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The Use and Development of Mathematics Within Creative Literature

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Synopsis

This paper presents a study on the extent to which creative literature been used as a vessel to carry forward the development of mathematical thought. The role of mathematics as a driving force for literature is highlighted, and while many examples exist that clearly show an attempt to disperse mathematical ideas, with Lewis Carroll, OuLiPo and ancient poetry considered, the argument that the sole purpose of the writings was for the sake of mathematical development is not clear-cut.

Keywords: literature, poetry, OuLiPo.

*... it is true that a
mathematician who is not
somewhat of a poet, will never
be a perfect mathematician.*

Karl Weierstrass, 1883 [21]

The assumption is often that mathematics and creative literature are at opposite ends of a spectrum, having no connections. However, there are many roles for mathematics within literature, implying that this assumption is not necessarily true. Combinatorics is very present in poetry; mathematical concepts can be the basis for literary works, and many have spread mathematical ideas through literature. Here I explore some examples to assess the importance of literature in the development of mathematics through their combined application.

Looking back: Hemachandra and Fibonacci

The study of literature, especially of poetry, throughout history has uncovered important mathematical concepts. Around 1150, about fifty years before the time of Fibonacci, the study of poetry and prosody in Sanskrit, the primary liturgical language of Hinduism, by the Jain scholar Acharya Hemachandra unearthed what are now known as the *Fibonacci Numbers* [12]. The importance of Sanskrit is that, unlike in English, where the meter of a poem is decided by the pattern of stressed and unstressed syllables, its meter is determined by the pattern of long and short syllables. Crucially, a long (L) syllable is twice the length of a short (S). Consider the space available in a line split into N units u , where:

$$L = 2u \text{ and } S = u.$$

Ancient poets asked how many permutations of syllables there were available to fill this space of N units, where order matters. Hemachandra noticed that for $N = 1$, a space of one unit, u , there is one option: one short syllable:

$$u = S.$$

For $N = 2$, a space of two units, $2u$, there are two options: two shorts, or one long:

$$2u = 2S = L.$$

For three units ($N = 3$), there are three options: three short, one long and one short, or one short followed by one long:

$$3u = 3S = L + S = S + L.$$

With four units ($N = 4$), five options are available:

$$4u = 4S = 2L = 2S + L = L + 2S = S + L + S.$$

The pattern emerging of options available as N increases is the sequence:

$$1, 2, 3, 5, 8, 13, 21\dots$$

Hemachandra claimed that the n^{th} number in this sequence counts the total available permutations of the syllables in a given space of n units. His explanation was that if you collect all the permutations of syllables possible in a

space of n units, and arrange them into two groups, one including those that end with a short syllable, and the other including those that end with a long, by removing the final syllable of all the permutations in both groups, you are left with: one group consisting of the total permutations available using $n - 1$ units (the result of removing the final short syllable (i.e. one unit) from those in the group of permutations ending in a short) and another group consisting of the number of permutations available using $n - 2$ units (the group that previously consisted of permutations ending with a long syllable). Thus, the total number of ways, $P(n)$, to permute syllables in a space of n units, for $n \in \mathbb{N}$ and $n > 2$ is:

$$P(n) = P(n - 1) + P(n - 2)$$

where

$$P(1) = 1 \text{ and } P(2) = 2, \text{ as shown above.}$$

That is, the recurrence relation for the *Fibonacci Numbers*.

While literature here has offered a different framework to consider a particular mathematical problem, showing an instance of the disciplines coming into contact, it cannot be claimed that the discussion above could have been pivotal in the development and use of the *Fibonacci Numbers*. I think this can be justified by the fact that it would not be until the 19th century that the sequence would gain recognition for its importance, following the work of French mathematician Édouard Lucas [19], who would be the first to attach Fibonacci's name to the numbers [7, page 153]. Moreover, the fact that Hemachandra's work predates the Italian's and that his name is relatively forgotten, implies a greater level of importance attached to the role of Fibonacci [17], and a mathematical set-up, in the development of this particular section of mathematics, compared to that of Hemachandra and his literary framework.

Looking back: Pingala and Pascal

Similarly, the binomial coefficients and their pattern were known earlier than the time of Pascal and his *Triangle*. Their origins have been traced as far back as 200 BCE to Indian scholar Pingala [13]. Like Hemachandra, Pingala worked with Sanskrit. In his *Chandaḥśāstra*, he enumerated all the possible poetic meters of a fixed number of syllables, again where syllables are either

long or short. For example, for four syllables, he outlined 16 different meters, where order of syllables matter:

- 1 meter of 4 short and 0 long syllables;
- 4 meters of 3 short and 1 long;
- 6 meters of 2 short and 2 long;
- 4 meters of 1 short and 3 long;
- 1 meter of 0 short and 4 long.

