Using Metaphor to Engage with Science

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“The greatest thing by far is to have a command of metaphor”

(Aristotle)

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ABSTRACT

There is a significant gap in the literature surrounding metaphor in science communication in terms of the use of metaphor to primarily engage, and secondarily educate. This thesis aims to provide a comprehensive overview of the value of metaphor as an engagement tool for science communicators, using a compilation of information from existing relevant scholarly works and an independent student engagement survey. With concerns of a decreasing population interested and proficient in science practices increasing, this thesis provides important information to help battle this issue.

The academic component of this thesis covers topics such as; metaphor theory, metaphor in science communication, using metaphor to engage, the cognitive science of metaphor, effective metaphors, storytelling, and the limitations of using metaphor to communicate science. In discussing and analysing the literature surrounding these topics, an argument is presented supporting metaphor as a valuable tool for science communicators to achieve engagement. A study, based upon a student engagement survey, supports the main points of this argument, identifying that; the majority of students studied were emotionally, cognitively and behaviourally disengaged, visual learners (those who benefit the most from communication through metaphor) were not a minority, and that metaphor/storytelling was an appealing communication technique. It was elucidated that for engagement purposes, as well as additional learning benefits, the strength of metaphor lies in its ability to link the unfamiliar or abstract to the familiar, creating more complex knowledge structures.

The creative component, ‘A Land Before Life’, is a metaphoric story about the theory of the ‘RNA World’. The adventure story, targeted at ages 11-14, aims to primarily entertain and engage the age bracket in the science of biochemistry, while giving indications to the literal scientific theory. Used as an advanced organiser, the story will provide students with a framework to structure their knowledge around. Through using the effective metaphor criteria outlined in chapter five, and the research on engagement, the book utilises the academic thesis in its favour.
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INTRODUCTION

This thesis discusses whether metaphor can be used as a way to engage people in science and better their understanding of scientific concepts. It aims to cover a crucial gap in the metaphor/science communication research field. Through looking at previous research and conducting an independent survey, the worth of metaphor as an engaging science communication tool will be exposed.

For approximately 40 years, there has been concern about the increasing negative attitude toward scientific content (Ateh & Charpentier, 2014; Ainley & Ainley, 2011; Osborne et al, 2003). This issue is not exclusively relevant to students as there is a good deal of scientific ignorance that exists in much of the population worldwide (Osborne et al, 2006). Science pervades society in many ways and this disinterest in science, that results in a lack of understanding, is concerning. The decreasing amount of scientists, and those who study science, will have a huge influence on the future of the subject. It will have implications in the way voters and taxpayers support science, as if the people do not understand it they may not see its worth to society (Ahlgren & Walberg, 1973). Scientific endeavours and discoveries make up a significant part of a country’s economic security and with decreasing numbers studying science, many nations may find themselves in trouble (Ainley & Ainley, 2011).

According to Silver & Rushton (2008), primary school children of ages eight and below have mostly positive attitudes towards science. This means that there is a point at which these attitudes are changed, as the majority of secondary school students think of science in a negative light (Osborne et al, 2006). Secondary school students have the perception that science is a difficult subject before they even enter the classroom. This results in minimal engagement and an unwillingness to learn. The trend, dubbed the ‘swing away from science’, shows that as a result of these negative attitudes and disengagement, when students are able to choose their subjects in secondary school they are more likely to choose subjects that are non-science based (Osborne et al, 2006). It is hugely important to maintain the positive attitudes seen in ages 8-14, as children are more likely to go on to study and work in scientific fields if they have a positive attitude to science in their secondary school years (Silver & Rushton, 2008; Ormerod & Duckworth, 1975).
The disinterest and poor attitude towards science can be, in part, attributed to poor communication/teaching of science (Osborne et al, 2006). With many of the topics being difficult to see with the naked eye (too microscopic or unimaginable distances from Earth), getting people interested in scientific subjects is hard. There is a clear difference in how primary school and secondary school science is taught; primary school focussing on discovery and hands-on activity, while secondary school curricula are less focussed on experimentation due to increased content to cover (Harlen & Qualter, 2014). The students become removed from the subject, which is why it is increasingly important for the communication of science to become more creative. This thesis will discuss the utilisation of metaphor to encourage engagement in science and aid with the difficult task of communicating it.

As the use of metaphor as a science engagement tool represents a significant gap in the field of science communication, some of the academic material referenced within this thesis has been sourced from other fields such as: psychology, education, and marketing. However, all information used is relevant to the argument presented.

The first chapter of this thesis evaluates the literature surrounding metaphor theory. To improve understanding and clarify the concept of metaphor, an analysis of the interaction, network, anomaly, metaphor drift and cognitive metaphor theories is conducted. In this first chapter the reader will gain a good understanding of the nuances of metaphor, which will help them as they continue through this body of work.

The second chapter explores how metaphor appears within the field of science communication and education; the reader being exposed to the much-debated role of metaphor within these disciplines. By discussing both the positive and negative views of the use of metaphor in science communication, this chapter poses the question of how valuable metaphor is as a science communication tool.

The third chapter outlines the crucial argument of this thesis, whether metaphor is in fact a valuable tool specifically for engagement. The argument is made using research from a number of different disciplines. This chapter is where the thesis differs from other studies on metaphor in science communication.
Next a set of criteria for effective metaphor use is created through combining and condensing a number of studies. Chapter five is useful for those who want to use metaphor effectively to communicate science.

Within science, metaphoric material often appears within the construct of an analogy or simile, while storytelling can be an application of these visualisation tools (Muscari, 1988). In terms of this thesis the three different terms; metaphor, analogy and simile, are interchangeable as they have similar attributes and effects as communicative tools. The basis of all three is the transfer of similar features of one, perhaps more familiar, concept to another, and in terms of science, infer information about a lesser-known concept. Even though metaphoric statements imply that one thing is a similar thing that it is in fact not, while analogy and simile compare the two things, the resulting understanding and/or visualisation occurs through similar routes. Storytelling can be an extension of this idea and chapter six explores the use of storytelling in a science communication role.

An independent study was undertaken to support this thesis. A survey, questioning a sample size of 55 tertiary level science students, helps to clarify whether students would benefit from the use of metaphor in the communication of science. All students surveyed had volunteered for extra help and are on the lower end of the achievement scale. The survey aims to identify what is causing these students to struggle to connect with the subject, whether they feel they would benefit from the use of metaphor, and how well the course encourages student engagement using identifiers distilled from chapter three and five.

The limitations and complications of the use of metaphor, as an engagement tool in science communication, are discussed in chapter eight. Here we look at situations where metaphor is likely to hinder engagement and understanding. Topics such as metaphor recognition and comprehension, and learning style are covered.

In the case of this thesis the term student is not necessarily restricted to a person within the primary, secondary and tertiary education systems. It can be assumed that the term student applies to anybody experiencing and learning new scientific information. For example a professor of a certain scientific field can also be a student of another; science’s extremely specialised and dynamic nature calls for almost
everyone to be deemed a student at some point, no matter their experience or background.

Throughout this thesis there is a set of terms, used exclusively, to describe the different components of the metaphor structure. The terms chosen to describe metaphor structure are subject and vehicle. The subject of the metaphor refers to the concept that the metaphor is used to describe, while the vehicle is the context, with similar, significant, and meaningful attributes, used to describe and familiarise the subject (Ward & Gaidis, 2001). This will be further explained in chapter one.

This thesis aims to contribute to the wealth of research on creating; interest, engagement and encouragement of science learning within society by providing research on whether using metaphor can help achieve these goals. Improving the way science is communicated is an excellent place to start in changing the way that science is perceived and received.

To fill a gap in the literature this thesis will discuss the topic of metaphor as an engagement tool, looking at its incorporation throughout communication in general and in science and moving through to educational storytelling.
CHAPTER ONE:
LITERATURE REVIEW OF METAPHOR

Example metaphor for this chapter is ‘Cells are the building blocks of life’.

There have been many attempts at describing metaphor throughout the literature. It is important to define metaphor from the outset, as it is the foundation of this thesis. Out of the many descriptions that exist, the description chosen is simple, yet touches upon all of the important features; metaphor is commonly known as describing one concept, while in the context of another, where meaning is imbedded through common features of the two subjects involved (Hoffman et al, 1990).

Metaphor is a crucial component of human communication, hugely affecting our understanding of the world around us due to their deep rooting in our experiences and the way we think (Lakoff & Johnson, 1979). As a rule, the human mind’s initial reaction when confronted with something new is to describe it in terms of its similarity with something already known, and this is the most primitive form of metaphor. According to Thibodeau (2011), metaphors are powerful enough to affect not only our understanding of abstract concepts but also our reasoning and actions. Through describing or explaining one concept in the context of another, metaphors have the ability to link new information to existing knowledge and in this way create added meaning and understanding (Hesse, 1988; Maasen et al, 1995; Faber et al, 2004). The importance of understanding how metaphor affects communication and comprehension can be demonstrated by the exponential growth in the literature surrounding it. In exploring the thesis statement, ‘metaphors can be used to engage audiences with science content’, it is important to discuss how metaphor is presented within the literature to gain an understanding of its past, and predictions of its future use.

Throughout the literature considering metaphor, there is a general consensus when it comes to defining it. Most agree that the defining feature of a metaphor is the transfer of a concept, with a specific context attached to it, to another context, in order to illuminate certain features of it (Maasen et al, 1995; Rose, 1999; Pauwels, 2013). Every metaphor contains a subject and a vehicle; the subject being the concept, and
the *vehicle*, the context used to explain said concept (Cameron, 2003). To explain this descriptive jargon a little better; in the metaphor ‘*cells are the building blocks of life*’, the cells are the *subject*, while the building blocks are the *vehicle*, as information about the more familiar building blocks is transferred to the concept of the biological cell. Cells make up larger organisms like building blocks make up large buildings. The transfer of meaning is the identifying characteristic of the tool (Maasen et al, 1995).

After the pioneering research on metaphor by Max Black and Mary Hesse, in the 1950’s and 60’s, metaphor is now considered much more than a decorative linguistic tool, but a device to assist the formation of concepts and theories (Lopez, 2007).

Max Black (1955), believed it was “old fashioned” to define a metaphor as “saying one thing and meaning another”, as metaphors are far more complex. This statement was very astute, as “saying one thing and meaning another” does not begin to describe the complexities of the cognitive choices involved in metaphor comprehension and use. Black (1955), was one of the first to take a truly analytical look at metaphor, weighing up previous theories and assumptions, and developing his own theory of how a metaphor should be defined. He presented his ‘interaction theory’ that listed seven requirements a metaphor must meet.

**Black’s (1955) Interaction Theory**

“In the form in which I have been expounding it, the ”interaction view ” is committed to the following seven claims:

1. A metaphorical statement has two distinct subjects a ”principal ” subject and a ” subsidiary” one.21
2. These subjects are often best regarded as ”systems of things ”, rather than ” things”.
3. The metaphor works by applying to the principal subject a system of ” associated implications ” characteristic of the subsidiary subject.
4. These implications usually consist of ” commonplaces” about the subsidiary subject, but may, in suitable cases, consist of deviant implications established ad hoc by the writer.
5. The metaphor selects, emphasizes, suppresses, and organizes features of the principal subject by implying statements about it that normally apply to the subsidiary subject.
6. This involves shifts in meaning of words belonging to the same family or system as the metaphorical expression; and some of these shifts, though not all may be metaphorical transfers. (The subordinate metaphors are, however, to be read less ” emphatically “.)
7. There is, in general, no simple ” ground ” for the necessary shifts of meaning no blanket reason why some metaphors work and others fail.”

Figure 1: Max Black’s interaction theory, taken from his paper, ‘Metaphor’, printed in the Proceedings of the Aristotelian Society (1955).
Where in this thesis, the two concepts that make up the metaphor are referred to as the *subject* and *vehicle*, Black (1955) names them *principal* and *subsidiary*; however, the different terms support the same ideas. There are a number of cognitive choices to be made when creating or receiving a metaphoric description, and the interaction theory stands to highlight this point as the most important. Points 3-6 of the interaction theory, describe the process of a receiver’s decision to include or exclude certain similarities and differences between the *subject* and *vehicle* (the systems Black (1955) mentions). For example, in the interpretation of, ‘*cells are the building blocks of life*’, we include the similar trait that both the cell and building blocks can create a larger unit; however, we choose to exclude the dissimilar shapes of building blocks and cells, as it takes away from the principal message of the metaphor.

With this theory, Black (1955) dispelled the previous substitution and simile theories, which both state that the “focus” of the metaphor, or the word(s) used metaphorically, could be directly substituted with a literal alternative. The substitution theory placed the use of metaphor as a form of convenience; the metaphor being a more convenient way to express the literal meaning. Black (1955) has shown that these two early theories of metaphor completely ignore the emotional, experiential and contextual value a word can have, and therefore the cognitive aspect of metaphor. This cognitive component is highlighted in the fifth claim of the interaction theory where Black (1955) identifies that a metaphor can highlight and hide certain aspects of a concept.

This characteristic of metaphor could be utilised in order to highlight aspects of interest to an audience, with the intent to engage them with the content. To take the metaphor ‘*cells are the building blocks of life*’ again, to prove this point, it is going to be a more effective metaphor for people who enjoy(ed) building with Lego pieces, as it is a personal interest and concrete experience. Overall, the interaction theory was well-defined and thought-out, generating a new way to think of metaphor and increasing the amount of analytical thought on the subject.

Mary Hesse (1988) built upon Black’s (1955) interaction theory, taking a nominalist approach to metaphor by claiming, “all language is metaphor”. She uses linguistic examples such as ‘heaviness’, to display the metaphoric content of a seemingly literal word, as it literally means the physical weight of an object but through metaphorical extension, can also refer to ‘the heaviness of the moment’, to provide evidence for her point. Her argument for the proposed, ‘network theory’, begins by dismissing the
Aristotelian theory of metaphor; described as “the transposition of a name that properly belongs to something else”, and arguing that the cognitive significance of metaphor is ignored. In reasoning that “all language is metaphor”, she makes her case that metaphor cannot be considered as an improper linguistic practice but that it, like the so-called literal meaning, sits within a dynamic network of meanings. Within her discussion she acknowledges that in using metaphor, there is extended meaning that the reader is exposed to. She discusses Black’s (1955) primary (literal meaning) and secondary (metaphorical meaning) system in which metaphor is “a filter through which we view the primary system” acknowledging the fifth claim to Black’s (1955) theory. She makes the point that “since meanings are thus affected, there can be no explicit translation or paraphrase of a metaphor without cognitive loss”; cognitive loss meaning implicitly inferred information loss (Hesse, 1988). If this extended meaning, that metaphors offer, was harnessed in a way that would ignite interest within an audience, many more people may become engaged in science. Mary Hesse’s (1988) thesis has strong opinions and analyses the cognitive component of metaphor well; however, the development of the network theory framework is weak. The more recent musings of Meyer et al (2012) and Lopez (2007) have made attempts in creating more solid theories, making up for what the network theory lacks.

Meyer et al (2012), proposed the ‘metaphor drift theory’, which describes in more detail how Hesse’s thesis statement “all language is metaphor” exists (Hesse, 1988). They have identified three different types of metaphor for analytical purpose; live, frozen and dormant. The ‘live’ metaphor is a metaphor that could never be confused as literal language, for example; ‘man is wolf’, could never be interpreted as literal as it is known that man and wolf are of different species. Metaphors that have become so commonly used that their metaphoric status, or nature, is no longer identified, are categorised as “frozen”. Frozen metaphors become commonplace in conversational language. An example of a frozen metaphor is the use of the word ‘run’ when describing the movement of anything but animals, such as a river. The last type of metaphor is the quasi- literal “dormant” metaphor, in which the metaphoric nature can be easily identified; yet the metaphor is used in a literal sense. An example for this type of metaphor is the term ‘organisational structures’ used to describe society, as a structure is a physical presence and an organisational structure is not necessarily physical, it is a metaphor; however it is used literally in colloquial language. These principals make up the metaphor drift theory, which involves the “live” metaphors.
becoming either “frozen” or “dormant” with excessive use over time (Meyer et al, 2012).

Like Hesse (1988) and Meyer et al (2012), Lopez (2007) drew attention to the dynamic behaviour of metaphors. He outlined the idea that with use and time the potential meanings of a certain metaphor will stabilise, due to the context and practice of their use. Unlike the previous two theories, Lopez (2007) has identified that although they will reach stability, this does not mean they become neutral. The connotations of the words used will always follow the concept, and the context in which the metaphor becomes stable may be different from the one that it was created in. The context and practices of use of the metaphor, along with time frame, all influence this stabilizing process and each metaphor will experience this (Lopez, 2007).

The anomaly theory is a theory that focuses on the process of recognising a metaphor, instead of the metaphor itself, an important aspect to cover. The anomaly theory is based on a two-step, recognition process. The sentence is first interpreted as literal, then when it is recognised as an anomaly, that does not make sense literally, a second, figurative interpretation occurs. If, after the figurative interpretation, the sentence still makes no sense, it is considered an anomaly and not a metaphor (de Zepetnek & Sywenky, 1997; Hoorn, 1997).

Lakoff and Johnson (1980) proposed that most human thought is in some way constructed through metaphor. In their book, ‘Metaphors We Live By’, they make a very convincing argument that metaphor pervades the way we think about almost everything. Using examples like; the ‘conduit metaphor’, that postulates even the way we think about thought and ideas is through the metaphor; ideas are ‘objects’, linguistic expressions are ‘containers’, and communication is ‘sending’, they create a very strong case for their argument. This idea seems to be a bit ambitious, however, Lakoff and Johnson (1980) provide an answer to the ‘chicken and egg’ questions that this theory creates; explaining that in order to have any meaning at all there must be some literal concept to ground our conceptual system, aligning themselves with the interaction theory on this point (Black, 1955). The simple spatial concepts, such as the orientation that our bodies experience (up, down, in front, behind, etc.), provide the foundation for many of the metaphors we live by, and are, according to the two
authors, literal (Lakoff & Johnson, 1980). This is something that is overlooked by Hesse (1988), who disagreed with Black’s (1955) interaction theory on the basis that he believed that if there were no literal concepts, meaning would be circular (Hesse, 1988). Lakoff and Johnson go as far to suggest that our experiences are made coherent through metaphors. Using the example that “argument is war”, they consider that the metaphor of war is used to comprehend the shift from conversation to argument and structure a person’s actions accordingly (Lakoff and Johnson, 1980). George Lakoff and Mark Johnson’s (1980) work influenced and inspired much of the more recent literature and is one of the most cited pieces on the subject.

As a result of the work of those mentioned above, metaphor is now often looked at in terms of cognitive science; the study of thought, learning and mental organisation. The idea that metaphors are firstly a cognitive tool, used to comprehend the unfamiliar or abstract, and then derivatively, a linguistic tool is the most popular in this dominant area of metaphor research (Reimer & Camp, 2008). The majority of the more current work on metaphor is aligned with the cognitive theory of metaphor, with injections of Black (1955) and Hesse’s (1988) work. Many seek to define, justify and better the pioneering work of Black (1955), Hesse (1988), Lakoff and Johnson (1980), as we have seen with Lopez (2007) and Meyer et al (2012) (Gibbs, 2011). While the controversy over metaphor theory has quietened in more recent years, a number of other controversies have ignited, namely the controversy of using metaphor as a communication and comprehension tool.

The most prominent strength of metaphor, as an educational and communicative tool, lies in its ability to facilitate connections between abstract concepts and the familiar. As a communication tool metaphors create the opportunity for extended learning and mutual understanding of abstract concepts by creating links to what is commonly known (Maasen et al, 1995). It has been identified by Faber et al (2004), that new concepts can never be solitary but must be related to what has come before them in order to be processed and understood. Metaphor is an imperative tool, used to create the interconnections between existing knowledge and new information, facilitating the comprehension of new information. Metaphor has been identified as essential and intellectually useful for communicative purpose by many authors (Raitz, 1979; Faber et al, 2004; Maasen, 1995; Bradie, 1999; Pauwels, 2013; Bucchi, 1996).
Though metaphors have been acknowledged as being fundamental to human communication, many studies in the field focus on the negatives or ‘dangers’ of using metaphor (Raitz, 1979; Meyer et al, 2012; Lopez, 2007; Turbayne, 1962; Thibodeau, 2011; Pauwels, 2013).

The ‘danger’ expressed by Raitz (1979), that there is the possibility of coming to believe that the metaphoric language used is actually the truth; that the ridiculous or “make-believe” component of a metaphor is left unrecognised. Believing that the metaphor is the truth is much worse than being completely blind to a concept. When a person believes that they have no knowledge, or an inadequate understanding, of a concept, they generally do not make judgements or act in accordance to what they know. However, if a person believes that they have an accurate understanding, through their literal interpretation of the metaphor, they can act upon this misinformed belief, and the action taken is where the problem lies. Failing to recognise metaphors is said to occur more frequently in the “moribund stages” of the metaphor, when the context in which it was created is no longer apparent (Raitz, 1979). Every metaphor carries with it a history, and throughout time the context and uses vary. “This is where metaphors become a hindrance to understanding,” (Raitz, 1979; Lopez, 2007). Although Raitz (1979) coherently explains why believing metaphoric language is truth is a danger, he does not present any evidence to suggest how this occurs and how often which greatly weakens his argument. Additionally, despite these concerns, Raitz (1979) believes that metaphor is “an extremely useful intellectual devise” that if executed properly will illuminate what is shadowed by literal language.

Further concern was expressed by Thibodeau (2011), who identified that “if metaphors in language invite conceptual analogies, then different metaphors should bring to mind different knowledge structures and suggest different analogical inference.” If multiple metaphors are used for the same concept, then multiple understanding, and therefore actions, may be assumed (Thibodeau, 2011; Meyer et al, 2012). This concern was countered by Meyer et al (2012), who suggested that to ensure complete understanding of a concept, it is more conducive to utilize the full range of metaphors that exists on the subject, showcasing each of their weaknesses and strengths. They believe that the use of a single metaphor could be potentially misleading as often no one metaphor could capture the complexity of a particular
concept (Meyer et al, 2012). A better understanding of metaphor’s effect will help ensure that it is used intelligently and will guard against its misuse (Raitz, 1979).

From this review of the literature regarding metaphor, it can be concluded that metaphor involves describing one concept, using the context of another, each having a topic and a vehicle. However, there is also evidence that this description is an oversimplified explanation - the most important attribute of metaphor left unidentified. The way in which metaphors can provide added meaning is essential to understanding them and the way they can be utilised. The characteristics of metaphor, such as their ability to highlight some aspects of a concept and hide others, along with the way they can facilitate a connection between familiar concepts and new, or abstract ones, are the most interesting and relevant to this thesis and will be discussed in further detail.

In terms of the thesis to be discussed, that metaphor can be used to engage audiences in scientific concepts, the work produced by the earlier theorists is very relevant. By defining metaphor as more than just a decorative linguistic tool, they have opened up the idea that metaphor can inject more meaning into a concept (Black, 1955; Hesse, 1988; Lakoff & Johnson, 1980). If that added meaning could connect the audience to scientific subject matter then it could create the engagement necessary for learning and retention. Black’s (1955) claim that much of our thought is facilitated by metaphor shows that metaphor is a cognitive tool and therefore should not hinder the learning process. Although this is a controversial opinion, it has sufficient evidence to support it. The ‘filter’ in which Hesse (1988) and Black (1955) speak of is one of the reasons metaphor is thought to complicate learning, as its nature of highlighting some aspects and shrouding others can lead to incomplete understanding (Thibodeau, 2011). However, this trait can be used to highlight the more interesting aspects of a concept that can create engagement, which can then lead to interest in the topic. The use of metaphor as a way to engage, instead of as an independent teaching tool, is where metaphor excels. The use of metaphor as, primarily, an engagement tool is where the scope of the literature fails.

There is plenty of research about how metaphor can be defined, and used to explain concepts, but there is a significant gap in the literature about using metaphor to create engagement in a topic. From the concerns voiced by the above academics, it can be assumed that metaphor may be unacceptable as the sole education tool to provide a
full understanding of a concept; however, the scholars have neglected to look at metaphor for the purpose of engagement (Pauwels, 2013; Faber et al, 2004; Bergmann, 1940; Bergmann and Spence 1941; MacCorquodale et al, 1957; Lopez, 2007; Hoffman, 1980). This is the primary level of learning, and initiates a student’s journey to understanding. It is almost impossible to convey information to a disengaged audience, so this thesis aims to explore how metaphor can be used, not just as a teaching or communicative tool, but as an engagement tool to ignite the interest of an audience in science.
CHAPTER TWO:
METAPHOR IN SCIENCE COMMUNICATION

Understanding the effects of metaphor is paramount to the science communication field as, despite the plentiful research on the interaction of metaphors within the communication of science, there is no clear consensus between authors on its role or value. There is support, among scholars, of Bradie’s (1999) view, that “metaphors are indispensable components of scientific methodology, as well as scientific communication,” although there are also numerous authors who warn against the use of metaphor in science communication (Pauwels, 2013; Faber et al, 2004; Bergmann, 1940; Bergmann and Spence 1941; MacCorquodale et al, 1957; Lopez, 2007).

Although metaphors have solidified their presence in the communication of scientific discovery and theory, there is some concern about how much they can mislead the public, and sometimes even scientists (Pauwels, 2013; Faber et al, 2004). Scientific explanation, according to some science philosophers, has been identified as innately logical; using laws and deductive reasoning to explain concepts and observations (Bergmann, 1940; Bergmann and Spence 1941). Metaphor, according to this view, does not deserve a place in the scientific language and act as unnecessary additions or “surplus meaning” (Hoffman, 1980; MacCorquodale et al, 1957). This is often the case when studies are discussed with other scientists of the same field and when work is published to ensure all the information is transferred from one scientist to another accurately, but it does not make for very engaging communication. As this thesis is aimed at engaging audiences, Hoffman (1980) and MacCorquodale et al’s (1957) dismissive view of metaphor in science communication does not have much persuasive weight.

