockets *upward*, and no way to get down.' (882) In a famous thought experiment, Einstein equated gravity with the force that presses a person down when a lift accelerates upward. So, 'finding yourself on the elevator ceiling as it rockets *upward*', a wine rush defies acceleration, the force equivalent to gravity, and the association with Einstein's thought experiment further ties the possibility of opposing gravity to the theory of relativity.

Relativity theory led to a new understanding of gravity and dispensed with the notion of gravity as a force. According to the new view, gravity is not a force but a *fiction*: 'Today it is believed by many scientists that gravitational force is merely a fiction, and that we live in a type of space in which the behavior of bodies can be explained without recourse to that fiction.' (Cooley et al. 597) In Einstein's theory, an object falls down not because of a gravitational force but because of a curvature of four-dimensional space-time: 'the concept of force of gravity is replaced by the mathematical idea that bodies move as they do because space is so formed that they can move in no other way' (Cooley et al. 589). Thus, Leibniz's belief that there is no cause of gravity and that 'it is a strange fiction to regard all matter as

having gravity' (Leibniz *Philosophical* 228) turned out to be correct, and gravity was accordingly termed a 'fictitious force'. Fitting Gottfried Wilhelm Leibniz's rejection of gravity as a causal force, in *Gravity's Rainbow*, his namesake Gottfried is the first person to overcome gravity in a rocket and, approaching the heavens, to enjoy free flight in the moment when 'Gravity dips away briefly' (901). Equally appropriately though, the constant relation is once again reaffirmed: 'This ascent will be betrayed to Gravity' (900). Regardless whether it is a real or a fictitious force or a constant and regulated relation, gravity has very real consequences.

With gravity emerging as a fictitious force, the related concept of control has to be revaluated: if even universal gravity is not a causal force but a fiction, then similarly, there is hope that Their control might have been wrongly perceived as ineluctable. Moreover, since gravity does not imply causal relations, Leibniz's insistence on free will and moral responsibility emerges as justified. The 'map's fictional quality' (Duyfhuizen 20), replacing a causal explanation with the notion of a Kute Korrespondence between rocket hits and Slothrop's stories, and the discovery of the force of gravity's fictitious nature thus inspire hope in the possibility of eluding Their grasp and leading a free, self-determined life.

c) The Need for Gravity

Significantly, Lyle Bland's experience of defying gravity is connected to a positive evaluation of gravity. Before he embarks on his Messianic experiments, Bland visits a room full of broken pinball machines that accommodate balls from the planetoid Katspiel. A planetoid's orbit depends on two main aspects: the planetoid's velocity and the gravitational force[5] exercised by the sun it circles. Katspiel's is a 'veryvery elliptical orbit – which is to say it passed by Earth only once, a long time ago, […] and nobody knows where Katspiel is now or when, or if, it'll be back. It's that familiar division between return and one-shot visitation. If Katspiel had enough energy to leave the sun's field forever, then it has left these kind round beings in eternal exile' (691). If, however, gravity is stronger than the energy due to the motion, the planetoid returns. Not only the fate of the pinballs depends on gravity, but so does the decision between 'return and one-shot visitation' of the universe as a whole. N. Katherine Hayles explains in her analysis of *Gravity's Rainbow*: 'The gravity that the narrator warns us is "taken so for granted" is the elusive power that can turn the Flight from the Center around. If Return is possible, it will be because gravity is pulling the universe

[5] As it is commonly used and easily graspable, I will continue to refer to a gravitational 'force' and only specify it as a fictitious force where significant to the argument.

together again.' (Hayles 196) The rebirth of the universe might thus rely on gravity; at the very least, it is responsible for keeping things together.

Just as gravity is not all negative, the associated force of control turns out to be necessary to life. A state without control, 'where nothing is connected to anything, [is] a condition not many of us can bear for long' (515): without causal relations and control, there only remains coincidence devoid of meaning. Thus, although trying to escape Their control, Slothrop muses: 'Either They have put him here for a reason, or he's just here. He isn't sure that he wouldn't, actually, rather have that *reason* …' (516). Moreover, *Gravity's Rainbow* points out that literature does not work without control and that it cannot elude the demand for meaning itself: 'You will want cause and effect' (786), the narrator understands. Thus, the reader, probably puzzled by the sometimes seemingly incoherent and random unfolding of the novel, is reminded that their reaction originates from being used to, or conditioned in terms of, causality, and they come to know first hand that if causal relations and control are inhibiting, they are also necessary to life. Even more, the reader also experiences that the fictionality of Slothrop's map or the fictitious force of gravity do not invalidate the concepts' explanatory function and the sense of certainty and predictability they instil, and thus realises that, if cause-and-effect is part of fiction, so fiction is part of science.

3. Brennschluss – Present – Infinitesimal Calculus

3.1 The Infinitesimal Moment of Brennschluss

On the highest point of its trajectory, the forces on the Rocket are in balance. Strictly speaking, the apex of the parabolic path is shortly after fuel cutoff as inertia makes the Rocket continue to rise, but while the novel acknowledges this fact, the Brennschlusspunkt nevertheless signifies as the point between ascent and descent. As such it is related to the present, the 'right here, right now' (see 101, 430, 558) of the moment of balance at the apex. The calculus, which describes motion, also provides a mathematical tool to arrest change and to determine a value at a particular point and time; with the infinitesimal calculus the 'right here, right now' can be determined: 'a point in space, a point hung precise as the point where burning must end, never launched, never to fall' (360).

Newton and Leibniz personify the two aspects of the calculus, describing continuous motion as well as the point of 'right here, right now'. While today it is generally agreed that Newton and Leibniz invented the calculus independently, the precedence was the object of a long and ignoble dispute between the two mathematicians. Their respective systems of notation varied, as did the underlying understanding of the nature of mathematics and its

relation to reality, and the contention fed as much on the diverse philosophical bases and implications as on purely mathematical issues. Most importantly, Newton considered mathematical quantities 'as described by a continuous motion' (Newton 107); for example, a curve would be described by a continuously moving point. Emphasizing the constitutive notion of motion, Newton called a varying quantity a 'fluent' and the corresponding rate of change a 'fluxion'. By contrast, Leibniz regarded discrete points on a curve by considering them as of infinitesimally small length. Leibniz's conception of the calculus is closely connected to his monadology, that is, the philosophical idea that the world is made up of 'indissoluble simple things, elementary substances, or as he likes to call them "monads"' (Savile 12). Both in Leibniz's concept of the calculus as well as in his monadology, entities are composed of an infinite number of parts that have no spatial extension but are infinitesimally small.

The concept of infinitesimals constituted a major aspect in the mathematical and philosophical dispute over the calculus. In *Gravity's Rainbow*, the idea of infinitesimals is introduced when Leni explains the notion of a moment 'as Δt approaching zero, eternally approaching, the slices of time growing thinner and thinner, a succession of rooms each with walls more silver, transparent, as the pure light of the zero comes nearer …' (188). A more formal definition of an infinitesimal is: 'An infinitely small quantity or amount, a quantity less than any assignable quantity.' (*OED* 'infinitesimal') Thus, an infinitesimal number, 'while not coinciding with zero, is in some sense smaller than any finite number' (Bell 16). As the definition does not point to a stable quantity and existence but only to a shifting and ungraspable 'smaller than any finite number', the notion of infinitesimals was highly contested. Infinitesimals were not only an object of discussion in the seventeenth century when the term was coined, but the uneasiness as to their elusiveness persisted over the next centuries: they were '[d]erided by Berkeley in the eighteenth century as "ghosts of departed quantities", in the nineteenth century execrated by Cantor as "cholera-bacilli" infecting mathematics, and in the twentieth roundly roundly condemned by Bertrand Russell as "unnecessary, erroneous, and self-contradictory"' (Bell 17). While Newton rejected the use of infinitesimals, Leibniz held that although infinitesimals did not 'really exist', they constituted useful fictions: 'Infinitesimals are mental fictions, though they have their place in calculations, like imaginary roots in algebra.' (Leibniz qtd. in Ross 32) (also see introductory chapter on the disputed existence of imaginary numbers). Thus, the discussion about the existence and usefulness of infinitesimals made visible fundamental differences in the understanding of mathematics' relation to physical reality and to fiction.

When Leibniz's version of the calculus asserted itself in Europe and English scientists stuck to Newton's way, insular mathematics grew isolated from the developments in mainland Europe. But this most famous instance of a mathematical 'war' had an impact far beyond the bounds of mathematics when 'the dispute between Leibniz and Newton came to be regarded not merely as a dispute between its two protagonists themselves, but also as in terms of national rivalry between Germany and England' (Brown and Phemister 11). In *Gravity's Rainbow*, the conflict between England and Germany is no longer of a mathematical and peaceful nature, yet, the seventeenth-century questions regarding the place of 'mental fictions' in science are still of concern.

3.2 Δt – Infinitesimals and Fiction

In *Gravity's Rainbow*, the concept of infinitesimals is explained in relation to the mathematical symbol Δ (delta) which signifies change, that is, the difference between two quantities: 'Three hundred years ago mathematicians were learning to break the cannonball's rise and fall into stairsteps of range and height, Δx and Δy, allowing them to grow smaller and smaller, approaching zero' (671-72). The image of the stairsteps is among the signals that Slothrop sees in the Zone: 'The most persistent of these, which seem to show up at the least real times of day, are the stairstep gables that front so many of these ancient north-German buildings' (671). The front of these buildings looks like a flight of stairs with a few stairs going upward and the same number going downward.

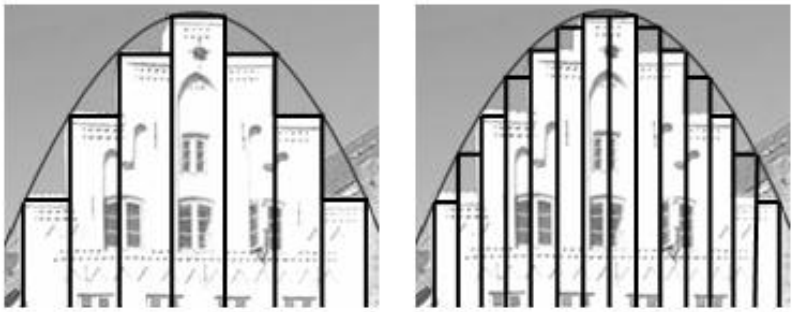

Figure 1: Stairstep gables approaching parabola shape

Connecting the corners of the stairs, a parabola emerges, and copying the stairstep gables and the parabola onto a coordinate system shows how the stairsteps ever growing smaller helps calculating a cannonball's rise and fall: Pökler finds 'the points he needed not by running the curve itself, not up on high stone and vulnerability, but instead tracing patiently

the *x*s and *y*s, […] moving always by safe right angles along the faint lines …' (474-75), and in the same way, it is possible to give an approximate value of the distance between two points on the parabola by calculating the range and height, the Δx and Δy, of the closest stairstep. The smaller the stairsteps, the closer they resemble the shape of the parabola and the more accurate do the results become. A stairstep of zero range and height would ultimately allow for an ideal calculation, but since such a step does not exist, Δx and Δy can only approach zero. Since describing the parabola through stairsteps relies on the concept of infinitesimals and their disputed existence, it is fitting that Slothrop sees the stairstep gables 'at the least real times of day' (671).

Transferred to the situation of the Rocket on its parabolic path, the value *y* designates its altitude, while *x* can be seen as the time of the Rocket's travel; it is therefore substituted by the letter *t* for 'time'. In analogy to the example of the stairsteps, the exact position and moment of the Rocket's travel, the 'right here, right now', can be determined by Δt and Δy approaching zero. Thus, the calculation of the Brennschlusspunkt, which determines the point of impact, is based on infinitesimals, the indeterminate 'ghosts of departed quantities' and 'erroneous, and self-contradictory' 'cholera-bacilli' of mathematics. Or in Leibniz's terms: the Rocket explodes at its target because of a 'mental fiction' (qtd. in Ross 32). In *Gravity's Rainbow*, seeing the effects of his calculations, Pökler holds that the reality of infinitesimals is not significant: '"The important thing is taking a function to its limit. Δt is just a convenience, so that it can happen."' (188) However fictional Δt and infinitesimals might be, the very real consequences of a Rocket directed by calculations involving this mathematical concept mean that it cannot simply be discarded as ineffectual because unreal. Rather, with infinitesimals a 'mental fiction' enters mathematics, and through the calculation fiction affects reality. So, as the literary scholar James Earl puts it, '[t]he delta-t is not just another mathematical tool, it is a compromise with reality' (Earl 241), demonstrating that fiction and reality are interrelated and converge, even in the domain of mathematics.