In response to the question of the number of patterns composed of n syllables one could form from long and short syllables, he claimed the answer was 2^n . Following his logic, and writing it into a table (see Figure 1), we see the formation of *Pascal's Triangle*.

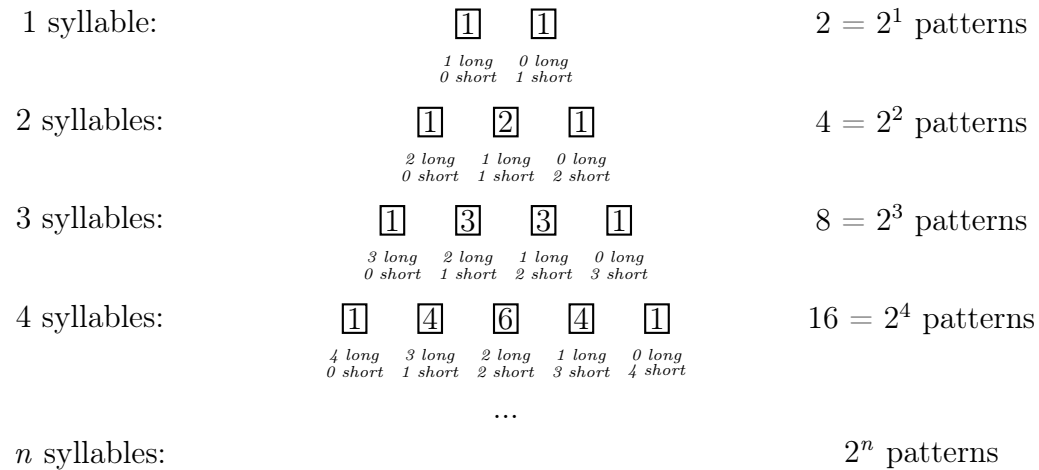


Figure 1: Permutations of n syllables.¹

Each box gives the number of different ways to permute the list of syllables written beneath. Thus the number in the i^{th} box ($i \in \mathbb{N} \cup \{0\}$) in the j^{th} row ($j \in \mathbb{N} \cup \{0\}$) row is given by:

¹ All figures in the paper are my own work.

$$\binom{j}{i} = \frac{j!}{i!(j-i)!}$$

where each box corresponds to $(j - i)$ long syllables and i short. We know that this equation gives the *Binomial Coefficients*. There is even evidence that Pingala determined algorithms to find the number of permutations [20].

Even so, just as with the work of Hemachandra and his application of the *Fibonacci Numbers*, we cannot conclude that the work done through literature has played an essential role in the development of a mathematical concept. It would take centuries of mathematical study before Pascal would employ the *Triangle* to solve problems in probability theory, in his 1665 posthumously published *Traité du triangle arithmétique*. Pingala seems to have worked these calculations for the sake of it, rather than for any practical gain [20]. As with the *Fibonacci Numbers*, the *Triangle* would eventually become associated to a mathematician (Pascal) later rather than the scholar coming upon it during his literary studies [6], once more suggesting that the real importance in its development lies in the construction from a mathematically based foundation. Of course many theorems and concepts in mathematics are not named after their discoverer; they are often named after an influential developer of the idea. Moreover, geographic and demographic biases often influence nominal credit. All these additional justifications aside, the claim that the literary studies led to a mathematical development remains, in my opinion, unproven.

Bell Numbers and Catalan Numbers in Poetry

It may be noted that problems of combinatorics arise frequently in poetry, indicating at least one bridge between mathematics and literature.² One of the mathematical topics that comes up often involves the so-called *Bell numbers* and *Catalan numbers* [11].

² EDITOR'S NOTE: See, for example, Mike Pinter, "How Do I Love Thee? Let Me Count the Ways for Syllabic Variation in Certain Poetic Forms" by Mike Pinter (*Journal of Humanistic Mathematics*, Volume 4 Issue 2 (July 2014), pages 94-100; available at: <https://scholarship.claremont.edu/jhm/vol4/iss2/10>).