The pioneers of metaphor theory, Black (1955) and Hesse (1988), produced their work on metaphors in order to encourage science philosophers to acknowledge metaphor as a legitimate element of science, and its communication (Hoffman, 1980). Christidou et al (2004), share this view, and firmly believe that the communication of science is accomplished competently through metaphor. For the lay public, an audience more relevant to this thesis, to understand science concepts they must be made relevant by relating the unfamiliar to the familiar, and this is often the intension.
of those who use metaphor in science communication. Metaphors “act as illustrative devices and provide a significant key to model-building in every aspect of cognition,” in other words; they create imagery to help comprehension of complex concepts (Christidou et al, 2004).

Additionally, there is much support for the use of metaphor from early, influential scientists. The famed physicist, James Maxwell, explicitly encouraged the use of creative thought in terms of science, endorsing the use of metaphors specifically. He stated that metaphors are not only “legitimate products of science, but are capable of generating science in turn,” (Maxwell, 1890). Another prominent scientist, Michael Faraday, also promoted the use of metaphor and utilised it in many of his theories. If these pioneers of modern science approved of the use of metaphor to communicate their theories, a significant amount of modern science must be based on some form of metaphor, and is therefore an integral and unavoidable part of the science communication field. Modern day scientists frequently resort to the use of metaphor, rather than strictly literal scientific language, as often the only way to describe certain elements of a concept is through likening them to another (Brown, 2003).

There is a distinct difference in the way a metaphor is appraised when used in the context of science, rather than language. Metaphors in science are critiqued in painstaking detail due to their controversial status within the field (Muscari, 1988). This is an unavoidable part of utilising metaphor due to the innately finicky nature of science; however the scientific enterprise is in need of tools to aid understanding and visualisation (Ganguly, 1995). Metaphor provides this and as a result it is extremely important to recognise their place in science communication and education.

According to Gilbert (1989), “analogical systems, that include metaphoric description” are useful as organisers of new information, creating patterns that add to the meaningfulness of the learning experience (Ganguly, 1995). In particular, he postulates that presenting metaphoric organisers, in advance to the specific curriculum requirements, can be hugely valuable, facilitating “more meaningful learning of new material” and promoting concept learning and retention (Gilbert, 1989). Gilbert (1989) conducted experiments to test his theories and, though some were inconclusive, it was evident that the students had incorporated his analogies into their knowledge structure. These trials indicated that the order to which the figurative
language organisers were presented affected their effectiveness, suggesting that analogies and metaphoric material in science communication can be more helpful in advance to the required information (Gilbey, 1989). This idea will be discussed further in chapter five, ‘Optimising the Effectiveness of Metaphors’.

The idea that metaphors and analogies can be useful as organisers, or frameworks, to structure new scientific information around is seconded by Muscari (1988). Muscari (1988) sees metaphor as a way students can connect to the abstract concepts in science and can “help them through what might seem like a congested maze” of abstract information. Much of the science that is taught can seem pedantic and inconsequential for students and it is difficult to discern the larger concept through all the content. Metaphors can remedy this problem for students and “it is becoming more evident that imaginational frameworks, and organizational structures, work with other memory components to affect the learning outcome and give meaningful direction to thought”. The greatest thing about using metaphor as a framework, or organiser, of new material is that it relates new information to existing knowledge, preventing new information from being too foreign and therefore un-comprehendible (Muscari, 1989).

Metaphors are used in education to lead learners to an understanding of complex concepts, and despite the conflict over their use, are most commonly used in science and mathematics (Cameron, 2003). In the study outlined throughout Cameron’s (2003) book, ‘Metaphor in Educational Discourse’, she observed children “talking and thinking” more when faced with a metaphor. Cameron suggests that effective teacher mediation can help to solidify a child’s understanding of a topic through the use of the metaphor.

There are multiple ways in which the use of metaphor can improve science communication. The degree of freedom and imagination stimulated by metaphor is key to encouraging good, well-rounded science communication (Duit, 1991; Ganguly, 1995; Muscari 1988). When there is such a vast amount of science content that is hidden from the naked human eye, imagination is hugely important when learning a new concept. Visualisation is a vital part of the learning process and metaphor can provide a vehicle to encourage imagination and visualisation of abstract scientific concepts (Duit, 1991). “Metaphors, like perceptions, are drawn from common
experiences and are a means to anchor scientist’s thought processes in generating a pattern that bridges the gap between the seen and unseen” (Ganguly, 1995). Many of the most renowned scientists, Maxwell, Faraday, Bohr and Einstein, were successful due to their impressive creativity and visualisation skills. “Visual thinking is a key tenet of scientific thinking,” making visualisation tools such as metaphor and analogy, an invaluable science communication tool for encouraging imagination and creativity amongst learners.

In recent times, it has become apparent to science communicators how important it is to show science as a human enterprise, rather than an unalterable set of truths. Metaphor can provide a means to highlight this view of science (Miller, 2001; Ganguly, 1995). Portraying science in terms of the process, rather than fact, keeps the public well informed. By increasing understanding of the scientific process, the publics’ capacity for accepting change in scientific information is increased, and mistrust of scientific information and communication is decreasing. There is a lot of work that indicates highlighting the exciting aspects of scientific discovery is effective in encouraging interest in scientific education (Hodson, 1988). Muscari (1988) believes that challenging metaphors in science can lead to a better understanding of the “human and dynamic side of the enterprise of science”, as one of the major characteristics a scientist possesses is an ability to challenge ideas.

Lopez (2007) believes that metaphor is not substantial enough to be used in a heuristic way but can serve adequately to frame contentious issues surrounding certain scientific topics. Metaphor is described in this paper in terms of its adequacy to promote learning of science but inadequacy to teach science. The simplification process that a scientific concept must endure in order to be explained by a metaphor is thought to confuse students (Lopez, 2007). Other authors question Lopez’s (2007) view, stating that the science taught to children must be relevant to them and the environment they are familiar with. Metaphor can be used to illustrate this relevance through linking the known to the unknown (Blough, 2006; Meyer et al, 2012). It is a device that can be used to explain and encourage recollection of information (Hoffman, 1980). Though Lopez’s (2007) overarching view opposes the stance of this thesis, in some ways, it supports the foundation of the thesis statement; metaphor can be used to engage people in scientific learning, because, as stated earlier, Lopez (2007) supports the use of metaphor to engage.
The flexibility of metaphor in science; the way in which there can be multiple metaphors for one concept, each with their benefits and flaws, can encourage students to think scientifically about what they are learning. Metaphors create a way for students to question what they are being taught, or how they are being taught, and thus encourages scientific thinking. “The best kind of learning is when students are doubting and challenging what has come before them; liberating them to think for themselves” (Muscari, 1988). This more optimistic view of the multiple metaphors that exist for one concept relies heavily upon the analytical skills of the students. If a student has poorly developed analytical skills then the multiplicity of metaphors may create confusion instead of a greater understanding. However, if students are taught to analyse and perhaps deconstruct metaphors, the skills necessary to benefit from this idea will be developed.

Metaphors have a fantastic quality of first aiding with understanding; providing the framework to structure the new knowledge around, and secondly creating an outlet to explore and practice learned information. Often a student’s rapidly expanding knowledge of a concept becomes detrimental to the original metaphor used to teach it. The most ideal outcome is that the student begins to deconstruct it, discovering the ways in which the metaphor does not fit the concept, or by extending it to fit the learnt information. This act of deconstructing or elaborating the metaphor is extremely helpful as it provides a means for the student to explore and consolidate their newly acquired knowledge; resulting in a deeper understanding of the concept. “The student who is not given the chance to reorder information, to alter existing categories, or to see new gestalts, cannot be said to be participating in a learning activity” (Muscari, 1988). Muscari (1988) has recognised that “the imagery of the speculative metaphor should gradually give way in science to the explicity and rationality of more select procedures. To maintain the metaphor after the relation has been discerned and defined might be to cling to the allurement and inhibit the scientific process”. This idea is supportive of the main thesis, that metaphor is a great way to begin communication, as it is engaging; however, it is important to let the literal language of science take over and fill the gaps metaphor may not cover.

It is important to recognise that although metaphor has a large role in science communication and education, whether endorsed or not, it cannot exist alone (Hoffman, 1980). Metaphors must embellish the literal language of science in order to
have any use or influence. “If a metaphor becomes popular within the public mind then it has the ability to shape the narrative of a particular field” (Hellsten, 2002). It is vitally important for scientists, science communicators, and science educators to understand the metaphoric implications of the communicative language they use. They must be aware of the metaphoric meaning behind the words they use and ensure that the meaning attached to those words helps to explain concept rather than hinder understanding (Brown, 2003).
CHAPTER THREE: ACHIEVING ENGAGEMENT THROUGH METAPHOR

In order to discuss how metaphor can be used to connect an audience to subject matter, we must look at what the term ‘engagement’ means exactly and what its achievement results in.

Through an overview of the literature discussing engagement, it is clear that there is a diverse range of definitions identified by scholars. In stating this, it must be conceded that there are two distinct groupings that these definitions can be divided into. On one side of the argument, many agree that engagement is the amount of work dedicated to a topic (Fredricks et al, 2004). Other scholars see engagement in terms of active involvement in learning, concentrating more on behaviour while the student is receiving the information (Axelson & Flick, 2010; Walker et al, 2006). For this thesis, it is more important to focus on the latter as using metaphor to engage is most relevant to the primary instance of communication and uptake of knowledge. Whether the use of metaphor can improve the amount of time dedicated to the subject, outside of the direct communication of information, is out of the scope of this thesis.

First, let us look at the behaviours of typically engaged and disengaged students to clarify what the outward portrayal of the term engagement looks like. According to a study by Garrett (2011) of students in class, the signs of a disengaged student were; “frequent absences from class sessions, sleeping in class, undisciplined chatting, reading materials not relevant to the course (e.g. newspapers, magazines, textbooks for other classes), chronic tardiness, not submitting assignments, being habitually silent during class discussions,” along with lack of eye contact. In the same study the behaviours of an engaged student were identified as; “involvement in class discussions, participating in learning activities, asking questions, responding to other comments, debating, bringing questions and problems to class that were discovered by reading out-of-class, writing response papers, emailing or posting discussion thread questions and comments to the instructor or others, blogging, researching independently, making connections with other texts and writers, and probing deeply into a text or a research problem.” Engaged behaviour may be defined simply as “eye contact, listening and being alert” throughout the presentation of information.
When attempting to define a phrase, it is often beneficial to take a look at the original or purest definition of the word. Historically, the word *engage* came from the Norman root word *gage*, which meant “pledge”; as in make a promise or take an oath tying yourself to a certain enterprise (Axelson & Flick, 2010). The Oxford dictionary offers definitions such as “occupy or attract [somebody’s attention]”, “participate or become involved in”, “establish a meaningful contact or connection with” or “pledge to enter into a contract to do something” (O. E. Dictionary, 2014). It can be inferred from these definitions that in order for metaphors to be able to engage an audience with scientific subject matter, they must be able to occupy or attract the attention of said audience and cause them to ‘pledge’ their attention to it.

The phrase that is most relevant to this thesis is ‘student engagement’ or ‘audience engagement’ and is often simplified to how involved or interested an audience is in the information being presented to them (Axelson & Flick, 2010). Three components have been identified to make up the umbrella statement of engagement: behavioural, emotional and cognitive. No one component of engagement has been identified as having a primary role in maximising student engagement and it has been suggested that student engagement is best thought of as a “multidimensional construct” involving all three components (Axelson & Flick, 2010). These types of engagement are significant to this thesis as it is essential to understand each form of engagement; emotional, cognitive and behavioural, to form an argument for the use of metaphor to create engagement. Though Axelson & Flick (2010) are likely to be correct in recognising that a combination of the behavioural, emotion and cognitive aspects of engagement have a role in student engagement, there has been little effort in studying how the three types interact. This will become an increasingly important topic of study if communicators want to know how better to engage their audience; however, it is not within the scope of this thesis.

Cognitive engagement describes the way in which people go about learning. Specifically, it refers to “the amount and type of strategies that learners employ.” A high level of cognitive engagement would call for meaningful processing of the new information, which “involves relating new information to one’s existing knowledge; thus creating a more complex knowledge structure,” (Walker et al, 2006; Helme & Clarke, 2001). Through utilising metaphor, a tool known for its ability to link new
information to existing, cognitive engagement can be directly facilitated, encouraging the creation of complex knowledge structures. Those who do not engage cognitively with information are said to have a shallow understanding of a topic, gained simply through rote learning and other forms of superficial learning strategies. Studies have shown that those who utilise meaningful processing, or demonstrate a high level of cognitive engagement, possess a better understanding of material and gain higher achievement (Walker et al., 2006; Graham & Golan, 1991; Greene & Miller, 1996; Kardash & Amlund, 1991; Meece et al., 1988; Nolen, 1988; Pintrich & Garcia, 1991).

This portrayal of cognitive engagement gives the impression that the level of cognitive engagement achieved is entirely up to the learner; however, that is not the case. A study performed by Blumenfeld et al (1992) showed that “different levels of cognitive engagement were associated with distinctly different teaching strategies”.

It appears that there has been a lesser effort in defining emotional engagement in comparison to cognitive engagement, and this could be a reflection of which component is perceived by academics as more important. Some define emotional engagement as the identification and value a student has for the institution they attend, while others define it as the way a student feels during teachings (Fredricks et al, 2004). Those that define emotional engagement as identifying with the institution, believe that the “positive and negative reactions to teacher, classmates, academics, and school” influence a student’s motivation to learn (Fredricks et al, 2004). In terms of this thesis, it is more relevant to view emotional engagement in terms of emotions felt by the student during the acquisition of knowledge. This is because using metaphor to create engagement is not an approach that is specific to institutional learning and can be applied to other forms of knowledge transfer (e.g. communication via conferences). This aspect of emotional engagement encompasses feelings including; interest, boredom, anxiety, happiness, sadness, curiosity, enjoyment and anger (Gonida et al., 2009; Fredricks et al 2004). Learner attitudes and values have a profound impact on emotional engagement and this component of engagement has been strongly linked to motivation (Fredricks et al, 2004). The research indicates that
those who have a high interest level, strong work values and positive emotions often achieve higher than those who do not (Gonida et al, 2009).

Interest, features prominently in much of the literature on emotional engagement and is discussed in two senses; situational interest and personal interest. Personal interest studies focus on the way people become interested in their favourite subjects or hobbies, while situational interest concentrates more on how interest can be created, *in situ*, to enhance learning in individuals (Reninger et al, 1992). Situational interest is the more relevant form for this thesis as it is more achievable for large audiences; however, personal interest is touched upon in chapter seven, ‘Independent Survey Research’. It is suggested that situational interest is aroused by the presence of novelty (Fredricks et al, 2004). In teaching or lecturing an appropriate, effective metaphor can provide novelty and therefore, interest if the *vehicle* of said metaphor is allowing. If a metaphor explains a new concept in a novel fashion, situational interest can be achieved. In addition, though more difficult, personal interest can be achieved if the metaphor used connects the new concept to a topic of mutual interest of the audience. The potential that metaphor has to deliver both situational and personal interest levels is extremely powerful in terms of creating engagement.

According to Leamson (1999), “interest in a task is clearly important” for the success of information transfer. If this is so, identifying what makes science interesting is an important part of ensuring engaging science communication occurs. Identifying what makes science interesting is simple as we can assume that science is inherently interesting to humans; as learning about ourselves, and the world we live in has been evolutionarily advantageous (Bazzaz, 1998). This leads me to think that the cause of disengagement lies elsewhere. Garrett (2011) has identified that disengagement occurs when a topic or concept appears either too easy or too hard. In science, if a student is disengaged because the content is too easy it is far simpler to rectify than if it is perceived as too hard as there are many levels of complexity to cover. For the sake of this thesis, it is beneficial to assume that for the majority of people struggling to understand science concepts, it is because the concept appears too hard or complex. If this is true, the concern raised by Lopez (2007), that metaphor’s effect of simplifying scientific concepts creates confusion, is void as in order for information to be transferred the receiver must be willing to learn. Willingness to learn is encouraged through engagement, which can be achieved through metaphor.
Behavioural engagement has been interpreted within this thesis as the result of emotional and cognitive engagement (Fredricks et al., 2004). Behavioural engagement is described as “energized as well as enervated” reactions to receiving new information. This includes behaviours such as; “initiation, concentrated attention, persistence, effort, or; avoidance, passivity, and giving up,” (Gonida et al., 2009). It is what deems a person as engaged or disengaged. It is the outward projection of how engaged the student is and is extremely important to identify as a science communicator as it is often the most prominent indicator of how engaged an audience is.

According to Park (2003), along with many other academics in the field, “students who actively engage with what they are studying tend to understand more, learn more, remember more, enjoy it more and be able to appreciate the relevance of what they have learnt” (Astin, 1985; Pascarella & Terenzini, 1991). Long-term studies, spanning years, have demonstrated that students showing early issues with behavioural engagement, the product of emotional and cognitive engagement, have enduring effect on their achievement (Fredricks et al., 2004). It is of a unanimous opinion among scholars that “learning begins with student engagement, which in turn leads to knowledge and understanding” (Shulman, 2002; Astin, 1985; Pascarella & Terenzini, 1991; Gonida et al., 2009; Fredricks et al., 2004; Garrett, 2011; Walker et al., 2006; Graham & Golan, 1991; Greene & Miller, 1996; Kardash & Amlund, 1991; Meece et al., 1988; Nolen, 1988; Pintrich & Garcia, 1991). This statement is the crux of this thesis as it is where the argument begins. The most important part of teaching, and communicating science, is engaging the audience because without first engaging the audience it is incredibly difficult to impart knowledge upon a student.
CHAPTER FOUR
COGNITIVE SCIENCE SUPPORT OF METAPHOR USE IN SCIENCE COMMUNICATION

Although there is little research covering the effect of metaphor on learning and retention from a neurological point of view, insight can be inferred through other studies. This section aims to interpret the cognitive science of metaphor comprehension in terms of learning and memory research, to discuss the effect of metaphoric communication of scientific concepts on student comprehension and retention.

The two hemispheres of the brain have been identified as having different strengths and weaknesses in processing. In terms of language, the left hemisphere of the brain “appears to govern the functions of speech, especially those involving syntax and phonology”. It also plays a large part in “perceptions of time, sequential ordering abilities and most analytical studies.” It is thought that the left part of the brain is recruited when a metaphor is first approached, then when there is no obvious linear meaning, the right hemisphere of the brain is recruited. This is because the right hemisphere is more responsible for the “determination of meaning (semantics)”. This analysis of metaphor comprehension links occurrences within the brain to the anomaly theory giving it added weight. The studies on the brain suggest that if the right hemisphere of the brain is damaged, metaphor comprehension will suffer (Morgan & Reichert, 1999). This will be discussed further in chapter eight of this thesis, ‘Limitations and Complications’.

Learning occurs through the development of neuronal networks throughout the brain, a process activated by sensory energy (Herrmann et al, 2006). A neuron is an electrically excitable cell in the brain that processes and transmits information through electrical and chemical signalling patterns (Cooper, 2011). The transmission of information between neurons, termed as firing, becomes stored as a ‘memory’ when the chemistry between spontaneously linked neurons changes enabling the same neurons fire again in the same sequence that when the information needs to be recalled (Herrmann et al, 2006). The entirety of a person’s memory is stored within
neurons in the brain and often multiple memories are stored in the same neurons, but within a different firing pattern or sequence (Mastin, 2010).

**Neuronal Patterning of Memory**

![Neuronal Patterning of Memory](image)

Figure 2: Schematic diagram of memory storage via neuronal patterning in the brain. The orange shapes represent a cluster of neurons, while the lines represent the electrical/chemical (depending on the synapse) signalling between neurons that occurs during acquisition and storage of memory. The two different colours of the lines depict how two different memories may use the same neurons but in a different pattern.

The process of learning, and as a result memory, includes encoding, consolidation, storage, and recall/retrieval (Mastin, 2010; Herrmann et al, 2006). The encoding stage of learning usually refers to the initial learning stage and the strategies used to understand the concept to be learnt. Consolidation is the processes of stabilizing a memory trace after the initial acquisition. These two components of learning determine whether a memory is stored in short or long-term memory and then how
well it can be recalled; for this reason they are the more relevant steps to discuss in this thesis.

Though there are other types of encoding, the semantic encoding process is the more relevant to this thesis as it is specific to meaning and context, of which the long-term memory is the most reliant (Mastin, 2010). The encoding stage of learning usually refers to the initial learning stage and the strategies used at this point. The number of strategies used to learn a concept enhances cognitive engagement, and similarly encoding is strengthened through strategies that encourage “elaboration, organisation and understanding” (Herrmann et al, 2006; Walker et al, 2006; Helme & Clarke, 2001). According to Hermann et al (2006), students’ skills are encoded more thoroughly through using visualisation techniques. A strength of metaphor as a teaching tool is its ability to enable visualisations for more abstract concepts therefore aiding the encoding process of learning. “To ensure memory is available over time, information needs to be elaborately processed in ways so that it is meaningful to us,” indicating that the ability of metaphor to link the abstract to the familiar and inferring meaning, can also be harnessed to better the encoding process (Herrmann et al, 2006).

Additionally, to enhance the encoding of information, it is extremely important to engage with the content (Herrmann et al, 2006). Metaphors can be very effective at creating both cognitive and emotional engagement due to their ability to more meaningful, complex knowledge structures and potential to achieve both situational and personal interest within the student (Walker et al, 2006; Helme & Clarke, 2001; Axelson & Flick, 2010).

“Human memory is fundamentally associative, meaning that a new piece of information is remembered better if it can be associated with previously acquired knowledge that is already firmly anchored in memory.” For even more effective encoding and consolidation it is wise to create personally meaningful associations (Mastin, 2010). Metaphor provides the vehicle for this to occur as it inherently links new information to one’s existing knowledge and personal interest can be incorporated into metaphor that can create a more personal, meaningful association (Maasen et al, 1995). “Elaborate processing that emphasizes meaning and associations that are familiar tends to lead to improved recall” (Mastin, 2010). Elaborate metaphors that link the new information to what is already stored in the long-term memory incorporate the learned information into a more complex knowledge
structure that can help to form a “coherent narrative structure,” strengthening the ability to recall the information when required (Walker et al, 2006; Helme & Clarke, 2001; Mastin, 2010).

As mentioned earlier, the strength of metaphors lies in their ability to facilitate connections between abstract concepts and the familiar. In linking research on the brain with that of teaching and learning, it can be identified that a large component of the learning process is the linking of new knowledge to existing knowledge within the neuronal connections in the brain. “Learning occurs through the growth of neural connections” from existing connections in the brain. The stronger the web of connections; a consequence of learning, and the more frequently used they are, the more automatic or memorable the information becomes (Hardiman, 2001). It is also important to note that learning and memory are strongly connected to, and encouraged by, powerful emotional connection (Rushton & Larkin, 2001). All of these factors are facilitated by metaphor; they have the power to connect new concepts to already acquired knowledge, facilitating a requirement of cognitive engagement, and can also affect the emotional engagement of the student.
CHAPTER FIVE:
OPTIMISING THE EFFECTIVENESS OF METAPHORS IN SCIENCE COMMUNICATION

Example metaphor for this chapter is “the cell is a molecular city”

Metaphors are crafted entities, and their creators are not exempt from judgment. In fact, within science communication they are subjected to harsher criticism than any other form of scientific explanation due to the controversy surrounding their use. In order for metaphors to be recognized as an excellent tool to create engagement and encourage deeper understanding of scientific concepts, critics and users must deem them effective. “Though using metaphor is natural, this innate ability can be improved upon to create truly effective metaphors” (Boozer et al, 1990). The following chapter will discuss the literature surrounding effective metaphor to develop a suggested set of criteria to follow when creating metaphoric science communication material.

It is universally agreed that for a metaphor to be effective it must be comprehensible to the audience receiving it (Ward, 2001). For example: the audience must be able to see how, in the example metaphor ‘the cell is a molecular city’, the cell might be meaningfully related to the complex infrastructures of a city. The effectiveness of a metaphor depends upon “what insights it provides, and what new meanings it can produce” (Yob, 2003). However, to be comprehensible, there is a need for the metaphor to be appropriate to the audience receiving it. The vehicle should be familiar to the audience and, if necessary, should be explained before presenting the metaphor (Curtis & Reigeluth, 1984). Boozer et al (1990) states that you must “speak the customer’s language”; in other words, you must use language that your audience, whoever they may be, are familiar with and understand. If you use jargon that is foreign to the audience, the metaphor is more likely to confuse rather than clarify. “An appropriate metaphor is one that uses familiar and attractive words, that create logical connections in the [audience’s] mind” (Boozer et al, 1990).

To interpret what is deemed effective from the proposed metaphor theories; interaction, cognitive, anomaly, network and metaphor-drift, is difficult as they have variant and opposing opinions.
The anomaly theory states that the most effective metaphors are those in which the *subject* and the *vehicle* are most dissimilar, before the point of incomprehension. Anomaly theorists believe that the dissimilarity between the *subject* and *vehicle* creates the “tension, incongruity and novelty” necessary to create interest and understanding within the audience (Ward, 2001). There is an obvious flaw to this theory; the more disparate the *subject* and *vehicle* become, the harder it is to comprehend, therefore breaking the first rule of creating effective metaphors; ensuring the audience can easily recognise and comprehend it. For example, the metaphor, ‘*the cell is a tennis ball*’, is both incomprehensible and lacking in meaningful relatedness, even though similarities between the two can be inferred (e.g. the tennis ball and the cell both have a protective wall around their exterior). They do however have a point in their comments on novelty-factor. In chapter 3, ‘Engagement Through Metaphor’, the importance of novelty to initiate the engagement of science students is noted, and in most cases novelty does cause the audience to be surprised, triggering a sense of curiosity and resulting in a piqued situational interest (Ward, 2001; Boozer et al, 1990).

Conversely, the comparison view postulates that the most effective or apt metaphors are those with *subjects* and *vehicles* with increased amounts of commonalities. However, the comparison view is often criticised as being too simple, as interpreting a metaphor is not merely listing the similarities but selecting certain similarities with meaning. The interaction view improves upon the comparison view by suggesting that the most effective metaphors cause the audience to see not only the *subject* in a different light but also the *vehicle* (Ward, 2001).