The concept of infinitesimals in mathematics is a striking but not the only instance in *Gravity's Rainbow* that illustrates the interconnectedness of reality and fiction and suggests the necessity to make a compromise with reality in order to live in and understand the world. The most prominent nonmathematical example of the interrelation of reality and fiction is film. The domains of the calculus and film are related through the shared concept of motion that can be arrested to show a certain point in time: 'There has been this strange connection between the German mind and the rapid flashing of successive stills to counterfeit movement, for at least two centuries – since Leibniz, in the process of inventing calculus,

used the same approach to break up the trajectories of cannonballs through the air.' (483)[6] As the infinite moments of the Rocket's flight form into the mathematical graph shaped like a parabola, so a film is made up of successive stills, of photographs: writing (*graphos*) made by light (*photos*). In this light-writing, reality is captured and fiction produced.

If the 'mental fiction' of the infinitesimals leads to the very real explosion of the Rocket, so in the domain of film, fiction turns into reality in *Gravity's Rainbow*; for example when a film set develops an existence outside the movie: 'The buildings are real, not a false front in sight. The boliche is stocked with real liquor, the pulpería with real food. […] Any of the extras who want to stay are welcome.' (726) The director von Göll explicitly wants his films to turn into reality: '"It is my mission […] to sow in the Zone seeds of reality. […] My images, somehow, have been chosen for incarnation."' (461) His images indeed literally beget reality and become embodied when the shooting and watching of von Göll's film leads to the conception of several children. But filmic fiction even more drastically transforms into reality when 'the fictional Schwarzkommando' (133) as invented in von Göll's movie, later turns out to actually exist: 'Who could have guessed there'd be *real* black rocket troops? That a story made up to scare last year's enemy should prove to be literally true' (328). Once 'his film has somehow brought them into being' (461), the fiction cannot be undone: 'no way now to stuff them back in the bottle or even say the spell backward' (328). And the reader is reminded that film not only influences life in *Gravity's Rainbow* but has shaped their reality as well, when being presented with the true story that '[t]he countdown as we know it, 10-9-8-u.s.w., was invented by Fritz Lang in 1929 for the Ufa film *Die Frau in* [sic] *Mond*.' (893) The passing from film into reality that at first might seem to only occur in fiction is thus revealed to actually happen in the reader's world; the idea crosses over from fiction into the domain of reality.

Film, controlled by the light-writing Elect, is not the only instance where fictional realities influence and convert to reality, but, left in the dark, the Preterite are needed to perform according to Their plans, first creating a theatre or movie reality which then replaces the former reality completely. Pökler 'was expected to behave a certain way – not just to play a role, but to live it' (495) and experiences that he 'grew into his new disguise […] often finding that it could indeed take him over' (495). Thus, for Pökler acting a role turns into reality, and he later realises both the chances and the dangers of playing along with a fiction. Accepting the version of reality that the Elect want him to embrace, Pökler creates a

[6] Howard Eves notes the similarity from the mathematical perspective: 'The older mathematics appears static while the newer appears dynamic, so that the older mathematics compares to the still-picture stage of photography while the newer mathematics compares to the moving-picture stage.' (Eves 23)

real bond to the child that is or impersonates his daughter: 'Pökler knew that while he played, this would have to be Ilse – truly his child, truly as he could make her. It was the real moment of conception, in which, years too late, he became her father.' (501) Taking on his assigned role signifies begetting a real child, but on the other hand, really caring about Ilse means to free her from Their plots. Pökler consequently decides to no longer play along with the fiction imposed by Them: 'Pökler committed then his act of courage. He quit the game.' (511) The case of Pökler thus illustrates that it might be as courageous to live a fiction as it can be to quit the game and face reality.

With the example of play-acting and film, *Gravity's Rainbow* demonstrates how fiction can influence and become reality. Allowing for more freedom than strict reality, fiction can help transform and solve actual problems, be it to help Pökler become a true father, or in the case of Slothrop's saving a town while impersonating the pig hero Plechnazunga: 'Has the morning been only a dress rehearsal? Is Slothrop expected to repel *real* foreign invaders now?' (676) And indeed, accepting his role, Slothrop saves 'a few kids, an old lady' (676) from the blows of the Russians. Similarly in mathematics, a fictional device such as infinitesimals denotes a problem, for example the impossibility of calculating a stairstep of zero range and height, and 'allows us to manipulate the name in order to solve all sorts of practical problems' (Earl 241). In life as in mathematics then, fiction can make a situation more easily manageable and be more useful than reality alone.

3.3 The Zero of Brennschluss and the Infinite Change of Singularities

At the apex of the parabola marking the transition from ascent to descent, the Rocket is in balance and not dominated by any force. In mathematical terms, the derivative, designating the vertical displacement of the Rocket, is zero at the apex: neither rising nor falling, the Rocket's rate of change is zero. As James McClintock notes: 'The zero is a definite sign that an interface or barrier has been reached. Such a moment occurs when a rocket reaches the peak of its trajectory.' (McClintock 488)[7] The Brennschlusspunkt marks the transition from ascent to descent, yet, the state after the 'interface' of the apex is already determined as the ascent and point of fuel cutoff set the conditions for the descent: the apex of the parabola thus describes an interface between two realities, the one (ascent) determining the other (descent), but it is not a point of change.

[7] Also see Ozier's examination of the mathematical images of Δt, the double integral, and the singular point as expressions of 'the idea of transformation from one world order into another or from one state of being into another' ('Calculus' 203).

If the apex is a point of zero change, there also is a point of infinite change: 'at a singularity the rate of change that the differential attempts to express goes to infinity' (Hayles 190). Moreover, if the Brennschlusspunkt fits perfectly into the shape of the parabola, determines and is determined by the ascent and the descent, at a singularity a function becomes discontinuous, meaning that the shape of the function right before and after the singularity does not necessarily match. In other words, a graph might lead up to a singularity and then continue at a completely different point after it; the graph jumps. In *Gravity's Rainbow*, experiencing a mathematical singularity is compared to being hit by lightening: 'it's a matter of continuity […] the ones who do get hit experience a singular point, a discontinuity in the curve of life' (786). Both a mathematical singularity and being hit by lightening open up a discontinuity and an infinite potential for change: 'do you know what the time rate of change *is* at a cusp? *Infinity*, that's what! A-and right across the point, it's *minus* infinity! How's *that* for sudden change, eh? Infinite miles per hour changing to the same speed *in reverse*, all in the gnat's-ass or red cunt hair of the Δt across the point.' (786-87) Breaking continuity and exhibiting an infinite rate of change, a singularity holds the potential to completely alter the course of a graph, life, or world. *Gravity's Rainbow* gives an example of a singularity's power of change when it mentions the scientific theory proposing that the universe created itself from a singularity: 'there is a cosmology: of nodes and cusps and points of osculation, mathematical kisses … *singularities!* […] according to the Russian mathematician Friedmann, the infinitely dense point from which the present Universe expanded …' (471). If the universe was born out of a singularity, then, so *Gravity's Rainbow* suggests, in a similar process new worlds, or at least new world-orders, can emerge from singularities. Like the apex of a parabola then, a singularity constitutes an interface, but in contrast, the 'other side' of the singularity is not predetermined: 'Isn't this an "interface" here? a meeting surface for two worlds … sure, but *which two?*' (791)

3.4 Singularities: Forks in the Road

Gravity's Rainbow presents the seventeenth century as a chance to make use of a singularity's infinite rate of change to create a new world or world-order when William Slothrop is taken to mark 'the fork in the road America never took, the singular point she jumped the wrong way from' (658). Arguing holiness for the Preterite, William leads the world to a 'singular point', but the potential of the infinite rate of change is not fulfilled; the graph of the world jumps the wrong way, and the distinction between elect and preterite remains. Three hundred years after William, in Tyrone Slothrop's time, the world has arrived

at another singular point when the Second World War radically discontinues past developments. As the anarchist Squalidozzi explains, the war is also characterised by an infinite rate of change, opening up entirely new paths: '"this War – this incredible War – just for the moment has wiped out the proliferation of little states that's prevailed in Germany for a thousand years. Wiped it clean. *Opened it*."' (315) With powers in abeyance, the post-war Zone provides another opportunity to abolish distinctions between elect and preterite and to establish the fair and equal world proposed by William. Squalidozzi expresses the hope for an anarchistic post-war society, free from suppression by ruling powers: '"We want to leave it open. We want it to grow, to change. In the openness of the German Zone, our hope is limitless."' (315) Yet, the openness and potential of a singular Zone cannot become a permanent condition: 'Suddenly, this awful branching: the two possibilities already beginning to fly apart at the speed of thought […] jump, choose –' (621). It is impossible to hold up all possibilities that the singularity encompasses but one of the infinite paths has to be chosen; as William's idea of an equal world still is not realised in post-war Europe, it seems not everybody jumps the right way from the singular point this time either.

Tyrone Slothrop maybe pursues the right path from the fork of the road opened up by the Second World War, but his case also illustrates the consequences of trying to keep possibilities open and go down several roads at once. He partly realises the possibilities introduced by his forefather, as their common learning from pigs most clearly indicates. William sets up a 'pig operation' (657) and elevates the disfavoured, 'preterite' pigs: 'Despite the folklore and the injunctions in his own Bible, William came to love their nobility and personal freedom […] – pigs out on the road, in company together' (657). The experience inspires William to argue for the holiness of the preterite '"second Sheep"' (658) and ultimately for mutual dependence and equality of elect and preterite that the pigs already embrace: they are possessed 'by trust for men, which the men kept betraying … possessed by innocence they couldn't lose … by faith in William as another variety of pig, at home with the Earth, sharing the same gift of life …' (658). In the openness of the singularity of the Zone, another Slothrop, Tyrone, pursues his ancestor's example and, becoming the first not to betray the pigs' trust in man, turns into another variety of pig. When he impersonates 'Plechazunga, the Pig-Hero' (672) – the costume 'seems to fit perfectly. Hmm.' (673) – and a real pig takes him as conspecific: 'He puts on the pig mask. She stares for a minute, then moves up to Slothrop and kisses him, snout-to-snout.' (679) Thus, while in William's time the pig is disadvantaged and ultimately driven to the slaughterhouse, Tyrone and the pig meet each other as equals; even more, Tyrone follows the pig rather than driving it: '"Thank you for bringing her back." "No, no – she brought me."' (682)

Tyrone Slothrop's porcine companion is called Frieda, a name closely resembling the German word *Friede* meaning 'peace'. True to her name, Frieda, appearing 'to know where she's going' (680), leads Slothrop away from 'another road, [where] a great cloud of dust hangs, crawling southward, maybe a Russian horse convoy' (680) and part of the 'Russian reinforcements' (675) that destroyed a city and hunted the Pig-hero earlier. Following Frieda, Slothrop has chosen a path that leads him away from aggression and towards a last sanctuary, Zwölfkinder. Wondering if it is his 'Destiny' (682) to have arrived there, Slothrop traces 'back the route Frieda the pig brought him along, trying to remember forks where they might have turned another way …' (682). He might thus have realised his feeling 'that there might be a route back' (659) to the fork in the road which opened in the seventeenth century: virtually becoming a pig, the twentieth-century Slothrop closes the gap between preterite pig and elect man, and resisting the increasing separation and distinctions forming in the Zone he progresses on the road towards equality and unity. Proving true the faith of William's pigs that man is 'another variety of pig, at home with the Earth, sharing the same gift of life' (658), Tyrone in the pig costume and becoming 'a crossroad' in the Zone, 'sees a very thick rainbow here, a stout rainbow cock driven down out of pubic clouds into Earth, green wet valleyed Earth, and his chest fills and he stands crying, not a thing in his head, just feeling natural …' (741). And living the equality of pig and man, elect and preterite, Slothrop experiences the feeling that 'he could *make it all fit*' (741). Frieda thus leads Slothrop towards a harmonious view of the world where everything is in agreement.

