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THE GEOMETRY OF NARRATIVE:

FROM NATURALISM TO POSTMODERNISM

BY

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CONTENTS

INTRODUCTION

Mathematics develops as a result of deriving solutions to what seemed impossible to past generations of mathematicians. In geometry, for instance, each new mathematician builds upon of the work of his predecessors, refining and proving theorems and thinking of possibilities unfathomable to those that came before.

Literary movements develop similarly. Born out of the zeitgeist of a generation, each new literary movement can be seen as a reaction to that of the older generation. One generation of writers focuses on order and representing society; the next turns to the individual, valuing the mind above the general effects of class; the following generation rebels against both, exploring when society and the individual escape our attempts to define them; Naturalism leads to modernism leads to postmodernism.

Both disciplines, literature and mathematics, despite frequently being seen as polar opposites, develop in a similar manner, continuously building off the work that has come before them while also accounting for what they see as the older generations' shortcomings. This similar development of the two fields is apparent when you examine the changes in both geometry and narrative form from the late eighteenth through the twentieth centuries, although one must be cautious about concluding that one field directly influenced the other. Any such statement would be pure speculation as culture, mathematics, and literature all feed into each other in a complex interplay that is not easily discerned or expressed. This paper, therefore aims to explore their inter-relationships rather than definitively state which ideas came first. It will do so by first

defining the key terms of narrative form and the three types of geometry to be used throughout the paper.

The first section will address the parallels between naturalist writing and Euclidean geometry, using *Nana* by Emile Zola as a case study. The second section will compare the development of both modern literature and hyperbolic geometry at the turn of the century. This time, we will analyze *Mrs. Dalloway* by Virginia Woolf. Lastly, the third section will explore the connection between postmodernist literature and fractal geometry. We will look at *The Crying of Lot 49* by Thomas Pynchon.

Narrative Form

Narrative is one of those fundamental terms that is both impossible to study literature without and tricky to define holistically. Narrative theorists have crafted numerous definitions that attempt to capture what narrative is, and the theory can be seen as the study of its components and how they work together. In one of its most straightforward forms, narrative theory breaks down a work into two main components. As Suzanne Keen states: "The 'what' of the story is distinguished from the 'how' of the narration." In more technical terms taken from Russian formalism, the narrative is composed of a fabula or story (the events as they actually happen) and a sjuzet or discourse (the events as they are narrated) (4). Narrative theory dissects the tension and cohesion between these two components. Thus, the theorist forms conclusions about the work based on how the elements, the fabula and sjuzet, interact with each other, how the course of events as they happen (although fictitious in this paper's case) are affected by how they are narrated in terms of style and timing. For instance: Is a narrator reliable? Are events out of order? One could also view narrative theory as the analysis of the

interaction between plot, story, and narrative, with sjuzet being divided between plot and narrative. The plot is the chain of cause and effect that dictates how events in the story are linked. The narrative is the showing and telling of such events (Cobley 5-6).

Narrative analysis is thus concerned with the different levels of communication operating within the work. The many complex relationships between author and reader are addressed both separately and together. Their order can be represented in Figure 1, with the double lines representing the elements within the work. The real author is the historical person who wrote the novels. The biographical facts about the author lie in this layer. Next is the implied author, the version of the author projected by the work. This level is how one can compare the style of the works of one author (Keen 36). Thinking of how the author in a biographical sense is always written about in the past tense (Zola was a French writer), whereas in the context of the work, the present tense is used (Zola implements Darwinism in *Nana*), is very helpful in differentiating between the two authors.

real author → || implied author → (narrator) → (narratee) → implied reader || → real reader

Figure 1. Adapted from *Narrative Form* by Suzanne Keen (35)

The narrator is responsible for the discourse of the story and assumes a variety of types—first-person, third person, internal, external, overt, covert, reliable, unreliable—that will be defined below. The communication of the narrator implies that a narratee must exist at this same level; the narrator must be telling the discourse to someone (Keen 37). In some works, this narratee remains unnamed because no direct address exists in the

work. The narratee nevertheless remains separate from the implied reader or the audience that the work assumes (Keen 37).

Characterization and how the work represents thought are also key components of narrative theory. There are also many ways in which consciousness is represented in a work. These dramatically change in fashion from literary movement to literary movement with obvious variations within each movement. Thus, these will also be defined throughout this paper as they are implemented.

Geometry

Originating from the Greek word *geometrein*, geometry began as the study of measurement (*metrein*) of the earth (*geo*) (Greenburg 5). It was developed as a way to explain the shape of the physical world but quickly began to encompass things beyond visual representation.

Euclidean

In a way, Euclidean geometry is geometry in its simplest form, although as one studies the concepts further, this simplicity is revealed to be deceptive. It is the geometry one can visualize and find easily in the physical world. While it contains all of the early geometry we are exposed to in high school, it also encompasses a vast amount of nuance and complexity. For the purpose of this paper, we will only consider the basics of the broad field of Euclidean geometry in order to establish a knowledge and allow for an exploration of its similarity to the narrative structure of naturalism.

Euclid was a Greek mathematician who wrote around 300 B.C.E, but geometry had been developing long before him (Greenburg 1). These early developments are still considered Euclidean, since his work follows them directly without altering any axioms.

Geometry is thought to have originated in Ancient Egypt, Babylon, India, and China. In its early states, it was primarily experimental, pragmatic, and approximate.

Geometry became what we now study when the Greeks adapted the experimentation of earlier civilizations into rational and generalizable statements. For instance, while the Egyptians knew that if a triangle has sides of length 3, 4, and 5, it was a right triangle, the Greeks proved that if a triangle has sides of lengths a, b, c and $a^2 + b^2 = c^2$, then the triangle is also a right one. It would be impossible to list all the different possible lengths to prove this by experimentation, but the logic of proofs provided mathematicians with the ability to state that it was true (Greenberg 8).

Euclid founded the methodology used in such proofs, the Axiomatic Method. The method begins with the acceptance of certain axioms or postulates, statements that are considered true without further justification. Such axioms are the conclusion of a line of reasoning used to prove a new theorem (Greenberg 9). This method of reasoning and formal proofs is now used universally and has led many mathematicians to only work in the realm of so called "pure mathematics" that only deals with theoretical truths and not their application. This method of reasoning also influences naturalistic narrative form, as explored in the next section.

Using the axiomatic method, Euclid developed a few postulates that were the foundation of classical geometry. From there he was able to deduce 465 propositions, encompassing all the geometric knowledge of his time (Greenberg 9). In the next section of this paper, we will see that many of these postulates that serve as the foundation for geometry are also echoed in naturalist literature.

For this paper's comparative purposes , perhaps the most important of Euclid's postulates is his parallel postulate. For every line l and point P that does not lie on l, there exists ($\exists$) a unique line m through P that is parallel ($\parallel$) to l. Intuitively, this seems straightforward and obvious. Two things that run parallel to one another have the same slope and therefore must never intersect. No two parallel lines, the way they are normally thought of, can pass through the same point (Figure 2). Yet, there is no truly definitive way to state that two lines will never meet, since they are infinite. This postulate has thus been contested throughout mathematic history (Greenberg 21). As we will see, it is also the postulate that does not apply in hyperbolic space, although the hyperbolic surface was not discovered until hundreds of years after Euclid's works.

a $\longleftrightarrow$

b $\longleftrightarrow$
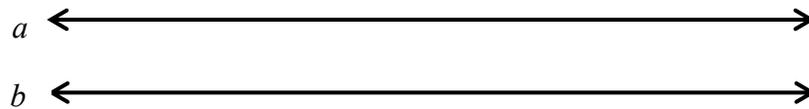
Figure 2. In which $a||b$.

This postulate is further complicated when the concept of a straight line is considered. From general geometry classes and idioms, a straight line is typically thought of as the shortest path between two points. Yet, it is impossible to measure *all* paths between two points, so under mathematical logic, this definition fails (Henderson and Taimina 14). Euclid defined a straight line as "a line that lies symmetrically with the points on itself." This is a much stronger definition but requires seven forms of symmetry (Henderson and Taimina 9). While many shapes and curves have some symmetries, only straight lines have reflection-in-line, reflection-to-the-line, half-turn, rigid-motion-along-itself, 3-dimensional-rotation, central, and self-similarity symmetry (Henderson and Taimina 17-21). These different symmetries provide a far more rigid and logically sound

definition of a straight line, which we will see is very visually different in hyperbolic geometry.

Before moving on to the other two geometries used in this paper, we must address the definition of dimension, a way of describing a mathematical space. We are most familiar with the Euclidean dimension (D_E). D_E is what is used in everyday life to describe objects. When one describes the dimensions of a piece of paper, one says it is 8.5 by 11 inches. The 2-dimensonal object is being described with two values: its length and width. One would add depth when describing a box. The Euclidean dimension is the number of coordinates needed to describe an object (Addison 11). For a point, one coordinate is needed, a line requires two, and a cube requires three. Euclidean dimensions also extend beyond the three physical ones to infinitely large dimensions that are not visualizable, but the Euclidean dimension system is not the only one, as will become apparent in the upcoming discussion of fractals.