In terms of using metaphors to engage audiences in science teachings, marketing research on promotional metaphors can be utilised. This research is relevant to science communicators as they are essentially aiming to promote the uptake of their information. Ward’s (2001) research on this topic indicates that “if the metaphor is ‘apt’, clever or insightful, it may create a more favourable attitude towards the information” being presented. Morgan & Reichert (1999) make the distinction between a concrete metaphor; a metaphor that “relies on comparisons that can be experienced directly, through the five senses,” and abstract metaphors, that are based upon something intangible akin to an emotion. For example a metaphor based on a
feeling such as ‘magnetic energy moves serenely’ is deemed abstract while, ‘magnetic energy moves in waves’ is tangible, therefore concrete. Through making this distinction, they have indicated that concrete metaphors are more easily comprehended (Morgan & Reichert, 1999; Boozer et al, 1990; Curtis & Reigeluth, 1984). “The degree to which a metaphor is grounded in a sensory experience” positively impacts the comprehension of the metaphor and is especially helpful in describing abstract concepts (Curtis & Reigeluth, 1984). “To increase the effectiveness of communication, words with meaningful referents are needed… Good instruction must include appropriate amounts of concrete and direct experiences to prepare the learner for more abstract, complex experiences. [Metaphors] are one way of providing these concrete experience” (Curtis & Reigeluth, 1984).

Effective metaphors “stimulate deeper levels of processing” by capitalising on the interests of the audience and creating curiosity about the subject matter (Morgan & Reichert, 1999). Boozer et al (1990) postulate that the ‘interest’ and ‘curiosity’, that create “deeper levels of processing,” mentioned by Morgan & Reichert (1999) is created through novelty. A metaphor that explains or describes a concept in a novel way will induce curiosity and interest in the information to follow. For this thesis, novelty is one of the most important qualities of an effective metaphor because in order to engage students in science it is essential to create curiosity and interest. This paper lists a number of features that denote an effective metaphor. Familiarity is mentioned in Boozer’s (1990) paper, stating that “to make the unfamiliar, familiar or unknown, known” is essentially the point of using the cognitive tool of metaphor. The authors value concise metaphors, however, as they are coming from a marketing perspective, where the customer spends very little time exposed to the metaphor; it may not be applicable to an educational metaphor (Boozer et al, 1990). Within an educational setting the sender has a lot more time to get the metaphor across to the audience. This setting lends itself far better to the idea that an effective metaphor “must communicate a total, comprehensible picture or theme” for the receiver. In order for this requirement to be achieved it becomes important for the metaphor to be extensible; to be able to incorporate the important information and facts that the concept relies upon (Boozer et al, 1990; Wells & Fuerst, 2000). “Extended metaphors can help to achieve this coherence and elaboration,” (Boozer et al, 1990).
The paragraph above outlines the importance of extensibility within a metaphor, and this is where a communicator can profit from the use of analogies. The premise of instructional analogies is similar to that of a metaphor, referring to “those instances in which some less familiar domain is made comprehensible by appealing to similarity relations with a more familiar domain”. The difference between the two being that a metaphor communicates information *implicitly*, whilst an analogy communicates *explicitly*, allowing for a more comprehensive comparison of appropriate similarities (Dagher, 1995). Although metaphors and analogies can be an interchangeable term within this thesis, as mentioned previously, the term analogy is predominantly “used more often in scientific and technical contexts” (Glynn et al, 1989).

Curtis & Reigeluth’s (1984) paper outlines their experiment studying “the use of analogies in written texts”. They chose to examine textbooks, as they are known to contain “a great number of complex concepts and principles.” They found that two forms of educational analogies existed; structural and functional. After analyzing their results it was discovered that the more difficult or abstract a concept was, the greater the use of functional analogies, whilst structural analogies appeared for more concrete, or ‘easier’ concepts. The authors also identified two styles of presentation; verbal/written, where the analogy appears in words only, and pictorial-verbal, where the analogy is reinforced by images. The majority, (84%), of the analogies studied were in the verbal/written style, lacking the reinforcing images seen in the pictorial-verbal analogies. The authors suggest that this “may be due to the high visualization powers of analogy.” It seems that the small percent of pictorial-verbal analogies, (16%), used in educational texts were used to describe more complex concepts or were aimed at lower ability students (Curtis & Reigeluth, 1984).

Within Dagher’s (1995) paper, there were many varying outlines of what is needed for an analogy to be effective. Most begun by encouraging the audience to identify the relevant comparisons and finished by encouraging the audience to then identify where the analogy fails (Radford, 1989; Miller, 1993; Glynn, 1991). This strategy “highlights the importance of helping students make sense of the analogy by establishing both the relevant and irrelevant features” of the subject and vehicle (Dagher, 1995). Radford’s (1989) model for analogical success included most of the important points. It consists of five steps; “(1) select a vehicle from the likely experience of the intended reader; (2) position the analogy as an advance organizer, or
integrate it throughout the material to be learned; (3) remind the reader of the characteristics of the vehicle that will be relevant to the analogy; (4) compare the vehicle to the target, point by point; and (5) caution the reader about how the target material differs from the familiar vehicle” (Radford, 1989). This suggests that “the level of guidance provided”, “the degree of interaction permitted” and “the way the analogy is positioned” are factors that determine whether the analogy is effective or successful (Dagher, 1995). This is a very logical and considered piece of work that is a primary influence to the criteria outlined in this thesis.

The position of the analogy/metaphor presentation is a significant concern to consider when utilising them in an educational setting, as indicated by point (2) of Radford’s (1989) outline. There are three main positions that analogies within educational texts appear in, and they can be translated to other presentations (such as oral presentation) directly. Presenting the analogy at the beginning of the instruction as an *advanced organizer* is effective as it “may provide background information necessary for learning new, unfamiliar content,” and allows the writer and learner to refer back to the analogy at various points of the instruction (Curtis & Reigeluth, 1984). Acting as an *embedded activator*, an analogy introduced during the instruction can help the learner to comprehend the concept when the content is becoming more abstract or difficult to learn. This internal positioning of the analogy encourages “the learner to utilize this cognitive strategy to facilitate learning” (Curtis & Reigeluth, 1984). The analogy may also appear at the end of the instruction acting as a *post synthesizer*, concluding and clarifying the topic. Curtis & Reigeluth (1984) endorse Radford’s (1989) outline, agreeing that, “the most effective analogies appear as either *advance organizers* or *embedded activators*”. Most of the analogies in the text books studies appeared as *embedded activators* though in terms of this thesis, using metaphor to create engagement, the use of analogy as an *advanced organizer* is more relevant, for in order to create the interest and curiosity needed to engage, the metaphor must be the first thing the learner is exposed to (Curtis & Reigeluth, 1984).

Donelly’s (1990) study “revealed positive findings in relation to comprehension and memory only when the analogy was accompanied by explicit instruction (about the presence of a similarity) and pictures,” supporting point (4) of the above ‘effective analogy’ outline by Radford (1989). Dagher’s (1995) review of effective analogies also supports the use of images, reporting that in Mayer’s (1989) experiment “the
comprehension increased with illustrations that help students focus attention and build connections.” The idea that metaphor accompanied by images is most effective has also been outlined by the advertising industry. Morgan & Reichert’s (1999) study contrasted adverts of visual and verbal nature and achieved confident results supporting the previous claim. An explanation supporting this claim is; if the metaphor-creator provides an accompanying image along with their metaphor, they have done half the work for the receiver, making it much easier to correctly comprehend (Whittock, 1990). This pairing of images with metaphor, though effective in advertising, may lessen the effect of metaphor to provoke active learning, and therefore lessen its effect as a learning tool. As mentioned above, images may be necessary to improve the effectiveness of an analogy when the concept is complex or abstract or when communicating to an audience with a lower ability (Curtis & Reigeluth, 1984).

Within the literature on effective metaphor, research from a sports-coaching background can be interpreted to contribute to this thesis. According to Gassner (1999) “metaphors have performance enhancing properties as they encourage active learning due to the necessity of the student to interpret the message of the metaphor.” According to Morgan & Reichert (1999), the extra effort required to interpret and understand a metaphor is considered pleasurable and stimulating for the student. Gassner (1999) opposes the anomaly view by valuing the level of similarity between the subject and vehicle to increase the effectiveness of a metaphor (Boozer et al, 1990; Taber, 2007). Metaphors should use “logical comparisons” (Boozer et al, 1990). There is an emphasis on the creativity and efficiency of the metaphor in order for it to be considered effective. The same paper proposes a “bridging technique” to optimise the effectiveness of the metaphor, “guarding against misinterpretation by clarifying the meaning of the metaphor so the receiver of the metaphor knows exactly what the sender intends.” This ‘bridging technique’ involves asking the receiver of the metaphor to explain the metaphoric implications back to the sender. This strategy maintains the crucial active learning quality of the tool whilst providing a ‘proof reading’ function to enable correction of misinterpreted metaphors (Gassner, 1999). As Curtis & Reigeluth (1984) identified, analogy within the text is different from the oral analogies of Gassner’s (1999) paper. With text-analogies there is no mechanism of receiving feedback and the bridging technique cannot be used. This may be why in
text it is helpful to provide a picture to accompany it and any vagueness or incompatibility that might confront the learner must be anticipated.

In agreement with Gassner (1999), Taber (2007) proposed that to be effective, the “metaphor must bear appropriate resemblance properties of the entity it is intended to describe.” This paper, along with others from an educational point of view, describes how effective a metaphor is in terms of the images they evoke. Both Miller (1976) and Taber (2007) use the word “vivid” to describe effective metaphor imagery. The Oxford dictionary definition of ‘vivid’ is: “producing powerful feelings or strong, clear images in the mind” (O. E. Dictionary, 2014). This word is inclusive of the emotion attached to the metaphor, which demonstrates that these two scholars value the ability of a metaphor to emotionally engage a student. “Effective metaphors create images that are vivid, easy to understand and clearly suggest resemblance to the new context in which they are applied. They evoke strong, familiar visual images” (Taber, 2007). Again, like Gassner (1999), there is an emphasis on the efficiency of a metaphor; whether the metaphor can convey a concept or point faster or more efficiently than the literal explanation. “Effective metaphors constrain and direct particularisation; the process of filling in the details of a statement by drawing upon our detailed knowledge of the world” (Miller, 1976).

Aubusson et al (2006) proposed that students could gain a deeper understanding of abstract scientific concepts through producing their own metaphors. The authors believe that through designing their own metaphors, students will participate in active learning on a greater level, with their minds fully engaged (Aubusson et al, 2006, Gassner, 1999). This concept is endorsed by Willox et al, (2010), who strongly believe that “through the active co-creation of metaphor, individuals are able to acquire, accommodate and assimilate new learning and new understanding.” They have suggested that the co-creation of metaphor can stimulate the imagination of students, reanimating tired metaphors, to make their learning more relevant and to give it context in terms of their experiences and thoughts (Willox et al, 2010). Most teachers would agree “educational strategies which take students out of the passive role and place them in an active thinking mode should be used” (Park, 2003). The authors do recognize that in order for the co-creation of metaphors to be conducive to learning, there are particular requirements that must be facilitated. Educators must provide intellectual and physical support, however, control of the classroom must be
conceded to enable the creative and intellectual process to occur (Willcox et al, 2010). Gassner (1999) proposed that “students often develop some of the most effective metaphors when trying to master something difficult.”

From this research it is clear that, although the use of metaphor is innate, the technique required to create them can certainly be improved upon. The following criteria encompass the most important requirements outlined in the papers studied, and provide the tools necessary to create an effective metaphor or analogy.

(1) The metaphor must be comprehensible to the audience; therefore appropriate language and familiar vehicles must be used. If necessary provide background information on the vehicle (Radford, 1989; Curtis & Reigeluth, 1984; Boozer et al, 1990; Ward, 2001).

(2) Metaphor should use “logical comparisons,” where subject and vehicle should have more attributes in common than not (Boozer et al, 1990; Gassner 1999).

(3) Endeavour to ensure the vehicle is concrete (“comparisons that can be experienced directly, through the five senses”), especially when describing abstract concepts (Morgan & Reichert, 1999; Boozer et al, 1990; Curtis & Reigeluth, 1984).

(4) Concentrate on creating novel metaphors to gain situational interest (Ward, 2001; Boozer et al, 1990).

(5) Creating an extensible metaphor can be made easier with the use of analogy. Analogy is often more affective for scientific concepts, so use when possible (Boozer et al, 1990).

(6) Position the metaphor or analogy as either an advanced organiser to achieve engagement (Radford, 1989; Curtis & Reigeluth, 1984).
(7) Use images when concepts become more complex or abstract, or when the audience has a lower ability (Donelly, 1990; Dagher, 1995; Mayer, 1989; Morgan & Reichert, 1999; Whittock, 1990; Curtis & Reigeluth, 1984).

(8) Use the bridging technique when possible and images when not (Gassner, 1999).

(9) Encourage the audience to break down the analogy or metaphor to identify the “relevant and irrelevant features” in order to consolidate their knowledge (Radford, 1989; Miller, 1993; Glynn, 1991).
CHAPTER SIX:
ENGAGEMENT & LEARNING THROUGH STORY

Storytelling, from the dawn of recorded history, and likely earlier, has been an ever-present method of passing-on information and has therefore been a crucial, long-lasting educational tool (Hokanson & Fraher, 2008). “The bible, ancient Greek myths, and children’s fairy tales are full of analogies, similes, parables and metaphorical stories that are designed to teach new concepts and foster greater understanding” (Gassner, 1999). The dominance of metaphor in educational storytelling makes it central to the discussion of this thesis. This chapter will discuss the literature on the use of storytelling in education and evaluate whether it contributes to engaging students in scientific material.

Before the concept of written communication was conceived, humans communicated through and relied upon oral storytelling. It was the dominant form through which discoveries, “history, news, values, cultural heritage, and attitudes were passed from person to person” and through generations. “Evolutionary biologists confirm that 100,000 years of reliance on stories have evolutionarily hardwired a predisposition into human brains to think in story terms. We are programmed to prefer stories and to think in story structures” (Haven, 2007). Plowman (1996) explains that the role of narrative is central to human cognition, helping you to “think, remember, communicate, and make sense of ourselves and the world,” harking back to Max Black’s (1955) claims of metaphor. The parallels in the description of educational storytelling and metaphor are due to the reliance of educational story or narrative upon metaphor and analogy (Hokanson & Fraher, 2008). Like metaphors they have imbedded meaning that the student must extract, and in many cases, relate more abstract concepts to the experiences of the learner, even if that experience is purely emotional.

“Across and within disciplines, educators are using storytelling to stimulate students’ critical thinking skills, encourage self review and convey practice realities” (Alterio & McDrury, 2003). Witheral (1991) explains that, “the creative use of story and dialogue lends power to educational experiences because of their capacity to expand our horizons of understanding and to provide rich contextual information.”
Storytelling enables educators to “help students make connections within and between self and other, subject and object, and thought and feeling,” supporting Zook’s (1991) claim that “for new information to be understood and remembered, it must be potentially meaningful to the learner” (Witheral, 1991; Erpestad, 2013). “Meaningfulness depends on the learner’s success in finding or creating connections between new information and pre-existing knowledge,” a process that is facilitated by storytelling (Zook, 1991; Witheral, 1991; Alterio, 2003). According to Athman & Monroe (2001) “learning can occur only when the new idea or concept can be integrated into the learner’s existing conceptual system,” indicating that for knowledge transfer to improve, communicators should try to “bring learner’s prior knowledge into the classroom so that students can use what they already know as the springboard for learning new information” (Erpestad, 2013).

Storytelling is “at the heart of all successful communication” (Alerio & McDrury, 2003; Hokanson & Fraher, 2008). In terms of education, metaphor’s power lies within its ability to “develop a schematic structure of understanding” (Hokanson & Fraher, 2008). This structure is assembled through the formation of connective webs, or schemata, within the students thought process. “Schemata educational theory holds that learners develop, build, and make meaningful their experiences and information through structured mental networks. Encouraging the development of cognitive structures is helpful to the learning process” (Hokanson & Fraher, 2008). This description of the power of storytelling in teaching, links strongly to the criteria for creating cognitive engagement within a student, discussed in chapter 5 of this thesis. The connective webs, encouraged by storytelling in an educational setting, contribute to creating the more “complex knowledge structures” that cognitive engagement calls for (Walker et al, 2006; Helme & Clarke, 2001). Storytelling can be a learning strategy to be employed by the student, and as “the amount and type of strategies” a learner employs is a signifier for cognitive engagement, it can be assumed that storytelling as a learning tool encourages it (Walker et al, 2006; Helme & Clarke, 2001).

It is a popular view that educational storytelling can provide a teacher with the ability to encourage student engagement (Matthews, 2014; Stinner, 1995; Alterio, 2003). According to Arons (1989) the best way to attract the attention of students within a classroom is to organize a science course by way of a “storyline” (Stinner, 1995).
use of stories in science communication humanises science and captures the students’ imagination, and therefore interest. The likelihood of successfully imparting knowledge is greatly improved if a topic is introduced using a storyline, rather than plunging straight into teaching “worthy (but boring)” facts. The authors recommend that “stories be presented to open up the possibility of involving the imagination and the participation of the student to give personal meaning” to the concept (Stinner, 1995). Matthews (2014), supports this view, stating that the use of stories in education is engaging because it gives the teller a voice, offering “an ideal vehicle with which to really listen and engage with.” In the same paper it is suggested that the humanizing nature of an educational story can encourage emotional engagement within students (Mathews, 2014; Bilson, 2007). In a study by Grainger et al (2004) it was confirmed that lecturers could emotionally engage students by the use of anecdote (a form of storytelling) and narrative. The same paper identifies that neurological studies confirm that effective teaching causes brain activity that “involves a combination of thought and feeling; intellectual learning and emotional involvement are linked together in the fabric of the brain.” Creating effective emotional engagement within educational settings is equally as important for adults and children (Grainger et al, 2004).

Haven (2007) supports the previous paragraphs claims by stating that she has “seen on countless occasions, the positive power, benefit and effect that stories have on audiences.” Haven (2007) backed up her anecdotal evidence of storytelling’s power to “entrance” an audience through writing the academic text, “Story Proof: The science behind the startling power of story,” which has an impressive reference list and strong, solid arguments. Of the “350 research studies from 15 different fields of science” analyzed in this text, all agreed that story is an “effective and efficient vehicle for teaching, for motivating, and for general communication of factual information, concepts and tacit information.” According to this research early exposure to educational storytelling and learning of story structure encourages development of “logical and analytical thinking as well as language literacy;” two skills that are essential for proficiency in science (Haven, 2007).

Erpestad (2013) agrees with Haven (2007) that storytelling develops not just literacy skills but can also be beneficial for the development of skills associated with science and mathematics. It has been identified by both Erpestad (2013) and Strauss (2006)
that storytelling aids the development of “critical and logical thinking skills,” crucial to succeed in studying or comprehending scientific concepts. Erpestad (2013) suggests that this positive effect of story on scientific teaching is due to its ability to make abstract concepts more concrete and helping to “make a concept easier to conceptualize.” Strauss (2006) considers the success in storytelling for science education to be due to the student “changing gears” to engage the creative and imaginative part of the brain, giving the logical side a chance to rest and digest the new information. The use of both logical and creative regions of the brain is beneficial to the “problem solving aspect of science” (Erpestad, 2013; Strauss, 2006). These works confirm that educational storytelling can be an effective tool, specifically for science communication.

It has been established in this chapter that using storytelling as a teaching tool can positively influence comprehension, engagement and acquisition of scientific skills in students. There is evidence from cognitive science research suggesting that storytelling can also encourage better recollection of learned information. Stories supply the brain with “reference points in the new material that access banks of prior knowledge or key information points in neural maps” (Haven 2007). All of the indices within a story, “locations, attitudes, quandaries, decisions, conclusions,” provide multiple places in which the information can be stored within one’s memory. This storage in multiple neurological connective webs (places), results in a higher chance of being able to relate existing knowledge and experiences to the new information and recollection at a later date. "In other words; the more indices, the greater the number of comparisons with prior experiences and hence the greater the learning” (Schank, 1990). It has also been identified by Hong & Lin-Siegler (2012) that “organising knowledge around people, when in combination with facts and abstract concepts, provides multiple retrieval routes to information, which may facilitate better access to relevant knowledge.” As stories are generally organized around characters (people, or human-like, in many cases) this observation is very relevant to the argument for the use of educational storytelling in science communication.

Educational storytelling does not only affect cognition and memory, but also attitudes and perceptions of learners. The attitudes of science students, and their perceptions of science, can hugely affect the way they engage with the subject. Often students do not associate science with people or, if they do, they assume that scientists are abnormally
smart people that are not subject to the same limitations and struggles that they are. This creates a disconnection between students and science content, perceiving it as out of their intellectual ability (Hong & Lin-Siegler, 2012). Hong & Lin-Siegler’s (2012) paper looks at whether the biographical stories of scientists – their personal background information, “experiences, efforts and struggles to make important scientific discoveries” helps to motivate students in physics. Their hypothesis that the background stories of scientists would encourage a higher level of situational interest in the learner was based on the situated learning theory. This theory states that, “learning should not be viewed a simply the transmission of abstract and decontextualized knowledge, but as a sociocultural process where-by knowledge is co-constructed in context.” The biographical information of the stories used in Hong & Lin-Sieger’s (2012) experiment act as contextual information. The authors correctly predicted that the use of biographical stories in teaching science would aid the learners: “(a) by helping students organize knowledge effectively to support recall; (b) by enhancing both the social and humanistic presence of scientists; (c) by increasing students’ interest in learning science; and (d) by offering students first hand experiences that provides insight into scientists’ thinking and promotes understanding of scientific theory development.” For this thesis the most important finding from this paper was that biographical stories of scientists increased situational interest (see chapter five) in students, therefore increasing their emotional engagement in the subject. “Humans, by nature, are highly interested in hearing stories about other humans” (Hong & Lin-Siegler, 2012).

The literature reviewed, especially the arguments presented by Haven’s (2007) book, “Story Proof: The science behind the startling power of story,” has left no doubt of the positive effect of storytelling in science communication and not only through achieving engagement but also by improving comprehension and recollection of complicated concepts. The evidence supporting the use of stories, as an educational tool, is colossal; however, many of these supportive research papers have yet to be recognized and utilized in mainstream educational organizations (Haven, 2007). This may be due to the creativity required to incorporate story into the curriculum of learning institutions, and the effort this would involve. However, creativity in the classroom provides a good learning space and the use of metaphor and story is a sign of a creative classroom that engages students on all three levels; cognitive, emotional
and behavioural (Grainger et al, 2004). For scientific education and communication to improve, it is clear that the use of creative storytelling is a step in the right direction.
CHAPTER SEVEN:  
INDEPENDENT STUDENT ENGAGEMENT RESEARCH

7.1 METHODS

In order to complement the research outlined throughout this thesis, an independent survey-based study was carried out. The survey prepared focussed on identifying; how engaged the students were in the content and course, whether visual learners were a minority party, the student appeal of storytelling as a teaching method (encompassing metaphor and analogy), and whether the students had shared interests that could be utilised to better tailor metaphors to groups.

The information from the student engagement survey was obtained from 55 first-year students, studying BIOC192; a level one biochemistry paper at the University of Otago in New Zealand. All of the participants had voluntarily attended additional tutorials provided by the university, specifically designed for those struggling with the content. All students, in order to continue through to the BIOC192 paper, had to pass a pre-requisite paper, CHEM191, and their participation in this paper is analysed. All students were over 18, and of both male and female sex. All participants were aware that their answers were completely anonymous.

The information was obtained via the student filling out of a short, 10-question survey. The survey question structure included a mixture of short answer, multiple-choice, ‘yes’ or ‘no’, and rating scales (Smith, 2014). The surveys were distributed over two different days, at the same tutorial but to different students. See Appendix one for survey.

7.2 RESULTS
Question one aimed to ascertain the students’ level of achievement in the pre-requisite paper, CHEM191, but also, and more importantly, whether the student thought that they could have achieved a higher grade. The majority of the students’ results fell in the lower end of the marking schedule, with 90.9% receiving a grade of C and under. This result was to be expected, due to their act of volunteering for extra assistance (in the form of tutorials). Interestingly, 90.9% (50/55) of students felt that they could have achieved a higher grade.

![Student grades for prerequisite paper](image)

Figure 3: Comparison of student grades in combination with data on whether they felt they could have achieved a better grade, or not, in the prerequisite CHEM191 paper. Colours correspond to information in the legend. (n = 55)

![Reason for Perceived Lower Achievement](image)

Figure 4: This pie chart depicts the proportions of students that circled reasons for achieving a perceived lower grade, seen in the legend. Colours correspond to information in the legend. (n = 55).

The final section of question one, provided information as to why the students perceived their grade as lower than what they were capable of. This question was only
relevant for those students that had identified that they could have achieved a higher grade. The largest proportion of the students, 47%, identified that ‘poor understanding’ contributed to the grade they received. Perhaps the most interesting result from this question was that only 7% of the students chose ‘Lack of Interest’ as the reason for their perceived poor performance. Those that provided ‘other’ explanations indicated that poor time management played a role. Examples of the ‘other’ answers are:

“Large amount of content and not enough time given to myself to learn it.”
“Bad exam timing; ran out of time to answer all of the questions”

In attempting to identify whether metaphor can be used to engage students in science, it was important to analyze whether the course was being taught with student engagement in mind. To determine this, criteria for assessing teaching practices were developed using the research on engagement in chapter three. The students were asked to comment on their own engagement (emotional and behavioural) through how they felt during class and amount of effort they put in.

2 (a). During the prerequisite paper, CHEM191, how much of your course work emphasized the following?

<table>
<thead>
<tr>
<th></th>
<th>Often</th>
<th>Sometimes</th>
<th>Seldom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memorisation of course material</td>
<td>40</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Use of visualization tools</td>
<td>9</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Relating of course material to personal environment/ interests</td>
<td>6</td>
<td>18</td>
<td>31</td>
</tr>
</tbody>
</table>

The course rarely used visualisation tools, nor related the course content to the student’s personal environment or interests. This is portrayed through the data; with almost half of the students, (47.3%), indicating that visualisation tools were ‘seldom’ used to teach and 56.4% indicating that the course content was ‘seldom’ related to their personal environment or interests. Additionally the course was deemed to rely upon memorisation of course material, with a very high percentage of students (72.7%) indicating they ‘often’ had to memorize. This information indicates that the
course is taught in a way that does not encourage cognitive engagement within their students.

Figure 5: This bar graph is an indication of how often the students deemed themselves ‘prepared for class’. (n = 55).