Not everybody follows pig Frieda, and as '[e]ach alternative Zone speeds away from all the others' (615), Slothrop's dimension, together with peace, moves away from the common post-war reality. The more the paths diverge, the more characters forget Slothrop: '"I don't know any more who Slothrop really was."' (781) Katje says, and '[m]ost of the others gave up long ago trying to hold him together, even as a concept – "It's just got too remote" 's what they usually say' (878-79). Finally, even Seaman Bodine, one of the last 'who can still see Slothrop as any sort of integral creature' (878) loses sight of him. The mathematical connotations of the term 'integral creature' imply that Slothrop ceases to be an integer, a whole number, and also that integration, one of the fundamental operations in calculus, no longer applies to him. In calculus, an integral can be visualised as an area under a graph, constituted by the sum of an infinite number of infinitely small quantities. When Slothrop ceases to be an 'integral creature', the infinite number of infinitesimals is no longer summed up to a unified quantity: he 'was sent into the Zone to be present at his own assembly […]. The plan went wrong. He is being broken down instead, and scattered.' (875) The infinitesimals of Slothrop are '[s]cattered all over the Zone' (845), and '[s]ome believe

that fragments of Slothrop have grown into consistent personae of their own. If so, there's no telling which of the Zone's present-day population are offshoots of his original scattering.' (881) Divided, Slothrop can take all paths at once, but keeping all possibilities open means sacrificing his integrity, his wholeness as well as his decency: 'It does annoy him that he can be so divided, so perfectly unable to come down on one side or another.' (802) He makes no choices: 'Decisions are never really *made* – at best they manage to emerge, from a chaos of peeves, whims, hallucinations and all-round assholery.' (801) Even though, therefore, 'Slothrop now observes his coalition with hopes for success and hopes for disaster about equally high' (802), his situation is not any more comfortable: people like him, '"the glozing neuters of the world" have no easy road to haul down' (802). Historically, for Puritans neuters are people 'that halt betweene two opinions […] the Lord abhorres such lukewarme tame fooles' (qtd. in Miller 58), and their '"[d]eadness of heart" was the most insupportable curse' (Miller 58). In Puritan terms, not having an opinion but embracing all possibilities, going down all roads, is thus a sign of the '[d]ullness, coldness, emptiness [that] were more to be lamented than any specific sin' (ibid), and Slothrop experiences the same consequences of indetermination: 'He is growing less anxious about betraying those who trust him. He feels obligations less immediately. There is, in fact, a general loss of emotion, a numbness he ought to be alarmed at, but can't quite … *Can't* …' (582). Not choosing a path, not taking any decision, thus also means failing to realise the appeal to '"[b]e compassionate"' (587).

Instead of submitting to an uncaring laissez-faire attitude where all possibilities are equally acceptable, Seaman Bodine, the last to keep Slothrop in mind, argues for working against Their flawed system. While the glozing Neuters in their indecisiveness have no impact on the world, the questionable actions of the bank-robber John Dillinger at least are a protest against the unsatisfactory state of things, so Bodine claims: '"he still did what he did. He went out socked Them right in the toilet privacy of Their banks. Who cares what he was *thinking* about, long as it didn't get in the way?"' (879) According to Bodine, Slothrop's neutrality and lived equality is threatened to remain a bloodless enterprise 'lacking in human feeling' (Merriam-Webster 'bloodless') if it bars him from acting on the world. He therefore wants Slothrop to have a cloth stained with Dillinger's blood and to understand that '"what we need isn't right reasons, but just that *grace*. The physical grace to keep it working. Courage, brains, sure, O.K., but without that grace? forget it."' (879-80) Bodine himself has already understood the need to act and to take decisions: the bloodstained cloth '"worked for me"' (880). He now wants to pass it on to Slothrop to save him from bloodless neutrality and deadness of heart: '"I'm out of the Dumbo stage now, I can fly without it. But you. Rocky.

You …"' (880). Bodine fails to reinfuse Slothrop with blood however; even he begins 'in shame, to let Slothrop go' (880), and Slothrop also disappears from the text's and therefore the reader's reality: his plotline thins out gradually in the final part of the novel, and he is last mentioned a couple of dozen pages before the end.

With his disappearance from the novel's world, Slothrop concludes the family tradition of growing inaction that is already implied in their name: 'Sloth-rop' refers to the scientific concept of inertia. The first Slothrops are 'assimilated in life to the dynamic that surrounded them' (32), they move along with the changing world, and the elements 'powering the American mobility' also 'claimed the Slothrops, clasped them for good to the country's fate' (32-33). Yet, the Slothrops 'did not prosper' (33), they do not move on in the world, and later, the family does not even keep up with its dynamic course: 'out of some reasoned inertia the Slothrops stayed east' (33). Tyrone Slothrop's disappearance is thus the culmination of his family's staying behind in a changing world. The relation to science also implies that Slothrop's neutrality and inaction is as harmful or at least ambiguous as Their control; a connection emerging when the novel alludes to Einstein's thought experiment illustrating that in an accelerating lift the effect of inertia equals gravity. If in accelerating surroundings inertia has the same effect as gravity, then accordingly, in a time of increased change such as in the post-war Zone when Europe is being redefined, sloth or inertia resembles gravity and the force exercised by Them. Thus, when Slothrop does not have blood and compassion enough to 'fly' (880) like Bodine, his inertia means he stays behind while the rest of the world moves on and that, without the physical force of acceleration, he literally lacks the '"physical grace to keep it working"' (879).

Slothrop might have taken the opportunity of the singularity of the open Zone after the Second World War to realise and enter an equal, harmonious world or to disperse in the plurality of possibilities, but the text and the reader have clearly not followed Frieda towards peace; the novel's reality again jumps the wrong way from a fork in the road. At the end of the novel, reality is once again threatened by a descending Rocket, while 'we' (902) – a term that refers to the audience in the cinema but also includes the reader – wait for continuation of a disrupted film. The discontinuation of the film constitutes a singular point, thus suggesting that the orientation away from William's vision of a fair, equal society is not necessarily final but that another singularity could open up possibilities again. The falling Rocket threatens to annihilate 'us' and all future possibilities, but destruction is not yet upon 'us'. Rather, the Rocket only 'reaches its last unmeasurable gap above the roof of this old theatre, the last delta-t' (902). As the infinitesimal Δt never becomes zero but only approaches it, there always remains time to join into 'a hymn by William Slothrop' (902)

which paints the image of an equal society where the distinction between Elect and Preterite is abandoned. Thus, however close the time of destruction, there still is hope for a better world if 'we' join forces and in with the song: 'Now everybody –' (902). The closing words of the novel refer to an earlier song that advocates treating people as neighbours and partners rather than passing them over and thus tries to infuse the Glozing Neuters of the world with blood and human feeling: 'just turn to the Glozing Neuter nearest you, even your own reflection in the mirror, and … just … sing, […] Maybe we should stick together part o' the way, and / Skies'll be bright-er some day! / Now *ev*'rybody –' (802). At the fork of the road that the end of the novel presents, at the interface between fiction and reality, the reader is asked to join into the hopeful song and to jump the right way from the singularity this time.

3.5 Singularities: Fiction and Reality

A singularity with its infinite rate of change is not graspable: as Hayles puts it, it 'represents a point where the behavior of the function ceases to be mathematically expressible, except in a purely formal way. Metaphorically, it is the point at which the function escapes from the delta increments of rational analysis into the unknown.' (Hayles 191-92) Or in the terms of *Gravity's Rainbow*, a singularity's 'change from point to no-point carries a luminosity and enigma at which something in us must leap and sing, or withdraw in fright' (471). Similarly, signifying an ungraspable quantity, infinitesimal Δt is at 'the borderlines of rational knowledge, the name we give to our inability to grasp reality clearly as it is' (Earl 241). Mathematical concepts such as singularities and infinitesimals thus are not purely rational or real, but they encompass a mysterious or 'unreal' element; they are 'a compromise with reality' (ibid). And it is exactly the enigmatic part that renders the mathematical concepts so fruitful to application; only the 'mental fictions' (Leibniz qtd. in Ross 32) in Leibniz's calculus make it a tool to investigate and understand reality. In *Gravity's Rainbow*, the idea that the non-real is a necessary part of reality is clarified in a nonmathematical domain when Tchitcherine argues that man is '"only real *at* the points of decision"' (832). Man is real only when they are free, when there is a choice between a path that will become reality and one that remains unrealised. Thus, seeing at least one 'unreality' is a precondition of being real, or in other words, being real necessitates fiction.

On several occasions, *Gravity's Rainbow* alludes to its own 'reality', that is, it reminds the reader that it makes decisions, realising only some out of many possibilities. Not least, the text chooses a course when taking a path closer to the reader's reality, thus losing sight of Slothrop until he literally vanishes from the text. As if making use of the infinite rate

of change at a mathematical singularity, the text jumps between different 'realities' when it first describes: 'A fly lands belly-up on the front fender of Roger's motorcycle, thrashes ten seconds, folds its veined and sensitive wings, and dies.' (748) and then presents another course of the event a few sentences later: 'The fly, who was not dead, unfolds its wings and zooms off to fool somebody else.' (748) Accepting uncertainty is possible as long as it does not affect one's own reality, as Thanatz realises when, having left the ship *Anubis*, he is once again concerned about the past events, while before 'there was no need to choose: the memory could have been left so far behind that one day its "reality" wouldn't matter any more. Of course it happened. Of course it didn't happen.' (790) Similarly, Andreas is not satisfied with the statement: '"Nothing's been 'settled.'"' but opposes: '"But it doesn't work for *us*. We have to know what's really going to happen."' (867) The text supposes the reader to feel a similar urge to decide between possibilities for a clear and unambiguous reality: 'Is the baby smiling, or is it just gas? Which do you want it to be?' (155) And the reader's expectation of a meaningful novel world is also alluded to in a direct turn to the reader: 'You will want cause and effect. All right.' (786) In both cases, the text exhibits its fictional nature but also draws attention to the role of the reader in deciding what is considered real, and it suggests that just as freedom from gravity results in liberating flight but also in the disintegration of the universe, so openness of (the novel's) reality needs to be checked in order to maintain integrity and to make life – and reading – bearable. However, although the novel acknowledges the need for certainty and does not equally uphold all possibilities itself, the reader cannot disregard the text's multilayered, contradicting 'real' nature and choose one version of reality in the novel without losing a great deal of the text. In order to grasp the book and its diverse layers of meaning and reality, the reader has to bear in mind the multiple possibilities present in the text and note that, pointing out its infinite rate of change and the possibility to jump between different realities, *Gravity's Rainbow* is indeed a singular text.

4. Descent – Future – Probability Theory

After the infinitesimal moment at the apex of the parabola, the Rocket begins its descent which, if all necessary information is known, can be 'predicted': 'Calculus allowed a mathematical description of continuous change – given a starting configuration, past and future configurations could be reconstructed.' (Gondhalekar 86) However, viewed from the target area, vital information such as the conditions of launch and the Brennschlusspunkt is missing so that the Rocket's path cannot be calculated; therefore, the potential victims have

to resort to other means of determining the likely point of impact. In *Gravity's Rainbow*, probability theory is introduced as such a method to predict the future.

Probability theory emerged in the seventeenth century, at a similar time as the calculus. As the mathematician James Franklin explains, the developing language of mathematics is one reason for the contemporaneous invention of the calculus and probability theory, but also, the 'science of the continuous, the calculus of Newton and Leibniz' (Franklin 341) naturally leads to questions about future developments and thus to the very issues probability theory addresses. Until the seventeenth century the future was largely seen as predetermined by God yet unpredictable, but the then emerging deterministic worldview paired with the discovery of natural laws rendered it conceivable to foretell the future according to scientific laws. The mathematical investigation into the probability of events is commonly said to begin in 1654 with the correspondence between Blaise Pascal and Pierre de Fermat concerning problems of games of chance. In *Gravity's Rainbow*, the relation between games of chance, and probability theory and rocket hits is introduced when Slothrop muses: 'After a while you adjusted – found yourself making small bets […] about where the next doodle would hit …' (24).