Hyperbolic

Non-Euclidean geometry was developed in the early nineteenth century by a number of mathematicians originally working independently from one another. Janos Bolyai published his first ideas about geometry outside of Euclid's postulates as an appendix to his father's work in 1831 (Greenberg 144). The famous mathematician, Carl Friedrich Gauss, had been working on non-Euclidean geometry since 1792. He received a copy of Bolyai's work and discovered much of it was similar to his work (Greenberg 143). Neither mathematician ever published further work on hyperbolic geometry. This is in part due to both of their perfectionist tendencies. They also avoided publishing out of fear of disputing the dominant philosophical view of the time.

In the late nineteenth century, philosopher Immanuel Kant had popularized the idea that "the concept of [Euclidean] space is by no means of empirical origin, but is an inevitable necessity of thought." Society was dominated by values of reason and expressions of the physical world. Challenging such a dominate idea with revolutionary discoveries would cause a dramatic polarizing argument that Gauss wanted no part of, so his works on the subject were not published until after his death in 1855 (Greenberg 145). Modernist writers faced a similar dilemma. This philosophical change will, therefore, be addressed further in the section comparing the two.

Nikolai Ivanovich Lobachevsky was the first to publish his work in 1829, although it was in Russian, so it did not gain much attention. After it was translated into German in 1840, his work came to the attention of Gauss. Lobachevsky continued to develop the subject throughout his life but did not achieve mathematical popularity until after his and Gauss's deaths. In 1868, Eugenio Beltrami finally showed that no proof of the parallel postulate was possible, solidifying non-Euclidean geometry as just as consistent as Euclidean geometry (Greenberg 147).

Although other non-Euclidean geometries exist, in this paper, when considering non-Euclidean geometry, we will focus on the hyperbolic. In hyperbolic geometry, all of the postulates of Euclidean geometry are assumed, but the parallel postulate is negated. This negated postulate is known as the "universal hyperbolic axiom," which states: given a line l and point P (not on l) $\exists$, at least two distinct lines parallel to l that pass through P (Greenberg 149). In other words, straight lines can move towards each other without ever intersecting (Henderson and Taimina 60). Moreover, a line can be parallel to two or more

intersecting lines. This axiom leads to the very interesting theorem that in hyperbolic geometry rectangles do not exist, and all triangles have an angular sum less than 180°.

But what does a space without rectangles and with these strange triangles look like? There are five different isometric constructions of hyperbolic planes as surfaces in three-space used to make sense of this geometry. Perhaps the simpliest expression of the hyperbolic space is a crocheted model such as in Figure 3.

Figure 3. Crocheted hyperbolic plane (Durova)

Hyperbolic space can thus only be approximated in the Euclidean seeming world. From a mathematical logical standpoint, however, we live in a non-Euclidean universe. Gauss is said to have tested the nature of our world by using three mountain peaks as the vertices of a triangle. The sum of the angles was found to be less than 180°. Thus, one cannot conclusively say that the world is Euclidean. Since our instruments are subject to error, the results were inconclusive. If the sum came out to be exactly 180°, we would need to account for this error. We could not be sure if it was infinitesimally incorrect. Had the measurement come out to be 179°, we could conclusively say that the sum was

9

less than 180, because 180 is outside the margin of error. Thus, a physical experiment can never conclusively prove that space is Euclidean. It could, however, prove it is non-Euclidean (Greenberg 337-338).

Fractal

The final type of geometry that will be used in this paper is found throughout the world. A fractal is a never-ending pattern that repeats itself at different scales: when each fragment is expanded, the structure resembles the whole. This property of looking roughly the same on any scale is called "self-similarity" (Addison 1, Lauwerier 1, Weisstein). While true fractals are the result of the repetition of certain mathematical functions, fractals can also be seen in a number of natural occurrences. These natural fractals are often the easiest to visualize. For instance, the shape of an oak tree is formed by the trunk branching in two distinct limbs, and then each branch thereafter repeatedly splitts off into two more. Thus, when you look only at one branch and the next sets of twigs, the section resembles the whole original tree (Figure 4). Fractals also extend beyond the natural and scientific worlds and can be found in things that are manmade. Their presence in the structure of settlements, architecture, design, art, and cosmologies both modern and ancient has been extensively researched.
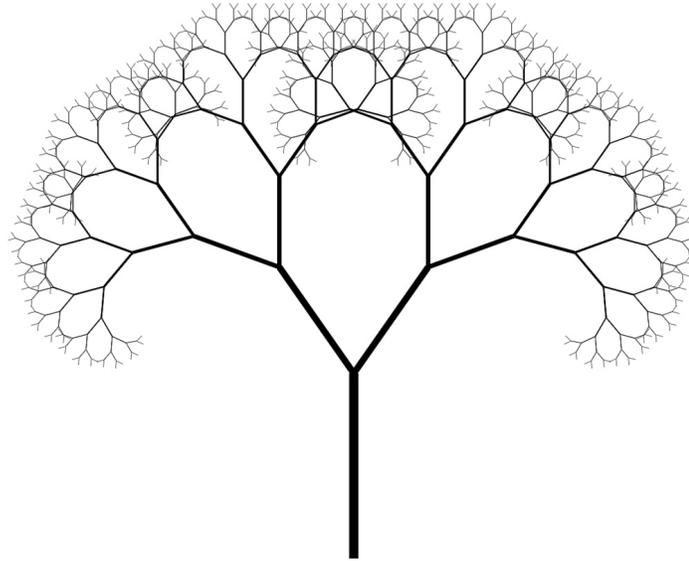
Figure 4. Fractal Tree (Reid)

This introductory section will focus on defining terms necessary for discussing fractals

mathematically. Much like the hyperbolic plane, it is easy to construct an approximation

of a fractal. The Koch curve is a particularly fascinating one discovered by Helge von

Koch in 1904. It is a fractal that has no tangents anywhere (Lauwerier 33). This means,

while it looks curved, the curve is an illusion, and it is composed of infinitely small

straight lines. Moreover, the whole Koch curve is infinitely long, despite fitting on this

page in Figure 5. If one were to disregard the issue of having a thin enough pencil and try

to trace the curve, it would take an infinite amount of time, even when drawing at the

speed of light (Lauwerier 33).
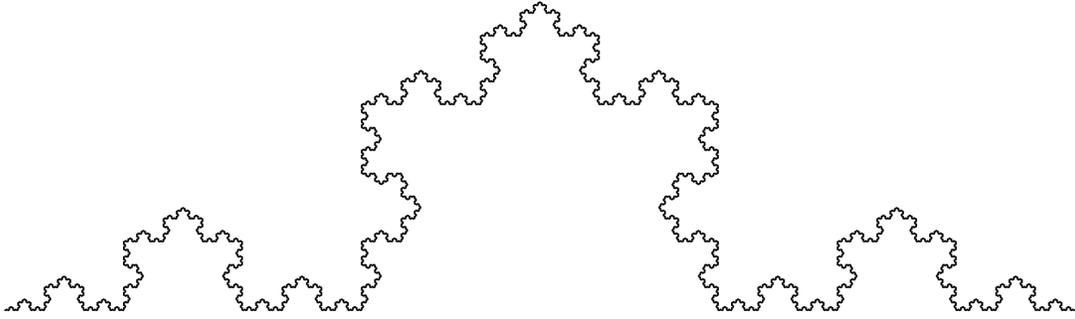
Figure 5. Koch Curve (Fibonacci)