The *Bell Numbers*, B_n , are a sequence of numbers such that the n^{th} term gives the number of ways to partition a set of n elements. The first few are

$$1, 1, 2, 5, 15, 52, 203, 877, \dots$$

with the partitions of sets represented as

$$B_0 = 1: \{\{\}\}$$

$$B_1 = 1: \{\{a\}\}$$

$$B_2 = 2: \{\{a,b\}\}, \{\{a\},\{b\}\}$$

$$B_3 = 5: \{\{a,b,c\}\}, \{\{a,b\},\{c\}\}, \{\{a,c\},\{b\}\}, \{\{a\},\{b,c\}\}, \{\{a\},\{b\},\{c\}\}$$

and so on.

Less significantly but still related, we have the *Catalan Numbers*, which are used in various counting problems. They begin similarly to the *Bell Numbers* but the sequence splits off after the first few terms:

$$1, 1, 2, 5, 14, 42, 132, 429, \dots$$

These sequences of numbers, more usefully the *Bell Numbers*, can be used to count the number of end-rhyming schemes available based on the number of lines in a stanza [8]. Consider $n \in \mathbb{N} \cup \{0\}$. Below is a poem, “In a Stanza Consisting of n Lines,” that I wrote to summarize the situation:

With n -line stanza climbs,
there's a way to count the schemes of rhymes,
without fail, it will work for all times.

Using the *Numbers Catalan* and *Bell*,
starting 1, 1, 2 and then 5,
the n^{th} in the sequence will always be, enough for you to tell.

They differ once n equal or greater than 4,
and to explain the implications, I would need far more,
than the 15 lines I have got.

3 lines per stanza, means there are 5 options,
 since 5 is Bell number 3.
 With limited choice now, I will use the scheme *ABB*.

Unfortunately now, my 5th option is,
 to allow no rhyme at all.
 An unsatisfying ending, but *ABC* had to come somewhere.

Each stanza follows a different end-rhyming scheme, and, as explained in the fourth, because they each consist of 3 lines, the third *Bell Number* (when listed with index starting at 0), $B(3) = 5$, is used to determine how many end-rhyming schemes there are. There are thus 5 stanzas, in order to use each scheme. The relevance of what happens for $n \geq 4$, when the n^{th} *Bell Number*, $B(n)$, is no longer equal to the n^{th} *Catalan Number*, $C(n)$, is that the *Bell Numbers* can be used to count a subtly different thing to what the *Catalan Numbers* can.

While the n^{th} *Bell Number* gives the total number of rhyming schemes available for a stanza of n lines, the n^{th} *Catalan Number* gives the number of end-rhyming schemes possible in n lines such that if you were to connect with a path each rhyming line in a stanza to the other lines in that stanza that it rhymes with, there would be no paths that have to cross each other:

Figure 2 displays the 15 end-rhyming schemes available for stanzas of 4 lines. Here, there is 1 scheme such that the paths between rhyming lines have to cross (*ABAB*, the 15th in this list). This is equal to the difference between the *Bell* and *Catalan Numbers* for $n = 4$. Honestly, this seems to have no practical use in poetry, since there is no reason to avoid such rhyming patterns.

However, there is no denying that the Bell numbers are related to poetry and rhyme patterns. Once more, mathematics is found hidden inside literature. I nonetheless believe that this relationship does not point towards a causal link from the world of literature to the world of mathematics. While both of the examples in these two sections definitely show that mathematics and literature are linked in certain ways, they do not point toward a strong reliance upon the work done within literature in the development of mathematics.