4.1 Combining One and Zero

Newton and Leibniz, the inventors of the calculus, also had an impact on the development of probability theory. Hacking argues that the fact that the law of universal gravitation was upheld even though Newton was unable to explain the cause of gravity meant that similarly, probability theory and the closely related statistics could be accepted without understanding their causality: 'statistical laws merely describe constant regularities. Just like gravity, they do not get at efficient causes.' (*Emergence* 174-75) That the notion of laws is broadened to include relations beyond those determined by unambiguous cause-and-effect linkages results in a loss of certainty, but the increased applicability also constitutes a strength: Laplace highlighted 'the advantages of the analysis of probabilities in the investigation of the laws of natural phenomena whose causes are unknown or so complicated that their results cannot be submitted to calculus' (Laplace 107). A twentieth-century perspective leads to a similar evaluation: 'it has been one of the glories of mathematical statistics that it can deal with events in which conditions weaker than causation obtain' (Daston 'Doctrine' 47). Thus, the mechanistic universe based on Newton's discoveries fuelled hope in the causal predictability of the future, while the nature of his law of universal gravitation paved the way for the mathematics of Kute Korrespondences and probability.

Leibniz argued that 'a generalized theory of games should be the foundation for making any quantitative decision' (Hacking *Emergence* 58) when causal explanations are lacking, but 'while combinatorial analysis is traditionally used in the calculation of probabilities' (Griard 378-79), Leibniz employed it to deduce the reasons for electing one of his four proposed candidates as King of Poland. In *Gravity's Rainbow*, Leibniz's combinatorial analysis is echoed in Brigadier Pudding's writing about '*Things That Can Happen in European Politics*' using 'combinatorial analysis' (90). Pudding despairs as ever-changing reality makes it impossible to keep up with the task: '"Ramsay MacDonald can die." By the time he went through resulting party alignments and possible permutations of cabinet posts, Ramsey MacDonald had died. "Never make it, […] it's changing out from under me."' (90-91) Moreover, Pudding's 'predictions' do not fit the actual development: 'the permutations 'n' combinations of Pudding's *Things That Can Happen in European Politics* […] don't give Hitler an outside chance' (328). Pudding's problems resemble Leibniz's experience of proposing the future King of Poland based on combinatorial analysis: not only was Leibniz's essay printed too late to have any influence on the election, but none of the four candidates considered by Leibniz was chosen. Instead, a fifth man – the outside chance – became king (see Griard's discussion in 'The *Specimen Demonstrationum Politicarum Pro Eligendo Rege Polonorum*'). Although turning out to be unsuccessful, both Leibniz's and Brigadier Pudding's combinatorial analyses render evident the fact that the calculation of mathematical probabilities inspired hope for devising a similar method to 'calculate' the path of the future in general.

Leibniz based his belief of the calculability of the future on his conviction that the universe is expressible with only two characters: 'one to designate an empty place, the other to mark that it is filled' (Ross 29). The world would then consist of combinations of the two basic characters: just as in mathematics, where 'the whole of arithmetic could be derived from 1 and 0, so the whole universe was generated out of pure being (God) and nothingness' (Ross 101). Adopting the mathematical characters, Leibniz uses '0' to denote the nonexistent, while '1' expresses the monad, the basic element of reality which denotes a necessary condition and pure being: 'monad' means '[t]he number one, unity' (*OED* 'monad'). Since 'for Leibniz what is real can only be something that possesses a true unity' (Savile 12) real things 'cannot be complex, for if they were they would be liable to come apart, to dissolve and disintegrate, and thus lose the unity which is essentially theirs' (Savile 12). At the same time, nothingness is necessary for the conception of the world as it is a combination of '0' and '1'. This idea of a world made up by combination of two opposed elements is, as the following shall demonstrate, also present in *Gravity's Rainbow*.

Leibniz's association of pure being with 'the sun, or 1, radiating its light on formless earth, or 0' (Ross 102) resonates in the imagery of darkness and light that pervades *Gravity's Rainbow*. The generative power and creativity of combining single units is also demonstrated when the phrase 'you never did the Kenosha Kid' is set in different contexts and acquires diverse meanings according to the units with which it is connected. Moreover, in one of the passages recombining the phrase, Slothrop encounters the idea that there is only 'one of each of everything' (80). Following the idea that the real has to be a unity, Slothrop enquires as to the reality of those not constituting the pure being of a monad: 'what about all the others? […] Are those people real, or what?' (82) He is told: 'Some are real, and some aren't.' (82), and further learns that the real ones are only necessary if advancing Their plans. The 'nonexistent' that do not belong to the real category of 'one of each' thus rely on their usefulness to Their plans to become real. When learning that They do have plans in mind, there is hope for the masses to enter reality: 'ten thousand stiffs […] take on the sunny Disneyfied look of numbered babies under white wool blankets, waiting to be sent to blessed parents' (82). So, as for Leibniz, combinations of elect 'ones' and the masses of 'zeros' describe possible worlds all of which could potentially exist, but in *Gravity's Rainbow*, the ruling Elect finally decide the actual state of the world. This also means that the world is not determined only by what is, but that, analogous to probability theory dealing 'with events in which conditions weaker than causation obtain' (Daston 'Doctrine' 47), conditions weaker than existence have to be taken into account in order to understand a world shaped by 'combinatorial analysis' of opposites: being/inexistence, elect/preterite, light/darkness, 1/0 …

4.2 Binary Thinking vs. Existing Between Zero and One

Pointsman, who does not see possible worlds but only one future defined by causality and conditioning, could be said to regard the universe as determined by 'a mosaic of tiny on/off elements […] each point is allowed only the two states: waking or sleep. One or zero.' (64) His belief in binary oppositions means that he 'can only possess the zero and the one' (64), numbers which in probability theory denote events that certainly will not take place (0) or that will certainly occur (1). Pointsman is contrasted to the statistician Roger Mexico to whom 'belongs the domain *between* zero and one' (65): 'If ever the Antipointsman existed, Roger Mexico is the man.' (64) As a statistician, Mexico is professionally wedded to the domain between zero and one, since all uncertain probabilities are expressed by fractions: for example, the probability to obtain 'heads' when flinging a

coin is $^1/_2$; the probability to roll a six with a die is $^1/_6$. Importantly, a probability is not a prediction of the future, it is impossible to tell if the coin will show heads or what number is rolled; and obviously, the coin will not show half heads, half tails. Thus, while '0' and '1' denote certain events and could therefore be said to predict the future, probabilities only indicate the chance of an event. Given a large number of cases, it can be 'predicted' that heads and tails of a coin will occur equally often, or that $^1/_6$ of the rolls of a die will show the number six, however, the general order of a large number of cases does not give any indication as to the probability of the individual event which consequently remains unpredictable: even after five 'heads' in a row, it is not any more or less probable to obtain another 'head', but the probability stays $^1/_2$.

Similarly to the 'prediction' of obtaining an equal number of heads and tails when flinging a coin very often, a large number of rocket hits is distributed in a predictable pattern, described by the Poisson distribution. The statistician Mexico follows the emergence of this pattern by keeping a map of London, 'ruled off into 576 squares, a quarter square kilometer each. Rocket strikes are represented by red circles. The Poisson equation will tell, for a number of total hits arbitrarily chosen, how many squares will get none, how many one, two, three, and so on.' (64) Analogous to the probability of 'heads' approaching $^1/_2$ when flinging a coin very often, so regarding Mexico's map of London there is a 'chance of 0.37 that, by the time he stops his count, a given square on his map will have suffered only one hit, 0.17 that it will suffer two …' (65). For a large number of cases, Mexico can thus 'predict' the distribution of the hits: 'Another "event" for Roger Mexico, a round-headed pin to be stuck in his map, a square graduating from two up to three hits, helping fill out the three prediction, which lately's being lagged behind …' (164). Yet, Mexico insists on the fact that he cannot prophesy individual hits but only keeps track of their developing according to a statistical distribution: 'It's not precognition […] all I'm doing is plugging numbers into a well-known equation, you can look it up in the book and do it yourself …' (64).

A hundred pages later, the Poisson equation is given in the text, and the reader could indeed plug in the numbers and dispel all doubts as to the difference between the randomness and unpredictability of an individual event and the calculability of a large number of cases. Readers not so inclined might identify with Mexico's girlfriend Jessica who has difficulties comprehending the possibility to foresee the general pattern of dispersion and the simultaneous impossibility of individual prediction. 'Roger has tried to explain to her the V-bomb statistics: the difference between distribution, in angel's-eye view, over the map of England, and their own chances, as seen from down here.' (63), but Jessica asks: '"Why is your equation here only for angels, Roger? […] Couldn't there be an equation

for us too, something to help us find a safer place?"' (63) While Mexico's answer is not particularly helpful: '"Why am I surrounded," his usual understanding self today, "by statistical illiterates?"' (63), a later explanation enlightens the matter: the information that the Poisson distribution also applies to 'cavalry accidents, blood counts, radioactive decay, number of wars per year …' (166) highlights the general applicability of the Poisson equation and indicates that the nature of the calculated, the content, is not taken into account, but that it is a general, statistical law. Thus, while Pointsman with his binary thinking and conditioning predicts individual cases with absolute certainty, Mexico's statistics only allow determining a probability and describing general developments for a large number of occurrences independently of their nature.

The opposition between Pointsman's binary and Mexico's statistical worldviews becomes manifest in their evaluation of the correspondence between Mexico's chart of rocket hits and Slothrop's star-adorned map of supposed sexual encounters. While Pointsman assumes a causal connection due to conditioning, by contrast, 'Roger Mexico thinks it's a statistical oddity' (100) and insists on the difference between random hits and conditioned effects when exclaiming: '"Bombs are not dogs. No link. No memory. No conditioning."' (65) The negation of any influence of past hits disconcerts Pointsman as he understands that Mexico also 'wrecks the elegant rooms of history, threatens the idea of cause and effect itself. What if Mexico's whole *generation* have turned out like this? Will Postwar be nothing but "events," newly created one moment to the next? No links? Is it the end of history?' (65) If events are not causally connected, the passage of time does not form into the supposedly meaningful progression of history, and consequently, the future is similarly not determined by the past and remains unpredictable. Rather, the notion of history and 'prediction' is only possible in hindsight, forming past events into a coherent succession and presenting the outcome as predictable. This interpretative and determining activity is reserved for the ruling powers, as Slothrop learns. The Elect, apparently controlling the course of history, do not predict or govern the future but the past: 'The odds They played here belonged to the past, the past only. Their odds were never probabilities, but frequencies *already observed*. It's the past that makes demands here.' (248) The Elect thus ascertain the view of the past which They form into a meaningful historical order, but only possessing the zero and the one which denote certain states, They cannot control the future which belongs to the domain between zero and one and is only describable in probabilities.

4.3 Living in Probabilities

Pointsman's and Mexico's worldviews might be opposed – the respective base in causal determinism and probability theory providing 'a mathematical metaphor for the difference between the two men' (Ozier 'Antipointsman/Antimexico' 78) – but they also determine each other as their common beginnings in the seventeenth century suggest. The two concepts even appear in the same book, as Daston points out: the 'classic statement of determinism occurs in Laplace's work on probabilities' ('Doctrine' 27); a fact that highlights the precondition of regarding nature as determined in order to base predictions on the grounds of scientific investigation. Since determinism and probability emerge together and depend on each other, Pointsman and Mexico play out a conflict originating in the seventeenth century.