One can, however, rather quickly get a feel for the curve by constructing the first few iterations. Begin with a line-segment (Figure 6a). Erase the middle third and fill the gap with the upright sides of an equilateral triangle (Figure 6b). There is now a bent line consisting of four equal line segments. Given that the base was of length 1, each segment will be of length 1/3. The resulting curve has a length of 4/3.This is what is called the motif of the fractal, what is repeated infinitely. Next each of these four segments is replaced with the motif. Now there is a bent line consisting of 16 line segments, with the total length of 16/9 or $(4/3)^2$ (Figure 6c). With each iteration, the bent line would get longer. Thus, when the motif iteration is performed infinitely, the resulting "curve" is infinite, as contained as it seems (Lauwerier 33).
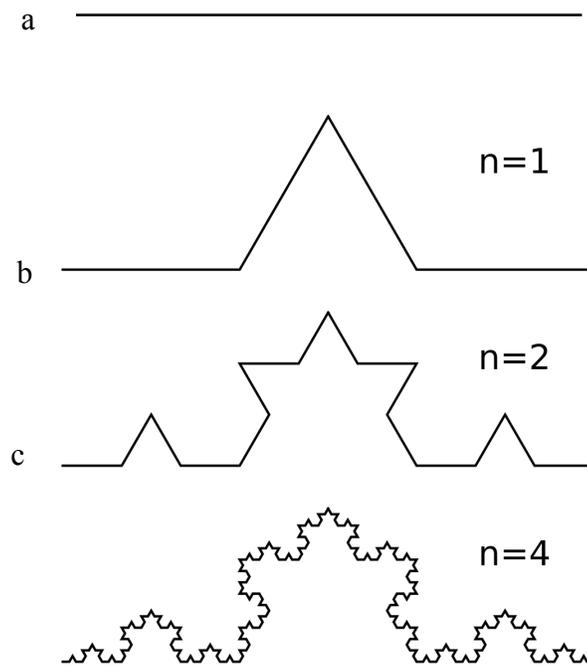
Figure 6a-c. Construction of the Koch Curve (Melikamp)

As alluded to earlier in the introduction, fractals are described by an additional set of dimensions beyond the Euclidean dimensions we are familiar with from the physical world. The fractal dimension is usually non-integer. It is also greater than the object's topological dimension (D_T) and less than its Euclidean dimension (D_E) (Addison 14). This paper is only concerned with the similarity dimension (D_S), although many others exist. The similarity dimension can be thought of as the degree to which a fractal is self-similar. This concept will be further explored in section IV.

Existing work on Literary Geometry

There has been much research on fractal literature in both mathematics and literary criticism. Very little work, however, has been done comparing non-fractal geometry to narrative structure. That portion of this paper will thus rely heavily on

narrative theory, which has looked at the structure of plot and narration in Naturalist and Modernist works.

In the study, "Multifractal Analysis of Sentence Lengths in English Literary Texts," Grabska-Gradzińska, Iwona, et al, created and implemented an algorithm that would assess the self-similarity of sentence length in works of literature. They found that works written in a stream-of-consciousness style were the most fractal (Grabska-Gradzińska, Iwona, et al.). Within this paper we will address how the fractal nature of our case studies is higher when stream-of-consciousness is used.

Many writers have also consciously incorporated fractals into their poems and prose, many of which are discussed in Michael Frame and Amelia Urry's *Fractal Worlds*. Frame and Urry also discuss James Cuttings' study of fractal shot distribution in films (114). They also summarized psychologist Lucy Pollard-Gott's method of box counting to assess the self-similarity of a poem (115). Frame and Urry conclude their section on fractal literature with a discussion of the fractal nature of the writing and reading processes themselves, extending the fractals beyond the page.

Many literary critics have also applied fractal analysis to individual works. Nina Mikkelsen looks at the fractals found in African American children's literature as related to the fractals in African design in "Diamonds within Diamonds within Diamonds: Ethnic Literature and the Fractal Aesthetic." Mikkelsen addresses the fractal nature of African American story-telling. She pays particular attention to Virginia Hamilton and Toni Morrison's children's literature. Peter Larkin has also looked at fractals in Romantic poetry in "Infinite Closure in 'Kubla Khan' and the 'Cave of Yordas.'" This article examines the infinite closure, a fractal structure, of two romantic poems, although

Larkin's analysis is focused on conceptual fractals rather than structural fractals that this paper will focus on.

In *Strange Attractors: Literature, Culture and Chaos Theory*, Harriet Hawkins explores how chaos theory and fractals affect literature. She focuses on the works of Shakespeare and Milton and examines how chaos fits into the works conceptually and the ways chaos theory can be used to look at a work's influences and the formation of the literary cannon. Similarly, N. Katherine Hayles looks at how chaos theory has affected postmodern literature in her book, *Chaos Bound*.

-I-

Euclidean and Naturalism: Social and Geometric Order

The first geometry and narrative connection this paper will examine is that of Euclidean geometry and Naturalism. Both schools of thought were deeply rooted in the Enlightenment ideal of reason and order. Naturalism imbedded the scientific influence of the time into literature. The writers of this movement thus centered their works on the current biological and evolutionary science, Darwinism. The naturalists focused specifically on social Darwinism or the belief that adapted Charles Darwin's ideas of natural selection to society. The trajectories of characters' lives are thus directly determined by their societal station at birth and what would have been seen as their innate qualities based on that standing. What class one was born into was directly related to who one was as a human being and where one's life would lead.

Émile Zola is frequently hailed as the leading writer and theorists of the movement. He wrote about the naturalist view that human behavior is a matter of "nerves" and "blood." He attacked the concept of free will, since all actions are dictated by what he called "the compulsion of their instincts" (qtd. Claridge). Within his and other naturalists' novels, characters' lives are thus dictated by a string of reason rather than their own will. Their lives are very much predetermined based on their social standing at birth.

In Zola's *Nana,* the title character is born to a poor, abusive family. In light of social Darwinism, she is thus naturally promiscuous and of weak morals. Throughout the novel, the origins of her immorality are highlighted: "Nana revenged herself for the

trouble people were causing her by cursing the male sex under her breath. Her foul language saddened the maid, for she saw to her distress that her mistress was not rising above her origins as quickly as she had hoped" (Zola 65). The narrator makes it clear that her character and everything that happens to her were the inevitable outcome of her birth.

The world is controlled by and explained through reason, since naturalism is a matter of cause and effect. In this way, it is very similar to Euclidean geometry and particularly the Axiomatic Method that was first described in the introduction. The method begins with the acceptance of certain axioms or postulates, statements that are accepted as true without further justification. For instance, the idea that equality is transitive and if $x=y$ and $y=w$, then $x=w$, is an axiom and therefore always accepted as truth. Axioms function as the fundamental building blocks of mathematics. To prove a statement, pure reasoning—which adheres to certain rules and techniques—is then used to demonstrate that one statement follows logically from another. This reasoning is continued in a chain until the proof reaches either an already proven statement or an axiom (Greenberg 9). Using the previous example, a proof could end by showing that your second to last statement must be true because equality is always transitive.

Naturalism can be viewed as applying this methodology to the plot of novels. Each event in a naturalist novel is clearly caused by the one preceding it since all events are governed by the scientific reasoning of the time, which heavily relied on logic. The reader is thus expected to consider the fabula (the events as they happen) and the plot portion of the sjuzet as one and the same. Because the novel works so closely within the scientific beliefs of the time, drawing upon the Axiomatic Method and its forefather the Scientific Method, the events of the novel unfold in a very linear fashion. The narrative

style of naturalist works is thus similar to that of Euclidean proofs. Since the plot element of the sjuzet is so linear, the narrator of naturalist works is generally an unidentified third-person observer. The influence of social Darwinism causes the detailed descriptions to take on an almost clinical tone in the hands of the naturalists.

This analytic and scientific narration style is particularly evident in the final passage of *Nana.* The novel closes with Nana lying dead in bed. The description spares no gruesome detail:

> [Rose] went out and shut the door. Nana was left alone, her face upturned in the light of the candle. What lay on the pillow was a charnel-house, a heap of pus and blood, a shovelful of putrid flesh. The pustules had invaded the whole face, so that on pock touched the next. Withered and sunken, they had taken on the greyish colour of mud, and on that shapeless pulp, in which the features had ceased to be discernible, they already looked like mould from the grave. (Zola 470)

By having Rose leave the room, the narrator is the only remaining witness of Nana's corpse. The narrator thus functions as the scientific observer to an even higher degree. He becomes a scientist recording the details of her death, rather than relating a story.

The passage is full of the morbid images of burial. A charnel-house was where skeletons would be stacked after they were dug up. Nana's body is covered in "putrid flesh" that appears to be covered in mud and mold. Her body is decomposing before the narrator's eyes. He is thus functioning as a pathologist preforming an autopsy on Nana, searching for the cause of her death. While it is known she died of smallpox, he is

accumulating evidence to determine the more metaphorical cause of her death within the theory of Social Darwinism. The description of her body continues:

> One eye, the left eye, had completely foundered in the bubbling purulence, and the other, which remained half open, looked like a dark, decaying hole. The nose was still suppurating. A large reddish crust starting on one of the cheeks was invading the mouth, twisting it into a terrible grin. (Zola 470)

The pathologist narrator itemizes each element of her decaying face, as if he were taking notes for a report. Clinical words such as "suppurating" and "purulence" add to the medical tone. He is accumulating the given elements of the situation he will draw upon in his Axiomatic argument that will close the novel:

> And around this grotesque and horrible mask of death, the hair, the beautiful hair, still blazed like sunlight and flowed in a stream of gold. Venus was decomposing. It was as if the poison she had picked up in the gutters, from the carcasses left there by the roadside, that ferment with which she had poisoned a whole people, had risen to her face and rotted it. (Zola 470)

Nana's outer beauty is gone, save her blonde hair. Left in its place is a gruesome representation of her inner character. In these final lines of the novel, the narrator connects her death with "the poison she had picked up in the gutters." At the time, gutters were full of filth and grime. Thus since 1811, "gutter" had functioned as slang for low and profane ("Gutter"). This lead's the reader to the passage's moralistic meaning. This poison from roadside carcasses thus represents her debaucherous behavior with the

lowlifes of the city. Moreover, it is representative of her place of birth in the gutter as a member of the lower-class. The "ferment," meaning at the time both bacteria and passion, that she had picked up in her childhood had poisoned her, and she in turn poisoned the higher-class people she interacted with as a prostitute ("Ferment"). Her death was the result of that poison, that debauchery.