Question two (b) showed that there was no significant differences between the three options, with relatively similar proportions of students that were prepared versus those who were not.

Figure 6: This bar graph indicates whether the feelings felt by the students during class were positive or negative. (n = 46).

However, Figure 5 shows a strong majority (76%) of the students felt negatively during class, with 76% of the students responding to this short answer questions with typically negative feelings. Examples of their feelings are:

“Bored and confused,“
“Quite overwhelmed, often confused. Getting left behind with the content,”
“Bored, confused, lack of interest,”
“Bored, sometimes overwhelmed,”
“Bored and confused,”
“Overwhelmed and confused.”

These negative feelings correspond to the student experiencing low emotional engagement.

According to section 7.1 of this thesis, for students who identify as learning best visually (including visualisation), metaphor is more effective (Donelly, 1990; Dagher, 1995; Mayer, 1989; Morgan & Reichert, 1999; Whittock, 1990; Curtis & Reigeluth, 1984). Question three aimed to find out the proportion of students who identified as visual learners. All learning styles were explained within the survey (see Appendix 1).

![Dominant learning styles of surveyed students](image)

**Dominant learning styles of surveyed students**

- Visual
- Auditory
- Kinaesthetic
- All
- Audio/Visual
- Visual/Kinaesthetic

As Figure 7 portrays; the highest proportion of students (40%) identified as visual learners. This positively supports the argument made in this thesis that metaphor can be used to engage people in science, as it shows that they are not a minority group. They are, in fact, the dominant proportion of learners.

The responses of students to storytelling as a teaching tool are important to define. The graph below depicts the students’ attitudes towards being taught science through story.
Figure 8: Chart displays the proportion of students that answered 'yes', 'no' and did not complete the question (DNC), to the question; "Would storytelling teaching techniques, as a guide to learning, appeal to you?" \( (n = 55) \).

The majority of the respondents were in favour of the use of storytelling in the course communication, with 35 \( (63.6\%) \) of the students stating that educational storytelling would appeal to them. This information supports the theory presented in this thesis.

Part B of question four, required the students to explain their answer to part A; explain why [storytelling] would/would not appeal to you. The explanations provided from the students who answered ‘yes’ to part A were very well aligned with the research presented throughout this thesis, and in particular chapter six, which discussed engagement and learning through story. Examples of responses were:

“\textit{Able to apply this to real life,}”

“\textit{Helps with my understanding of difficult concepts,}”

“\textit{Puts in another perspective, easier to relate to,}”

“\textit{Makes it more interesting,}”

“\textit{A different way to learn, making it possibly easier to understand and recollect,}”

“\textit{More meaningful/interesting,}”

“\textit{It would appeal to me because you can associate a story with a concept and remember the concept better,}”

“\textit{It is easier to understand in a simpler context,}”

“\textit{Yes, because this allows for links to be built mentally so its not just rote learning,}”
“Change can be good. Makes it more memorable,”
“Could be more interesting/attention grabbing.”

The majority of the students who answered ‘no’ to part A of question four reasoned that they were either; uninterested in the concept, preferred a more hands-on approach, knew that the tool did not work for them, or, that they found it hard to link stories back to the content. Examples of responses were:

“Sounds a bit odd and uninteresting.”
”Doesn’t sound very interesting to me,”
“I like more hands on activities,”
“I’m the type of person that likes to be hands on. I can’t sit in one place and listen to someone I always need something to do,”
“I know how I learn best”
“Storytelling approach to teaching could confuse me, I prefer a more straightforward approach”
“Because I would find it hard to link it back”
“I tend to lose where it fits into overall sense of things”

Of the students that identified that teaching through storytelling would not appeal to them (16), three did not completely understand the concept:

“I don’t understand how storytelling could relate to a subject like chemistry or biochemistry,”
“I am not completely certain what that would mean,”
“Sounds childish.”

One student identified that as English was their second language, storytelling would not appeal to them. This is a valid reason and it is outlined in chapter eight that international students may have trouble with metaphor use in education (Littlemore, 2001; Littlemore, 2003; Littlemore et al, 2011).

The last question of the survey, question five (see Appendix one), aimed to discover whether it was possible to harness personal interest, within a metaphor, to engage the
majority of a large group. The students were asked to, “list a few of [their] personal interests or hobbies,” and the answers were as follows in figure nine:

![Student's Personal Interests](image)

**Figure 9:** Personal interests and hobbies listed by surveyed students. DNC is an abbreviation for ‘Did Not Complete’. n = 55, however, each participant could list more than one interest.

It was discovered that over half the class, 60%, had a personal interest in sports and fitness. A large cohort of students had a common interest in music, 34.5%. These figures show that for this particular sample group, a metaphor on sports/fitness or music will likely engage a large majority of the class through their personal interests, thereby achieving better engagement and therefore potential understanding, for these students.
7.3 DISCUSSION

The grades received by the students surveyed were unsurprising as the tutorial from which the students were selected was targeted to those who were struggling or in need of extra assistance. The outliers were the students who achieved a mark higher than a C+ taking up just 5.5% of the sample group. This cohort was specifically selected for in the study, as the thesis is focused on how to use metaphor to engage people in science. By selecting students who are currently struggling with science content it can be distinguished whether they are struggling because they are disengaged, and also whether metaphor would help these students engage.

In part B of question one, outliers existed in the form of students who expressed that they thought they could not have achieved a better mark (9.01%). Four out of the five students suggested that they were seldom prepared for class, indicating that they were not behaviourally engaged in the course. The other suggested that they were only sometimes prepared. If the students had an increase in behavioural engagement, it is likely that their grade would increase too. It is possible that the low grade could have affected these students’ confidence in their ability, causing them to state that they could not have done better when evidence from the survey suggests otherwise. For the other 90.9% of the sample group who recognised that they could have achieved a better grade, it was clear that, in part, the communication of content had its flaws. It can be assumed from the information gained from question two, that the course was lacking a focus on gaining student engagement as; the high level of rote learning required by the student, the infrequent linking to the student’s environment/interests and the lack in visualization tools, are all indicators of a low level of cognitive engagement encouragement. Not only did the course lack cognitive engagement tools but also did not achieve emotional engagement within these students, most probably due to the consequence of failing to understand, a carry-on effect of poor cognitive engagement.

The most common reason for achieving a lower grade than the student could have, was ‘poor understanding’. As ‘poor understanding’ is, in part, the outcome of a lack of engagement in students, this result suggests that many of the students surveyed were disengaged (Fredricks et al, 2004; Shulman, 2002). This information provides
additional support for the assumption stated in chapter three that ‘for the majority of people struggling to understand science concepts, it is because the concept appears too hard or complex,’ rather than too easy (Garrett, 2011). ‘Poor effort’, the second largest reason specified, is a direct indication of the students’ poor behavioural engagement and, although this is not necessarily true for all, is usually a result of low emotional and cognitive engagement (Fredricks et al, 2004; Gonida et al, 2009). The reasons given for ‘other’, suggesting the students had issues with time management, could either suggest that the students were displaying behavioural disengagement by putting off their work, although, it is also possible that personal extra curricular activities had a confounding effect on the results. This result had led to the conclusion that it would have been wise to add the option of ‘time management’ to the list of possible answer-choices displayed on the survey, in addition to ‘other’. The seven students who suggested a lack of interest as contributing to the grade they received, could be emotionally disengaged, as situational interest is a key indicator of emotional engagement (Reninger et al, 1992). As this thesis suggests, novelty, and in particular novel metaphor within teachings, can increase situational interest within a student; however, four of the students have identified that storytelling (a way to introduce novelty into the classroom) would not appeal to them, limiting the ways in which their interest can be piqued (Fredricks et al, 2004).

Question two discerned whether the students were engaging with the science content through indicating whether the course encouraged certain aspects of learning and teaching. The act of rote learning or memorization of facts is often indicative of a lack of cognitive engagement, as it requires few learning strategies (Walker et al, 2006; Helme & Clarke, 2001; Corno et al, 1983). As 72.7% of those surveyed indicated that they felt the course often encouraged memorization often, it would indicate the course was not cognitively engaging the students, leading to a shallow understanding of the scientific concepts (Corno et al, 1983). Additionally, according to Walker et al (2006) and Helme & Clarke (2001), “a high level of cognitive engagement would call for meaningful processing of the new information, which “involves relating new information to one’s existing knowledge”. This, according to the students that completed the survey, occurred rarely. This result provides a reason for the majority of students feeling that the reason they did not achieve the grade they could have was because of a ‘poor understanding’ of the concepts. The negative emotions portrayed by 63.6% of the students suggest that the course was failing to emotionally engage
them. The emotions specified; “boredom”, “confusion”, “overwhelmed” and “tired”, are typical of an emotionally disengaged student and can affect their behavioural engagement/effort immensely (Gonida et al, 2009; Fredricks et al 2004). This emotional disengagement experienced by the majority of the students can be linked to the explanation of poor effort in question one (c) and also the large proportion of students that admitted they were seldom prepared for class.

The rating scales inquiring the amount of visualization tools and student environment/interest relation in question two (a), provides insight to whether metaphor or analogy was being used in the surveyed students’ lectures. In both cases more students indicated that there was seldom any use of visualization tools and that the course content was hardly ever related back to their environment or interests. Though to lesser agreement, there was a significant proportion of students that suggested both teaching tools were sometimes used, revealing that it is likely that visualization and relation to student environment did occur from time to time within the course. Perhaps those that indicated that they were seldom used had trouble identifying them, or perhaps they were ineffective forms that may not have adhered to the criteria outlined in chapter five of this thesis.

Metaphor is an excellent visualization tool, especially when crafted effectively. As 40% of the students identified visual learning as their dominant learning style, the incorporation of such visualization tools into teachings is very likely to aid in their understanding. For visual learners, being able to visualize the concept is essential to their understanding, so the vivid and meaningful descriptions created through educational metaphor and analogy is sure to be an effective teaching strategy for 40% of the learners surveyed. The 14 who identified as auditory learners are also likely to benefit from such metaphors, especially if they are spoken out loud to them, as it is another form of oral teaching for the learner to be exposed to. For the 12 students who chose kinesthetic learning as their dominant learning style, it is likely that educational metaphor will not greatly improve the communication of science content on its own. However, as presented in chapter five of this thesis, it can be effective for metaphors to be generated by the students themselves. If this teaching technique were used, the kinesthetic learners would receive the more hands-on approach to learning that they prefer (Aubusson et al, 2006, Gassner, 1999; Willox et al, 2010).
With 63.6% of students reacting positively toward being taught through story, this technique would appear to be popular among students. With consideration to emotional engagement factors, it can be assumed that this positive response can indicate that storytelling to communicate science is popular and therefore effective at engaging students. It was clear from the short answers of question four (b), “explain why [storytelling teaching techniques] would/would not appeal to you,” that these students were vaguely aware of the academic research, or at least the findings, behind storytelling as a teaching tool. The majority of the main points made about the effectiveness of storytelling in chapter six, were crudely touched upon by the student’s short answers. Many recognized that storytelling could aid their retention of information, while others identified the power of storytelling (metaphor/analogy) to be novel and “attention grabbing.” The ability of storytelling to link new information to existing information was recognized by some, one student stating that by being exposed to stories they are “able to apply [information] to real life.” Much of the short answers to question four (b), from students who stated that educational storytelling did not appeal, were disappointingly simple, making it difficult to discern exactly what did not appeal to them. For example “I know how I learn best” and “sounds a bit odd and uninteresting” were answers that lacked background information to help understand why they felt that way.

Lastly, the information obtained through question five, indicated that is was possible for a large group to have common interests, in this case 60%, over half the students in a sample size of 55, had an interest in sport/fitness. If a sport and fitness metaphor/analogy were to be used to teach this cohort of people, over half would experience piqued personal interest, which would, in turn, increase their emotional engagement; improving their attention and understanding. This is a promising result to show that ascertaining information about the personal interests of a cohort is good preparation for communicating to them, as it can increase the effectiveness of educational metaphors used.
CHAPTER EIGHT:
LIMITATIONS AND COMPLICATIONS

8.1 POLITICS OF METAPHOR IN SCIENCE COMMUNICATION

The nature of metaphor includes highlighting points while shrouding others, and this trait has resulted in the use of metaphor to persuade audiences of certain opinions more favourable to the communicators’ message. In politics, especially, it is a tool that is often used in this way, and as a result, metaphor can become a tool to be wary of in science communication. Metaphors can be manipulated by both scientists and science communicators, to influence different agendas and can cause the public to mistrust information (Hellsten, 2002). Mistrust is a hurdle to overcome for science communicators and, therefore, understanding the politics behind metaphor is crucial.

There is an obvious disparity in the value systems between science communicators and scientists in terms of the work they produce. Scientists’ value knowledge for the sake of knowing more, technical language and details, describing their work in the most accurate of terms and often their work is slow – not being subjected to deadlines. Science communicators generally value knowledge in terms of its value to society, and simple language is used to ensure this value. They are often generalists and produce their work speedily to meet the demands of deadlines. “Many of the typical barriers noted between these two professional cultures results from differences in process: the restraints of peer review rather than the demands of editors and audiences, the precision of jargon versus translating and interpretation by a lay audience” (Valenti, 1999). These differences in each of the professions’ values can result in each utilising metaphor in different ways; “often journalists want to sensationalise a story and this may mean portraying the science in a negative light, while scientists want to portray their work in a positive light in order to get more funding” (Hellsten, 2002). Occasionally their conflicting agendas can lead to mistrust between the two, however, as both have acknowledged that, “neither science or technology can thrive in the absence of strong public support” it has been deemed necessary for scientists to work with science communicators (Valenti, 1999).
As the public’s ‘no-questions-asked’ support of science has lessened, scientists have been forced to adjust their priorities in order to gain the support needed to continue their work. “Scientists often use metaphor to excite the public and gain support” through contextual and emotional manipulation. An example of this is the way in which the field of genetics has used metaphor to influence the public view. Biblical contexts or connotations of godliness (genes are like the “bible” or the “holy grail”) have been used to directly affect and manipulate the way the public feels about the science of genetics in order to change policies or attract support and/or funding (Nelkin, 1994). In terms of public acceptance of certain views and images of science, “metaphors may prove to be indispensable tools,” however, this use of metaphor may ruin an effective way to reach out to and educate the public (Hellsten, 2002). The way metaphor encourages “two-way communication to enhance both public understanding of science and scientists understanding of the public view, is far more promising than tests of science literacy” (Valenti, 1999). It cannot be expected that the public will know as much about science as the scientists due to the extremely specialised nature of science – even scientists have trouble understanding topics outside of their specialised field. This use of metaphor, to taut or influence opinion, takes away from its value as a tool to educate and communicate, lending it to a manipulative purpose.

Pauwels (2013) has a particularly pessimistic view, stating that the use of metaphor “widens the gap” between the public and scientist knowledge, as over simplification can make the science seem insignificant. This view, that science is insignificant, can then propagate into politics causing misrepresentation of science in policy, a common fear amongst scientists. Wilson et al (2005) counters Pauwels (2013), by suggesting that metaphor could be used in a positive way to influence policy makers to better the political scientific view. Lopez (2007), however, agrees with Pauwels (2013), describing the simplified metaphors used in science as “limiting”, suggesting that the solution is not to remove metaphor but to create “better metaphors that would provide more accurate, nuanced and richer meanings.” It has also been suggested that metaphor can be used to portray science in a selfish light in order to influence the way people feel about a concept. Every word has a meaning, and some words take on a metaphorical significance in particular contexts. Pauwels (2013) warns that scientists must use metaphors with care and caution to ensure the meaning is not misconstrued or misused. There is much less danger of using metaphors between scientists as they
are more likely to recognise the subtleties that a metaphor may not cover (Pauwels, 2013).

Miller (1976) has a similar view to Pauwels (2013), arguing that metaphors are used to mislead the public, playing on their emotions or to “carry an argument by means of distortion and overemphasis.” The way that metaphors are, in nature, emotionally loaded expression allows the user to impart a feeling upon the reader “without committing themselves to any substantive comments” (Miller, 1976). Another political issue with metaphor, adding to the mistrust of them, is that often in order to gain meaning from metaphors the comparisons between the *subject* and *vehicle* must be exaggerated and distorted to fit (Miller, 1976).

This section identifies issues that arise with using metaphor to communicate with the public, and highlights the way in which they can be used to manipulate, instead of educate. For metaphors to be used appropriately for the use of educational communication, or to engage students in scientific concepts, communicators must be wary of overtly emotive contexts or words. It is extremely important to get the balance between emotionally engaging, but not manipulative, in order to gain the trust of the audience and effectively communicate scientific information. Additionally, as stated in chapter six, in science education the use of analogy in story is a more commonly used variant of metaphor. This may be because in these forms, the metaphor is not as apparent, and therefore the audience is less aware of the use of a tool that they may have learnt to be wary of. In terms of educating the public, Pauwels (2013) argument that metaphors oversimplify science, has poor evidence to suggest that it negatively affects learners. Simplifying scientific material to something that is familiar and comprehensible is essential for a positive result in public or lay audience understanding as “learning can occur only when the new idea or concept can be integrated into the learners existing conceptual system,” (Athman & Monroe, 2001).
8.2 LIMITATIONS TO METAPHOR COMPREHENSION

An important question to consider when tackling this thesis, is which audiences will have difficulty recognising and comprehending metaphor? In chapter three of this thesis, it is outlined that tailoring the metaphor or analogy to the audience it is intended for, is an important step in creating an effective metaphor. However, sometimes you simply cannot tailor a metaphor to an audience, no matter what language, context or “pleasing or attractive associations” are used (Boozer et al, 1990). This is because there are cohorts of people that are predisposed to having difficulty understanding or identifying metaphor, and this section will discuss a few (Cameron, 2003; Vosniadou, 1987; Littlemore, 2001; Littlemore, 2003; Littlemore et al, 2011; Gold & Faust, 2010; Norbury, 2005).

The primary factors that contribute to metaphor comprehension are context and language. Firstly, for a metaphor to be understood the listener must have an adequate understanding of the language used, so often, it is best to use simple vocabulary. Secondly, it is essential for them to be familiar with the context and, attach to it the same connotations as the speaker (Vosniadou, 1987). The development of the right hemisphere of the brain is also crucial in developing the ability to recognize and glean meaning from metaphors (Gold & Faust, 2010). Another factor that will affect the comprehension or effectiveness of metaphor is the different dominant learning styles of individuals. These will be outlined and discussed in this chapter.

“Educational researchers postulate that everyone has a learning style and, if instruction is adapted to accommodate that style, it is anticipated that improved learning will result” (Murphy et al, 2004). Learning style has been defined as the “composite of characteristic cognitive, affective, and physiological characters that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment.” This “results in one teaching style being effective for some, and ineffective for others” (Keefe, 1987; Dunn et al, 2002). These learning styles are the result of a combination of the individual’s biology and experiences (Dunn et al, 2002, Murphy et al, 2004; Rizvi, 2011; Derby, 2013). For this thesis, it is important to identify which of the four learning preferences; visual, auditory, kinesthetic, benefit from the use of educational metaphor/storytelling.
Visual learners are those who think and relate to concepts through images, and are therefore more partial to teachings that involve images or imagery (Derby, 2013). This type of student enjoys learning by receiving or drawing images (Murphy et al, 2004). Metaphor has been described as possessing the ability to conjure up vivid images to aid the description of a concept (Miller, 1976; Taber, 2007). A metaphor can often help a visual learner to picture an image that is appropriate and meaningful to a concept, and is therefore a teaching tool that is beneficial to visual learners. As identified in chapter five, ‘Optimising the Effectiveness of Metaphor’, sometimes metaphors can be more effective when accompanied by images, which in the case of visual learners, would further increase their effectiveness (Donelly, 1990; Dagher, 1995; Mayer, 1989; Morgan & Reichert, 1999; Whittock, 1990; Curtis & Reigeluth, 1984).

Metaphor, as an all-encompassing teaching tool, is less effective for auditory learners than for visual learners. This is because auditory learners benefit from teaching activities that involve listening to, and discussing information, meaning that only oral metaphors will positively affect their learning (Murphy et al, 2004). However, metaphor does provide the communicator the opportunity to present information orally in a creative and novel way, reaching the auditory learners on another level. Likewise, kinaesthetic learners will not benefit from metaphor unless they are directly involved in the creative process. This is because they prefer to learn through hands-on, tactile activities, “in other words; the kinaesthetic learner has to feel or live the experience in order to learn it,” (Murphy et al, 2004). As suggested in chapter five, encouraging students to create their own metaphors can positively influence their learning (Willox et al, 2010; Aubusson et al, 2006; Gassner, 1999). Although educational metaphors/stories have differing effects on learners, a study by McDowell (2010) suggests that, “storytelling had the highest overall learning preference of all the options,” and can act to bridge differences in learning preference as it is enjoyed by all.

One of the most obvious problems with metaphor comprehension will occur with those who are too young to understand or recognise them because their brain is still undergoing development. It has, however, been discovered that metaphor is an excellent tool to use when teaching children. In the study outlined in Cameron’s
(2003) book, ‘Metaphor in Educational Discourse’, she observed children “talking and thinking” more when faced with a metaphor. Cameron suggests that affective teacher mediation can help to solidify a child’s understanding of a topic through the use of the metaphor. To aid comprehension, science taught to children must be relevant to them and their environment. Metaphor can be used to illustrate this relevance (Blough, 2006; Meyer et al, 2012). A child’s literacy skills must be of a high level to be able to understand metaphor for it to have this positive effect. Knowing the age at which children can comprehend metaphor is essential in order to use the tool on the appropriate audience.

The age at which children can comprehend metaphorical expressions is highly important to this thesis, as if used before children are able to comprehend them, it will likely disengage rather than engage. In order to understand metaphoric concepts, they must possess the ability to see similarities within their surroundings. Metaphoric comprehension is not complete until a child’s conceptual and linguistic knowledge is of similar calibre to adults. It does, however, improve greatly during the primary school years. The contributing factors of metaphor comprehension, context and language, play a role in what age children will be able comprehend metaphor. If the language used is too complex, and the context unfamiliar, the child will not comprehend. Metaphors made for children must be crafted with these factors in mind (Vosniadou, 1987). If a child struggles with metaphor comprehension, they are likely to have learning difficulties (Winner, 1988). Cameron (2003) would go as far to say that a student’s interaction with metaphor could be a driving force behind learning and conceptual development.

Cultural and language barriers exist for metaphor comprehension, especially for international students (Littlemore, 2001; Littlemore, 2003; Littlemore et al, 2011). International students have difficulty with both of the comprehension factors outlined above. The language they are taught in is not their first language and therefore it is likely that they have vocabulary deficits. The cultural differences of international students can cause the context to be misunderstood. Metaphor is a “typically culturally loaded expression, whose meaning has to be inferred through reference to shared cultural knowledge” (Littlemore, 2003; Charteris, 2003, Deignan, 2003). Different cultural backgrounds have dissimilar shared cultural knowledge, so often “the speaker and listener attach different connotations to aspects of the metaphor,”
giving rise to misunderstanding (Littlemore, 2003; D’Andrade, 1987). According to Littlemore (2001), “there are two types of comprehension difficulties: misunderstanding and non-understanding”, the prior being the more damaging due to the student believing they have an adequate understanding and not seeking further explanation (Littlemore et al, 2011). In the experiment outlined in the Littlemore et al (2011) paper, it was found that 26% of the metaphors within a teaching session had an invalid interpretation, and the students were only aware of only 4% of these failures. More often it is the cultural differences, rather than vocabulary, that hinders understanding (Littlemore, 2001). These results show that using metaphor, to transfer knowledge to international students, has a negative effect on understanding and should be avoided.

Individuals with spectrum disorders such as Asperger Syndrome and Autism are known to find it difficult to comprehend figurative language (Gold & Faust, 2010; Norbury, 2005). This was discovered to be due to a lower functioning right hemisphere of the brain (Gold & Faust, 2010). Norbury (2005) discovered that a lack of semantic ability was a strong influence in ability to comprehend metaphor. The right hemisphere functions in semantics, and therefore those with damaged or underdeveloped right hemispheres have difficulty understanding or recognising metaphors. Metaphors are often observed as literal statements by this demographic and thus can hinder their learning.

This section outlines just a few of the demographics that struggle with metaphor comprehension and therefore limit the ability of metaphor to engage audiences in science communication. It provides examples and highlights the importance of taking the audience into account when using metaphor. Although metaphor can be a successful tool to create engagement in those that have the ability to comprehend them, there are limitations to the audiences they positively affect.
CHAPTER NINE:  
ACADEMIC SUPPORT FOR CREATIVE COMPONENT

To complement this body of academic work, the corresponding creative component is a book that utilises metaphor, analogy and story, to communicate the biochemical theory of the ‘RNA World’ or ‘The First Macromolecule of Life’. This book, named ‘A Land Before Life’, is of the adventure genre and targets ages 11-14. It is a novella of 10 chapters and approximately 21,000 words. The aim of this book is not necessarily to teach readers about the theory, though some will pick up on the interwoven information, but to inspire their imagination and engage them with what the science of biochemistry has to offer.

The target age group of 11-14 was chosen due to the research suggesting that in order for interest in science to propagate into high school, and then into later life, positive attitudes to science must be nurtured in children aged 8-14 (Reed, 1988). As a more complex scientific topic was chosen to be the subject of ‘A Land Before Life’, the latter years of this age bracket were a more appropriate target audience. This is also the age that “the peak of reading interest occurs” and is an age group that has likely already undergone the significant improvement of metaphor comprehension that occurs in the primary school years (Reed, 1988; Vosniadou, 1987). The novella length has been deemed appropriate by several online sources and has been confirmed through research on popular books for this age group (Whalin, 2014).

The adventure genre, and the journey to discovery taken by the characters, in ‘A Land Before Life’ parallel the journey a scientist takes to discovery. The adventure genre can help to mimic the excitement of scientific discovery, and by highlighting this important feature of science, may encourage student interest. With a push in the right direction, students may be able to recognise that although not the same type of adventure, scientific discovery can be just as exciting.