In the twentieth century, discoveries in quantum physics redefine the relation between determinism and probability theory, and, as Alan Friedman demonstrates, along with 'the eighteenth-century clockwork universe, [and] the nineteenth-century statistical rules' (Friedman 94) quantum theory is one of the three 'distinct images from science' that serve 'as metaphors for the strategies for success that characters in *Gravity's Rainbow* adopt' (Friedman 95).[8] In *Gravity's Rainbow*, Tchitcherine, talking about the problem of creating highly effective pain killers without causing addiction, alludes to the most famous example of the far-reaching consequences of discoveries in quantum physics: '"We seem up against a dilemma built into Nature, much like the Heisenberg situation. […] It appears we can't have one property without the other, any more than a particle physicist can specify position without suffering an uncertainty as to the particle's velocity –"' (414) Comparable to the linkage of a greater effect of pain killers with a higher degree of addiction, Heisenberg's uncertainty principle states that the more exact the momentum of an electron is determined, the greater becomes the uncertainty as to its position and vice versa. Hence, while in everyday life, we can very well measure both the speed of a car and its location with practical certainty, this is not possible for a subatomic particle; instead of determining position and momentum exactly, they can only be given as probabilities. Scientific developments in the twentieth century thus reveal that prediction is possible only in probabilities and not in certainties, not due to man's limited knowledge but because unknowability is intrinsic in the basic building blocks of the universe. Hacking describes this discovery as the 'most decisive conceptual event of twentieth century physics […].

[8] For a detailed explanation of the physical worldviews in *Gravity's Rainbow* also see Nadeau.

Causality, long the bastion of metaphysics, was toppled, or at least tilted: the past does not determine exactly what happens next.' (*Taming* 1)

Since probability replaces determination and causal relations at the subatomic level, Mexico is right in saying: '"there's a feeling about that cause-and-effect may have been taken as far as it will go. That for science to carry on at all, it must look for a less narrow, a less … sterile set of assumptions. The next great breakthrough may come when we have the courage to junk cause-and-effect entirely, and strike off at some other angle."' (104-5) Here, Mexico does not speak as a scientist in the Second World War who would probably be familiar with the cataclysmic developments of quantum physics, but he assumes a state of mind much closer to the beginnings of the conflicting concepts in the seventeenth century. Where Mexico and Pointsman embody the opposed yet mutually determining seventeenth-century views, Enzian fully embraces – and exaggerates – the twentieth century discovery that existence is only probable: '"Well, I think we're here, but only in a statistical way. […] our own chances of being right here right now are only a little better than even – the slightest shift in the probabilities and we're gone – schnapp! like that."' (430) As one of the Hereros, the passed-over from history, Enzian is particularly apt to understand the randomness of existence implied by quantum physics: '"Forty years ago, in Südwest, we were nearly exterminated: There was no reason. Can you understand that? *No reason*."' (430) Existing in probabilities thus also entails accepting the random succession of events without cause, reason, and meaning.

As their respective reactions to probabilities indicate, Pointsman, Mexico, and Enzian personify three scientific worldviews: a deterministic universe tied to Newtonian physics, a statistical universe based on probabilities, and the universe of quantum physics with its fundamental uncertainty. While the seventeenth-century pair Pointsman/Mexico is concerned with possible knowledge of the future and considers '0', '1', and the domain in-between on an epistemological level, Enzian experiences the essential uncertainty of living in probabilities as an ontological situation. The three characters thus can be said to embody the shift from modernist fiction and its epistemological dominant to the ontological focus of postmodernist fiction (McHale *Postmodernist Fiction* 9-10). Concerning the world of *Gravity's Rainbow*, Enzian's understanding of ontological uncertainty is obviously more adequate. As Brian McHale shows: 'the minds of *Gravity's Rainbow* give us access only to provisional "realities" which are always liable to be contradicted and cancelled out' ('Modernist Reading' 91) as they turn out to be characters' fantasies or hallucinations or vanish together with the mind as is the case when Slothrop's existence becomes less and less certain. The effect of the impossibility to determine the truth- and

reality-status of an episode 'is radically to destabilize novelistic ontology' (ibid 106), since what has been taken as novelistic reality might be eradicated with the next sentence '"schnapp! like that"' (430).

4.4 Freedom in the Normal Distribution

The thought and implications of a world based on probability rather than on cause-and-effect relations might be unsettling, but it also has the effect of negating planning and control and thus upholds the possibility of individual freedom. The feasibility of escaping control is once again introduced in relation to mathematics. Mexico, 'trying to piss Jeremy off', confronts him with: '"Little sigma, times P of s-over-little-sigma, equals one over the square root of two pi, times e to the minus s squared over two little-sigma squared."' (841) Jeremy is right to feel unsettled by the formula as it describes the so-called normal distribution, the most common probability distribution. The corresponding graph is bell-shaped, has its peak at the mean value, and decreases on both sides. Significantly, although probabilities further distanced from the mean value can quickly become very small, the value never actually becomes zero: in an event described by the normal distribution, no probability is completely impossible. Accordingly, as Schachterle and Aravind convincingly argue, by citing the equation, Mexico draws attention to the fact that however small a probability, it is never inexistent. After the encounter with Jeremy, Mexico and Bodine demonstrate the power of the outside chance and subvert a dinner of the powerful Elect by talking about newly invented dishes that are both alliterative and highly disgusting. Thus, when threatening Jeremy with the normal distribution, Mexico 'challenges the determinism of the Firm just as his and Seaman Bodine's gross menu suggestions upset Their banquet' (Schachterle and Aravind 168); like the law of large numbers which affirms a determined general pattern without precluding individual randomness, the normal distribution describes a usual outcome but also always allows for deviations from the expected.

In *Gravity's Rainbow*, the very improbable occurs fairly often: Pudding does not 'give Hitler an outside chance' (328) but is, of course, proved wrong by history; Ludwig finds his lemming 'at last and after all and despite everything. […] So not all lemmings go over the cliff' (865); thus there is, once in a while, 'the stray freak particle, by accident, drifting against the major flow …' (60). If small chances always exist, it just takes a big enough number of cases for the nearly impossible to happen: while Enzian does not think that there is a rocket named 00000, he relativises his conviction: '"I don't

believe there is one." "Zero probability?" "I think it will depend on the number of searchers."' (432) He thereby acknowledges that even though the probability might be close to zero, a large enough number of searchers means that somebody will hit on the outside chance sooner or later. Even death, the seemingly inevitable, can be circumvented: 'Statistically (so Their story goes), every n-thousandth light bulb is gonna be perfect, all the delta-q's piling up just right, so we shouldn't be surprised that this one's still around, burning brightly. But the truth is even more stupendous. This bulb is *immortal!*' (766) In human terms, too, immortality is possible if less literally: sometimes '– though it is not often Death is told so clearly to fuck off – the living genetic chains prove even labyrinthine enough to preserve some human face down ten or twenty generations …' (11). As these instances show, the margins of the normal distribution play a bigger role in history and life than their small probabilities seem to warrant, and Mexico's putting his hope on the outside chance of upsetting Their order is not entirely displaced. Already Aristotle argues in his *Poetics* that 'it is probable that improbable things occur' (Aristotle 135), a thought that also informs the writer Hans Magnus Enzensberger's critique of the unquestioned use of the standard probability distribution: 'every historical review demonstrates that not the common events but the unusual ones cause the most tremendous changes'[9] (Enzensberger 34). Brigadier Pudding's difficulties with predicting the future by combinatorial analysis thus point to a more general problem but also entail hope: somebody might always seize the outside chance.

If the improbable happens unusually often, so conversely, the probable can be least likely to occur. In *Gravity's Rainbow*, the calculated point of impact of the Rocket exemplifies that the expected and well-prepared is bound to fail: 'Chances are astronomically against a perfect hit, of course, that is why one is safest at the center of the target area.' (505) Trying to increase a probability to a 100% through perfect control is futile in general: 'there is Murphy's Law to consider, that brash Irish proletarian restatement of Gödel's Theorem – *when everything has been taken care of, when nothing can go wrong, or even surprise us ... something will*.' (327-28) As explained in the introductory chapter, Kurt Gödel's incompleteness theorem demonstrates that a mathematical system cannot be proven complete and consistent, so in the terms of everyday life, Gödel's theorem and Murphy's law suggest that trusting the well-planned and losing sight of outside chances is dangerous, since the improbable might always happen and change the world dramatically. Thus, while with the calculus mathematics is presented as a means of control

[9] 'wie jeder historische Rückblick zeigt, sind es gerade nicht die häufigen, sondern die seltenen Ereignisse, welche die enormsten Folgen zeitigen'.

with which the Rocket's ascent can be determined, probability theory discloses the existence of freedom and uncontrolled events. Tracing its development from the seventeenth to the twentieth century, *Gravity's Rainbow* illustrates how mathematics 'increasingly allows for pointlessness, contingency, probability' (Hendin 45) and renders understandable how mathematics can simultaneously be a means of determinism and control as well as promote freedom in probabilities.

4.5 Not Prediction but Fiction

The common occurrence of highly improbable events stresses the fact that mathematical probabilities are not predictions of the future: 'Reality is improbable, and that is the problem.'[10] (Esposito 50) Even a highly probable outcome cannot be considered certain as the most likely future development is by no means guaranteed, but if a probability does not draw upon or refer to the future reality and does not eradicate the uncertainty of the future, 'what relation does it have to reality then?'[11] (Esposito 10) The sociologist Elena Esposito elaborates that probabilities do not predict the actual future reality but indicate possible futures, some with higher, others with lower probability of actually taking place. Since probability theory takes into account all possibilities rather than predicting the future reality, it opens up 'a vast field of inquiry apart from the actual or real'[12] (Esposito 21), and in this sense, probability theory encompasses fictive realities – imaginable but not actualised versions of reality. As Esposito puts it, the numbers in probability theory form 'a fictive reality that does not compete with real reality but forms an alternative description'[13] (Esposito 31). Probability accordingly works in a similar way as literary fiction, which 'constructs a coherent world on the basis of explicitly fictive premises'[14] (Esposito 55-56). In other words, describing coherent worlds apart from the given, fiction and probability theory have a comparable relation to reality.

Since probability does not predict the future reality, it is not proved right or wrong by the unfolding events, but its correctness is independent from the actual development: 'the results of probability theory are not true, nor should they be, because they do not refer to real

[10] 'Die Realität ist unwahrscheinlich, und das ist das Problem.'
[11] 'in welchem Verhältnis steht sie dann überhaupt zur Realität?'
[12] 'ein riesiges Untersuchungsfeld jenseits des Tatsächlichen bzw. Wirklichen'.
[13] 'eine fiktive Realität, die nicht mit der realen Realität konkurriert, sondern eine alternative Beschreibung darstellt'.
[14] Fiktion 'konstruiert eine kohärente Welt auf der Grundlage ausdrücklich imaginärer Prämissen'.

reality […]. At the same time, they are not false either, as they are neither errors nor lies.'[15] (Esposito 69) In this respect, too, probability theory resembles fiction to which the categories 'right' and 'wrong' cannot be applied in the same way as to reality. However, despite their fictitiousness, fiction and probability theory can be employed as an orientation in the real world; they might not refer to real events but describe realistic developments – events that can even be more realistic than the highly improbable course taken by reality. Esposito argues: 'People do not take fictional texts as a guide because they are real or because they think they were, but because they are realistic. They present an explicitly fictive reality that the observer can nevertheless take as an orientation.'[16] (Esposito 56) Similarly, mathematical probabilities refer to fictive realities but can still be employed in making real-world decisions: 'statistics and probability theory constitute an unreal but realistic reality'[17] (Esposito 57). Unreal yet realistic, probability theory and fiction provide leads according to which the course of the world is shaped; observing probabilities in financial speculations and the taking over of the countdown from Lang's film just being two examples. Since such fictive realities are part of reality and have an impact on the course of the world, it is impossible to comprehend reality without considering the influence of fiction, but reality and fiction have to be understood as interrelated.

The depiction of probability theory and film in *Gravity's Rainbow* leads to the conclusion that by creating realistic alternative realities, fiction can have real effects in the world. For example, von Göll's films do, as he claims, '"sow in the Zone seeds of reality"' (461) and result in real children being born, and seizing the outside chance described by the normal distribution Mexico realises the possibility of upsetting the Elect's stomachs as well as their governing system. That fictive systems turn into reality suggests that the domains of fiction and reality are linked by crossover points. The connecting interface not only allows fiction to become reality, but it can be passed through in the other direction as well; for example when Blodgett Waxwing holds that Slothrop's fight with an octopus, which the reader has earlier experienced as 'really happening', is only a story: '"This really happened tonight. But that octopus didn't."' (295) As McHale examines in more detail, the reader can never fully trust the text, as passages 'are always liable to be retroactively qualified as dream, fantasy, or hallucination' ('Modernist Reading' 106). There

[15] 'die Ergebnisse der Wahrscheinlichkeitsrechnung [sind] nicht wahr, und sie sollen es auch gar nicht sein, da sie sich nicht auf die reale Realität beziehen […]. Gleichzeitig sind sie allerdings auch nicht falsch, denn es handelt sich weder um Irrtümer noch um Lügen.'