While the passage resembles an autopsy, it can also be figuratively viewed as an Axiomatic Proof, which works under the postulates and axioms of the social Darwinist views of the time. The theorem of Social Darwinism being proven is a woman dies a gruesome death that causes her to immediately decompose such as Nana's if and only if (iff) she is morally inferior.

Proof.

Assume: Nana is covered by rotting pustules and appears to be decomposing. She is also born of a lower class and has worked as a prostitute.

Show: She is morally debased.

It is given that Nana is covered with pustules. She thus must have been poisoned by something, since poison causes such a horrific death.

It is also known she was lower class, $\Rightarrow$ she grew up in the gutter of society.

She thus must have been exposed to the filth of the streets, including moral filth.

People are a product of where they are born and the people they surround themselves with according to the axiom of Social Darwinism, therefore Nana is morally inferior.

QED

A corollary stemming from this proof would be that those who are morally corrupt infect everyone they interact with.

This scientific observation of naturalist writing was recognized by the writers of the time. In the words of Zola, the author of the work is both observer and experimenter: "The observer in him presents data as he has observed them, determines the point of departure, establishes the solid ground on which his characters will stand and his phenomena take place. Then the experimenter appears and institutes the experiment, that is, sets the characters of a particular story in motion, in order to show that the series of events will be those demanded by the determinism of the phenomena under study" (qtd. Claridge). Using narrative theory, one can analyze how the fabula and sjuzet interact in this view of the role of the author. By placing an emphasis on scientific observation, Zola equates the fabula and the sjuzet. Both the events of a naturalist novel and the narrative surrounding them are products of science. Thus, transitively, they are the same.

The narrative choices available to the naturalist are thus much more limited than those used by their successors. Using *Nana* as an example again, the observing narrator dictating a social experiment of sorts is always a third-person, omniscient, external, and covert narrator. The narrator knows all the characters' thoughts, exists outside of the work, remains nameless and does not draw attention to his role. Furthermore, the reader is supposed to believe the narrator is reliable beyond all doubt. The narrator is expected to be trusted because he is operating within the scientific framework as an observer following the Axiomatic Method. Each element of Nana's life leads logically to the next and finally to her inevitable death due to the axiom of natural selection.

Nowhere along the way is it hinted that the reader should doubt what she is being told. The narrative does not doubt the credibility of naturalistic views but continually refers back to them in descriptions of characters. Each character is described by their profession and social class with all the resulting moral characteristics.

For instance, when describing the origins of various prostitutes, the narrator details the origins of many of them, explaining the way their lives progressed to lead them to such a profession, how they got lost after coming to the city as a governess, or how they had been forced into the profession by the men in their lives. For others, however, their motivations are summed up as follows: "And then there were Maria Blond, and Louise Violaine, and Léa de Horn, who had all been reared in the gutters of Paris, not to mention Tatan Néné who had been a cowherd in the poorer part of Champagne till she was twenty" (Zola 112). The fact that they were born in poverty is enough to support their career choice. It logically follows from the given statement that they were born in the gutter of the city or on a poor farm.

Euclidean geometry's influence on naturalism extends beyond the Axiomatic Method. Euclid's debated and famed parallel postulate also helps define naturalist literature. The shape of a naturalist narrative is very much dictated by the parallel postulate, particularly the way the omniscient narrator addresses the thoughts of each character. Recall, the parallel postulate states: for every line l and point P that does not lie on l, $\exists$ a unique line m through P $\parallel$ to l (Greenberg 21). In other words, multiple unique lines of the same slope cannot pass through the same point. Furthermore, two parallel lines cannot intersect, unlike in hyperbolic geometry, as mentioned in the introduction.

Naturalist literature exists in Euclidean space; parallel lines never intersect. This is evident in the shape of the narrative. In *Nana*, the plot is very linear. Events take place one after the other in a chain of cause and effect. The trajectory of Nana's life retains a constant rate of change as she becomes more and more morally depraved, taking on more lovers to pay for her outlandish tastes.

The focus of the narration switches from character to character, circling Nana. Her story thus functions as line l. Each of the other characters can be represented as a separate parallel line through a unique point. They each travel parallel to the main story line, but we never see the same instant from more than one character. This is evident in the following passage:

> While he was talking, he watched the banker over Blanche's shoulders to see if it was coming off with Nana. But for the last few minutes Rose and Fauchery, who were talking very close together, had been getting on his nerves. Surely Rose wasn't going to waste time on a fellow like that? In that sort of case, dammit all, he put his spoke in. And making a great show of his fine hands, with the diamond flashing on his little finger, he finished off a fillet of venison.
>
> Meanwhile the conversation about children was still going on. La Faloise, excited by the immediate proximity of Gaga, asked after her daughter, whom he had the pleasure of noticing in her company at the Variétés. (Zola 110)

The first paragraph uses narrated monologue to express Mignon's thoughts. This style of expression of consciousness reveals the thoughts of a character in his mode of expression

while maintaining the tense and person of the narration. The tags of "he thought" are omitted in favor of making the thoughts part of the narrative (Keen 62). "Surely Rose wasn't going to waste time on a fellow like that?" is stated as if it were the narrator's observation, despite being within Mignon's patterns of speech.

The narration then switches to "psycho-narration", defined by Keen as the most traditional style of narration, that states the narrator's discourse about a character's thoughts. It is recognizable through the use of a number of tags that identify the character (Keen 61). La Faloise's excitement and thoughts about Gaga's daughter are stated in direct reference to him, not as the narrator's own observations. Furthermore, La Faloise's thoughts are about a different conversation than those of Mignon. They thus do not brake the parallel postulate.

This multi-modal expression of consciousness in the third person exists throughout the novel and helps achieve the many parallel views that do not comment on the same interaction. By switching between these different modes of conscious expression, the narrator is able to function as a scientific observer while also presenting the inner thoughts of the characters.

Euclidean geometry was also a large part of the philosophical views of the late nineteenth century. Immanuel Kant was a German Enlightenment philosopher whose ideas still dominated the western world. He was notorious for his faith in Euclidean geometry, Aristotelian logic, and Newtonian physics (Palmquist 1). He closely linked human existence with reason and scientific thought. In his philosophical view, the whole world was dictated by pure reason and was at its heart controlled by Euclidean mathematics. This philosophical view is evident in social Darwinism, which applies the

scientific concept of survival of the fittest to human life, even at a moralistic level. As will be explored in the next section, this dominant view of a Euclidean world would be challenged at the turn of the century in both geometry and literature.

-II-

Hyperbolic and Modernism: Multiplicity in Parallel Lines, Plot, and Consciousness

Kant's view of the world as ordered and Euclidean was challenged at the turn of the century in all disciplines. This is seen in the development of hyperbolic geometry and modernist literature, both of which sought to counter the dominant views in the western world at the time. Hyperbolic geometry asserted that spaces outside of the familiar Euclidean spaces existed and that within them, Euclid's parallel postulate does not hold. Modernism challenged the conventions established by realism and strove to create a deeper more nuanced expression of consciousness working outside what they saw as the limitation of Naturalism (Buchanan).

The word "modern" did not arise with the movement of modernism but rather existed long before. The movement took place between the late nineteenth and mid-twentieth centuries. The word modern is derived from the Latin "modo" meaning current. Until the mid-nineteenth century, however, it had no connotation. The term was thus only used towards the end of the movement. It is not known conclusively how the term came to represent the movement of writers, artists, and directors who went against convention (Buchanan). The exact definition of modernism thus remains hotly debated.

The movement is frequently encapsulated by modernist poet, Ezra Pound's phrase, "make it new." The modernist philosophy encompassed foregoing tradition in favor of experimentation. What caused this change towards the "new" is deeply debated by scholars. The primary though still disputed view is that modernism as an aesthetic

movement came along with the modernization of industrial technology (Buchanan). As society, particularly urban society, changed to accommodate this new technology, people had new concepts to explore in art and thus craved a new form different from that of previous generations.