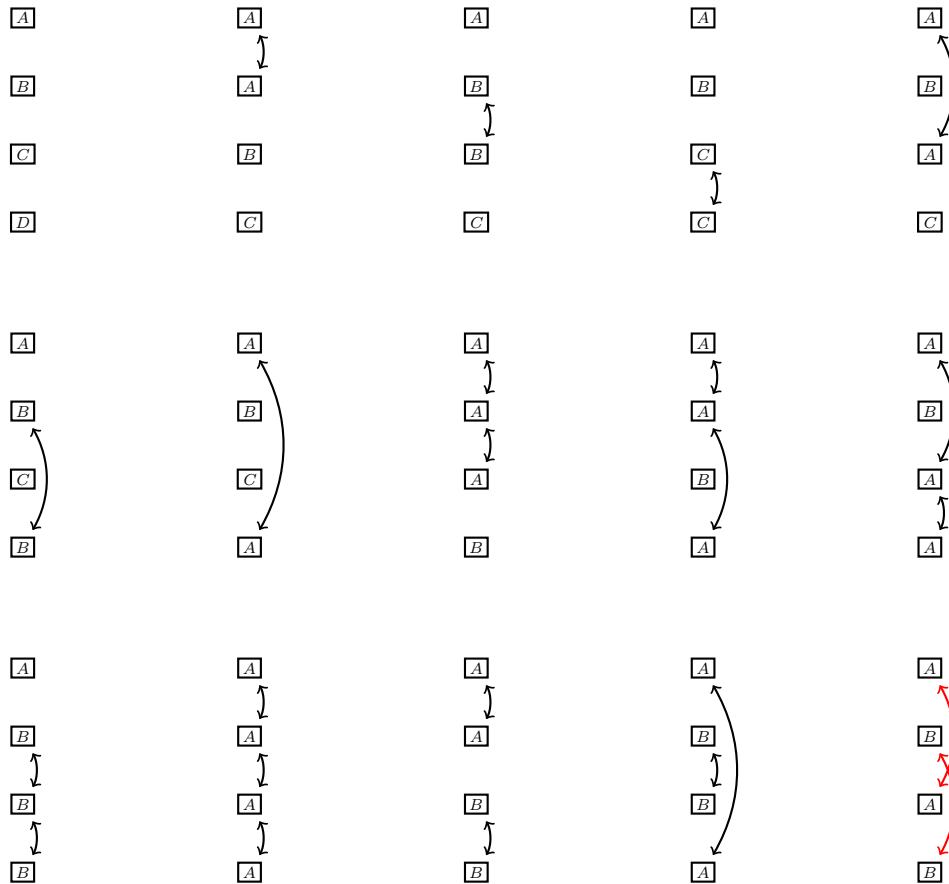


Figure 2: Rhyming schemes for $n = 4$, with their rhyme-paths.

Mathematics for Structure

Another link between the two disciplines is found in the use of mathematics to structure, and to base upon in order to create, literary works. It has been argued [2, 14] that Lewis Carroll’s 1865 *Alice’s Adventures in Wonderland* hides within its seemingly nonsensical scenes, satirical criticisms of what he considered unorthodox mathematical ideas, and that Carroll parodied ideas such as projective geometry and William Hamilton’s *quaternions*. Carroll, the pen name of 19th century mathematician Charles Dodgson, was very conservative when it came to mathematical ideas [16], and viewed the contemporary mathematics, with ideas such as imaginary numbers, as semi-logical.

As a staunch Euclidean, he saw these new developments as an unwanted departure from the physical reality into the abstract. In the scene in which Alice finds the Duchess nursing her baby in the kitchen, the Duchess proceeds to hand Alice the baby, who suddenly changes form into a pig. The supposed target of the writing is projective geometry, a topic in mathematics which examines the properties of figures that remain the same despite a projection onto another surface. Crucially, the baby-turned-pig retains most of its original features, as it would within the framework of projective geometry. Here, the baby has been projected onto a new surface, Alice, and the therianthropy comes across as ridiculous, as per the aim of Dodgson. The oxymoron is that the projective geometry says this isn't ridiculous. Dodgson is saying that what works for a triangle should work for a baby, unless the principle is incorrect.

Following this line of argument, it can be said that Dodgson used his knowledge of mathematics to structure a work of literature, and that his most famous scenes for the book originate in mathematics. For another example, the Mad Hatter's tea party can be considered as Dodgson's exploration of the *quaternions*, the system extension of the complex numbers. The *quaternions* are defined as follows:

$$\mathbb{Q} = \{a + bi + cj + dk : a, b, c, d \in \mathbb{R}\}$$

where i , j and k are the fundamental *quaternion units* — each acting in the same way that i does in the *complex numbers*, \mathbb{C} , but multiplying by each other in a cyclic, non-commutative manner:

| | | | | |
|----------|-----|-------|-------|-------|
| \times | 1 | i | j | k |
| 1 | 1 | i | j | k |
| i | i | -1 | k | - j |
| j | j | - k | -1 | i |
| k | k | j | - i | -1 |

Figure 3: Multiplication table for the quaternions.

Alice joins the Hatter, Hare and Dormouse at the table, and is informed that the character Time is absent from the party. Hamilton considered that

the fourth unit in his *quaternions* could represent time.³ Without Time, the characters at the tea-table, who represent the other three *quaternion* units, are stuck rotating around it, and since Alice is not Time, even her inclusion does not allow them to break out of this three-dimensional space. Again, Dodgson is trying to ridicule a mathematical idea in the form of nonsensical prose.