[16] 'Wer sich an fiktionalen Texten orientiert, tut das nicht, weil sie real sind oder weil er das glaubt, sondern weil sie realistisch sind. Sie präsentieren eine explizit fiktive Realität, an der sich der Beobachter trotz allem ausrichten kann.'

[17] 'Statistik und Wahrscheinlichkeitstheorie stellen so eine irreale, aber realistische Realität dar'.

then is no stable boundary between the worlds of fiction and reality in *Gravity's Rainbow*, but they are connected through an interface that allows for exchange. Esposito's theoretical evaluation of probabilistic and literary fiction thus agrees with the picture emerging from the illustration of similar concerns in the imaginative context of *Gravity's Rainbow*: since probabilistic and fictional prognoses and realities have real consequences, predicting the course of the world without taking into account the effects of the unreal but realistic realities described by mathematics and literature misses a part of reality. Instead, realistic prediction has to take into account fiction.

5. Closing the Circle: *Gravity's Rainbow*

5.1 The Limits of Mathematics and Fiction

The Elect have an interest in maintaining the reality They control. In order to be controllable, Their worldview 'interlock[s] in a reasonable way, like They-systems do […] "*They're* the rational ones."' (756) As the Elect define the normal and govern the mainstream, it is in Their interest to reduce possibilities to the most common cases, and devising a controllable system built on reason, They could be seen to pursue what Daston describes to be '[t]he recurring Enlightenment dream of a calculus that would convert judgment and inference into a set of rules' (*Classical Probability* xv). Adhering to mathematical reasoning, the development of the They-system would be predictable and easily controllable and ultimately lead to the unambiguous worldview proposed by Leibniz: 'The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate, without further ado, in order to see who is right.' ('Art of Discovery' 51) Yet, in *Gravity's Rainbow*, Osbie Feel assures Mexico that three hundred years have not been enough to implement the mathematical way of thinking: '"We piss on Their rational arrangements."' (756) Mexico literally does so in a conference of the Elect, and his action is so far removed from Their rational understanding that They are 'not quite willing to admit that this is happening, you know, in any world that really touches, at too many points, the one *they're* accustomed to …' (753-54). Osbie Feel's revealing 'a Porky Pig tattoo on his stomach' (756) further suggests that this unusual world comprehends the counter-movement initiated by William Slothrop and his pigs, and that the envisioned equality of Preterite and Elect threatens Their rational system.

Mexico does not immediately understand the idea of a governing They-system: '"what is a 'They-system,' I don't pull Chebychev's Theorem on you, do I?"' (756) Chebychev's theorem, named after the mathematician Pafnuty Chebychev, can be used to prove the weak law of large numbers in probability theory. While according to the strong law of large numbers a value will almost surely converge to the expected mean value, the weak law states that 'nearly all' values do so. But if only nearly all values behave according to the probabilistic prediction, a small number might differ. Chebychev's Theorem can thus be seen as another instance of freedom warranted by probability theory, and it supports Pirate Prentice's conviction that it is possible to elude the governing They-system. Prentice explains that the Preterite develop another worldview, a '"We-system"' (756) to counteract the They-system and its reasonable order. Spontaneous and unorganised, the We-system does not follow a calculable pattern but responds to immediate and varied needs: Slothrop embarks on 'one small impromptu counter-conspiracy' (252), and he finds 'thousands of arrangements, for warmth, love, food […]. No more or less real than all these others so private, silent, and lost to History.' (346-47) So Mexico's comparison of the They-system and Chebychev's Theorem proves adequate: the rational They-system might govern 'nearly all' instances, but 'nearly all' precisely means 'not all' and leaves room for alternatives.

Neither the They-system nor the We-system covers everything, and consequently, neither comprehends reality but each creates an artificial order: '"We don't have to worry about questions of real or unreal."' (756), Pirate Prentice claims. While the relation to reality is of no importance, the intrasystemic consistency counts: '"It's the *system* that matters. How the data arrange themselves inside it. Some are consistent, others fall apart."' (756) Similar to Pirate Prentice who is satisfied to play '"Their game"' (756) and construct a thorough We–system '"[o]ut of expediency"' (756) as long as it does not lose sight of its necessarily incomplete character, which, '"[s]eeing as we haven't won yet, it isn't really much of a problem"' (756), Esposito argues in relation to fictive worlds: 'The inherent coherence thus is the only, but extraordinary save guarantee of the subjectivist construction'[18] (Esposito 38). In this demand for consistency there lies hope to be spared Leibniz's vision of a completely rational world: as stated by Murphy's law for everyday occasions and by Gödel's incompleteness theorem for mathematics, a complete and consistent system is an impossibility. And if a system can be either consistent or complete, then the logical consequence of Pirate Prentice's stressing the necessary consistency of a

[18] 'Die interne Kohärenz stellt also die einzige, dabei aber ausgesprochen sichere Garantie der subjektivistischen Konstruktion dar.'

system is that the system is incomplete, thus allowing for the formation of a counterforce in the uncontrolled spaces. Conversely, a system is never complete and fully in control without being inconsistent, so 'any System which cannot tolerate heresy [… is] a system which, by its nature, must sooner or later fall' (887). Therefore, regardless of how much the They-system tries to govern everything, there necessarily always exists a counter-movement and possibility of subversion.

'"We don't have to worry about questions of real or unreal"' (756), Prentice claims; yet, a fictive system can never replace or be completely disconnected from reality. Enzian upholds the priority of reality: '"They'd only be passing a story along, another story. But the truth must mean something to you."' (782) And he assures Katje: '"There *are* things to hold to. None of it may look real, but some of it is."' (781) The misleading attractiveness of untenable fictional systems appears most clearly when the correspondence of Slothrop's sexual encounters and the rocket hits is discovered to be unfounded as '"the names on Slothrop's map do not appear to have counterparts in the body of fact"' (323). Even if fiction provides a better explanation of reality by inventing causal reasons that render the world understandable and meaningful, the undeniable facts urge us to accept the random nature of reality. Esposito similarly notices: 'The relation to the world serves as the corrective of fiction.'[19] (Esposito 114) *Gravity's Rainbow* then also illustrates that if stories cannot replace reality, seeing the world through the limited lens of reason and calculation is equally insufficient. An engineer reports a problem with the chamber pressure of the Rocket: '"Our calculations show that a working pressure of 40 atü would be the most desirable. But all the data we know of are grouped around a value of only around 10 atü."' (374) Enzian argues for the precedence of the reality of facts over calculation: '"What are these data, if not direct revelation? […] How do you presume to compare a number you have only derived on paper with a number that is the Rocket's own?"' (374-75) The correctness of a calculation is unimportant if it does not fit the facts – mathematics is not reality, and Leibniz's 'rectified' reasoning based on mathematics does not arrive at what or 'who is right' (Leibniz 'Art of Discovery' 51). Mexico, too, learns that reality is not always reflected in mathematics. He at first relies on numbers to reveal the existence of 'the Other World' after death: 'If anything's there it will show in the experimental data won't it, in the numbers …' (47). But the facts he finally receives are not given as number but as emotion; he feels Jessica and himself united in love: 'here is the first, the very first real magic: data he can't argue away' (45). The facts of reality thus inhibit both the construction of purely fictional and of entirely mathematical systems – opposed poles that are, of course, themselves impossible: mathematics

[19] 'Der Bezug zur Welt dient der Korrektur der Fiktion'.

incorporates 'mental fictions' such as infinitesimals, and fiction without relation to reality would be inconceivable. In this sense, excluded middles are bad shit indeed,[20] as middles are the only thing we have.

5.2 Opposites Together: Whole Reality

Oppositions point to the importance of states other than the visible and governing: the Elect cannot exist without the Preterite invisible '"in their darkness"' (204), '"[t]he dead are as real as the living"' (181-82), and Rocket 00000 is matched by 'the 00001, the second in its series' which perhaps 'will be painted black' (859). The Rocket thus does not only illustrate life in its three-stage path, but it is also tied to the idea that existence does not end with the visible course but is completed by a dark counterpart.

What could be called a 'counter-Rocket' succeeds '"the quintuple zero"' (432) and its absolute zero point. It is made of discarded pieces of earlier rockets and is 'scavenged all summer piece by piece clear across the Zone' (797): 'So the assembly of the 00001 is occurring also in a geographical way, […] seeds of exile flying inward in a modest preview of gravitational collapse' (874). On the bigger scale, a 'gravitational collapse' would decide 'between return and one-shot visitation' (691) and lead to the birth of a new universe; concerning the Rocket, the term means that the parts dispersed in the big bang of its explosion are brought together again. The renewal takes place outside the Rocket's parabola-shaped life, in the dark inside of the earth: the Rocket is not 'bounded below by the line of the Earth it "rises from" and the Earth it "strikes" […] Of Course It Begins Infinitely Below The Earth And Goes On Infinitely Back Into The Earth' (861). Inside the earth, due to gravity 'having hugged to its holy center the wastes of dead species, gathered, packed, transmuted, realigned, and rewoven molecules' (698-99), the dispersed parts of dead life-forms are reassembled into new patterns. Similarly, the counter-Rocket is made from old pieces after the Rocket's life has ended, thus 'resurrecting' the rockets and forming them into new life. The Rocket's path across the sky is thus only an insufficient half of its existence; its 'life' is complemented by a passage through 'the other silent world' (861) that begins with the Rocket's 'death' and 'burial' in the earth, and it is then resurrected into the new unity of the 00001.

Mathematical functions and the calculus can be used to describe the parabola-shaped path of the Rocket's life, but the complete circular passage cannot be expressed by those

[20] Pynchon's *The Crying of Lot 49* illustrates that there are more possibilities than the certainties of 0 and 1: 'She had heard all about excluded middles; they were bad shit, to be avoided' (*Crying* 125).

means: a function demands that each value *x* corresponds to only one value *y*, so it can describe a semi-circle and a parabola, but not a circle where each *x* is linked to two values *y*.[21] The means by which the Rocket's parabolic path is determined is thus insufficient to take account of the complete route that resembles a circle. Instead of being expressed in mathematical terms, the semi-circle of the dark passage through death and the earth is rendered by a myth of the Hereros: they believe that the sun lives in the sky until in the evening it is speared 'to death until its blood runs out over the horizon and sky' (383). Then, 'under the earth, in the night, the sun is born again, to come back each dawn, new and the same' (383). Relating the sun's death and rebirth, the Hereros' story covers the part of existence that the calculus cannot cover. *Gravity's Rainbow* thus illustrates a similar idea as informs Jean-François Lyotard's argument that 'scientific knowledge does not represent the totality of knowledge; it has always existed in addition to, and in competition and conflict with, another kind of knowledge, which I will call narrative' (Lyotard 7). In the novel, the mathematics of the calculus exemplifying seventeenth-century Enlightenment thinking and rationality can only give a description of daylight existence, while the dark counterpart is covered by complementing narrative. The path of Enlightenment chosen after the publication of Newton's *Principia Mathematica* thus constitutes a jump away from a comprehensive understanding of the world as it disregards an essential half of existence. Hope lies in the still possible reappropriation of non-scientific, nonrational knowledge, such as Lyle Bland's overriding the seventeenth-century understanding of gravity as force. Defying gravity in flight, Bland proves that the Masonic knowledge is not lost: 'the words, moves, and machinery have been more or less faithfully carried down over the millennia, through the grim rationalizing of the World, and so the magic is still there, though latent, needing only to touch the right sensitive head to reassert itself' (696). Thus, although Enlightenment science prevails and the Second World War, seen 'as a world revolution, out of which would rise […] a rational structure' (195), might further increase the hold of Their rational system, a nonrational, narrative knowledge and power still exists.