A key effect of this industrial modernization was a change in the philosophical conceptualization of time. Before industrialization, time was predominantly viewed in Newtonian terms as "'objective,' self-same, and simply a surrounding 'ether' to events" (Schleifer 6). Time was viewed as always the same and separate from what was happening to individuals. Experience was thus viewed as atemporal (Schleifer 2). As seen in *Nana's* Eucledian narrative, this sense of time manifested in naturalist literature as a narrative of inevitable movement forward in time. Realist and naturalist works were thus "underwritten by the depiction of inner and outer worlds – though with the former strictly subordinated to the latter, and always subsequent to it. The stability of individual experience was dependent upon the stability of its world" (Sheehan 123). Time controlled the narrative because time was seen as unchanging and objective.

Modernization revolutionized the western view of time. The increased number of commodities at the turn of the twentieth century signaled a change in the way people experienced it. As British economist, John Maynard Keynes, stated in his 1930 essay, "Economic Possibilities for our Grandchildren," the material needs that were "the primary, most pressing problem of the human race" up until that point would no longer dominate human life, and instead "'man will be faced with his real, his permanent problem' of discovering value in freedom and leisure without the absolutizing measure of material need" (qtd. Schleifer 30). The modernist view of time was thus highly

subjective. It moved differently for each person and was very much connected to the event at hand; time was re-humanized (Sheehan 122). Time was thus no longer viewed as something linear and Euclidean in nature.

This sense of subjective time and desire for a new aesthetic form to match was only furthered by the devastation of World War One. The mass destruction it caused throughout Europe brought a new sense of urgency to life and physically wiped out much of the tradition that came before (Buchanan). The turn of the century also brought revolutionary changes in psychology. Freud and his contemporaries discovered that the self was also highly subjective and at war with itself. This view of the human psyche resonated with the devastated society. These revolutionary psychological views paired with the conception of subjective time to create what is frequently called "psychological time," in which "events do not take place in a homogeneous medium, measurable by instrumental means; they are coextensive and permeable, stored as memory below the level of consciousness" (Sheehan 124). Thus, much of the modernist movement focuses on better representing the inner world of people, rather than their greater role dictated by society (Buchanan). This involves creating a new form that rebels against those that came before and represents time as it functions in the new non-Newtonian view.

Modernist literature is thus characterized by the rejection of prior literary authority and the rationalism that proceeded it. Skepticism was the basis of modern thought and disrupted the axiomatic structure of narrative. Modernist narratives are thus fragmented in style and deeply psychological in focus. Narrated monologue or free indirect discourse became the lead expression of the thoughts of characters, giving way to stream-of-consciousness narratives. It is in these narratives that use this new stream-of-

consciousness, such as James Joyce's and Virginia Woolf's works, that these non-Newtonian sense of time, non-Enlightenment sense of self, and non-Euclidean narrative structure are most evident.

Before a comparison between these two movements can be made, it is necessary to clarify hyperbolic geometry. As stated in in the introduction, hyperbolic geometry is one of many forms of non-Euclidean geometry to appear in the nineteenth century. In hyperbolic geometry, all of the postulates of Euclidean geometry are assumed, but the parallel postulate is negated. Given a line l and point P (not on l) $\exists$, at least two distinct lines parallel to l pass through P (Greenberg 149). In other words, straight lines can move towards each other without ever intersecting (Henderson and Taimina 60). Moreover, a line can be parallel to two or more intersecting lines. This makes no sense in the Euclidean space in which one typically views geometry. Therefore, it is hard to picture a space where parallel lines are not conventionally defined.

It is thus helpful to construct an approximation of a hyperbolic plane by hand, as described by Henderson and Taimina. Cut out many annular (an "annulus" is the region between two concentric circles) strips of paper. They must have the same inner and outer radius but can be of different lengths. Attach all these strips together by taping the inner circle of one to the outer circle of the other. The resulting shape will be an approximation of a hyperbolic plane when one annular strip is kept flat. In order to represent the plane accurately, the width of each strip (δ in Figure 7) would need to approach zero (Henderson and Taimina 63).

Figure 7. Handmade construction of hyperbolic plan. See Henderosn and Taimina 62

Notice in the construction that the shape of the plane is dependent on the size of the radius of the annuli. Changing the value of δ and making additional models would illustrate this point. As the radius increases, the hyperbolic plane will get flatter and flatter. When the radius of the annuli approaches infinity, the resulting construction would be indistinguishable from the Euclidean plane. The Euclidean plane can thus be thought of as a hyperbolic plane with annuli of infinite radius, rather than a distinctly different plane (Henderson and Taimina 64).

A straight line looks very different on such a surface. The curves that run radially along the annular strips are intrinsically straight (Henderson and Taimina 66). This is what causes the differences in the parallel postulate to occur. As described above, straight lines can approach each other without intersecting, something that seems impossible in our world that resembles Euclidean geometry. Lines drawn on separate annuli that follow the curvature of the model illustrate how these lines behave. Geometry was revolutionized. The 2000 years of complete faith in Euclid's postulates were shown to be limited and not the only way of seeing geometry. Hyperbolic geometry is thus similar to modernism in that it challenged the idea that the existing tradition was the only possible way of thought and opened the door to the expression of parallel possibilities.

This similarity becomes clear in the narrative form of modernist works. Gone is the scientific observer of naturalism; it is replaced by a vehicle for the characters' minds. In *Mrs. Dalloway* by Virginia Woolf, a prominent modernist work, for instance, the narrator is external, third-person, omniscient, figural, and has a shifting focus, as in *Nana.*

In this case however, the narrator is very overt, meaning he or she makes judgements and has a distinct personality. While the narrator of the work remains unnamed with no physical description, his or her opinions are still evident throughout the work, giving him or her a personality (Keen 42).

This distinct narrative personality is seen to varying degrees throughout the work. The narrator offers an opinion of the characters and their actions. This narrative personality is frequently evident in the descriptions of characters in *Mrs. Dalloway:* "Septimus Warren Smith, aged about thirty, pale-faced, beak-nosed, wearing brown shoes and a shabby overcoat, with hazel eyes which had that look of apprehension in them which makes complete strangers apprehensive too. The world had raised its whip; where will it descend?" (Woolf 14). The description of Septimus's eyes illustrates both his psychology and the psychology of those who interact with him. Unlike the narrative style of Zola, this description does not connect his eyes to his social standing or anything else outside of himself. As seen in *Nana,* the narrator attributes Nana's personality, appearance, and gruesome death all to her social class. In Woolf's case, the narrator attributes the apprehensive feeling Septimus gives others to his eyes and the psychological turmoil raging behind them.

This highlights the difference in the nature of the third-person narrator common to a modernist work compared to that of a naturalist narrator. Rather than a narrator who presents the story under the constraints of rigid postulates of human behavior, the modernist narrator accounts for the complexity of human psychology, exploring where past traditions did not. Like hyperbolic geometers, modernists complicate what their predecessors saw as a given. As Euclid's parallel postulate was proved to be limited,

modernists sought to show that societal interactions were not the only defining elements of a person but rather the individuals themselves and the individual viewing them have more of an effect on their character.

The last line of the quote illustrates the other defining characteristic of Woolf's modernist writing: the expression of the characters' consciousness in the narrative. "The world had raised its whip; where will it descend?" is an element of Septimus's bleak thoughts stated as part of the narrative, an implementation of narrated monologue or free indirect discourse. This narrative form presents the thoughts of a character as part of the narrator's discourse. While this technique was used by naturalist and other writers prior to the modernist movement, it was not used to the same extent. As seen in *Nana,* the narrator often expresses the thoughts of characters within his own discourse. What distinguishes the two narrative forms is that in *Nana* the reader was never privy to more than one character's inner thoughts at a time, whereas in *Mrs. Dalloway,* the narrator shows the reader the thoughts of multiple characters in quick succession, evidence of the subjectivity of time in modernist works. Frequent use of narrated monologue is a key innovation of the modernist novel (Keen 62). Woolf mixes this free indirect discourse with psycho-narration to create a narrative that feels like the famed stream-of-consciousness of James Joyce's works, only in the third person.

This intermixing of narrative techniques is seen throughout the novel and allows for a unique mixture of exposition, dialogue, and thought. It is highly visually evident in the following:

The aeroplane turned and raced and swooped exactly where it liked, swiftly, freely, like a skater—

"That's an E," said Mrs. Bletchley—or a dancer—

"It's toffee," murmured Mr. Bowley—

(and the car went in at the gates and nobody looked at it), and shutting off the smoke, away and away it rushed, and the smoke faded and assembled itself round the broad white shapes of the clouds. (Woolf 21)

The dashes in the passage serve to separate the characters' speech form the narrator's opinion about the plane above their heads.