Moreover, the ideas of commutativity are used to create this scene.⁴ Dodgson viewed non-commutativity as a contradiction to the basic laws of algebra. Figure 3 shows the *quaternions* to not be commutative. Upon puzzling over a riddle, Alice gives a non-commutative answer, offering to “*mean what I say*” in response to being asked to “*say what you mean*” [4, page 68]. Alice is claiming that this non-commutative statement is true; in other words, she representing a typical contemporary mathematician who supports the idea of non-commutativity. That these statements do not mean the same thing pokes fun at the concept of non-commutativity.

Though it would not be surprising if Dodgson had really based a lot of his ideas for *Alice* on his views and knowledge of mathematics, it would be hard to justify that his use of mathematics in his piece of prose was an attempt to develop mathematical concepts, or to influence the general public’s opinion on contemporary mathematics, especially considering how hidden the mathematics is in the story. Moreover, the original version of *Alice*, *Alice’s Adventures Under Ground*, of 1864, was written as a gift for Alice Liddell [3, 18], daughter of Henry Liddell, the Dean of Christ Church, Dodgson’s college, and that earlier version did not contain the aforementioned episodes, nor other abstract scenes. This implies that it was not Dodgson’s initial aim to write a story on mathematical foundations. What can be said is that Dodgson merely saw this as an opportunity to integrate his views on particular mathematical branches with his previously written story for satirical purposes.

³ “Time is said to have only one dimension, and space to have three dimensions. [...] The mathematical quaternion partakes of both these elements; in technical language it may be said to be “time plus space”, or “space plus time” William Rowan Hamilton, as quoted in *Life of Sir William Rowan Hamilton* by R.P. Graves (Arno Press, New York, 1975).

⁴ A binary operation $*$ on a set S is *commutative* if $x * y = y * x$ for all $x, y \in S$.

Thus, while mathematics can be and has been used to create literature, in this instance, we cannot really say that mathematics was the main purpose of the creation of the work under discussion. Subsequently, it can not be said to be an example of a literary work that goes any distance in developing any mathematical ideas, or even holding sway on opinions of them.

Besides Dodgson, many have very intentionally taken concepts from mathematics and used them to structure works of literature. Carl Andre's *On the Sadness* [9, page 77] is a poem constructed using the *Fundamental Theorem of Arithmetic*. Consisting of 46 lines, each corresponding to the number $(48 - n)$, where n is the line number in the poem (so the first line corresponds to 47, and the final line corresponds to 2), it is essentially built from the final line up to the first. For each line that corresponds to a prime number, a new statement is introduced, whereas each line corresponding to a nonprime is written in terms of the lines corresponding to the numbers that appear in its unique prime factorisation. The words "then" and "if" are used for *to the power of* and *multiplied by* respectively. Thus the final 5 lines, corresponding to the numbers 6 ($= 2 \times 3$), 5 (prime), 4 ($= 2^2$), 3 (prime) and 2 (prime), are:

We are going to die if the sky is blue
 The grass is green
 We are going to die then we are going to die
 The sky is blue
 We are going to die

Similarly, the OuLiPo (*Ouvroir de littérature potentielle*, roughly meaning *workshop of potential literature*) group, founded 1960 by a group of French writers, mathematicians and others, often work within strict mathematical constraints to produce works of creative writing. Their techniques include $S + 7$, where each substantive word in an existing poem is replaced by the seventh subsequent substantive word in a dictionary, and *snowballing*, where each line has more words in it than the previous line [10]. The members of OuLiPo have created works based on many mathematical ideas, from the knight's tour of a chess board (Georges Perec's *Life: A User's Manual*), to combinatorics (Raymond Queneau's *One Hundred Thousand Billion Poems*, a book of 10 sonnets, with the 14 lines of each being interchangeable with their corresponding line in the other 9 sonnets, allowing for 10^{14} sonnets).

While both the work of Andre and that of the members of OuLiPo are heavily influenced and inspired by mathematics, just as I concluded regarding the study of Sanskrit poetry, I think we can once again conclude that they were not necessary for the development of any mathematics. They are done for the purposes of entertainment or to stimulate creativity, or in Andre's case, to help emphasise the point of the poem. They do however offer more examples of mathematics being used within literature.