Since the Rocket's and the sun's path above ground, the mathematical instrument of the calculus, and life in light and preferment only constitute one half and are complemented by a dark counterpart, opposites have to be considered together in order to grasp the whole reality. Von Göll understands: '"we define each other. Elite and preterite, we move through a cosmic design of darkness and light, and in all humility, I am one of the very few who can comprehend it *in toto*"' (587). *Gravity's Rainbow* places the realisation of the

[21] A circle can be described by mathematical means, of course, but not in the language of the calculus as employed in *Gravity's Rainbow*.

interdependence of opposites with William Slothrop who argues 'holiness for these "second Sheep," without whom there'd be no elect' (658). In the seventeenth century when William realises the importance of the Preterite, there also occurs a decisive step in the valuation of fictive systems for the understanding of reality. Most significantly, the seventeenth century saw the rise of the novel, a genre that created realistic characters and settings and followed the premise that '[f]iction had to seem like fact' (Shapiro 264). In her book on seventeenth-century conceptions of the nature of truth, *Probability and Certainty in Seventeenth-Century England*, Barbara Shapiro puts the emergence of the realistic but fictional novelistic 'reality' in relation to the notion of truth created by probability theory. Esposito similarly develops that at the same time as fiction approached reality, with the emergence of probability theory and the consequent concern with fictive future realities, mathematics took a turn towards fiction: 'Probability theory and the modern novel emerged almost simultaneously.'[22] (Esposito 7) Esposito pursues the fruitful hypothesis that, with the domains of fiction and fact converging, 'in the 17th century a historically new relation to reality developed; indeed, that here the doubling of reality which is typical for modern societies can be experienced for the first time'[23] (Esposito 8). So with the seventeenth-century emergences of the novel and probability theory, the formerly uniform reality became a 'coexistence' of different possible and realistic realities. As Esposito explains, the result is a '"pluralism of realities", as fictive as each reality on its own might be. Each […] claims to be a reality, that is, not only a fantasy, a hallucination or an arbitrary creation.'[24] (Esposito 68) At the same time, 'real reality' first became perceivable when it was distinguished against the fictive realities of the novel and probability theory, that is, when it was seen as different from 'something that is described as either not-real or realistic in another way'[25] (Esposito 8). In this way, seventeenth-century mathematics and literature doubled reality, adding fictive versions against which reality could define itself, thus demonstrating that reality and fiction influence each other.

Von Göll explains that elite and preterite define each other and that the aim is to '"comprehend it *in toto*"' (587). When he wants his films to '"sow in the Zone seeds of reality"' (461) he also understands that reality and fiction have to be perceived together, as opposed and determining halves forming a whole. Esposito draws a similar conclusion from

[22] 'Die Wahrscheinlichkeitsrechnung und der moderne Roman entstanden beinahe zeitgleich.'
[23] 'daß im 17. Jahrhundert ein historisch neuartiges Verhältnis zur Realität entstand, ja, daß hier zum ersten Mal jene Realitätsverdoppelung erfahrbar wurde, die typisch ist für moderne Gesellschaften.'
[24] '"Realitätspluralismus", so fiktiv jede Realität für sich auch sein mag. Jede […] beansprucht, eine Realität zu sein, d. h. nicht nur eine Phantasie, eine Halluzination oder ein willkürliches Gebilde.'
[25] Etwas 'das entweder als nicht-real oder als auf andere Weise realistisch beschrieben wird'.

her examination of the simultaneous emergence of the novel and probability theory: 'reality in its full sense comprehends both levels including the relations between them'[26] (Esposito 86). As fiction is part of and influences reality, '[r]eality cannot be understood if ignorant of the forms and meanings of fiction'[27] (Esposito 120), but both aspects have to be taken into account. Slothrop understands the potential of considering the world not only in terms of one governing reality when he learns 'that the Zone can sustain many other plots besides those polarized upon himself […] – and that by riding each branch the proper distance, knowing when to transfer, keeping some state of minimum grace though it might often look like he's headed the wrong way, this network of all plots may yet carry him to freedom' (714). Only seeing a world 'polarized upon himself' results in the paranoid view of a universe where everything conspires to stifle freedom. Conversely, regarding the universe in terms of 'anti-paranoia' (515) 'where nothing is connected to anything' (515) does not allow riding any branch or making any impact on the world. Yet, from the in-between of such states of paranoia or anti-paranoia, of absolute or zero connectedness, the plurality and interconnections of possible states of reality can be seen, and being aware of multiple possibilities and interfaces allows for 'transfer' between plots, for '"[c]reative paranoia"' (756). Thus, by taking into account both aspects – the stable overall pattern and individual freedom, the general probability distribution and the random single event, the given reality and fictive creations – one might be allowed to keep 'some state of minimum grace' and achieve individual freedom (714) like Slothrop; or, infused with blood, human feeling, and '"[t]he physical grace to keep it working"' (879), creative paranoia and taking advantage of the dual nature of reality can help approach William's vision of a just and equal world.

When, as Shapiro and Esposito argue in their respective works, the seventeenth century witnesses conflicting concepts of truth and reality, the world can be said to miss the opportunity to widely acknowledge the interrelations of reality and fiction and adopted a one-sided view focused on the visible part of existence describable by the Enlightenment means of reason and mathematics. The status of reality is again put into question in the twentieth century when discoveries in quantum physics point to the essential uncertainty of reality on the subatomic level and when the world might have arrived at the time predicted by von Göll: '"Springer, this ain't the fuckin' *movies* now, come on." "Not yet. Maybe not quite yet."' (625) In the reader's reality when 'film is fast enough, the equipment pocket-size and burdenless and selling at people's prices' (625), reality might not have quite turned into

[26] 'Allerdings umfaßt die Realität im vollständigen Sinn beide Ebenen einschließlich der Beziehungen zwischen ihnen.'
[27] 'Man kann die Realität nicht verstehen, wenn man Formen und Bedeutung der Fiktion nicht kennt.'

the movies, but the understanding of reality is once again being redefined. And at the end of the novel, novelistic 'real reality' and the virtual reality of film do indeed merge: the Rocket does not only fall in the movie but also in the spectator's reality. At least in the fiction of *Gravity's Rainbow*, reality is '"the fuckin' *movies*"'. This time of uncertainty and redefinition opens another chance to recognise the whole of reality, and the reader is given the fiction of the last Δt to realise the potential for change inherent in the real and imaginary components of reality. The direct addresses to the reader in the novel's final paragraphs draw attention to the coexisting levels of fiction and the reader's reality, and, so *Gravity's Rainbow* suggests, the reader could take advantage of the crossover of reality and fiction and use the singular point at the ending of the novel where continuity is broken and an infinite rate of change occurs, not just to jump back into their 'real reality' but to help William's ideas, which are expressed in the final song, to cross the interface and realise the three hundred year old dream of doing justice to the whole of reality.

Gravity's Rainbow itself realises William's ideas when it constitutes a world in which historical reality and exuberantly imaginative fiction, light and dark, mathematics and fiction, and various discourses, possibilities, probabilities, and realities coexist, connect, and turn into each other. Not least, *Gravity's Rainbow* brings its own opposites together. Before reading the novel, its title might seem to forcibly combine a scientific term with a poetic image. This brings to mind John Keats's famous accusation that, through its scientific investigation, Newton 'had destroyed all the poetry of the rainbow' (Haydon 317); conversely, Newton might have claimed gravity to only belong to the scientific sphere. In the course of *Gravity's Rainbow* however, the respective attribution to the domains of science and literature is reversed: the rainbow, similar in shape to a parabola, is related to mathematical and scientific concepts, while gravity is revealed to be a fictitious force. Yet ultimately, considering *Gravity's Rainbow* as a whole, the interrelations and complementing of scientific and literary aspects suggest that scientific investigations do not destroy the poetry of the rainbow, nor fictional elements discredit the explanatory function of science, but that we have to take into account diverse levels at once: the individual where specific disciplinary conditions rule, as well as the general where, comprehending '"[o]pposites together"' (667), everything fits.

All that Counts: Mathematics in Literature – Modernist Interrelations

In Pynchon's, Broch's, and Musil's novels the early twentieth century is presented as a time of deep transformation in the social, cultural, and political sphere and also in mathematics whose modern development is presented as distinctive of the wider change. As this study has demonstrated, the novels illustrate the 'modernist transformation' (Gray *Plato's Ghost* 1) of mathematics as mirroring and interrelated with changes in other areas, and the novels by Pynchon, Broch, and Musil also illuminate the redefined connection of mathematics to reality. Not least, the works of the three writers highlight similarities between mathematics and literature and suggest convergences between the domains in comparable modernist characteristics. Conclusions from this study can thus be drawn regarding the field of literature and mathematics studies and in relation to the area of modernist studies.

The novels discussed take an exceptional position in the growing field of mathematical literature since they present mathematics as part of broader encyclopaedic endeavours. Relating mathematics to its historical and cultural contexts, the works lend themselves particularly well to examine modernist interrelations between diverse fields, and they address concerns that animate the relatively recent reorientation in the history of mathematics and cultural science studies. Significantly, the novels' strategies to illustrate mathematics' embeddedness in the early twentieth century highlight differences between the modernist authors' almost contemporary treatment of the period and Pynchon's writing from a perspective up to a century after the events. Broch and Musil are especially concerned with changes in the relation of the rational and the non-rational to which twentieth-century developments in mathematics contribute, and the stylistic innovations of their works reflect this focus. To some extent, their modernist novels employ a theoretical style when presenting the rational domain mathematics and its interrelations: in *The Sleepwalkers*, the trilogy's use of mathematics as an example of the period's transformation is discussed in an integrated essay, and the essayistic style in *The Man without Qualities* allows the introduction of mathematical concepts outside the storyline and is aimed at combining the scientific and the artistic sphere. In contrast, Pynchon's postmodern revisiting of earlier periods and digestion of mathematical concerns is, while firmly rooted in historical actuality, stylistically fully dedicated to the novels' exuberant fictionalities of theme and practice. Thus, where Broch and Musil directly and instructively introduce modern mathematics as

'the clearest example'[1] of a 'sweeping revolution in the style of thinking' (*SW* 481) and as 'the new method of thought itself, […] the primal source of an incredible transformation' (*MwQ* 35), Pynchon's *Against the Day* imaginatively illustrates mathematics to be at the core of the period's transformation when the First World War is suggested to be caused by the mathematical Quaternion weapon. The imaginative treatment of mathematics is similarly characteristic of *Gravity's Rainbow*, and the novels by Pynchon also share a focus on the relation between mathematics and reality which undergoes a significant redefinition as part of the 'modernist transformation' (Gray *Plato's Ghost* 1) of mathematics. The modernist novels' concern with the role of mathematics regarding the interplay of the rational and the non-rational and their partly adopting more rational, essayistic styles to integrate mathematics into the sphere of literature are thus contrasted with Pynchon's postmodern interest in the nature of and transition between reality and fiction and his novels' fully absorbing mathematics into their exuberant literary imagination. This distinction also accords with Brian McHale's identification of a tendency towards epistemological concerns in modernist texts and a dominance of ontological concerns in postmodern texts.

This study has examined four works that are exceptional in the extent to which they are informed by mathematics and the history of mathematics and whose encyclopaedic visions illustrate mathematics as intricately interrelated with social, cultural, and political concerns of its time. Contrasting texts from the time of changing relations in the early twentieth century and from the perspective of the revived interest in their connections in the later twentieth century, this study contributes to the emerging field of literature and mathematics studies by taking account of literary works from two decisive moments in the relation of literature and mathematics and pointing towards a changed focus in the novels' engagement with mathematics that accords with more general characteristics of modernist and postmodernist texts.