This technique of narrated monologue mixed with psycho-narration allows Woolf to interweave numerous parallel plots throughout the novel, all of which intersect at Mrs. Dalloway's party. The narrative takes place on one June day, but the reader is privy to the experiences of multiple characters. The modernist view of time as subjective allows the narrative to not follow the rigid movement of time but rather double back and explore memory. This shifting focus is where the connection to the negated parallel postulate of hyperbolic geometry is clearest. Each character's story runs parallel to the plot of that day in the city as numerous lines of the same slope. Yet, they all intersect at Mrs. Dalloway's party. This is illustrated in Figure 8. Similar to that used in the explanation of the negated parallel postulate, this figure demonstrates how the different plots of the novel function as different parallel lines that intersect, a phenomenon only possible in hyperbolic space.
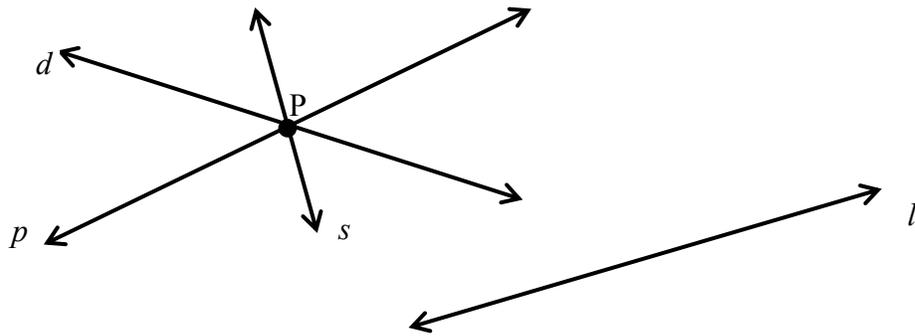
Figure 8. In which *l*=plot of the novel, *d*= Mrs. Dalloway, *p*= Peter, *s*= Septimus, P= the

party and *l* ∥ *p* ∥ *s* ∥ *d* and *p, s, d* all pass through P.

These simultaneous plot lines add to the novel's focus on subjectivity and the

personal psychological experience of each character. The subjectivity of modernist time

is evident in this figure. As each character experiences the day at a different pace, time

moves differently for each of them. They reveal a complexity of life that prior

movements of writing did not directly address in favor of focusing on what was seen as

more important to the social human experience at the time, much like how hyperbolic

space was not considered until mathematicians began to question if everything was in

fact Euclidean as had always been believed.

When the plots intersect at the party, as all the guests assemble and talk about

Septimus's suicide, the switching between narrative foci is even more apparent. Mrs.

Dalloway stages these parties in an effort "to bring people together, to feel their

continuous existence" (Sheehan 126). It is thus at these parties that the parallel lines

intersect, and the fragmented, subjective time of each character converges. This is evident

in the following passage:

"How delightful to see you!" said Clarissa. She said it to everyone. How

delightful to see you! She was at her worst—effusive, insincere. It was a great

mistake to have come. He should have stayed at home and read his book, thought

Peter Walsh; should have gone to a music hall; he should have stayed home, for

he knew no one.

Oh dear, it was going to be a failure; a complete failure; a complete failure,

Clarissa felt it in her bones as dear old Lord Lexham stood there apologizing for

his wife who had caught cold at the Buckingham Palace garden party. She could

see Peter out of the tail of her eye, criticizing her, there, in the corner. Why, after

all, did she do these things? Why seek pinnacles and stand drenched in fire?

Might it consume her anyhow! Burn her to cinders! (Woolf 176)

The first paragraph demonstrates how the mixture of narrated monologue and psycho-

narration blur the lines of the narrative personality and the individual character's views.

"She was at her worst—effusive, insincere" appears within the narrative discourse. It is

only made evident that this is Peter's thought when "Thought Peter Walsh" is added in

the following sentence. In the following paragraph the narration follows Peter's gaze to

focus on Mrs. Dalloway. The paragraph addresses her anxieties, but as the narrative

moves further into her thoughts, it quickly turns to narrated monologue. The narrator

presents Mrs. Dalloway's inner doubts as third-person questions. It seems as though they

are the narrator's thoughts but are clearly Mrs. Dalloway's anxieties.

This plurality of experience and time is also seen in the narrator's physical

descriptions of the city. At the start of the novel, the narrator expresses Mrs. Dalloway

love for the city:

For having lived in Westminster—how many years now? over twenty, —one

feels even in the midst of the traffic, or walking at night, Clarissa was positive, a

particular hush, or solemnity; an indescribable pause; a suspense (but that might

be her heart, affected, they said, by influenza) before Big Ben strikes. There! Out

it boomed. First a warning, musical; then the hour, irrevocable. (Woolf 4)

Not only is this passage a wonderful example of mixed expressions of consciousness, but

it also presents Mrs. Dalloway's highly subjective experience of the city. Shortly after,

this view of the city is countered by an objective description of it:

In people's eyes, in the swing, tramp and trudge; in the bellow and the uproar;

the carriages, motor cars, omnibuses, vans, sandwich men shuffling swinging;

brass bands; barrel organs; in the triumph and the jingle and the strange high

singing of some aeroplane overheard (Woolf 4)

Noises and chaos are abundant. It is clear that the actuality of the city is not the peaceful

retreat as Mrs. Dalloway experiences it. Her experience of the city and that of the

"people's eyes" run parallel to one another.

On the following page, a third description of the city is presented that expresses

what Mrs. Dalloway hears that morning:

And everywhere, though it was early, there was a beating, a stirring of

galloping ponies, tapping of cricket bats; Lords, Ascot, Ranelagh and all the rest

of it; wrapped in the soft mesh of the grey-blue morning air, which, as the day

went on, would unwind them, and set down on their lawns and pitches the

bouncing ponies, whose forefeet just struck the ground and up they sprung, the

whirling young men, and laughing girls…" (Woolf 5)

Amongst the clamor of working-class London, Mrs. Dalloway hears ponies, cricket, and laughter. She hears upper-class noise of leisure. This is a direct comment on her subjective view of the world as an upper-class woman only briefly in the busy city center to buy flowers. Social standing affects her thoughts and view of the world from the modernist perspective, rather than dictating the character's life as was the case in naturalism. These three descriptions of one city morning illustrate that numerous things are happening parallel to one another in the city and intersect in Mrs. Dalloway's subjective perspective.

The modern conceptualization of time as subjective is at work throughout modernist narrative. The narrative thus takes a very different shape than its Naturalist predecessor; it needs to account for the multiplicity of time. Thus, hyperbolic geometry, with its intersecting parallel lines, lends itself perfectly to the literary movement.

-III-

Fractal and Postmodern: Ordered Chaos

While modernists worked to show not everything was as ordered as the Euclidean thinkers before them believed, the next generation of thinkers focused on showing the whole world was in fact in perpetual disorder. This mid- to late- twentieth- and early-twenty-first-century movement focuses on disorder because disorder "offers the possibility of escaping from what are increasingly perceived as coercive structures of order" (Hayles 265). As seen in the previous section, modernism began the shift to understanding earlier paradigms as constructions rather than innate facts. Postmodernism, continued this process, further expanding it. As Hayles states, "When the essential components of human experience are denatured, they are not merely revealed as constructions. The human subject who stands as the putative source of experience is also deconstructed and then reconstructed in ways that fundamentally alter what it means to be human." (266). While modernists worked to expose previous systems of thought as valid, yet not a given element of the world, postmodernists examine how that new way of thinking affects greater systems of communication, our conception of the universe, and the human experience.

Hayles identifies three waves of denaturing that culminated in the formation of the postmodern mindset: language, context, and time, each of which started in the modernist period and were expanded upon by the next generation. She defines denaturing something as "to deprive it of its natural qualities" (Hayles 261-266).

In the early twentieth century there was an effort across disciplines to try and create an unambiguous and non-self-referential metalanguage uncorrupted by the "assumption of the other object" (Hayles 267). Each of these efforts ultimately failed. With their failure came the realization that language is innately ambiguous and self-referential, and as Niels Bohr observed, "we are suspended in language" (Hayles 267).

Saussuerean linguistics then became the popular school of thought and was expanded beyond Saussure's original beliefs. This view of linguistics dictated that language is "a sign system generating significance through differences between language elements" and "imagined language as an interactive field in which the meaning of any one element depends upon the interaction present in the feild as a whole." This view of language was extended to support the view that all utterance is "ungrounded and indeterminate" (Hayles 268). The postmodern view thus revolved around "the sense that language is constantly unraveling, even as one weaves it into a design; that any utterance can be deconstructed to show that it already presupposes what it would say and hence has no prior ground on which to rest; that all texts are penetrated by infinite numbers of intertexts so that contextual horizons are always constructions rather than givens; in short, that signification is a construction rather than a natural result of speaking or writing" (Hayles 268). World War II was the point at which these ideas ceased to be merely the concern of theorists and entered the mainstream of the culture through information technology. Context was also denatured by the increase in information access. Information could now be displaced from its origin point. Context thus no longer defined form.