In order to provide the background information necessary to analyse the book, it is necessary to explain the theory it is based upon. The first macromolecule of life is inferred to be the RNA (ribonucleic acid) molecule that gave rise to an "RNA World" from which a modern molecular world evolved. RNA has both replicating (a gene-
like function) and catalyzing properties (catalyzing is an interaction with other substances to create new products) and has been shown to facilitate the evolution of important macromolecules like proteins and DNA, and, ultimately the cell, therefore life on earth (Bernhardt & Tate, 2012a). In modern day cells, there are three main RNA varieties: messenger RNA (mRNA), ribosomal RNA (rRNA) and transfer RNA (tRNA) (Fromm & Hargrove, 2012). The three RNA molecules have different functions that co-operatively facilitate a catalytic reaction that results in the joining of amino acids to form proteins (the most common molecule within the cell). The messenger RNA in modern cells acts as a translator from the DNA, trapped within the nucleus, and the ribosome (a construct made up primarily of ribosomal RNA and the molecular factory that makes the proteins required by the cell). Messenger RNA carries information about the order of amino acids to make a particular protein, from the DNA to the ribosome. The tRNA molecules attach to single amino acids and deliver them to the ribosome according to the coding instructions from the mRNA. When all three RNA molecules combine on the ribosome in the correct conformation, catalysis occurs, resulting in the incoming amino acid (bound to the tRNA molecule) being connected to the growing protein chain. This process continues in iterative cycles until the full string of amino acids required to make the protein are connected in the correct order. In the ‘RNA World’, however, the pre-mRNA molecule did not have a coding role, but likely acted to stabilize the pre-tRNA and pre-rRNA molecules so they were proximal enough and rigid enough to perform the protein forming reaction. The fledgling pre-rRNA molecules had yet to form the comprehensive structure of the rRNA in the modern ribosome and functioned as a primitive proto-ribosome but with similar catalytic abilities. The pre-tRNA are thought to have delivered the amino acids in a similar manner to the modern day tRNA, but without programming by mRNA coding, simply by binding spontaneously (Bernhardt & Tate, 2012b).

In ‘A Land Before Life’, the characters are based upon the RNA molecules that are central to the ‘RNA World’ theory. These molecules have been anthropomorphised to become members of tribes; a tribe associated with the mRNA, rRNA and tRNA molecular subspecies. This anthropomorphising of the molecules provides the platform for the overriding metaphor used throughout; the interactions between the tribes are consistent with the physical interactions between the molecules. For
example; the mRNA tribe members within in the story, stabilise the volatile social relationship between the rRNA and tRNA tribe members to enable them to work together (this occurs prominently in chapter seven of the creative component), corresponding to the hypothesised stabilising of the physical connection between the pre-tRNA and pre-rRNA molecules by the pre-mRNA molecules to enable the catalysis reaction to occur, in ‘RNA World’ theory (Bernhardt & Tate, 2012b). So in this case the subject of the metaphor is the pre-mRNA molecule binding to the pre-tRNA and pre-rRNA molecules to physically stabilise them, and the vehicle is the mRNA tribe members stabilising the social relationship between tRNA and rRNA tribe members through breaking up disputes. Additionally, scattered throughout the book, there are underlying metaphors. For example; the ‘amino-building blocks’ refer to the way that amino acids within the cell can be connected to one another to build proteins. In this case the subject is the amino acid’s function to combine to create larger units (proteins), and the vehicle is the building blocks that function also to build larger units (buildings).

To ensure that the story and the imbedded metaphor were effective, the criteria outlined in chapter five were taken into careful consideration.

In keeping with the first criterion, the metaphor must be comprehensible; the language used throughout the story was kept simple and appropriate for audiences of 11 and older (Radford, 1989; Curtis & Reigeluth, 1984; Boozer et al, 1990; Ward, 2001). The vehicles used (social interactions, building blocks, etc.) throughout were those that most, if not all, 11 year olds and older would be familiar with. Though the subject matter is complex, the vehicles and platform for which the metaphor relies upon to be communicated are comprehensible for the target age.

For the overarching metaphor, the second criterion that the metaphor should use logical comparisons was difficult to carry out. The task was to make a clear and ‘logical’ comparison between the biochemical process (subject) and a vehicle that an 11 year old would be familiar with (Boozer et al, 1990; Gassner, 1999). To ensure the comparisons were effective the vehicle chosen, social interactions, though vast, was set within the construct of the story. The story provided a limitation of social interactions to be compared, to ensure that the comparison is clear.
Though the over arching vehicle, social interactions between tribes, is not strictly concrete, all children of 11-14 have experienced social interactions between people. These experiences are concrete; therefore the overriding metaphor remains solid. The ‘amino acids are building blocks’ metaphor is very true to criterion number three as building blocks are as close to concrete as you can get (Morgan & Reichert, 1999; Boozer et al, 1990; Curtis & Reigeluth, 1984). Children of this age are likely to have played with building blocks of some sort in the past, so the vehicle of this metaphor is something they have concrete experience with. They are likely to have held a building block in their hands, and built something with them in the past. The features of a building block are clear and easy to recognise, making this metaphor extremely solid.

The plot of the story and its adventure genre, ensures that the piece of work is novel, thus abiding by criterion number four (Ward, 2001; Boozer et al, 1990). The novelty of the work is also one of the reasons the book can create engagement with the topic. Situational interest is encouraged through novelty, and is a contributing factor to emotional engagement ((Stinner, 1995).

Within this book, pictures are dotted throughout each chapter as they will aid the metaphor comprehension and encourage visualisation. Number six of the criteria states that using images is important as the concept becomes more complex or abstract (Donnelly, 1990; Dagher, 1995; Mayer, 1989; Morgan & Reichert, 1999; Whittock, 1990; Curtis & Reigeluth, 1984). As in this case, the entire extended metaphor is of a complex and abstract nature, images are included in each chapter. These pictures also help to maintain a reader’s attention, as they are dotted at random, rather than in a repetitive manner, maintaining the novelty required to maintain situational interest.

The criteria that have not been mentioned are those that relate to how the metaphor is received and worked upon by the student or teacher. Criterion number five suggests that metaphors are more effective as advanced organisers and this is why, ideally, the book would be exposed to students (either read or read to) before they continue on to the more dense information (Radford, 1989; Curtis & Reigeluth, 1984). That way, the story can be taken at face value (as an adventure story) and as the student gains more
information on the topic, links can be made to the book ensuring that the information is not completely unfamiliar. The book can be used as a construct to organise the new knowledge around, facilitating the cognitive model-building concept Christidou et al (2004) mentioned, and building “more meaningful learning of the new material” (Gilbert, 1989). Using the bridging technique and encouraging the audience to break down the metaphor are both methods that are required to be employed by the teacher or communicator. The metaphor used in ‘A Land Before Life’ is very generalised, allowing room for student appraisal and improvement as their knowledge of the topic expands, and eventually giving way to the literal science (Muscari, 1988).

As the primary objective of the creative component of this thesis, is to inspire engagement with biochemistry, it is important for the research to have influenced the work. The book was designed to be used as an advanced organiser so that it is the first form of communication, where achieving engagement is of paramount importance. In order for the students to pledge themselves to the learning of the material, they must be engaged on all three levels; cognitive, emotional, and behavioural engagement (Axelson & Flick, 2010).

To achieve a high level of cognitive engagement, a number of different learning strategies are required. As the book is designed to be used along side other teaching techniques, it provides one of these learning strategies and ensures that at least two learning strategies are being employed. Cognitive engagement involves creating complex knowledge structures and this can be achieved through relating new information to already existing knowledge. The metaphor used throughout the book, links the abstract concept of RNA molecules interacting with one another to create the complex environment of the cell, with social interactions between groups of characters to achieve a safer, better home. The vehicle is a subject familiar to this age group and therefore helps create the link between the abstract and familiar to create the complex knowledge structures required to achieve cognitive engagement (Walker et al, 2006; Helme & Clarke, 2001).

The emotional engagement of a student is met through creating positive attitudes towards the subject matter. If the student feels emotionally connected to the topic on some level, then they are emotionally engaged. Though “anthropomorphism has long
been considered a bad word in science,” it has its benefits as demonstrated by its enduring presence and popularity. Its strength is in the ability for the reader to connect with the emotions presented through it (Burns, 2014). In this case, the RNA molecules of the ‘RNA Word’ did not experience emotions, however, the characters within the story do, to provide a vehicle for emotional engagement. If the reader connects emotionally with the characters within the book, they are more likely to continue engaging with the content within. “Humans, by nature, are highly interested in hearing stories about other humans” (Hong & Lin-Seigler, 2012).

Behavioural engagement is the result of achieving emotional and cognitive engagement and is shown through the maintenance of the student’s attention throughout the communicative session. Arons (1989) believes that the best way to attract students’ attention is by way of storyline. The story element of this book effectively facilitates the process of connecting new information to existing knowledge to create a meaningful learning experience (Witheral, 1991; Zook, 1991; Alterio, 2003). The story creates a schematic structure of understanding; a student should take from the book that the rRNA and tRNA molecules will not work together, to produce a protein, unless the mRNA molecule is present to stabilise the interaction through the inference taken from Mordecai’s (the main character) act of making the two other tribes get along and work together. The adventure storyline and interesting characters have the potential to capture students’ imaginations and therefore interest, situational interest being a very important component of student engagement (Stinner, 1995).

The mere use of storytelling as a communicative devise has had strongly positive effects on behavioural engagement throughout human history. For 100,000 years or more, humans have relied upon story telling to communicate knowledge, and through this habit, human brains are now hard-wired to prefer this form of communication (Haven, 2007). Research by Haven (2007) indicates that not only does the use of story to communicate science help to engage students, but it also encourages the development of “logical and analytical thinking skills as well as language literacy;” skills that are valued in science. This means that my story is not only set to engage students in biochemistry, but also improve the skills needed to excel in it.
In terms of future implications of using this book as an advanced organiser, or even as an embedded activator, the student will benefit from better memory storage and recollection. This is because stories supply the brain with “reference points in the new material that access banks of prior knowledge or key information points in neural maps” (Haven 2007). The details that help pad out the story such as “locations, attitudes, quandaries, decisions, [and] conclusions,” are indices that provide multiple places in which the information can be stored in ones memory and provide multiple routes for recollection. According to Hong & Lin-Siegler (2012) “organising knowledge around people when in combination with facts and abstract concepts, provides multiple retrieval routes to information, which may facilitate better access to relevant knowledge,” meaning that the acts of the characters in ‘A Land Before Life’ are, in fact, aiding with memorization and retrieval of new knowledge.

It has been discovered through the survey carried out for this thesis that educational storytelling is appealing to the majority of students. This positive response towards the use of storytelling ensures that simply using ‘A Land Before Life’ as a communicative tool will have a positive effect on a student’s emotional engagement.

Taking into account the section on complications and limitations, the book was written with some of the concerns outlined in mind. For example, the book was written with no other objective than to engage students in the topic and to impart the general concept of the ‘RNA World theory,’ making sure that it is not used as the sole communicative devise. To ensure that the use of metaphor did not raise alarm bells in those who are wary of them, the metaphor was imbedded in story, an approach that has been proposed as a way to quell aversions to metaphors due to political misuse.

A limitation for this story is that it is likely to be more effective for those students who identify as being visual learners, and less for those that are kinaesthetic or auditory (unless it is read aloud to them). From the information observed in the survey outlined in chapter seven, this should not be a problem for the majority of the class as visual learning was found to be the dominant preference. It is also unlikely to be affective for international students, or those with lower functioning right hemispheres of their brain (Gold & Faust, 2010; Norbury, 2005; Littlemore, 2003; D’Andrade, 1987). However, as much of the issues surrounding
comprehension of metaphors by international students is due to difference in contextual connotations, the *vehicles* of the metaphors in ‘A Land Before Life’ are those that have internationally common connotations and features. For example the vehicle of the mRNA breaking up a fight and stabilising the relationship between tRNA and rRNA characters is unlikely to be misinterpreted as fights and mediators exist in all cultures. Likewise, all cultures have use for and are familiar with the idea of building blocks. Although this may help international students, there is no guarantee that they will understand all the vocabulary use, at the target age, to be able to reap the benefits of this book.

A clear discovery this thesis has made is that metaphors cannot exist alone when communicating science (Hoffman, 1980). The book, ‘A Land Before Life’, is designed by no means as a sole communicative tool. It was created to firstly entertain and engage students in the biochemical sciences, then to teach, and always to be followed up with raw, literal science. As mentioned earlier, the likelihood of successful communication is greatly improved when the topic is introduced through story rather than delving straight into “worthy (but boring)” facts (Stinner, 1995).
CONCLUSIONS AND RECOMMENDATIONS

The primary aim of this thesis was to study whether metaphor is a viable tool for science communicators to achieve audience engagement and secondarily to improve understanding. Using information sourced from relevant literature, combined with survey data from the independent study carried out, this thesis has provided a comprehensive review of metaphor as an engagement tool. Though there are those who possess a negative view of metaphor use in science communication, the evidence presented in this thesis proves that metaphor can be a useful tool to engage students in science when used appropriately and responsibly.

It was important to define metaphor from the outset of this thesis, and through reviewing the literature on metaphor theory clarity was gained. For the purpose of this thesis, the use of metaphor was defined as describing one concept while in the context of another, where meaning is imbedded through common features (Hoffman et al, 1990). The structure was outlined and the terms subject (the concept being described), and vehicle (the context in which the subject is described) (Cameron, 2003). The power of metaphor was demonstrated though a number of theorists work and it was deemed that the most important aspect, of the chosen definition, was the meaning imbedded in the metaphor through the common features of the subject and vehicle (Black, 1955; Hesse, 1988; Lakoff & Johnson, 1979). If the latter is within the audience’s existing knowledge, it can provide efficient communication and create understanding of new concepts (Hesse, 1988; Maasen et al, 1995; Faber et al, 2004). Meyer (2012), Lopez (2007) and Hesse (1988) formed theories on the premise that all language is metaphor, while Lakoff & Johnson (1979) took this a step further postulating that all human thought is in terms of metaphor. These theories proved that metaphor is a valuable and inherent communicative tool (Lopez, 2007; Hesse, 1988; Lakoff & Johnson, 1979).

As the thesis statement; metaphors can be used to engage people in science, is based upon the effect metaphor has in science communication, it was important to gauge the attitudes towards its use in this field. To find a consensus in opinion proved to be a hard task as many of the scholars had opposing views. Pauwels (2013) and Faber et al (2004) had concerns about whether metaphors in science communication misled the
audience and hindered understanding due to over simplification. Some thought that metaphor merely acted to provide unnecessary additions or “surplus meaning” (Hoffman, 1980; MacCorquodale et al, 1957). However, this body of work’s position is more in keeping with the positive views of many other theorists. These theorists praise metaphor for its ability to link new information to one’s existing knowledge to help with visualisation and therefore understanding and retention (Gilbert, 1989). The work on metaphor as a means to structure new knowledge, presents the tool’s quality of first aiding with understanding, and secondly creating an outlet to explore and practice learnt information. When students are encouraged to analyse the limitations or pitfalls of a metaphor they are consolidating and building upon their knowledge of the concept (Muscari, 1988). The conclusion to be taken from chapter two is that metaphor is unavoidable in science communication as it has existed there for many years, with some of the most renowned scientists work based upon them, but, however effective the tool is to communicate a concept, it is never sufficient by itself (Hoffman, 1980).

The conclusion taken from chapter two, fittingly led the thesis to explore what it was exactly that solidifies the presence of metaphor in science communication. To explore the hypothesis that metaphors aid in creating engagement in audiences, chapter three discussed this possibility. First it was concluded that for this thesis’s purpose, engagement was to be viewed in terms of active involvement in learning, concentrating on the behaviour of students while they are receiving new information (Axelson & Flick, 2010). It was then discerned that engagement was achieved through the combination of three routes; cognitive, emotional and behavioural engagement, none of which have been proven to be more significant than the other (Axelson & Flick, 2010). It was found that cognitive engagement; “the amount and type of strategies that learners employ,” was positively affected by the use of metaphor as it provided a tool to encourage more meaningful processing of new information by linking it to existing knowledge (Walker et al, 2006; Helme & Clark, 2001). Emotional engagement was defined for this thesis as being based upon learner attitudes and emotions during the acquisition of knowledge (Gonida et al, 2009; Fredricks et al 2004). Gaining a student’s interest played a large part of achieving emotional engagement and it was suggested that interest could be achieved through metaphor as it presents information in a novel way (Fredricks et al, 2004). Emotional
engagement can also be influenced if the metaphor is based upon a personal interest, as this creates positive attitudes (Reninger et al, 1992). Behavioural engagement; the outward projection of how engaged a student is, has been said to be a result of how emotionally and cognitively engaged they are (Fredricks et al, 2004). This chapter explains clearly how metaphor can be used to achieve engagement within an audience and was supported by the cognitive science outlined in chapter four. The method in which the brain learns and stores new information is postulated to be encouraged through the use of metaphor. The way metaphor can make a new concept meaningful by linking it to existing knowledge improves the encoding process, and also provides more points of reference for retrieval (Herrman et al, 2006).

Once it was established that metaphor was an effective tool to use in order to engage audiences, it seemed important to develop a set of criteria for effective metaphor use to make this thesis practically useful for science communicators. The fifth chapter aimed to improve the use of metaphor in science communication so that the concerns about its worth can be quelled. The many metaphor theories, that were explored in chapter one, had opposing views for what made a metaphor effective, however, it was gleaned that the anomaly theory had a valid point in saying that an effective metaphor was one with a novelty factor, and it was deemed that the interaction theory was the best at defining an effective metaphor. This claim, of the interaction theory, is due to its suggestion that the most effective metaphors cause the audience to see not only the subject in different light but also the vehicle, as the audience is making more meaningful connections (Ward, 2001). The set of criteria (see page 41) were based upon numerous scholarly works, gleaning the most useful points and forming one solid set of criteria for communicators to follow. It covers both the creation of metaphors and the distribution.

The dominance of metaphor in educational story telling meant that it was central to the discussion of this thesis. Evolutionary biologists have discovered that years and years of storytelling, from pre-history to present day, have actually hardwired the human brain to think best in terms of story structure (Haven, 2007). The ability of educational narrative to improve thinking, memory and communication is partly a result of the common metaphoric component (Plowman, 1996). By embedding
educational metaphors in story, the learner is provided with a richer set of contextual information to organise and structure their knowledge around, adding power to the tool (Zook, 1991; Witheral, 1991, Erpestad, 2013). This is why in the creative component of this thesis, the metaphor was imbedded within an adventure story. Storytelling also provides a strong base to encourage cognitive and emotional engagement as it helps create complex mental networks through the meaningful inferences made, whilst characters affect the emotional engagement of a student through their struggles, triumphs and in general the humanisation of science (Hokson & Fraher, 2008; Walker et al, 2006; Helme & Clarke, 2001). Not only does story present metaphor in an improved, more palatable form but it has also been linked to the development of “logical and analytical thinking, as well as language literacy,” so is set to improve the skills necessary for scientific thinking (Haven, 2007). Storytelling has been deemed effective in science communication due to its ability to improve conceptualization of concepts by making them more concrete, a requirement suggested by the effective metaphor criteria in chapter five. This chapter left no doubt of the positive influence storytelling, and the metaphoric content imbedded within them, have upon science communication and education.

The survey experiment, outlined in chapter seven, provided positive support for the argument presented within this thesis that metaphor can be used to engage people in science content. The findings showed that the poor results the students surveyed were achieving were, in part, due to a teaching method that lacked focus on achieving student engagement. It was also discovered that the majority of the students were visual learners and that storytelling teaching techniques appealed to them, indicating the potential the tool has to improve learning. Lastly, the survey data indicated that it was possible for a larger group of people to have common personal interests that when incorporated into a metaphor could achieve personal interest, and therefore improved emotional engagement, as well as a familiar, concrete vehicle to improve metaphor comprehension.

As with anything, the concept of using metaphor to engage people with science has its limitations and aspects that complicate its use. A major complication in using metaphor for educational purposes (especially for the general public), is in its past use. Metaphors, for years, have been use in the political world to sway opinion and
persuade audiences in a manipulative fashion (Hellsten, 2002). This prevailing use of metaphor has caused a sense of mistrust for the tool because the public does not appreciate being manipulated into thinking a certain way (Nelkin, 1994). There are some that think that science communication to the public should be free of metaphor as there is less chance of the metaphor being misunderstood or misused. However, metaphor provides one of the only means of effective scientific communication to a lay audience and so it is more likely to occur in communication to the public (Pauwels, 2013). It was concluded that for metaphor to be received well, communicators must be wary of using overly emotive words; the balance between manipulative and engaging is a fine line that must be monitored closely.

Limitations to this theory occur when metaphor comprehension is compromised. Metaphor comprehension is based upon an adequate understanding of the language used to convey the metaphor, and a familiarity with the context or vehicle used; the audience must attach the same connotations as the communicator (Vosniadou, 1987). Certain cohorts are likely to have trouble with the steps of metaphor comprehension; young children, international students, and those with brains with lower functioning right hemispheres, such as those with injuries, Aspergers syndrome or Autism, are some of these cohorts (Gold & Faust, 2010; Littlemore, 2001). Lastly, there are three defined learning styles or preferences that affect how effective a metaphor can be. It was found the visual learners benefited the most from metaphoric communication but were less effective communication tool for other learning preferences. However, according to the survey performed, visual learners made up a larger proportion of the sample size. This means that if the sample size is representative of the population, there will be a larger amount of visual learners present and therefore the use of metaphor will be beneficial for many students. The study by McDowell (2010) confirms that, “storytelling had the highest overall learning preference of all the options,” and can act to bridge differences in learning preference as it is enjoyed by all.

Lastly, in order to link the creative component to the academic, chapter nine outlines how the research on metaphor as an engagement and communicative tool in science communication, influenced decision making in regards to the book. In the conception of the creative component, the academic thesis influenced the target audience chosen,
as it was exposed that the ages 11-14 were the cohort that needed to have positive and engaging science experiences to continue their interest in later life (Reed, 1988; Vosniadou, 1987). In the production of the book, the research in chapter five became an invaluable source to ensure the book was deemed effective. Using the set of criteria outlined in this chapter, the story and format of the book were crafted in keeping with it as much as possible. Then, to make sure the book achieved its purpose, to engage students, the research on engagement, outlined in chapter three, was key to its production. As a result of outlining the complications and limitations, the creative component has avoided them as much as possible.

With regard to the aim of this thesis; to provide a body of work to illustrate whether metaphor was an effective tool to engage students/audiences in science, it has provided a comprehensive appraisal of the literature.

Through the works that explored metaphor theory, metaphor has been shown to be more than just a linguistic tool, but a cognitive tool with a solid place in communications (Lopez, 2007). Chapters two and five outline what makes metaphor an effective communication tool for education and in particular science communication. The dominating opinion is that metaphor aids with science teaching and communicating through linking the abstract to the familiar and helping to visualise concepts that are difficult to see as concrete (Zook, 1991; Witheral, 1991, Erpestad, 2013).

Most importantly, and where this thesis differs from others, is the work on how metaphor can be used to engage students. Once it was determined that metaphor was a viable and valuable communication tool, the thesis statement could be explored. Through appraising and analysing numerous studies, definitions and theories, from many different disciplines, an understanding of what engagement is was obtained. Then using the prior work on defining metaphor and the way it can be utilised, it was argued that metaphor would provide a good basis for creating engagement – especially within science communication. This approach, using metaphor, as a tool to engage students, was not well reviewed, and this thesis fills that gap in the literature.
This thesis has comprehensively reviewed the value of metaphor to engage audiences in science communication, and confirms the worth of further study on the topic. The next step would be to conduct an experiment to test the effectiveness of metaphor to achieve engagement directly on subjects. This would entail studying a particular metaphor’s effect on engagement, with comparison to literal teachings, on many cohorts such as primary, secondary, and tertiary education students, along with the lay public. The subjects’ behavioural engagement, behaviours outlined in chapter three, would need to be monitored during the communication session and their emotional engagement inquired upon in a similar fashion to the survey discussed in chapter seven. To take inference about their cognitive engagement between the two communicative techniques, a test of their understanding could be analysed.

Another direction of study could be the worth, and accuracy of the ‘effective metaphor’ criteria outlined in chapter five.
REFERENCES


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APPENDICES

APPENDIX ONE: STUDENT ENGAGEMENT SURVEY

This survey is for the sole purpose of use in Asia Rattenbury’s Master of Science Communication thesis. It is a self-reflection survey aimed to find out how BIOC192 PAL tutorial attendees feel about their level of engagement in the course. **If you are under 18 please DO NOT fill out this survey.**

1 (a) Circle the grade you received in the pre-requisite CHEM191 paper?

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(b) Do you think you could have achieved a better grade?  Yes / No

(c) If answer circled is ‘yes’ to 1 (b), circle what you think contributed to the grade you received?

Poor effort  Poor understanding  Lack of interest  Other: (Please describe)

2 (a) During the prerequisite paper, CHEM191, how much of your course work emphasized the following?

- Memorizing of course material  
  - Often  
  - x  
  - Seldom

- Use of visualization tools  
  - Often  
  - Seldom

- Relating course material to your environment/ interests  
  - Often  
  - Seldom

(b) How often were you prepared for class?

- Often  
- Seldom

(c) How did you feel during lectures?

3. What do you think your dominant learning style is? Tick the appropriate box.

- **AUDITORY** – learners learn best listening to an explanation rather than reading one. Actions like reading out loud or playing music in the background are common study practices.

- **VISUAL** – learns best through looking at graphics, watching demonstrations or visualizing the concept.

- **KINESTHETIC (TOUCH)** – learn best by performing “hands-on” learning activities. Doing the activity is the best way to learn.

4 (a) Would story-telling, teaching techniques as a guide to learning appeal to you?  
   Yes / No

(b) Explain why they would or wouldn’t appeal to you.

5. List a few of your personal interests or hobbies (activities out of university).
A LAND BEFORE LIFE

A metaphoric interpretation of the RNA-world theory and the beginnings of life on Earth
This story is a metaphoric representation of the scientific theory of the ‘RNA World’ and the first molecule of life. The journey taken to form the cell took billions of years and was the product of trial and error. The characters within this book are representative of the unimaginable numbers of RNA molecules that were responsible for creating life on earth. The formation of the cell was far more complicated than represented in this story and took a vast amount of time.