Dissemination

Mathematics has also been used in literature to more obviously disseminate mathematical ideas to a general reader. Edwin Abbott's *Flatland*, more blatantly mathematical than *Alice*, attempts to open the reader's eye to the possibilities of the fourth dimension: "*In Three Dimensions, did not a moving Square produce [...] that blessed Being, a Cube, with eight terminal points? And in Four Dimensions shall not a moving Cube [...] result in a still more divine Organization with sixteen terminal points?*" [1, page 104]. Russell Maloney's *Inflexible Logic* discusses probability through the idea of chimpanzees writing endlessly to produce all possible written works. The chimpanzees are immediately successful in replicating famous works for months without error [15]. The point of the story is to highlight a general lack of understanding of probability in many repeated trials: "*Uninformed people might create a sensation if they knew [about the chimpanzees' success]*" [5, page 95], since if continued indefinitely, the chimpanzees would hit a long stretch of intelligible writing, though intuitively most assume this would be impossible.⁵ Topology is a popular topic of mathematical fiction. Martin Gardner's *No-Sided Professor* defines in simple terms what topology is: "*One way to put it is to say that topology studies the mathematical properties of an object which remain constant regardless of how the object is distorted*" [5, page 100], while William Upson's *A. Botts and the Möbius Strip* playfully explains the Möbius Strip ("*Get yourself a strip of paper about a yard long and an inch wide.*

⁵ The *gambler's fallacy* is a real-world application of such a misunderstanding of probability: many gamblers instinctively believe that a run of failed gambles long enough to bankrupt them will not occur due to the improbability of those results succeeding each other. But with enough gambles, the likelihood of that streak occurring increases.

Lay this flat on your desk, lift the two ends [...], turn one of them over and bring the two ends together" [5, page 162]), both likely introducing a new branch of mathematics to general readers. Arthur Porges' *The Devil and Simon Flagg* acquaints readers with Russell's paradox (*a village with one barber who shaves all of those, and only those, who don't shave themselves. 'Who shaves the barber?' they asked*) [5, page 64]⁶ and Fermat's Last Theorem [5, page 65], a proof of which wasn't to be published for another 41 years.

Though these stories, and many more, do incorporate mathematics into literature, they were not solely written for the purpose of injecting mathematical concepts onto a layperson, and as a consequence, do not. A common occurrence in the stories from *Fantasia Mathematica* [5] is that the mathematical details are spared: "[the] topological curiosities [...] are too complex to explain here" [5, page 103] and "[...] which makes a minimum of the integral - I won't go into details" [5, page 130]. Furthermore, *Flatland* is more comprehensibly an attack on the hierarchy of Victorian Britain than an explanation of higher dimensions [1, *Introduction*, page *vii*]. Frequently, mathematics is used to base a storyline on, but the story is not used to teach or develop the ideas used. This is because it is not always straightforward to fully explain a mathematical concept, and as with all lines of study, it can take years to gain a full understanding of it; it is not surprising that a short piece of creative writing cannot offer such an in-depth study.

It could be argued that since gambling is accredited as a driving force behind many areas of probability that it should be plausible for something like literature to do the same for some mathematical ideas. To this I point out the upper-hand an understanding of the mathematics behind gambling gives the gambler. The bottom line is that there is no such upper-hand a writer can gain in understanding mathematics. Mathematics is often used within literature, but not to the end of developing itself. At the very least it can be said that mathematics within literature can be used to create an awareness, and initiate a better understanding, of its concepts. While noble and worthwhile, and one cannot fully dismiss the utility of this dissemina-

⁶ EDITOR'S NOTE: This issue of the *Journal of Humanistic Mathematics* contains a short story inspired by this very paradox. See "Astor Palace Barber" by Audrey Nasar.

tion of knowledge, this is not the same as developing mathematical ideas. In other words, I have yet to see a case where any work of literature has definitively led to the development of mathematics.

Last Words

Mathematics and literature can undoubtedly coincide. Mathematics is occasionally used as a tool to write both verse and prose, combinatorics hides in the structure of poetry, and important branches of mathematics have been seen through the study of literature long before they were considered through the study of numbers. In this article, I have argued that this role mathematics plays within literature is, however, as far as it goes. Creative literature cannot be considered as essential for the development of the concepts it has brought to light, nor can it claim to act as a route to effectively teach mathematics. But this is not its aim. There is merit in introducing mathematical ideas to those who may not necessarily have encountered them.

There are interchangeable skills, as opined by Weierstrass [21], who implied that the application of imagination is relevant to both mathematics and creative writing. This may be so, but the main question here is the relationship between the two realms. And the common occurrence is that mathematics is used for the purpose of yielding writing, rather than literature being used to develop mathematics. Outside of the types of examples considered, mathematics and literature have little in common. Thus, though not necessarily at opposite ends of a spectrum, these two disciplines could be considered as two sets in a *Venn diagram*, with a minor intersection.

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