Time was the final wave in denaturalization. Modernists began the idea that time is nonlinear and personalized; time was already understood not to be a given at the start of the postmodern period. The denaturing of the other areas influenced this conceptualization of time and extended it to examine how it would affect the human experience. As Jorge Luis Borges theorizes in "New Refutation of Time" (1964), human identity is deeply linked with memory, and memory depends upon time being a continuous linear progression. Once time is considered non-sequential, memory fails. As Borges suggests, "every man who reads Shakespeare becomes, for that moment, Shakespeare" when time is not considered sequential (Hayles 279). In postmodernist thought, time is no longer a "a continuum along which human action can meaningfully be plotted" (Hayles 279). Without linear time, human life is lost in the ether, and all previous attempts to put it in sequence fail.

This new conception of time was reflected in postmodern narrative. It is as if postmodern writers took what the modernist had done with stream of consciousness and applied it to the structure of the novel as a whole. The new perspective of the effect of non-linear time on human life enabled postmodern writers to create fragmented timelines. Plot points are as jumbled as thoughts were in modernist writing. Furthermore, they are acutely aware of the fact that they are writing and make the reader aware of it as well. Every construction from time to context to language is revealed as such even as they are implemented in the narrative. While metafiction, fragmented plot, mixed context, self-referential language, and non-chronological plot are found in texts from all periods, the combination and interconnectedness of the different elements is only found in

postmodern fiction (Hayles 295). This new form of fiction thus takes on a different geometrical shape: the fractal.

As stated in the introduction, a fractal is self-similar shape that appears the same at any scale. Fractals are also closely related to cultural postmodernism, in that they are the image of chaos. Chaos theory accounts for the mathematical side of the postmodern interest in disorder. Simple nonlinear systems can behave in a seemingly unpredictable manner called chaos. A deterministic mathematical model (which has no randomness associated with it) can yield apparently unpredictable behavior (Addison 6). Visually, these systems become fractals. Thus, the self-similar objects fit closely into postmodern thought.

A helpful visualization of a fractal is a coastline. Lewis Fray Richardson measured Britain's west coastline and discovered the result was dependent on the scale of the map used. A map with 1 cm corresponding to 100km (scale 1: 10000000) shows much less detail than one in which 1 cm corresponds to a just 1km (scale 1:100000) (Lauwerier 29).

Figure 9. The results of Richardson's study. See Lauwerier 30

Richardson's results are shown in Figure 9. The measuring unit is plotted on the *x*-axis on a logarithmic scale, indicated by *a*. The measured length, *s*, is plotted on the *y*-axis, also on a logarithmic scale. The resulting lengths are indicated by small circles. s_1 denotes the length when using a measuring unit of 1 km. Thus, Britain's coastline can be expressed by

$$\log s = 0.22 \log a + \log s_1$$

Which equals

$$s = s_1 \left(\frac{1}{a}\right)^{0.22}$$

As one decreases the measurement unit, a will approach zero. Since a is in the

denominator of a fraction, as a approaches zero the function would approach infinity.

Thus, one could conclude that the coastline of Britain is infinitely long. But that would be

true only if the meandering of the coastline goes on repeating itself on an ever-

diminishing scale. To an extent this makes sense; as the measuring scale decreases, one

will pay attention to smaller and smaller pebbles, adding turns to your measurement. It is

thus useful to have a number to designate the degree to which something meanders: the

fractal dimension of a figure (Lauwerier 29).

Fractals are described by an additional set of dimensions beyond the Euclidean

dimensions. The fractal dimension (D) is usually non-integer, meaning it is not denoted

by whole numbers. It is also greater than the objects topological dimension (D_T) and less

than its Euclidean dimension (D_E) (Addison 14). This paper is only concerned with the

similarity dimension (D_S), although many others exist.

The similarity dimension can be thought of as the degree to which a fractal is self-

similar. Think of a line of length 1 divided into N parts of length ε. Its length could be

expressed as

$$L = N\varepsilon = 1$$

Now consider the unit area (1x1) divided again into N segments of area ε^2. The area

could be expressed as

$$A = N\varepsilon^2 = 1.$$

Similarly, consider the unit cube (1x1x1) divided into N segments of volume ε^3. The volume could be expressed as

$$V = N\varepsilon^3 = 1.$$

Figure 10. An illustration of the different unit measurements. See Lauwerier 32

By looking at the above expressions, it is clear that the exponent of ε is representative of the similarity dimension of the object. In general, one could write

$$N\varepsilon^{Ds} = 1.$$

Where ε represents the unit of measurement being used ($\frac{1}{a}$ in the coastline example). Using the rules of logarithms would yield:

$$D_S = \frac{\log(N)}{\ln \varepsilon}.$$

Although we derived the above equation form familiar Euclidian objects for which $D_E=D_S=D_T$, it can be applied to fractal objects where D_S is non-integer and lies in between the values of the other two dimensions (Addison 14-15, Lauwerier 32).

Postmodernists novels can be examined through their fractal structure. The fragmented and self-referential style of postmodernist writing creates a fractal. While the scaling of the fractal are limited, as with all not purely mathematical fractals, examining the levels of self-similarity within postmodern texts is very illuminating as to how postmodernists ideas permeate the syntax, narrative form, theme, plot, and reader's experience of the works.

This paper will examine the fractal structure of Thomas Pynchon's *The Crying of Lot 49,* since no such study has been conducted on the novel. One approach to the fractal structure of the novel is to look at the conceptual similarities at different levels of the

text. The largest scale of this fractal is the reader's experience of the novel. The reader must try to connect the different plot points along with the protagonist, Oedipa. The novel has a fragmented and disjointed quest structure. Readers and Oedipa expect a linear progression towards the solution to the various conspiracies; they expect the clear-cut connections of typical quests. Instead, Oedipa and the reader only find a series of loose possible connections and numerous dead ends. A leap of faith is required to find any meaning, leading to only more conspiracies rather than definitive answers. The novel is dominated by disorder and chaos.

This fragmentation is seen at the very start of Oedipa's quest, when she finds drawings on the bathroom wall. She sees the acronym WASTE written in *lipstick* and below it the drawing of the muted post horn in *pencil*. Oedipa immediately connects the two, and the reader goes along with it, but can either be sure of the connection? The word and drawing were written with different implements "among lipsticked obscenities" (Pynchon 38).

It is quite likely the connection that Oedipa made and based all further connections on was purely a product of her imagination. The "clues" could have been written by two unrelated people and could have a number of meanings. Neither she nor the reader have definitive proof of their significance. This lack of conclusive meaning continues throughout the novel, leading Oedipa further astray and further confusing the reader. Thus, her experience is self-similar to the reader's experience of the novel as a whole, creating the first scaling of the fractal.

Pynchon again replicates the reader and Oedipa's experience of searching for meaning behind an endless supply of loosely connected signs of Tristero in his long and

disjointed sentences, causing the reader to go through the same fruitless search for meaning at another level. The first paragraph of the novel is jarring to the reader:

> One summer afternoon Mrs. Oedipa Maas came home from a Tupperware party whose hostess had put perhaps too much kirsch in the fondue to find that she, Oedipa, had been named executor, or she supposed executrix, of the estate of one Pierce Inverarity, a California real estate mogul who had once lost two million dollars in his spare time but still had assets numerous and tangled enough to make the job of sorting it all out more than honorary. Oedipa stood in the living room, stared at by the greenish dead eye of the TV tube, spoke the name of God, tried to feel as drunk as possible. But this did not work. (Pynchon 1)

The passage is told in the mixed expression of consciousness, which has become more and more complicated in each literary movement addressed in this paper. Yet in this case, as the narrator switches between psycho-narration and glimpses into Oedipa's thoughts within the narrated monologue, the content of the sentence jumps around as well. Each element of the first sentence and the individual sentences to follow jump from one topic to the next, disrupting the reader's sense of how a paragraph should work and leaving him or her without any sense of connection. Following Oedipa's drunken and worried thoughts, the reader is jerked about, thus leaving the reader in chaos. While phrases like "the greenish dead eye of the TV tube" seem to hold some greater meaning, the reader is not given enough information to find it. Therefore, when the reader reads this paragraph, he or she has just as much difficulty deriving meaning as when looking at the plot.

Pynchon reproduces this quest for meaning at the individual word level as well, creating the final scale of the fractal structure. The name Oedipa, for instance, brings to mind the story of Oedipus, but no real connections between the characters are supported in the text. The reader tries to create some sort of relationship between Oedipa's quest for Tristero and Oedipus's quest that results in killing his father and marrying his mother, but there is no definitive link between the two. Each odd name seems to lead somewhere else (to an allusion to a famous work or the etymology of a word), but in the end they are just oddities. Any attempt at creating meaning at the word, sentence, or plot level simply creates a conspiracy theory that can be challenged just as much as it can be supported. The search for meaning in the novel is as futile as trying to find Tristero; it is a fractal of hopeless search for meaning.