This study's examination of works with a common focus on the early twentieth century but produced at different points in the reassessment of the relation between mathematics, reality, and the imagination also contributes to modernist studies and the renewed focus on the First World War as it approaches its centennial. *Against the Day*, *The Sleepwalkers*, and *The Man without Qualities* put the First World War at their centre, establishing it as the most dramatic manifestation of change and crisis in the early twentieth century. The First World War as an overwhelmingly negative result of scientific progress and rationalisation gives rise to increased critique of Enlightenment values and the

[1] 'am deutlichsten' (533).

foundations of modernity in science and reason, and the assessment often includes a critique of mathematics and mathematisation. When mathematics as the epitome of reason undergoes change however, the related notions of science and reason are also affected, and the works by Pynchon, Broch, and Musil illustrate these wider consequences of mathematics' modernist transformation. Taking account of the changes in mathematics, the novels do present it as an instrument of rationalisation and control but more importantly, they identify a positive 'modernist' potential in modern mathematics' independence of reality and explore the counter-modern intuitionist view which promises a reintroduction of a unifying human factor into mathematics and the increasingly rationalised and disintegrated world. In other words: when, in their different ways, *Against the Day*, *The Sleepwalkers*, *The Man without Qualities*, and *Gravity's Rainbow* engage with the crisis of modernity and its symbolic height in the First World War, their (post)modernist responses illuminate the non-rational in mathematics and highlight the freedom at the heart of this epitome of reason. Thus, ultimately, this study's focus on encyclopaedic novels illustrating interrelations between mathematics and other areas from modernist and postmodernist perspectives, reveals the imaginative uses to which suggestions of a convergence of literature and mathematics in common modernist characteristics are put: a promotion of freedom and imaginary doublings of reality, be they mathematical or literary.

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Appendix: Glossary

Axiom of Choice: The axiom of choice is an axiom in *set theory*, formulated by Ernst Zermelo in 1904. It allows making selections from infinite collections of sets. The axiom of choice is not universally accepted in intuitionism.

Banach-Tarski Paradox: The Banach-Tarski paradox is a theorem in *set theory*, formulated by Stefan Banach and Alfred Tarski in 1924. It implies that a ball can be decomposed into pieces and then be reassembled into two balls of the same size as the original ball. This also means that a big ball can be reassembled into a small ball and vice versa. Because of its counter-intuitive nature, the theorem is termed a paradox, but it complies with the rules of set theory and is not a mathematical paradox in the sense of the *Russell paradox*.

Calculus: The calculus is a branch of mathematics concerned with change, for example motion. Examples of application are calculations with velocity, acceleration, arc length, and centre of mass. Independently from each other, Newton and Leibniz invented the calculus in the seventeenth century.

Cantor's Continuum: The term *continuum* refers to *real numbers*. Cantor compared the sizes of infinite *sets* and formulated the hypothesis that there exists no set whose power is between the power of the set of *integers* and the power of the set of real numbers. Cantor could not prove his hypothesis, and it was later shown that Cantor's continuum hypothesis can neither be proved nor disproved in the framework of standard set theory.

Chebychev's Theorem: Chebychev's theorem can be used to prove the *law of large numbers*. It states that 'nearly all' values in a probability distribution group around the mean value. This means that values deviating significantly from the mean value are highly improbable, though not impossible.

Commutativity: Commutativity means that in a calculatory process the order of the elements can be changed without affecting the result. For example: $4 * 3 = 3 * 4$, or $a + b = b + a$. The multiplication of *Quaternions* is not commutative, but: $i * j = -j * i$.

Complex Number: A complex number has the form $x + yi$ and consists of a *real* unit (x) and an *imaginary* unit (yi). A complex number can be interpreted as a *vector* in a plane which starts from the origin and goes to the point $x + yi$ with x units on the real x-axis and y units of the imaginary number axis i, which is the perpendicular y-axis.

Continuum: In set theory, the continuum is a name for the *real* numbers.

Delta t, Δt: Delta denotes a small quantity, here the difference in time. In calculus, delta t can become *infinitesimally* small, so that delta t corresponds to a moment in time that is almost (but not exactly) zero.

Differentiation: Differentiation finds the derivative of a *function*. The derivative measures the quantity of change at a certain point of a function, which is indicated by the slope of the tangent at that point. For example, the derivative of a function describing position in relation to time shows velocity. The reverse process of differentiation is *integration*.

Fluent: 'Fluent' is Newton's term for the integral *calculus*. In Newton's terminology, the fluent is the *integral* of a *fluxion* and can be used to determine a sum of values of a function, which can be visualised as the area between the x-axis and the graph of the function. Newton's terminology is no longer in use.

Fluxion: 'Fluxion' is Newton's term for the differential *calculus*. In Newton's terminology, the fluxion is the derivative of a *fluent* and can be used to measure the quantity of change at a certain point described by the function. Newton's terminology is no longer in use.

Function: A function relates an input value to exactly one output value. Functions can be visualised as graphs.

Imaginary Number: The term 'imaginary number' is sometimes used as a synonym for '*complex number*' which consists of a *real* part (x) and an imaginary part *(*yi): $x + yi$. More specifically, the term 'imaginary number' refers to the element i of a complex number: $i^2 = -1$, or also: $i = \sqrt{-1}$. Negative squares are defined in the complex number system, but not in the real number system; imaginary numbers were therefore said to 'not exist'. Imaginary numbers can be thought of as set on an axis perpendicular to the real number line.

Incompleteness theorem: The incompleteness theorem states that mathematics cannot be proven complete and consistent. There are always statements in mathematics that are regarded as true but cannot be proven. The theorem was formulated by Kurt Gödel in 1931 and ended the hope that the formalist programme could determine the foundations of mathematics.

Infinitesimal: An infinitesimal is an infinitely small quantity, a value that is approaching zero but is infinitesimally greater than it.

Infinity: *Cantor's continuum* hypothesis showed that there are different sizes of infinity. For example, both the set of *integers* and the set of *real* numbers are infinite, but the set of integers is smaller than the set of real numbers.

Actual Infinity: Actual infinity denotes an actual, completed totality. Actual infinity was long considered a paradoxical idea, and infinity was understood as *potential infinity,* which is never completed as potentially elements can always be added to it. Sets are collections of numbers that form actual, completed totalities, so actual infinity is an important concept in set theory.

Potential Infinity: Potential infinity corresponds to the traditional understanding of infinity. It denotes not a completed totality but an infinite series to which an element can always be added. For example, whole numbers 1, 2, 3, … constitute a potential infinity since there is always a next number that can be added after the 'last' number.

Integer: A whole number, such as 1, 2, 3, …

Integration: Integration is a concept in the *calculus.* It is the reverse process of *differentiation* and accordingly recovers a function from its derivative. For example, if the velocity at a certain point is given, the function describing the law of motion can be recovered through integration. An integral can be visualised as the area between the *x*-axis and the graph of the function.

Irrational Number: An irrational number is a *real* number that cannot be expressed as a ratio of two whole numbers. Examples are π and $\sqrt{2}$.

Law of Excluded Middle: The law of excluded middle states that either a proposition is true or the negation of the proposition is true. It is also known as 'tertium non datur', meaning that there is no third possibility between the proposition and its negation. Intuitionist mathematics does not accept the law of excluded middle as an axiom.

Law of Large Numbers: The law of large numbers is a theorem in probability theory, stating that over a large number of cases, the average value will be close to the expected value. For example, when flinging a coin, the outcome of a single throw cannot be predicted, but over a larger number of cases, heads and tails will come up equally often.

Minkowskian Space-Time: Minkowskian space-time refers to the geometrical understanding of Einstein's theory of relativity as four-dimensional space-time, combining three dimensions of space and the dimension of time. It was formulated by Hermann Minkowski in 1907.

Non-Euclidean Geometry: In non-Euclidean geometries Euclid's *parallel postulate* does not hold, that is, parallel lines can meet and, as an implication of the inapplicability of the parallel postulate, the angular sum of a triangle is not necessarily 180 degrees. For example, geometry on the globe is elliptic: on the globe, a triangle can be defined by two longitudinal lines, which meet at the pole, and the equator connecting them. Since longitudes cut the equator at right angles, the two angles at the basis of the triangle already sum up to 180 degrees. When the angle at the pole, where the two longitudes intersect, is added, the angular sum of the triangle is greater than 180 degrees, thus contradicting Euclid's postulate. Non-Euclidean geometries were discovered in the nineteenth century.

Normal Distribution: The normal distribution is the most common probability distribution. The function is shaped like a bell with the peak at the mean value and probabilities decreasing on both sides of the mean value.

Parallel Postulate: Euclid's axiom states that in a geometric system there are two straight lines that are at constant distance from each other. In *non-Euclidean geometry*, which was discovered in the nineteenth century, the parallel postulate does not hold.

Poisson Distribution: The Poisson distribution is a probability distribution describing the probability that a given number of events occur in an interval of time or over a number of experiments. For example, if on average 2 goals occur in a football match, there might be matches with 0 goals and others with 4 goals; the Poisson distribution describes the probability of seeing a match with no goal, 1 goal or 2 goals etc. The Poisson distribution was introduced by Siméon Poisson in 1837.

Quaternion: Quaternions are hypercomplex numbers and extend the *complex number* system from two to four dimensions. While *complex numbers* describe the location of points on a plane, Quaternions describe the location of points in space. A Quaternion consists of a *scalar* or *real* part (*a*) and the remaining *vector* or *imaginary* part: $a + bi + cj + dk$, whereby i, j, and k are *imaginary numbers*. Quaternions were discovered by William Rowan Hamilton in 1843.

Rational Numbers: A rational number can be expressed as a ratio of whole numbers, for example $^1/_2$, $^4/_7$, etc. In contrast, *irrational* numbers cannot be expressed as ratios of whole numbers.

Real Number: The real number system includes *rational* and *irrational* numbers, but does not include *complex* or *imaginary* numbers. Real numbers can be considered as points on the number line.

Riemann sphere: The Riemann sphere extends the plane described by the *complex numbers* into a sphere. It was described in the nineteenth century by Bernhard Riemann who also developed Riemann geometry, which works with higher dimensions.

Russell's Paradox: Russell's paradox was discovered by Bertrand Russell in 1901. It concerns the question whether the set of all sets that are not members of themselves is a member of itself. As the question cannot be answered but any answer creates a paradox, it demonstrated that *set theory* leads to contradictions.

Scalar: 'Scalar' is a term defined by William Rowan Hamilton to describe the scalar or *real* part of a *Quaternion*. A scalar is a *variable* that can be expressed as a real number and has only quantity, not direction. In contrast, a *vector* has both quantity and direction.

Set Theory: Set theory studies mathematical sets, that is, collections of objects. Nearly all mathematical objects can be formulated in set theory, making it a foundational theory of mathematics. Set theory was developed in the nineteenth century, but in the early twentieth century, paradoxes such as the *Russell paradox* were discovered and challenged the belief that a secure foundation of mathematics could be established through set theory.

Singularity: A singularity is a point at which an equation is not defined or behaves in an anomalous way; for example, a point where a function is not continuous or differentiable. The graph of a function can lead up to a singularly and then continue at a completely different point or in a completely different direction after the singularity. A singular point cannot be *differentiated*; the rate of change is infinite or is not defined.

Tetractys: The tetractys consists of ten points, arranged into rows of one, two, three, and four points, which thus form a triangle. The Pythagoreans employed the tetractys as a mystical symbol.

Third Law of Motion: The third law of motion is one of three physical laws formulated by Newton. It states that to every action there is a reaction of equal force in the opposite direction: '*actio = reactio*'.

Variable: A variable stands for a value that may vary. It usually refers to *real numbers*. In a *complex number* $x + yi$, the values x and y are variables, whereas i is not a variable but a constant: i is always $\sqrt{-1}$.

Vector: A vector is characterised by its length and by its direction. It can be imagined as a directed line in a coordinate system, originating in one point and pointing to another.

Weierstrass Function: The Weierstrass function was formulated by Karl Weierstrass in 1872. By proving that there are continuous functions that are nowhere *differentiable*, the Weierstrass function challenged popular belief in the mathematical community.

Zermelo's Axiom of Choice: see *axiom of choice*.

Zeta-Function / Riemann's ζ-Function: The zeta-function considers the distribution of prime numbers in a *complex number* system. The famous Riemann hypothesis, formulated by Bernhard Riemann in 1859, is about the distribution of the zeros of the zeta-function. While it can easily be shown that the zeta-function has zeros at the negative even *integers* such as -2, -4, -6, …, Riemann conjectured that the non-trivial zeros occur at complex values that vary in their *imaginary* component but all have the *real* part $^1/_2$. The conjecture has remained unproven to today.