Cover Art by Andrés Cruz, (CC), taken from; https://www.flickr.com/photos/acruzarte
PROLOGUE

Many billions of years ago, the white-hot star that is now known as the Sun, spat out the pieces of a planet in a fiery tantrum. Upon impact, these pieces of burning rock and metal were molded into a smoldering-hot, spinning globe that circled the sun.

Pushed away from its creator, the planet cooled and a hard, rocky crust formed around the sphere. With thunder and lightning crackling above, the skies began to shed water onto the newly formed land below. An ocean was fashioned, unlike the cool waters of today. It was a hot, bubbling broth that birthed an environment bountiful enough for life to evolve.

This story begins 3.8 billion years ago, before the first forms of life as we know it had come to existence. The cells that make up the familiar creatures of the world were yet to be formed. Instead the young planet was ruled by a different set of beings known now as RNA's, who though not technically living by human standards, were active on Earth in their own way.

They roamed the primordial soup that became our Oceans and are thought to have given rise to, and are now part of, all living creatures. Through putting together the ingredients provided by earth’s atmosphere, these mysterious creatures gave rise to the cells that make up our bodies and those of every living thing around us. Matter such as aminoes, and lipids became the building blocks of life, to be manipulated by these magnificent RNA molecules.

In this case, as in many others, the smallest of beings make the mightiest of moves. For a creature so small, the distance of a grain of sand is a journey of epic proportions. With no living creatures around; no plants, animals, or even bacteria, this miniscule, grain-of-sand sized land that this story takes place in, was stark and bare despite being drenched in water.

Though this story may seem to be set in a fantasyland, it is in fact the Earth we call home, but many years before we existed. The struggles faced by
these brave beings are the difference between the vibrant and lively earth of today, or nothing at all.
CHAPTER ONE
THE DREAMER

First the earth rumbled and shook beneath them. Then, in the lead-up to catastrophe, the temperature rose. With the volcanic eruption came extreme destruction.

The wall of water charged at the miniscule m-RNA community, a writhing and frothing mass. Mordecai had spotted the unusual form on the horizon and, transfixed, watched it come closer and closer. It was not until the waveform was almost upon them did the curious boy realize the danger it posed. He was young. How could he have known?

The searing hot water hit the m-RNA tribe with catastrophic force. Mordecai was pulled under and thrown upwards, his body torn in all directions. He tried to yell for help but the pressure of the tidal wave choked his screams back. Searching frantically through his spiraling world, he caught glimpses of his kin being thrashed around violently, the wave a lethal puppeteer.
In the swirling mess, debris flew from every angle, forcing Mordecai to duck and dodge them madly. He could hear others yelling and screaming, their voices distorted by the crashing of the water. His mother’s frantic shrieks pierced through the chaos and her face flashed before him.

“MMMOOORDDEEECAAI!!!!”

Just for a second, then she was gone again.

The surge was accelerating, thriving off their despair. Mordecai tried to fight against the keen undertow and towards his mother. It was no use; under he went for another cycle. Crushed by the weight of the water, he felt himself slide out of consciousness. The foaming disarray flickered out of sight.

He came to, with protective arms grappling with his limp body. The wave still bulldozing ahead.

“Mordecai? Mordecai? Are you awake?” his father’s voice strained against the wave’s deafening roar.

Mordecai groaned, groggily.

“Mordecai wake up! You have to hold on!” another voice said, desperately.

“We’re losing you!” screeched a shrill, girl’s voice.

Mordecai opened his eyes forcefully. A group of his clan, most of whom were as young as him, were bonded to one another in a tight circle, listening intently for instruction from Mordecai’s father. Mordecai was in the middle of this formation but rapidly slipping away with every tumble of the colossal wave. Mordecai looked around the group and six faces stared back. His mother’s was not one of them.

With Mordecai once again conscious, his father opened the circle cautiously to incorporate him into the strong knot of m-RNAs. Mordecai reached up, and Maddox, a boy of his age, bonded to him tightly on one side. Just as they grasped each other, the wave took an unexpected turn, flinging his father from the group. It had happened so fast. The youngsters, with no adult to lead them, grappled with Mordecai, quickly closing the circle once more as they careened onward.
There was no time for concern. They were being pushed downwards, the heavy water pummeling them towards the sea floor. Through the fogginess of the white froth a cliff face came into view, and the battered group of m-RNAs had no time to brace themselves before slamming into it, hard. Once again Mordecai fluttered out of consciousness, his last sight the tremendous wave rolling over them.

Mordecai woke with a start, the rush of angry water still ringing in his ears despite his calm surroundings. There were ripples working their way gently through the water and away from him. He groaned; he must have been thrashing in his sleep again.

Though many years had passed since the eruption, Mordecai was still haunted by that cruel experience. He had lost both his parents, along with half his kin. The group of youngsters, his father had mustered, had lost many of those dear to them. Some were luckier than others, when in the following hours and days, more of the m-RNAs managed to find them; brothers, sisters, mothers, fathers, uncles, aunts, and friends turned up. They waited, and waited but after a while no more came. Mordecai had lost his parents for good.

Those that remained had settled in the shelter of the rocky ridge that had broken the children’s turmoil. It seemed a good enough place at the time, and so there they were, all those years later. In honour of those they had lost, they named the rocky range the Amissas Ridge, or ‘the lost’.

The rest of the m-RNA tribe continued to sleep, and the rare silence that hung over the community gave Mordecai time to gather himself. He carefully made his way out of the throng of his slumbering tribe and began to scale the Amissas. Sometimes swimming, sometimes climbing, he eventually reached the cliff top. There he sat, watching the dim flickers of lightning far above the surface of the ocean.

As the light of the Sun began to show itself, creeping its shimmering rays up the far side of the rugged crest, Mordecai felt someone join him. Morley, one of the children that had saved him, had scooted in next to him.

“Morning, Morde!” she said brightly.

“Good Morning to you too, Morley. So kind of you to join me up here,” he replied, giving her a cheeky grin. They often sat here together, taking in the
beautifully stark seafloor with the sea creating patterns on it in the changing light. “What are you doing up so early, then?”

“Oh, I don’t know? Your ever so graceful exit this morning woke me up! I tried to go back to sleep but I’ve given up. Come to annoy you instead,” she teased.

The group of six children, that survived the tragedy together, had become very close. Morley and Mordecai shared a special bond though; they both suffered from the same tormented dreams. The others were less affected, or more accurately, affected in other ways. Maddox, Meeko and Marcella whizzed around, making the most of every moment, while Maverick’s protective instinct meant that he was constantly chasing after them to make sure they didn’t do anything too stupid.

“Come on, let’s go down. Look, the others are getting up now,” Morley suggested after a while, gesturing towards two small dots far below them that were waking another up boisterously. She chuckled fondly.
CHAPTER TWO
THE SIX SURVIVORS

Allowing themselves to drift down towards the m-RNA settlement, Morley and Mordecai joined Marcella, Maddox, Meeko and Maverick.

“We wondered when you two would come down from up there!” Maddox said, looking up from a play-fight, while holding Meeko down proudly.

From his uncomfortable position Meeko jeered; “Have a nice date, did you?”

At that, Morley joined the rumble and tumble, throwing herself wildly at Meeko, “Shut it, would you? It’s not like that!” she screeched.

Mordecai and Marcella burst out laughing; Meeko knew all the right things to say in order to push Morley’s buttons and it never ceased to amuse them. Everyone knew that Mordecai and Morley’s friendship was akin to brother and sister but nothing riled her up more than suggesting otherwise. Eventually, they all collapsed in an entangled pile. They shrieked with laughter; nothing was ever serious for long with this lot.

“So what’s the plan for today, guys?” Mordecai asked the group.

“We were thinking of going to the canyon today. Maybe chill-out by the blowhole, what do you think?” replied Marcella enthusiastically.

“Oh yeah! I’d love that!” said Morley; she loved to bathe in the hot, bubbling water around the edges of the underwater blowhole nearby.

The four boys chimed in their agreement and they all set off, chatting amiably. It was a particularly warm day, in fact a particularly warm few weeks, but RNAs love the heat and it only contributed to the carefree and jolly vibe of the group.

Walking past the ‘Three Heads’, a group of boulders that were shaped remarkably like the heads of m-RNAs, the blowhole came into view. Though the center of the underwater geyser was a fierce jet of water, fighting its way up to the surface, the outer edges were inviting with their gentle bubbling. The gases, escaping from the ground there, were captured in bubbles and making their way up to the surface and out of their watery cage. On either side, they could see the dark lines that ran off into the distance, marking the deep canyon that existed on either side.
Before long, they could feel the heat coming off the blowhole. They settled on the outskirts, where the bubbling was gentler. The two girls, Marcella and Morley, made themselves comfortable in a placid jet, rising and falling with the bubbles and gossiping lazily. Meeko and Maddox scampered off to the edge of the canyon, while Mordecai and Maverick began playing around with a wandering bubble.

Maverick looked around at the other two boys restlessly, worried about their safety. Soon enough, they gave him reason to worry; Meeko and Maddox had completely disappeared.

Mordecai and Maverick rushed toward to the edge of the canyon, but just before they reached it, they heard squeals of delight and the two hooligans shot up high above them. They had jumped down into the canyon, timing it just right, so that a powerful jet of bubbles blasted them back out. They were catapulted out and landed in a heap near the other two boys.

“Wahhoo!! Did you see that?” cried Maddox, elated.

“Let’s go again! Come on!” called Meeko, already running towards the edge again.

“Are you two crazy?” Maverick yelled after them, “If you get caught in the main jet you’ll be thrown out of the ocean and up, out there!”

The central surge of the geyser was extremely powerful and Maverick had a point, if the boys found themselves in the middle of it they would be blown sky high and an eternity away.

“We’re being careful, you big worry-wart! Come and see!” Meeko shouted back.

“It did look fun…” Mordecai said to Maverick, a twinkle in his eye and a sly smile creeping over his face.

“Oh alright, we’ll go check it out, but that doesn’t mean that I’m going to do it.” Maverick allowed.

The four boys reached the edge of the canyon, Meeko indicating with a quick gesture that they needed to wait. Peering over the side, they could see a small jet quietly bubbling away from deep within the trench. All of a sudden it sprayed up and blasted into life, Meeko and Maddox pulled, a howling, Maverick and, a laughing, Mordecai down into the dark canyon. All four boys
were launched dramatically back into the light, water whooshing past them, flipping them over and out, back towards the girls.

“WAHHOOOO!” yelled Mordecai, marveling at the thrill of it!

“You guys!” yelled Maverick accusatorily, but quickly gave into relieved and exhilarated laughter.

“Let’s go again!” said Mordecai, and they made their way back towards the jumping-spot.

“Hey! Wait for us!” Marcella called out; terrified of missing out. Morley trotted along behind her eagerly.

They had almost reached the brink of the drop-off, when a shudder went through Mordecai sending him sprawling, at high-speed, onto the ground. At first, he thought he’d been knocked over by one of the others as they raced
over, but he soon realized that the other five were also feeling the effect and
the ground was shaking. A deep rumbling came from within, and they could
feel the pressure growing through the movement beneath them. The seabed
was coming to life.

The six m-RNAs were shunted forwards towards the powerful blowhole.
Closer, and closer they went. Meeko, who was ahead of the pack, was sliding
uncontrollably towards the dangerous fountain of water. He reached the
edge and toppled in.

“MEEKO! NOOOOO!” Marcella screamed, while Maverick lunged forward
reaching after him.

After disappearing for a moment, he shot back up; the hot water flinging him
out of the ravine. He was struggling against the pull of the whirling and
fizzling inner jet, terror etched all over his face. Mordecai jumped into action,
realizing, in horror, that if they didn’t do anything Meeko would be shot a
million miles away and lost to them forever.

“Maverick, grab onto me!” he ordered, trying to stay as calm as he could,
“We are going to have to link together and pull him out!”

Maverick followed his order obediently and Mordecai signaled to Morley,
grabbing her around the middle. Marcella followed, and with Maddox at the
end of the m-RNA chain, the five of them edged toward Meeko.

“Come on, Meeko, just a little further!” coaxed Maddox, while Meeko
desperately fought against the powerful tugging of the rushing water.

“You’re almost there!” yelled Morley.

Meeko, in an almighty effort, propelled himself forwards, grasping Maddox
triumphantly. With difficulty, Maverick and Mordecai tugged against the
others, inching them back out of the fizzing geyser.

“Hold on tight. Whatever you do, don’t let go!” Mordecai said, straining
against the continuing strength of the central jet.

Eventually, the blowhole released their friend from its grip and as soon as it
was deemed safe to let go, Maverick stalked away from the group in a huff.
“Mavs! Wait up!” Meeko panted, “What’s his problem? It wasn’t my fault!” he said, pausing to turn back to the others, then hurtled after the sulking Maverick, unsteadily.

“He’s right…” said Mordecai to the girls and Maddox, thoughtfully “It actually wasn’t his fault. The earth was moving!”

“I know! That hasn’t happened since… well since the tidal wave that brought us here!” Morley pointed out, visibly alarmed.

“Nah, it’ll just be a powerful jet bursting from in the geyser. I’m sure of it.” Maddox shrugged, true to form, he was completely unfazed.

“No. Haven’t you guys noticed? The temperature. Its been getting warmer and warmer lately. All the signs are there! There’s going to be another eruption!” said Mordecai, his voice growing pitchy with panic.

Marcella and Maddox rolled their eyes knowingly at Mordecai, wordlessly wandering off to pacify Meeko and Maverick. The group knew about Mordecai’s night terrors and it was becoming commonplace for Mordecai to become paranoid at the tiniest crumble of rock.

“You’re worried too, aren’t you Morley?” Mordecai implored desperately, “Think about it. That shaking was not ordinary!”

“Yeah. You’re right, I am worried, but I’m always worried, Morde,” she replied tentatively, looking over at the others, “ They don’t seem to think anything of it and lets face it, they are usually right about this stuff. We’re a bit jumpy about this sort of thing…” she finished.

“You can’t be serious, Morley? They are my best friends, but they can be idiots sometimes! This is serious. I know it, and I can’t lose anyone else. I just cant.” Mordecai grimaced.

“I know. You think I can?” Morley asked, “Look, we’ll play it by ear. There’s no point alarming the tribe unless we know another eruption is actually going to happen.”

Mordecai nodded reluctantly, and with Meeko and Maverick, who had evidently been charmed into forgiving Meeko, they headed back to the m-RNA settlement.
As they passed the ‘Three Heads’, on their journey home, Mordecai was acutely aware that one of the giant boulders had toppled over. The sight made his stomach turn.
CHAPTER THREE  
NEW CONNECTIONS

It was early. Very early, but Mordecai couldn’t wait any longer. He had been up all night with the thought of re-living his painful past once more.

“Wake up. I’m leaving, Morley.” he whispered soberly to his closest friend.


“I can’t do it. I can’t wait around for the eruption that I know is going to happen, when I know that we won’t survive it without losses.” he rambled, frenzied with the idea of it. “I’m going now. I’m going to find better shelter. When I do… if I do, I’ll come back for everyone.”

“No, Mordecai.” she was bolt awake now. “You can’t leave us. You just can’t!” Morley stuttered, stubbornly.

“Yes I can. I have to. I’ll go crazy if I don’t try, and I know you don’t think that there will be an eruption but I do.” He said firmly, “I just need you to tell the others and make sure they don’t come after me. I have to find a better place for us. I need to make sure that we will be safe.”

Morley nodded sombrely. She knew there was nothing she could do or say. He had made up his mind. All she could hope for is that he came back to them.

Mordecai had been travelling for almost a day, feverishly trudging across the deserted seabed. He did not know where he was going, or even in which direction. The only thing he recognised of his stark surroundings was the now-small mound of the Amissas Ridge that sheltered his clan, but even that was long passed and behind him.

“It’s coming. The volcano will erupt again. The signs. The signs. They’re all there.” he muttered to himself.

He had been punctuating his trek with these restless mumurs; however, the mutterings were becoming less frequent now and had the panicked edge of self-doubt. The troubled m-RNA didn’t know where to start. He had no idea
how he was going to find better shelter for his clan. He didn’t even know if it existed.

This was the first time he had ever truly been alone, and boy was it lonely. After the bustling community of m-RNAs, he found himself smothered by the silence that enveloped him. There was nothing but the bubbling and gentle swaying his hot-water environment.

*Should I just turn around and go back?*

*No! I’ve got to find a better way. I need to protect them.*

The internal struggle was almost too much to bear. He felt helpless and exhausted. Slumping to the ground, he curled his long, slender body into a ball around him. He couldn’t help but miss Morley. She always knew the right thing to say when he felt low, or at least she always tried. His oldest friend, she had always been there for him and in his lonesome despair he pined for her.

One of the large amino-units, that drifted in numbers through the deserted ocean, gently tapped him as it passed. For a startled second his heart leapt at the thought that someone had come after him.

*Don’t! Don’t be weak. You’re doing this to protect them.*

Leaving was the hardest thing Mordecai had ever done, and only now was he realising this. Those five goofs were the closest things to family Mordecai had, and he had left them, without even so much as a goodbye. He thought of them now; Maverick would be beside himself, yelling at Morley to tell him which way he had gone. Marcella sobbing on Maddox’s shoulder, a rare and unsettling frown upon his sad face and Meeko, well Mordecai knew that out of everyone Meeko would be saddest. He would think it was his fault.

Mordecai slowly drifted of to sleep with his guilt blanketing him. He resolved to head back home when he woke and fix things. Maybe he could get them to join him...

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Slowly, Mordecai woke to a persistent prodding in his side. He refused to open his eyes right away, hoping fervently that it had all been a dream and the prod, prod, prod that woke him was Morley.
As his mind defogged, he realised that the repetitive jabbing was not nattering away at him as Morley would have been, and he opened his eyes with a start. As he looked around defensively he quickly took in his surroundings; he was not where he had fallen asleep. He found himself shoved between a large rock and the ocean floor, the jabbing-culprit, a piece of the jagged boulder that stuck into him with each ebbing of the current. Panicking, he quickly jumped to his feet. There was what seemed to be a large crevasse in the sea floor behind him, it reminded him curiously of the trench by the blowhole at home, yet it was much wider. Other than that the landscape was completely flat and deserted; he recognised nothing. Feeling the flow of water moving past him, he realised that while he had slept it had dragged him further away from home.

“Why? Why would you do this to me? Gahhh!" he complained, yelling at the universe and thrashing at the gently moving water surrounding him. White crested ripples spread out in front of him.

A silence followed his outburst and he stopped for a second.

Wait, if it’s silent now… doesn’t that mean that there was noise before?

He was unsure of his reasoning, so scrambled towards the split in the ground to peek over the edge of the wide trench. To his utter amazement a community of what looked like an RNA tribe existed far below. There was a hushed atmosphere and he could see the residents trying to figure out where the noise from his emotional outburst had come from. He shrunk backwards swiftly.

With mixed feelings of excitement and foreboding, Mordecai tried to concentrate on what to do next.

Should I approach them or not? After all, they might be able to help me.

Mordecai’s initial instinct was to go down and introduce himself, he was, after all, a friendly and charismatic being of the m-RNA tribe… but he had never met anybody outside his clan and this made him nervous.

The activity below had begun to stir again, but Mordecai waited until the hubbub of the tribe below had resumed before edging himself over the ledge again, to take another look.

On second glance he almost thought he had been mistaken in thinking that they were another tribe of his kin. These Beings were shorter, broader, and
more robust than he, however, as their voices drifted up to him he caught odd words that he understood.

*They talk like me… Does that mean they are RNA’s after all? Perhaps just not m-RNAs.*

Though this information eased some of his anxiety, communication being his most valuable weapon, he decided to play it safe for now. He would watch them for a while to gauge whether it would be safe to go down and interact with them.

As Mordecai looked on from above, life went on as usual for the folk of the unknown tribe. They seemed to be milling about each other in the same way as his tribe did and, though a little more reserved than his rowdy bunch, they did not seem aggressive or dangerous. They fascinated him with their odd appearances and he decided to take a closer look. He wanted to hear what they were saying.

First, Mordecai returned to the boulder that he’d slept under that night. He quickly made a note of the direction of the current that took him there. He thought this was a wise move for if things turned sour. He then set off along the gentle slope toward the base of the trench where it opened into a small valley. As he came closer to the entrance of the gorge Mordecai slowed his progress, moving more gently; trying not to disturb any debris. He was forced to double over in order to be hidden from view. Close now, their voices were clearer and more defined. Once at the entrance he found that there was a convenient pile of aminoes stacked there. He got down on his front and hid there.

All along this end of the valley there were patches of aminoes, stacked uniformly, and blocking off the community. On closer investigation, Mordecai found that they had been fused together somehow, as though this blockade was purposeful. He made his way to a gap in the construct to view the strangers better.

He jumped with fright as the tribe came into view. One of them was leaning up against the other side of the amino-wall that screened him. He tucked away quickly and pushed himself against the ground, hoping desperately that they hadn’t heard him.

“Hmm, hmmm hmmm, hm hm.”

Mordecai heard what was clearly a female voice, humming from the other side of the strange amino-wall. The humming was melodic, the tune
unknown, but rather chirpy. He moved himself up the wall, carefully edging over it to view the girl. She was fiddling about with some aminoes. This was something he had never seen anybody do before; in his tribe they were annoyances, always getting in the way, not toys.

She was trying to connect the two together and after a while, succeeded. She turned towards a gap in the wall where Mordecai stood, but before she had a chance to notice him, Mordecai ducked down.

It was just then that the earth began to groan. A series of small, but sharp jolts shook their way through the land. Both of the RNA's, on either side of the wall, waited with bated breath for it to stop. It was a small earthquake this time but not small enough; the movement beneath the wall caused it to topple over, revealing Mordecai to the foreign girl.

She leapt back and took in a sharp breath preparing to scream.

“It’s ok. It’s ok. I’m not going to hurt you. Just shhhhh, shhhhh” he said soothingly, trying to think on his feet.
“Wh- Wh- Who are you??” She stuttered backing away, trembling violently.

Mordecai stopped moving towards her, leaning casually against the wall’s remains - thinking that this would make him appear less threatening but instead sent more aminoes flying at her. He quickly retracted, apologising profusely and trying to stabilise the wall. They were just out of sight of the distant community but any loud noises would lead them straight to him and Mordecai wasn’t sure what their reaction would be.

“Hi! I’m Mordecai.” He said brightly, “but my friends call me Morde. You can too if you like.” He could tell that his clumsy appearance and apologetic nature had calmed her and to his relief nobody else had noticed the commotion.

“What are you doing here? Where are you from? You look all… different,” said the girl, obviously regaining some of her confidence and appraised him inquisitively.

“I am from the m-RNA colony, way over there, under the Amissas Ridge” he said waving in what he thought was the general direction of his home. She shrugged at this, so he continued, “I came across you guys by accident really,” he said sheepishly, “What’s your name?”

“Well…” she still looked a little unsure but conceded, “I’m Reva, of the r-RNA tribe”

“Pleased to meet you Reva of the r-RNA tribe. I thought you might be of the RNA variety.” he said, pleased with himself, “Isn’t it funny that our tribes have never met before when we live not so far away?”

“Yeah, well we actually haven’t been here long. According to our elders, a volcano eruption is in our near future. The land below us keeps moving, plus it’s sweltering hot, so we recently relocated to find more protection. We haven’t been here long. We hope that if we can block off each end of this trench it will stay calm and sheltered in here.” Reva said, relaxing her stance a little and indicating to the ruins, “but as you can see we are going to have to build them a lot thicker if they are going to hold up.”

“Did you feel the big shake not long ago?” asked Mordecai, “The last time the earth moved like that, it was the beginning of a terrible disaster for my tribe,” he looked away, his charismatic energy flickering for a second. “So what were you doing over here, I’m sorry that I was watching but I’ve never
seen anyone do that with an amino. It was fascinating!” he said, regaining his enthusiasm.

“What do you mean you’ve never seen anything like that before? Everybody does it. I was just putting some aminoes together, they are the building-blocks we use to make this blockade, it’s nothing to get excited over,” she stated, matter-of-factly.

Now that she mentioned it, he had seen, from his cliff-perch, the r-RNA’s grabbing at aminoes as they passed through. He had assumed that they too thought of the floating rubble as a nuisance and had been trying to get rid of them. It had never occurred to him that they were utilising them to help provide shelter. It was ingenious!

“That’s it!” he exclaimed excitedly, causing Reva to jump back again. He laughed and she too, feeling a little embarrassed, laughed back.

“What’s ‘it’?” she teased the excitable newcomer.

“This is how I’m going to protect my tribe!” he said, “Have you done this before? Has it worked? How do you put the aminoes together?” Mordecai questioned the r-RNA girl in rapid fire.

“Well not me specifically, but yes, my tribe has.” she started, clearly overwhelmed by all the questions, “Ruarc, the oldest member of our tribe, has lived through plenty of volcanic eruptions. He’s told us all about them; they’re all different you know? Some spit ash into our ocean, others spray hot gooey stuff and some, make huge, powerful waves that ruin everything in their path.” she tried to explain, getting a little off track.

“Yeah, we experienced one of those waves a while back. That was the disaster I mentioned. It tore my tribe apart. Tragic, it was.” Mordecai cut in solemnly, “That’s why I’m here actually. I’m trying to find a way to stop my tribe from being separated again. Have your walls ever worked?” Mordecai asked again, reminding her of his question.

“Well, no. Not yet,” she said, a little embarrassed, “But that’s why we moved. Ruarc thinks we were too exposed at our old settlement; there was too much pressure on the walls. They were too thin in areas and were weak as well. He’s convinced that in this canyon, with only two walls at either end needed, the walls will hold up better. We just have to make them thicker.”
“Hey… is there any chance you could teach me how to make this?” Mordecai asked thoughtfully, indicating to the crumbled wall next to him.

She nodded enthusiastically. Starting work on two aminoes that looked the same, she talked Mordecai through the process.

When she was finished she said, “Look, these two make a flexible, but strong unit,” demonstrating their qualities.

Mordecai made himself comfortable next to her and as she continued to teach him about the aminoes and how they could fit together, they shared in easy conversation.

Mordecai admired her as she worked. She had a way with construction, he could see that clearly, the way she manipulated the materials was masterful and before long she had four identical aminoes joined together. The result was a sturdy, yet flexible sheet of aminoes.

“Here, you have a go” she said after a while, lumbering a few aminoes over to him, “But be careful with them. We don’t have many aminoes and we need all we can get.” she said as an after thought.