The fractal structure of the novel is also seen in Pynchon's ability to weave overblown detailed descriptions and powerful insight together, both at plot and sentence levels. At first the plot appears to be a bunch of chaotic conspiracies, but within each seemingly unrelated event lies insightful satire, which brings the whole novel together. For instance, Oedipa's meeting with Dr. Nefastis about Maxwell's Demon leads her nowhere closer to Tristero. Yet, at this point in the convoluted plot, Pynchon comments on the flaws in language, the pitfall of connecting things based on vague similarities and insanity. Nefastis struggles greatly to define the word "entropy" and seems disturbed by his inability to convey the scientific concept surrounding Maxwell's Demon to Oedipa, "Entropy is a figure of speech then, [...] a metaphor. [...] The Demon makes the metaphor not only verbally graceful, but objectively true" (Pynchon 85).

This struggle to describe something in words shows up at various points throughout the novel's detailed plot. The strange detail of Maxwell's Demon also highlights the flaws in Oedipa's tendency to make quick connections. The machine was created because the equations of the two kinds of entropy happened to look similar: "It was a coincidence" (Pynchon 84). The machine's ultimate failure and Nefastis's apparent insanity further show the connections Oedipa herself makes cannot be trusted.

This same intermixing of detail and insight is seen at the sentence level. In the midst of a long, complex, and detailed sentence, Pynchon will place insights into characters and over-arching ideas. This can be seen in the following sentence which takes up almost half a page in the novel. What would normally be a simple biographical detail, why Mucho left selling cars to become a DJ, is dragged into a complex wonder of a sentence:

> Yet at least he had believed in cars. Maybe to excess: how could he not, seeing people poorer than him come in, Negro, Mexican, cracker, a parade seven days a week, bringing the most godawful of trade-ins: motorized, metal extensions of themselves, of their families and what their whole lives must be like, out there so naked for anybody, a stranger like himself, to look at, frame cockeyed, rusty underneath, fender repainted in a shade just off enough to depress the value, if not Mucho himself, inside smelling hopelessly of children, supermarket booze, two, sometimes three generations of cigarette smokers, or only of dust—and when the cars were swept out you had to look at the actual residue of these lives, and there was no way of telling what things had been truly refused (when so little he

47

supposed came by that out of fear most of it had to be taken and kept) and

what had simply (perhaps tragically) been lost: clipped coupons promising

savings of 5 or 10 cents, trading stamps, pink flyers advertising specials at

the markets, butts, tooth-shy combs, help-wanted ads, Yellow Pages torn

from the phone book, rags of old underwear or dresses that already were

period costumes, for wiping your own breath off the inside of a windshield

with so you could see whatever it was, a movie, a woman or car you

coveted, a cop who might pull you over just for drill, all the bits and

pieces coated uniformly, like a salad of despair, in a gray dressing of ash,

condensed exhaust, dust, body wastes—it made him sick to look, but he

had to look. (Pynchon 4)

This sentence's complex grammatical structure mirrors the complex structure of the plot.

The sentence moves between exhaustive physical details of the used cars and Mucho's

introspection, much like the novel moves between countless plot points and moments of

insight. On their own, each clause of the sentence makes little sense–a jumble of thoughts

and details–but when taken as a whole, it could serve as a comment on consumer culture.

Mucho's disgust towards the cars and the description of trade-ins as "a salad of despair"

would not make sense if not paired with the extensive details Pynchon had just provided;

similarly, the details would hold no purpose without the metaphor.

It appears to be the postmodernist extension of stream-of-consciousness and

mixed modal narration to the structure of the novel as a whole that leads it to this fractal

structure. After detailed statistical analysis of sentence-length variability, researchers at

Poland's Institute of Nuclear Physics found fractal patterns in a number of literary works.

Out of all the works they studied, the researchers found James Joyce's *Finnegan's Wake* to be the closest to purely mathematical multifractals or interwoven sets of fractals. They partially attributed this complexity of the fractals they found in the novel to Joyce's use of stream-of-consciousness (Flood). Stanislaw Drożdż, one author of the study, stated that the structure of stream-of-consciousness "best reflects 'how nature works'" and, thus, the fractals authors observed in the world were encoded in their texts long before being discover by mathematicians (Flood). While Joyce's work is modernist, the connection between the two literary movements supports the idea that if a similar study were to be done on postmodern texts taking into account more structural details than sentence length, fractals would also appear. Perhaps the fractal structure of stream-of-consciousness and similar narratives is what allows a reader to appreciate and understand the jumbled text he or she is reading; the fractals provide symmetry and order which humans crave and see as beautiful. Thus, what was once a bunch of unconnected conspiracies and sentences becomes a cohesive novel. The fractal structure of the *Crying of Lot 49* is, thus, the image of the chaos of Tristero, just as fractals function as the image of chaos in postmodern mathematics.

Conclusion:

The Aesthetic Value of Different Narrative Geometries

Frequently in existing works of fractal literary criticism, the question of the aesthetic value of the fractal structure is brought up. Often, fractal literature is mistakenly put on a pedestal as the ultimate narrative form. The sheer range of criticism written about fractal literature is evidence of its popularity. But is there something innately superior in the fractal structure of postmodernist work? Should postmodern works be considered the best literature because of this structure?

This paper has aimed to accumulate evidence that this is not the case. There is nothing intrinsically better about fractal literature. Through the three case studies in this paper, it has become evident that the shape narrative form of a novel, be it Euclidean, hyperbolic, or fractal, is shaped by the content of the work and the assumptions dominating the world at the time.

The style of writing in each literary movement is suited to the needs of those works and the ideology of the time. Naturalism, which is concerned with applying scientific thought to society, thus works closely with reason and therefore takes a Euclidean narrative shape, which is itself controlled by order. Modernism turns its attention to understanding the human mind and thus re-conceptualizes time and therefore takes a hyperbolic narrative shape that allows multiplicity. Postmodernism is fascinated with disorder and therefore takes on a fractal form, the image of chaos.

As Hilgemeier observes in his essay in *Fractal Horizons*, the zeitgeist of a generation can frequently be expressed by a mathematical metaphor. The mathematics in

vogue at the time match the overall dominate thoughts of that generation. In the baroque period, the zeitgeist was expressed by the ellipse. The ellipse was used in physics, astronomy, engineering: "The ellipse permeated the understanding of the structure of reality as well as the architect's construction of churches and palaces" (Hilgemeier 138). Mathematics contributes to and is shaped by the dominant thoughts of the time and can thus be analyzed to understand the surrounding culture.

The same could be said of the late twentieth century and the fractal. The mathematical metaphor of fractals and deterministic chaos applies to many fields, including biology, economics, art and design, management, marketing, engineering, government and international relations (Hilgemeir 138). The fractals can thus explain the period of thought they were born out of. In the early twentieth century, hyperbolic geometry similarly can be used to describe the search for dismantling previous concepts considered as given in all fields, yet hyperbolic geometry was born out of such thoughts. And Euclidean geometry may be a perfect metaphor for order and reason, but it was also born out of such reason.

The metaphor of geometry as a representation of the zeitgeist of a period and narrative form can be expanded to help clarify the question of literary merit. No mathematician would argue that one form of geometry was overall superior to those that had developed before it. Fractal geometry is not almighty, even if it fills in the gaps left by pervious ways of conceptualizing geometry by allowing chaos to be understood; hyperbolic geometry is not better due to its questioning of postulates that came before; and Euclidean geometry is not superior as the "original" geometry either. As Jason Rosenhouse suggests, "The modern view is that there are many systems of geometry

available to us, and the criterion for deciding among them is usefulness, not correctness" (Rosenhouse 297). This paper suggests a similar approach be applied to literary movements and their respective style. No text is superior due to its form alone but rather how it utilizes such form within its goals as a work and its cultural surroundings. The style and shape of narrative form should be judged by its usefulness within the cultural landscape and the work itself rather than on its own value. If *Nana* were to be rewritten to have a self-similar fractal structure, it would not be made better in any way by the pleasing symmetry of a fractal. Rather, it would be far removed from its message of the Social Darwinist reason it was working within. The fractal structure would not match the work and thus would not be useful within the work.

Each of the three geometric narrative forms we have seen have touched upon fundamental things humans crave: reason, complexity, and symmetry. They thus each have a great value on their own and are very appealing to readers. Their value comparatively should be assessed purely on a case-by-case basis. The needs of the work are more important in assessing aesthetic value of a narrative than the form's beauty in isolation.

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