He set to work trying to imitate the way Reva had manipulated the aminoes, but to no avail. The way he handled them was clumsy and no matter how hard he tried to put them together the aminoes just would not stick. Mordecai laughed at his ungainly attempts and Reva continued to coach him, suppressing her own giggles.

“Keep trying.” encouraged Reva, stifling a chuckle and getting up to leave. “I’m sorry. I’d better get back. My family will wonder where I am. I’ll come back tomorrow and help, I promise.”

Mordecai thanked Reva for trying to help him, playfully pushing her when she started to imitate his uncoordinated attempts.

The sun was sinking and Mordecai, a little disheartened and very tired, tottered back up the slope to the boulder and fell asleep hoping the next day would be more of a success.
“Why can’t I do this?” yelled Mordecai, in frustration. All the hilarity of the previous day had disappeared and instead Mordecai was feeling an immense sense of failure. Looking up at Reva’s concerned face he added softly, “I’m sorry, it’s just that... I thought this was the answer to my problem. I need to protect my family, but I’m useless!”

“You’re not useless Mordecai... Maybe you’re just not made for this kind of work?” she suggested cautiously. “We are just different, you and I, anyone can see it! Your good at things Mordecai, just not this.” she said, grimacing slightly.

“Oh yeah? So what am I good at then, Reva?” he asked sulkily, not really expecting an answer.
“Talking.” she replied matter-of-factly, “You’ve spent as little as one day with me and now I’m compelled to spend all of my time helping you! Gosh, I don’t even know you and here I am spending my days teaching you something you’re clearly terrible at!”

Guilt dawned upon him. Realising for the first time that he had been wasting her time, Mordecai looked up apprehensively, but to his surprise she was smiling.

“Why don’t you come back with me and meet my tribe? Perhaps you can use that magic mouth of yours to convince Ruarc to let your tribe join us here for the eruption? If the other m-RNAs are as great as you, it will be fun!” she suggested brightly.

“That’s not a bad idea, Reva. The other m-RNAs are 10-times better than I am but you’d have to put up with me for a while! You’re sure you could handle that?” he asked jokingly.

“You’ve got to convince Ruarc before you convince me, Morde!” she said in mock warning.

Mordecai knew Reva had been joking but as they walked toward the bustling r-RNA community, a paralysing fear came over him. He had never been nervous or shy, but meeting the r-RNAs, with so much at stake, was a lot of pressure. They had to like him.

Seeing him wide-eyed and tense, Reva petted him gently, “You’ll be fine Morde. They’re going to love you as much as I do.” Immediately, she turned bright red and quickly took a step away from him, “Come on then clumsy,” she jibed, trying to cover her embarrassment.

Walking into the throng of r-RNAs, Mordecai had never felt so out of place. He towered above them all, lanky and ungainly. As he passed each member, they stared at him, unashamed. He could sense their guardedness, but the presence of Reva at his side stilled their fear. Once they had reached the centre of the community Reva spoke.

“This is Mordecai of the m-RNA tribe.” she said confidently, “Over to you, Morde.”

There was a surge of whispers and Mordecai could see that the r-RNAs were confused by his presence in their community. Reva had cruelly put him on the
spot but out of the corner of his eye he saw a sly smile creep onto her face. She was testing him and he accepted the challenge.

“Hi, ah, hello r-RNA’s. I am Mordecai from the m-RNA tribe, and I know your all wondering why I look so different and what the heck I’m doing here,” he began with an awkward nervousness, “I came across your clan by accident really. I had left my tribe with the aim of discovering a way of life that could provide more protection for my family – I too have read the signs and think we can expect another volcanic eruption.” he was becoming more confident; the charismatic Mordecai was starting to shine through and a few of the r-RNAs were nodding in agreement and understanding. “Your work with the aminoes, it’s fantastic, and I am hoping that your tribe would be so kind as to help me to protect my tribe.”

The r-RNA’s erupted in noisy discussion and it appeared Mordecai had flattered them with his praise. He was rushed by r-RNAs; who encircled him shooting questions at him left right and centre.

Where are the other mRNAs? How did you get so tall? Would you like me to show you this, that and the next thing?

Overall, the introduction had been a resounding success and the r-RNAs were buzzing with excitement about their new visitor. Mordecai couldn’t help but feel proud of the way he had won the majority of them over, but he had yet to meet the notorious Ruarc, the one person he needed approval from the most.

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Mordecai had been with the r-RNAs for a few nights now and hadn’t had a spare minute to himself, let alone to do what he had set out to do. The r-RNAs were an enthusiastic and friendly bunch; when one was finished showing him their current project, another whisked him away to be shown another example of r-RNA ingenuity. He was yet to speak with Ruarc, and it seemed that he was the only r-RNA member that didn’t want anything to do with him.

Freeing himself from yet another r-RNA teaching session, that, like Reva’s, had ended in frustration, Mordecai latched onto Reva as she strolled past. They walked around the periphery of the settlement, Mordecai relishing the time to relax. He enjoyed Reva’s company; she was fun, passionate and smart. The two found that they had plenty to talk about and were only interrupted when they overheard a lively conversation.
“How are we ever going to finish the two amino-walls before the eruption when all that we get is a measly dribble of aminoes through our settlement each day?” croaked an older voice, despairingly.

“We are going to have to figure out a way to collect and store them before we can even begin to build the second layer,” said a voice that Mordecai recognised as his new friend Rubena’s, a hint of frustration in her voice.

In the dim light of late afternoon, Reva and Mordecai made out a select group of r-RNAs having what looked like a meeting. Mordecai’s heart leapt; one of the members of this group was Ruarc, the ancient r-RNA leader.

“Yes,” Ruarc spoke up, his voice pensive. The others waited patiently for him to mull over the issue, “We will have to go out in search of the source; these aminoes have to be coming from somewhere.”

“Really? You think there will be a source?” asked another r-RNA, an enormously rotund male that went by the name of Romey.

“Yes, I should think so.” said Ruarc slowly, “But we don’t have many workers to spare—”

This was all Mordecai needed. An opportunity to prove his tribe’s worth. To show Ruarc that he could be useful and that they could earn their place in the safety of their valley.

“I can help with that!” Mordecai said, leaping, unannounced, into the conversation.

Ruarc appraised him disapprovingly, “Help with what? Don’t you know that it’s rude to eavesdrop young man?”

Reva rolled her eyes at Mordecai’s eagerness and appealed to Ruarc, “I’m sorry, we weren’t eavesdropping. We were just walking by and overheard that we might need some extra help. That’s all Mordecai wants to do.”

“Yes. Exactly. I’m sorry. I just think that my friends and I could help. We could search for the amino source, leaving your tribe members free to work on the wall.” Mordecai blurted out hurriedly.

The small group present at the meeting were looking from one another approvingly. They were nodding at the idea but all waited for Ruarc’s response.
“He has a point there, Ruarc.” cajoled Romey.

“We really do need to search for more aminoes and we can’t afford to lose many workers.” pushed Rubena.

Eventually Ruarc caved, “So what? Are you going to return to your tribe and gather a search team?” he asked.

“That is exactly what I’ll do!” said Mordecai, and then added with a cheeky grin, “Anything to ensure my tribe’s protection.”

“Well, we’ll see about that –“ Ruarc said to Mordecai’s quickly disappearing form.
CHAPTER FIVE
THE REUNION OF FRIENDS

Mordecai was halfway back to the boulder that he had carved the direction home in, when he heard Reva chasing him down.

“So you’re going to leave? Just like that? No goodbye Reva, it’s been nice knowing you?” Reva pouted, hurt souring her pretty face.

“No. Oh no. I’m so sorry! I didn’t mean to –” he replied, mortified. In his desperation to please Ruarc and help his family he’d forgotten Reva. He felt awful; after all, the whole plan had been her idea. He quickly grabbed her and wrapped her up in his gangly arms and said, “Let’s not say goodbye - because hopefully it won’t be. See you later, alright?”

Still a little angry, she muttered, “See you later,” but did not let go of him. After a short while she released him and said, “You’d better come back, otherwise who else have I got to tease?”

She walked away imitating Mordecai’s lumbering stride, turning back once to show him a flash of her smile.

Mordecai made his way up the steeply sloping land and towards the boulder. Upon arrival, he circled it searching for his small carving. Finding it nestled beneath the jut that had prodded him awake, almost a week ago now, he positioned himself to face towards the indicated direction and started his journey back.

The terrain was flat, bland and terribly boring so for the majority of the first day he wished that he were asleep, as he was on the way there. This journey was different though; he had more motivation. He was powering back; the thought of the destruction that was bound to come their way propelled him onwards. He had a clear purpose this time; he needed to warn his tribe and get them to safety in time. There was also a tiny part of him that wanted to sit atop the Amissas Ridge just one last time and take in the beauty of his homeland.

Lost in his thoughts, Mordecai was taken by surprise when a loud booming sound erupted from the ground next to him. A powerful stream of water that had escaped from the seafloor pushed him onto his back. As he got to his feat shakily, another geyser exploded, sending him galloping for shelter.
Mordecai made his way towards the only shelter in sight, a small rocky spine, darkened against the setting sun. He swerved through the exploding geysers, thrown off his feet every now and again. When he finally reached the safe zone at the base of the cliff, he pushed himself against the wall. He couldn’t believe he had made it.

The dark of night was all consuming down under the sea, and it was getting hard to see. Still shaking, he felt his way along the rock face hoping to find an inlay of sorts and sure enough, he soon felt his hands disappear into dead space. His eyes strained through the creeping darkness and he could make out the outline of a small cave, just big enough for him to fit into.

Manoeuvring himself into the cramped space, he felt something slide, quickly and soundlessly, past him. His body stiffened in fear and he let out an almost inaudible scream. He yelled into the cave to scare anything else lurking within, but nothing else appeared. The last light of day showed the silhouette of the creature heading off into the distance, its movement fluid and spontaneous.
Trying to calm himself after his treacherous ordeal, he reminded himself of his aim, over and over. Shaken and nervous, he watched the small mysterious creature disappear before letting himself slip off to sleep.

He rose early the next day, after a restless and uncomfortable sleep. Peering out of the cave, he searched his immediate area for the mysterious and possibly dangerous creature from the night before.

Finally emerging from the tiny cave, Mordecai climbed the rock formation he’d slept within, searching the horizon for the familiar shape of the Amissas Ridge, the rock-form that sheltered the m-RNA tribe. To his surprise he found that it broke the land’s monotony not so far off; his escapade the previous night had actually led him closer to home. Mordecai would be seeing his friends again before sunset at this rate.

The thought of seeing them again spurred him on with added zealous. Morley, Maddox, Meeko, Maverick and Marcella would be so excited to see him… at least he hoped they would be. He was reminded of Reva, so angry that he would leave without saying goodbye. He had done exactly that to his five best friends.

Would they be happy to see him again or furious?

After almost a full day of travel, Mordecai found himself at the base of the Amissas. Rather than going around the base of the large rocky mound Mordecai started to make his way up and over it. He paused at the top indulging in the familiar view. The sight of his home wrapped him up like a warm blanket. He took it in, his eyes tracing the landscape and settlement below – the knowledge that this could be the last time he sat atop this cliff made him want to tattoo it to his memory.

From a deep and dark part of his memory, the sound of his mother’s screams bubbled up. He relived the pummelling tidal wave experience from his memory. Saw his father fly away through the crashing and thrashing water. He shook his head violently as though it would get the images out of his head.

That’s it. I have to go. I can’t let something like that happen again. I just can’t.

Taking a deep breath, he started to make the decent towards the bustling and vibrant community of his clan. The closer he got, the tighter the nagging
knot in his stomach grew. He had no idea how he was going to be received by his friends.

An ecstatic shriek met Mordecai as he walked the short distance from the cliff to the settlement, shortly followed by the impact of bodies. Morley, Marcella and Maddox had charged him down, excitement and relief flowing from them.

“You’re back!” shrieked Morley, breathing a heavy sigh of relief and refusing to release him from her grasp.

“We were so worried, Morde! Where have you been? Come over here and tell us all about it.” gushed Marcella leading him over to Meeko and Maverick, a stoic looking pair.

The two boys met Mordecai’s gaze, it was clear that Maverick was furious with him. Meeko, however, was standing back and looked away guiltily.

Breaking the oppressing silence, Mordecai greeted the two of them, “Maverick, Meeko,” he nodded, then in his excitement to see them, gushed, “You guys are a sight for sore eyes! It’s so good to see you.”

“Good to see you too Mordecai.” Maverick gave in, “I was convinced I’d never get to say that again,” he said in a slightly snarkier tone.

Meeko still said nothing. His silence was more awkward than most.

“Come on Meeko. He’s back now. It’s alright!” Marcella said, goading him to welcome Mordecai home.

“Welcome back, Mordecai.” Meeko said tensely, his tone not angry, but stilted.

That seemed to be good enough for everyone and the questioning began once more. Mordecai resolved to make things right with Maverick and Meeko later and began to tell his tale.

“Well, I left here not really knowing where to start. I’m sure Morley told you why I left?” he looked around the group questioningly and noticed Meeko grimace at this. He carried on regardless thinking that maybe his discoveries might help break the tension between the two of them, “I travelled for ages, and you know what? It’s not all that fun when you’re alone!” he laughed, making some of the group giggle. “I actually decided to turn back after the
first day but while I slept the current took me way off in that direction.” he pointed back the way he’d come.

“Oh my!” exclaimed Morley, “How awful! I’m so glad you found your way back. You must have been very lost to have taken so long to get back.”

“Ah. Well, actually it turned out that it took only two days to get back here.” Mordecai said.

“Wait, then how come you were away for almost two weeks?” Maddox asked, enthralled by his friend’s adventure.

“Yeah. Why were you gone for so long?” Maverick cut in. “To make us suffer longer I suppose.” he muttered, just audibly.

Mordecai rolled his eyes at Maverick, “Don’t be ridiculous. I didn’t leave for any other reason other than to find a more protected place for us to live. The eruption is going to happen.” Mordecai stressed.

“How do you know?” Maverick retorted.

“Because, if you’d let me finish my story, I met some other RNA’s and they were preparing for the disaster that will be.”

At this, the small group of m-RNAs exploded with more questions and the scene they created attracted the attention of many others. A few of the elders near by approached to see what the fuss was about and when they saw Mordecai they yelled to the other members. Soon enough, the whole community surrounded Mordecai, waiting expectantly for his story.

Catching them all up, Mordecai continued from when he’d arrived at the r-RNA settlement. The knowledge of others living so close, sent a wave of concern through the crowd.

“What happened Morde? Did you talk to them?” Morley probed.

“Yes, I did. As I was saying; they were preparing for the eruption. Yes everybody, another volcanic eruption, like the one that was responsible for the tidal wave that took us here, is on its way but please, don’t panic because I have a plan.” he waited for the gathering to quieten again before he continued, “I made contact with an r-RNA and she took me under her wing and into her tribe. They were kind and welcoming – for the most part.” he added remembering Ruarc’s reluctance to help them. “They were building
walls of aminoes at each end of their settlement, deep within a canyon, to form a protective barrier against whatever is to come. It’s amazing how they manipulate those things to make them useful.”

“Are we going to do the same here?” Meeko piped up. Mordecai had finally caught his attention.

Thrilled to have broken through to Meeko, he shot him a smile but he was nervous to answer. He knew it might be an unpopular plan.

He cautiously broached the subject, “Well, I’m afraid I couldn’t do it. I tried to learn how to put the aminoes together like Reva, the r-RNA girl I met, and she tried to teach me but we just aren’t built the same as the r-RNAs. I couldn’t do it.”

Once again the m-RNA tribe burst into life as panic spread like a plague.

“What are we going to do, Mordecai? You said you had a solution!” pushed Marcella, looking at him desperately.

“I’ve made a deal with their leader. The r-RNAs need more aminoes to build sturdy walls in time for whatever the eruption will throw at us, and this is where we come in. I’ve offered up a team of us to go in search of the amino source and in return the r-RNAs will allow us to refuge with them.” A bleak and unbelieving silence followed Mordecai’s last suggestion. He looked hopefully at his gang, “Are you with me?” he whispered to them imploringly.

The five of them look at each other unsurely. After a tense pause it was Meeko that finally spoke.

“We have to.” he said to the group, “If Mordecai’s right, we can’t just stay here and do nothing. Besides, it could be an adventure!” The mischievous glint of his was back and he grabbed Mordecai, embracing him tightly, “I’m sorry… I just felt so guilty. I thought it was my fault that you left.” he apologised, a little awkwardly.

“It wasn’t your fault, Meeko. You didn’t cause that earthquake, did you?” Mordecai replied with a chuckle at the ridiculousness of it.

The crowd of m-RNAs was dispersing; Mordecai had left them with a lot to discuss. Leaving this place, that had been their home for many years, was not a decision to be made lightly. Mordecai took the opportunity to talk to his five friends about a plan of action.
“So you’re in?” he asked them.

“Well, I’m in Morde. Can’t let you have all the fun can I?” Meeko said, beaming with excitement.

“Me too!” Maddox raced to say.

Mordecai turned to the two girls and Maverick, “How about you?”

“Well to be honest Mordecai, I’m going to need some more information. You’ve been pretty reckless lately,” said Maverick. Mordecai could see that he still hadn’t forgiven him for leaving in the first place.

“Yeah… I guess I just want to know if you have a plan or not. Do you even know where to start searching?” Marcella chimed in, logical as ever.

Mordecai looked pointedly at Morley as if to say, ‘Are you really not going to help me?’

“Oh you know I couldn’t bear to see the three of you go without me,” she said despairingly, “but yes, can we at least make a plan. For example; do we know how much time we have to prepare? Will the r-RNAs really accept us?” and she continued this line of questioning until Mordecai halted her mid-sentence.

“Look you’re right you three. We do need a plan but at this point offering our help to the r-RNAs is our best chance at keeping our tribe together. They will accept us, I’m sure of it. Most were nothing if not welcoming to me. As for a plan, I think it’s best if we all make the journey back to the r-RNA settlement and work together; Rs and Ms combined. After all, the r-RNAs are ahead of us in preparations. They have elders that have experienced many, many eruptions -”

“Ok we get it. We need their help and they need ours. These r-RNAs you speak of are our best bet but what about the rest of the tribe? You expect them all to up and leave, just like that?” queried Maverick, coming around to the idea.

“I’m hoping that’s were you’ll help me.” Mordecai said, “Will you help me convince the tribe to come?”
His six friends spread themselves amongst the camp, testing their persuasive powers on the other members of the m-RNA tribe. Some groups needed less convincing, while others were adamant that they were staying. It took the best part of three days to get the m-RNAs to a consensus. Once the danger of the approaching volcanic eruption had been spelt out to them, many of the unsure members had changed their tune. Then, like all tribal beings, nobody wanted to be left behind, so even the most reluctant were convinced to relocate.

It took a lot to organise a travel party the size of an entire tribe, and by Mordecai’s fifth day at home they were ready to make the journey back to the r-RNA valley. They set off with the rising sun, Mordecai leading the way and Morley, Maddox, Meeko, Marcella and Maverick set to keep everybody moving and together.

The slower pace meant that it took the large troop of m-RNAs double the time it took Mordecai to arrive at the r-RNA trench. On the fourth day, Mordecai could tell they were getting closer but the longer they took the more anxious he got.

*What if they’ve left without us? What if they no longer need our help?*

It would deem them homeless, and far worse off than before, if his plan did not work. He was also feeling guilty about showing up with his whole tribe, instead of just a search team but what other choice did he have? He wasn’t going to risk leaving them there, exposed to the elements, any longer.

The oldest and youngest of the m-RNA pack were struggling. They were tired and weakened by the seemingly endless journey. Meeko, Maddox and Marcella were doing a tremendous job at keeping everybody’s spirits up; encouraging them to sing songs and tell old tribal tales the whole way. Morley and Maverick were taking responsibility for those falling further behind. Mordecai could not have been prouder of his friends and he couldn’t wait for the r-RNAs to meet them, especially Reva.

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At mid afternoon on the fifth day of travel, Mordecai led the bedraggled bunch down the slope to the entrance of the r-RNA canyon. He could see that in the time he’d been away, the wall-building progress had slowed and some of the walls had even fallen. Although this was disheartening Mordecai thought it might help the m-RNA’s case. It was simple; the r-RNAs needed help and they were there to provide it.
“Is this it? Are we here?” Meeko asked, his weariness fading for a second, giving way to excitement.

“Yes, we made it - finally.” Mordecai replied with a sigh of relief, “I think only a few of us should go in first, show some respect and all, and wait for everybody else to be invited in.” Mordecai suggested.

With his five friends at his side, they entered the valley through one of the many gaps in the flimsy amino-wall. There were a few r-RNAs working near by who rushed to greet Mordecai. Seeing their positive reactions made his friends relax a little more.

“Mordecai! Oh that’s wonderful, we are so happy to have you back.” said Rubena in a fond and motherly fashion, “Is this the search party? We really are struggling without the aminoes we need -”

“Now, now Ruby. Give the lad a minute.” scolded the man she had been talking to, “I’m Radek. Come with me and make your selves comfortable. You must be tired after your journey.”

“Oh. Yes, yes!” Rubena cried, looking a little sheepish. “I must tell Reva you’re here! She’s been so worried. What took you so long? Oh never mind, I’ll be back in a jiffy.” the robust woman waddled off at pace.

Radek led the group of m-RNAs toward the centre of camp and settled them in a comfortable spot. Mordecai was so tired he could have fallen asleep right there and then but the rest of his tribe’s entrance into the valley was a pressing matter that could not wait. Luckily he didn’t get a chance to rest; all the r-RNAs that wanted to catch up with him and meet his friends made sure of that.

Reva showed up with a tumble and a bump, embracing Mordecai fondly. After introducing his close friends to Reva, Mordecai explained why they took so long to return. The news that an entire tribe was awaiting entrance made Reva’s face crumple with concern.

“Oh, I see. Well I can’t say Ruarc is going to be too pleased,” Reva said, “but as you can see construction hasn’t been going too well and we really do need help. Come on, no point dragging this out.”

She led the team of m-RNAs to Ruarc, who looked to be deep in thought upon their arrival. He resided in a small hollow in one of the trench walls.
Reva cleared her throat loudly at the entrance of the small cave and Ruarc turned around with a start.

“What do you want Reva?” His voice was harsh but there was a twinkle of affection in the old man’s eyes.

“Hi Ruarc. Sorry to disturb you but the m-RNAs have arrived.” she explained.

“What? They came back? I thought we’d seen the last of them.” he said slightly confused. Then peering out he saw them just beyond Reva and regained his composure, “So you still want to help us then? Is this your search party? They’d better be good.”

“Good evening Sir,” Mordecai addressed him, “Yes, we have come back to help you. These are my friends; Morley, Maverick, Marcella, Maddox and Meeko.”

Meeko leapt forward as his name was called, “Pleased to meet you Sir,” and his exuberance was hard to ignore.

“Are you prepared to go searching for these aminoes that we need young man?” Ruarc questioned, testing him.

Meeko puffed up his chest replying, “I sure am. You couldn’t find a better team than us. We are always searching for a bit of adventure.”

“This will not be an adventure. This is serious.” Ruarc retorted.

“With all due respect Sir, whether the reason for embarking on a journey is serious or not, has no affect on whether it is an adventure or not.” Meeko replied in earnest.

Ruarc cracked a small smile and it was apparent that Meeko had passed the test, “Alright Mordecai, it seems your team is raring to go. I see no reason to keep you here any longer.”

“Yes Sir, indeed, but before we leave to help you,” said Mordecai reminding him gently of their purpose, “There is something you should know. I had to bring my tribe with us. They are currently just outside the entrance to your valley.” he spat out hurriedly.

“What do you mean? Your tribe is outside my walls and wanting to come in? You haven’t earned them a place in here!” Ruarc exploded.
“He had no choice, Ruarc. He couldn’t leave them there out in the open waiting for the eruption to destroy them.” Reva jumped in, defensively.

“I couldn’t leave them unprotected while I left them to help you. Surely you of all the RNAs could understand that.” Mordecai said, stressing the point.

After a long rant, Ruarc finally calmed down enough to say, “Well you haven’t given me any choice have you? I can’t have hundreds of RNAs on my doorstep. It just won’t do. Let them in and get out of my sight. All of you.” He retreated back into his cave mumbling what sounded like, “Where do you think we are going to put all these strangers!”

“I’ll gather my search team and leave in the morning too.” Reva said, backing away from the angry elder.

Once they were out of earshot, the m-RNAs whooped with triumph.

“We did it!” Mordecai exclaimed.

“Gosh, isn’t he scary though!” said Meeko, “I almost swallowed my tongue when I realised I had talked back to him!”

“Oh, he’s not bad. He just likes everyone to think he’s a grump but he’s a softy really,” Reva said as they parted ways to prepare for the next day.
CHAPTER SIX
MEEKO’S DISCOVERY

After they had brought in the m-RNA tribe, the excited mingling of the two tribes had escalated into a full-blown celebration. All the fatigue from travel had dissipated and the party raged on for half the night – even old Ruarc showed his face for a while.

Those who were part of search parties woke early the next day with great reluctance. The party may have been fun but it had not been a wise decision to stay up half the night. Yawning widely, they met with a select group of elders at the far end of the canyon; away from the sleeping community. As the group of six m-RNAs made their way there, the mixture of M’s and R’s sleeping together in groups was testament to the success of their integration. This meant Mordecai could leave with a lighter heart; knowing his tribe was safe and happy here was a real relief.

“Ah the m-RNA team is here, we can begin.” Radek announced as they approached the two r-RNA search teams. He was appointed by Ruarc to make the arrangements, as he was an expert on the tides and amino trends. He was sure to send the teams in the right direction.

“So according to my observations, our best bet is to set each of you off in different directions. Amino-frequency tends to vary with direction of the sea-currents.” Radek explained, “The most aminoes wash through here when the current is pushing water from the north,” he signalled, “A lesser amount, though still significant comes from the East at times. As this is all we’ve got to go on both of your teams should head North in slightly different courses,” he said pointing to Mordecai and Reva, “While the remaining team heads East.” he concluded confidently.

“Sounds good to us,” confirmed Mordecai, and the other two team-leaders agreed.

After saying their goodbyes each team set out on the hunt for a plentiful source of aminoes.

They had been travelling for some time now, with Maddox and Meeko playing around, Marcella chatting idly to Maverick, and Morley ahead with Mordecai, plodding contently.
“So you like her, huh?” Morley broke her and Mordecai’s comfortable silence, snapping him out of his daydream.


“Reva! She’s very nice and you two get along well don’t you? So I figured you must like her, that’s all.” Morley pointed out, feigning innocence.

Mordecai’s cheeks flushed crimson, “Shhhh. I don’t want the others to know. They’ll just tease me and I have no idea how long we’ll be on this trip!” Mordecai said jokingly, in fake-exasperation.

“Yeah ok. I just thought you might like some pointers is all…” Morley said slyly, causing panic to settle on Mordecai’s face.

“What do you mean pointers? I don’t need dating-tips! Do I -?” he started to fret.

Morley didn’t get a chance to answer as Marcella called out from the top of a large boulder she’d climbed, “Hey guys! I can see a heap of aminoes on the horizon.” Straining her eyes against the glare of the filtered sun, she continued, “We should head that way to meet them, it might give us a clue as to where they came from.” she said, instructing them to veer off their current course, a little.

Mordecai agreed quickly, shaking Reva from his mind and reminding himself of the important task at hand. If he was honest, he had no more idea where the aminoes came from than anyone else.

They continued along and eventually he began to feel drowsy. He looked back to see the others lagging. Meeko was trying to pep them up, but even his high-energy personality was fading.

“Time to make camp I think.” suggested Mordecai to the expectant group. They all nodded in weary agreement. “First we should find somewhere that is sheltered. We don’t want to make the same mistake I did and get taken off by the current in our sleep.”

The group searched the desolate landscape but there wasn’t much in the way of shelter nearby.

Maddox pointed towards a small rocky outcrop not too far away, “Will that work?”
“Yeah, I suppose it’ll have to do. Not many other options, huh?” Mordecai patted him on the back and the group made their way over to them.

As luck would have it, the rocks were larger than they had appeared and Mordecai chose a spot amongst them between three of the largest. He figured that in this spot, even if the current changed while they slept, they’d be sheltered from all directions.

They all made themselves comfortable and after a while settled into sleep; Maverick taking a little longer than the others as he convinced himself that this was the safest place on offer.

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When Mordecai woke he noticed that there had been a change in the current. It was now coming from due north and the aminoes Marcella had seen upon the horizon were making their way towards the slumbering travellers.

*What a pain!* Mordecai thought with a grumble. *This will make for harder travelling.*

He wondered how everybody would fare with the added resistance of the water against them. He hoped Morley was going to be able to keep up – she was smaller than the others.

Rolling towards the rest of the group, he quickly realised that there were only five of them sleeping soundly – Meeko was missing! Alarmed, Mordecai leapt up; *What if something has happened to him?* He scrambled around the rock behind him to get a better view of the plains beyond, and what he saw terrified him.

A little way off he saw a group of - well he didn’t know what they were - surrounding Meeko. The small creatures had large, bobbly heads with two squiggly tentacles coming straight out of them. They were darting around Meeko speedily. The strange things began to link to one another, forming a writhing mass. To Mordecai’s horror the form they took was a menacing circle encroaching in on Meeko, trapping him.
Jumping into action, Mordecai woke the sleeping group suddenly.

“What? What’s wrong?” Maverick asked, immediately assuming the worst.

“They’ve got Meeko. Hurry!!” Mordecai yelled, his voice cracking in fear; “We have to shoo them away!” he instructed, waving wildly in Meeko’s direction.

The others followed him without question. The five m-RNAs bowled at the strange swarm that surrounded Meeko, screaming and yelling madly.

With another stroke of luck the mob of unfamiliar creatures scattered and flitted away at high speed. The gang rushed at Meeko to make sure he was unharmed.

“Are you alright?” Marcella screeched.

“What were those horrible things?” Maverick said, disgust in his voice.
“Guys! What did you do that for? What do you mean by horrible things?” Meeko broke in, confused and disappointed.

His response flawed the group.

“We just saved you, Meeko. What did you expect us to do? Leave you?” said Mordecai said in disbelief, “I saw them! They were closing in on you!”

“What? Closing in on me? No! They were playing with me! Aren’t they beautiful!” Meeko finished dreamily, in wonder of his new discovery, “just look at them.”

The team focused their attention on the horde, which had settled not far off. With the new light Meeko had shed upon them, the swarm appeared different. They danced and flickered, moving together as one. The way the swarm linked on to one another made for silky, flowing transitions into beautiful flickering shapes. Meeko was right; they had a playful quality to them.

“See.” said Meeko, observing the others as they ogled his new friends, “I woke up to one of them tickling me! I followed it out and found a whole school of them. They started to play with me but then you all ruined it when you chased them away.” he finished a little sulkily.

“I’m so sorry Meeko!” Mordecai said, sincerely feeling horrible. They had been harmless, and as he looked at them moving around gleefully in the distance he understood Meeko’s disappointment.

“Did you know what they were, Meeks?” asked Morley, gazing longingly at them.

“No, I had no idea!” Meeko laughed and Maverick took his opportunity to scold him.

“Right then. So you could have got yourself in serious trouble couldn’t you?” he said.

“Gosh Maverick! How many dangerous things do you know that lure in their prey by tickling them?” Meeko said incredulously and this argument was enough to send everyone, including Maverick, into uncontrollable giggles.

“Well we’d better get moving anyway guys. Sorry.” Mordecai said regretfully.
Reluctantly turning their attention back to the search, the group was surprised to find that the aminoes Marcella had described were just a short distance away now. The current, increasing in strength, was forcefully pushing the debris towards them. Mordecai felt triumphant, they were surely on the right track with the amount of aminoes upon them!

They set off, battling against the current. Shortly, steady streams of aminoes were floating past the small group. There was definitely more than Mordecai had ever seen and the others confirmed this enthusiastically. They had to be close to where the amino-building-blocks came from and this knowledge spurred the group forward, despite the harrowing current.

The amount of amino units that were sweeping past them was relentless and the group was forced to weave their way through in order to avoid collision. They were approaching a large ridge that appeared to be the fount of the intensifying amount of debris.

Fighting their way through, they finally reached the sheer cliff face of the ridge. They pressed hard against it for protection from the mad amino cascade. When they looked up they could see the varying shapes of different amino-building blocks. They were being catapulted over the rocky landform that towered above and washed down past them. There was no doubt in their minds now; they had found the source.

In all the excitement, Mordecai looked around to share it with Reva, only to remember that she was far off in another direction. Slightly embarrassed, he was thankful the others couldn’t read his mind; although he had a suspicion that Morley was on to him.

Morley and Mordecai decided to climb to the top of the ledge and take a look at what they had discovered. They were absolutely convinced the source would be waiting for them on the other side.

“You guys make camp here, we need to rest. You all look like your sleep walking!” Mordecai commented cheerfully, “We’ll climb to the top of the cliff and take a look at what we have got ahead of us tomorrow. We did it guys! I think we’ve found it!”

While the others gratefully rested their exhausted bodies, gushing about their probable achievement, the two climbers made their way gingerly up to the apex of the jagged wall. When they reached the top, water whipped around their heads causing their vision to blur, however, that did nothing to hide what was in front of them. A pyramid of aminoes towered in front of
them; the pile so high that the top layers were being lifted off and over the cliff by the relentless current. If Mordecai was seeing things correctly, there had to be thousands of the precious building blocks. Enough for at least half the r-RNA wall! A shadow cast itself upon their triumph; this was clearly not the source, merely a spot where the units had accumulated.

Making his way, with Morley, back down to the group, Mordecai tried to hide his disappointment. After all, they had found enough aminoes to make a start, and the sooner they started the more likely it would be that they finished before the eruption. That ticking time bomb had been weighing heavily on Mordecai.

“Just on the other side of this cliff face is a giant stack of them.” Mordecai reported back to the group as he slid down the last bit of the ridge, “I’m talking thousands, enough to finish a portion of the wall! We should sleep here and go check it out when we wake.” he concluded triumphantly, “Hopefully this current subsides by then.”

They began to get comfortable, curling up together under the rippling water and stars beyond.

A large jolt sent them all sprawling. They got up unsteadily, the shaking seabed doing its best to get them off their feet again. They rushed, swinging from side to side on the wavering ground, at the cliff face to seek protection from the aminoes that had started to tumble down onto them. Reaching the rocky wall, they cowered silently under an overhang, cringing every time a heavy amino hit the rooftop. The shaking ceased, leaving the group restless and worried. It took everyone, especially Mordecai, a long time to fall asleep that night.

His mind was preoccupied with the thoughts that kept them all up. He replayed the event of many years ago in his head. He knew that the increased amount of earthquakes couldn’t mean anything good.

He also couldn’t stop thinking about the little creatures of Meeko’s; there was something familiar about the way they moved and it was bugging him. He searched the abyss of his mind for where this memory lay and finally, on the verge of giving up, he remembered. The ‘something’ that had frightened him on his journey home to the m-RNA settlement. He recalled the thing as it slipped past him in the little cave he’d slept in; it was the same movement he had seen today! A burning desire welled up from within; he had to find out what the creatures were. The new realisation did little to help Mordecai sleep but he tossed and turned until sheer exhaustion took him off.
They arose to a quieter, more settled world. The current had subsided and the amount of amino debris had decreased due to the stilled water.

“Come on! Let’s go and take a look at this mountain of aminoes!” exclaimed Maddox. Everyone was eager to share in what Mordecai and Morley had seen the day before.

Making their way around the rock face they eventually made it to the base of the immense amino-mountain. The size of the amino-mound was much more impressive from down there and the five travellers stared in awe.

Marcella and Maverick were eager to see how many aminoes each of them could carry back to camp, so they set about gathering them up. The m-RNA team grappled clumsily with the aminoes for some time, struggling to get a decent grip. Frustrated and weakened by their efforts, they slumped into a pile and gazed dejectedly up at the giant amino-mound. Mordecai was pulled out of his worrisome thoughts when Meeko suddenly broke the gloomy silence.

“Hey look!” Meeko shouted suddenly, “They’re back!”

Sure enough a hundred or so, tiny heads were poking out from behind the heap of aminoes but as soon as the m-RNA’s focus was drawn to them, the creature’s heads disappeared as though they never existed. The only giveaway was a few tardy tentacle legs flapping around the sides.

“They followed me!” Meeko squealed in delight. He jumped up and raced around the mound. The tiny creatures immediately began to play with him; a game of hide-and-seek commenced.

“Come back here, you naughty little monsters!” Meeko called to them, laughing elatedly and tearing of after the swift things.

The others watched him interact with them curiously. The creatures seemed to love Meeko; bounding up to him then back away again, circling him and sometimes tickling him with their wiggly little legs.

“What on earth do you think your doing?!” a voice as harsh as gravel boomed, putting an instant halt to Meeko’s performance.
Turning to see where the voice had come from, they were faced with a giant of a man. His intimidating stature, nothing, in comparison to the wrathful look upon his face. They were in some serious trouble.

“HOW DARE YOU STEAL FROM THE T-RNA TRIBE’S AMINO-STASH!!” he continued, irate.

Turning his hulking form, he beckoned to five equally enormous members of his tribe, ordering them to, “Take them back to the cave. We will decide what to do with them there.”

With that, the five t-RNA thugs scooped up the observing m-RNAs, but as the sixth made a move for Meeko the little creatures quickly surrounded him, forming a protective globe all the way around him, and span off into the distance, carrying Meeko with him.

“ARGGG. Those damn lipids!” the apparent leader cursed as they disappeared with Meeko.
Mordecai caught a glimpse of Meeko being taken off from under the arm of the thug that held him. He coughed and spluttered in protest, trying to get free and help Meeko but it felt as though a rock sat on his chest. The heart wrenching pain he recognised from long ago was back. He had lost somebody all over again.

Without another word to the captives, the t-RNA goliaths strode away.

Mordecai’s thoughts were scattered. Between his worry for Meeko and utter confusion at the situation they were in, he couldn’t piece together who the colossal Beings were. Let alone why they were taking them.

**What had he said to us?** Mordecai searched his memory in a desperate attempt to gain some information about their situation.

**Something about stealing… did he say they were from a tribe? Yes, what was it again… the t-RNA tribe? So they are RNA like us, but… no. Never heard of them.**

Maddox was frantically trying to get through to the beast that had him, asking question after question, and eventually earning himself a solid blow to the head. Mordecai signalled frantically to Morley, Marcella and Maverick to keep quiet. He knew one thing for certain; if they wanted to get out of this mess, brute force was not going to be the answer.

As they got nearer to the t-RNA colony, Mordecai strained to catch any more information about these folk, though he could hardly see anything past the ground bobbing below him. Hearing snippets of useless conversations, he tried to gather what he was going to say in order to rectify the situation; it was obviously just a big misunderstanding. The community was growing quieter; a few catcalls came their way every now and then, but a hush was present.

The gang threw them down in the centre of the t-RNA settlement, a large cave eroded into a crag. At the entrance, they saw piles and piles of aminoes stacked up and almost blocking it off – *that’s not going to be good for a mad dash*. They scrambled around on the floor to form a tight circle, in a pathetic attempt to protect each other.

“MORDECAI!!” screeched a voice that made his heart stop.

He turned around to see Reva and her search team being man handled by some more hefty t-RNAs. They were being held captive and it looked as if they had been there a while judging by their bedraggled appearances.
CHAPTER SEVEN
THE TESTING OF TRIBES

The t-RNAs were yelling abusively at the r-RNAs, who were giving back as good as they got. Reva and her search party were violently lashing out at the massive t-RNAs, despite their comparatively miniscule frames. Though they were doing little real harm to the t-RNAs, it was clear things had become very ugly between the two tribes.

Mordecai was scared. With the relationship between the two other tribes so bad the chances of patching things up and continuing on to save the M and R tribes were slim – even if the six m-RNAs were endowed with the gift of the gab.

_There are only five of us now_, Mordecai reminded himself, hoping fervently that Meeko was ok. He figured that he was probably in a better situation than they were, anyhow.

All of a sudden Mordecai was knocked off his feet. Soon everyone within the cave had joined him on the rough floor.

_Not again! The earthquakes come more often than Maverick groans now!_

The shaking beneath them continued still and the rocky room was stiff and silent. The only sound was the deep grumbling from within the land. They all waited, hoping nervously that the cave would hold up as rocks fell spontaneously from the roof. It went on and on this time, sending the piles of aminoes at the door throughout the cave. The large, irregularly shaped units were crashing into people causing screams of agony to echo throughout the dwelling.

For some time after the shaking had ceased, nobody moved. Fear permeated throughout the room. Slowly and shakily the t-RNAs began to check the cave and tend to those that had suffered injuries.

Mordecai scanned over his group and apart from a couple of very close calls and some minor scratches and bruises, they had come out unscathed. He could see through the mass of huge bodies that the r-RNAs were all right. The anger from before had momentarily disappeared and they were huddled together, clearly distressed.

From over by the entrance he heard the man, apparently named Tuhoi, gasp in despair, “Everyone is ok, but the aminoes didn’t hold up at all!”
“They weren’t packed in tight enough Tuhoi, that’s all,” comforted a young woman who, though slight, almost matched his towering height.

Tuhoi covered his furrowed face with one hand and leant against the curved wall of the cave opening, “I just don’t know what to do. The earth won’t stop moving. The waves are insane, and there’s nothing I can do to keep my tribe safe!” he said, searching the horizon intently, as though the answer to his problems lay out there.

Out of the corner of his eye, Mordecai saw Morley get up and make her way towards the t-RNA leader. She was a mere third of the man’s size, but none-the-less she rested a small hand comfortingly on his vast shoulder, uttering something Mordecai couldn’t quite hear. He was already bowling his way over there, ready to protect her from the beast, with Maverick and Maddox at his tail, when Tuhoi slid down the wall and sat next to Morley amiably. Mordecai marvelled at his friend’s bravery and was curious to find out what she had said to him.

As they reached Morley and the two t-RNAs, they heard her say, “Maybe we can help? The r-RNAs over there do wonders with these aminoes. Back at their settlement they’ve bonded them together to make magnificent, solid walls.”

“Yeah, it’s pretty amazing what they can do,” Mordecai chimed in.

Tuhoi looked at Mordecai despairingly, their eyes level despite him being seated, “I just don’t know what to do. We have all these aminoes and we’ve been stacking them up to close the entrance to our cave off, but it’s no use, they just continue to fall down. As for those r-RNAs, they won’t help us I’m sure of that.” he spat.

The giant seamed far less threatening now. Mordecai could see that they were just as helpless as the rest of them and that they needed aid also.

“Wait there, I’ll go and speak to the r-RNAs and see if I can bring them round. Perhaps we can strike a deal.” Mordecai said, before making his way across to the r-RNAs.

They were huddled together and Mordecai could see Reva was spiritedly discussing something; it appeared they were formulating a plan. When he arrived to the scene Reva filled him in willingly.
“Mordecai! We are going to make a break for it. The earthquake did us a favour; those brutes are distracted now and we need to take advantage of it. We are going to take all the aminoes we can carry and escape,” she said in hushed determination, “Go on, what are you waiting for? Get your team together and wait for my signal!”

“Whoa, whoa. Reva, have you thought this though? Do you really think you could outrun the t-RNAs? They’re more than twice your size.” Mordecai asked incredulously, knowing how big a mistake this would be. “Even if you did manage to get away, how would it help? We’d be stuck with the same problem.”

“Oh, well –” she started, clearly put out, “If you don’t like our plan, what’s yours then? Huh?”

“Look, it’s obvious the t-RNAs are in as much trouble as we are.” Mordecai started.

“So?” interrupted another r-RNA, with attitude.

“If we help them, maybe they will help us.” said Morley, slipping in next to Mordecai. He was thankful for the support.

“As we can see, the t-RNAs have plentiful resources and are very efficient at collecting aminoes, but lets be honest, they have no idea what to do with them. You guys know how to manipulate the aminoes but don’t have enough to work with. Why don’t you offer your help and build them a wall – it won’t take long with all the aminoes they have lying around, and then maybe they will be inclined to supply you guys with the aminoes you need to build your wall.” Mordecai concluded.

There was a short silence while the r-RNAs mulled this over.

“It’s win-win guys.” Morley chimed in persuasively.

“Yes, I see where you coming from.” said Reva through gritted teeth, “Looks like we don’t have much of a choice do we?” With that she stalked off towards Tuhoi to make the offer. The niceties were spared.

“Oi! We’ll build you a wall if you let us go AND supply us with aminoes.” she proposed.
Mordecai cringed inwardly and rushed over to smooth things out, “What she meant to say is that the team of r-RNAs here are willing to build you a more secure wall, in return for your help with theirs. Help in the form of aminoes, which might I point out, you have plenty of.”

Tuhoi, surprised and desperate for help graciously accepted Reva’s offer, “Really? You would do that for us?” he said, overwhelmed with emotion. “We- we would be so grateful for your help, and of course, you can have all the aminoes you need!”

Reva was taken aback by Tuhoi’s change of tune and, with a nudge from Mordecai, thanked him too.

“Right,” said Mordecai brushing his hands together. “My work here is done.”

“Oh no. Don’t you even try to leave this cave!” Tuhoi thundered, panic in his voice, “This was your idea. You’re not leaving ‘till I get my wall!”

Mordecai hadn’t had any sort of plans but now it was very clear; leaving was not an option. At least, not until the t-RNAs had got what they needed.

The r-RNA team started work immediately; using the amino-building blocks that were scattered around the entrance, they began to bond them together. The structure was infinitely better than the piles from before and the t-RNAs could hardly contain their wonder and excitement. Many began bringing the aminoes to the busy r-RNAs to speed up construction and, for a while, this worked well.

As time moved forward, everybody began to feel tense; it was only a matter of time now till the eruption and t-RNAs started to become pushy. They could provide the aminoes much faster than they could be put together and their impatience was beginning to show.

“Here, hurry up. Use this one!” Mordecai overheard a t-RNA say to Reva, insistently.

Reva ignored the supplier as politely as she could and continued her work, though anybody could see she was grated. All along the wall, Mordecai could see similar interactions going down, and the construction site was becoming stressed.

“GET OUT OF MY FACE!” exploded an r-RNA, a little way off, in response to another pushy t-RNA.
All hell broke loose.

The fragile relationship between the two tribes had been hurt, and once again they were at each other’s throats. The m-RNAs looked at one another in shock and Mordecai heard Maddox groan, “Why can’t we just all get along?”

“Split them up! Split them up!” Mordecai shouted at his crew.

The m-RNAs jumped into midst of the fight, getting between the arguing tribes and trying desperately to calm everybody down.

“STOP IT! JUST STOP IT, EVERYONE!” Mordecai bellowed over top of the din, “Please, please. I understand everybody is feeling the pressure, we can all see the signs. The eruption is near.”

With that the t-RNAs began yelling at the r-RNAs to hurry up again, and Mordecai quickly realised he had taken the wrong tact. He could have hit himself for saying that.

“That’s not going to help, so pack it in!” yelled Morley.

“Yes, exactly. We need to work together. The r-RNAs are working as fast as they can, so stop pushing them. You were working so well together and the wall was coming along nicely. How’s the wall coming along now?” Mordecai questioned.
The two tribes took in the halted progress and seeing the error in their ways, Tuhoi stepped up to Reva, amino in hand, as a sort of peace offering. She took it gracefully and Mordecai swelled with pride.

Work resumed and Morley called Mordecai, Maverick, Maddox and Marcella around her. There was a hole in the circle that should have been filled by Meeko. They looked at it awkwardly before Maddox mournfully closed it.

“I wonder where he is?” he said.

“Yeah. I hope he’s all right,” Marcella chimed in.

“Mmmm.” Morley agreed, “If we want to get out of here and find him, we are going to have to make sure these two tribes carry on working together. They are just terrible communicators!” she exclaimed shaking her head.

“Yeah. You’re right, Morley. We should take up positions along the wall and sort out any disputes that may arise. That way construction won’t come to a standstill again,” Maverick chimed in.

“They need to realise that they each have the same goal and that they need one another to carry them out!” said Marcella shrewdly.

The team distributed themselves throughout the construction site, to set about their task.

It was almost the end of the day and the construction of the wall had gone much smoother with the m-RNAs stabilising the two tribe’s interactions. The wall reached half way up the opening to the cave and Tuhoi seemed very pleased with the r-RNA’s new technique.

Mordecai suggested ending the day; he had the foresight to see that a tired team would be edgy and the tenuous intertribal relationship couldn’t handle any more outbursts.

They retreated into the cave wearily and formed groups chatting idly with one another. Things were still tense between the Ts and Rs; both tribes setting themselves apart. After chatting with the r-RNA circle for a while Mordecai got up to find some answers.

He made his way over to the imposing figure that was Tuhoi, “May I join you?” he asked politely.
“Of course you can. How are you, Mordecai? I really have to thank you for helping us get along today. We would have got nowhere without you.” said Tuhoi gratefully.

“Oh that’s alright.” Mordecai said, pushing on with his agenda, “I actually wanted to ask you something, I’ve been really worried about my friend Meeko, you know the one that was taken off by those peculiar creatures -”

“Oh yes! Those blasted Lipids. Such a nuisance, they are! Seemed to like your friend a lot!” Tuhoi interjected.

“Lipids, did you say? Is that what they are called?” Mordecai asked, adding a little reluctantly, “They’re not dangerous are they?”

Tuhoi burst into booming laughter and those who’d overheard joined him heartily.

“Not to worry lad!” said a great big fellow, clapping Mordecai on the back supportively, though the effect was to send him flying forward, “the worst you could get from a lipid is a nasty tickle!”

“You could die of annoyance though!” chimed in a woman.

“Your friend will be fine! Let’s just hope the didn’t take him too far away, the little hooligans!” Tuhoi said, “They tend to get over excited.”

This relieved Mordecai somewhat but he worried still that Meeko wouldn’t be able to find his way back to them. He wandered back to the small m-RNA group that he found mingling pleasantly with a number of t-RNAs. Marcella and Morley had managed to convince Reva and a few of the other r-RNAs to join them.

Before long, the group of many tribes had dispersed and the sleepy m-RNAs snuggled in together. Before drifting off Mordecai had relayed what he’d found out to the group. They all agreed they could rest a little easier knowing Meeko wasn’t in any immediate danger.
CHAPTER EIGHT
GLOOMY PROSPECTS

It wasn’t long before the cave was awoken. All through the night the earth had growled angrily, sending shivers through the ground beneath the sleepless community. It was clear that they were quickly running out of time. The eruption was near; it could be days away now. Even hours.

A serious and determined attitude was commonplace the next morning. The severity of everybody’s situation, t-RNA, m-RNA and r-RNA alike, had become very real overnight. The temperature had risen catastrophically and the teams building the protective wall were suffering in the heat despite their ability to handle high temperatures.

For Mordecai, there was much to worry about; Meeko was still missing, time was running out and they needed to get back to their own tribes and build the protective amino-walls there, all before the earth’s explosion. In addition to the time pressures, there was also a very large question mark over whether the r-RNA construction would hold up against a powerful wave or whatever else the volcano threw at them. He hoped desperately that they had at least a week or two before the searing hot destruction reached them. The same worries haunted them all and the m-RNAs had a hard job keeping the r-RNAs on task as they kept suggesting they leave for home at any chance.

“Right that’s it. I can’t work in this heat anymore! Especially as it’s not even for my own cause!” said Reva with finality.

Mordecai overheard her exclamation and immediately dropped what he was doing, to placate Reva. It had become common knowledge that whenever Reva was on the warpath it was Mordecai who could calm her. It was his gentle logic and patience that cured her of her fury and stubbornness most of the time.

“Reva, I know it’s hard but think about our families.” He encouraged gently, “We won’t be able to finish the walls back at our settlement without the t-RNA manpower, will we?”

“We won’t get back at all if we carry on like this!” she fumed.

“Look at the progress you’ve all achieved though, you’re almost there.” Mordecai said.
“Yeah well... look I just don’t like all this shaking and grumbling beneath us. The earth is going to explode at any minute and we aren’t prepared at all!” she ranted manically.

Mordecai pulled her in for a hug and after fighting him off half-heartedly she melted into him, “We are all scared, and I know you’re tired. Don’t worry. We are doing as much as we can and that will be enough. I promise. We just have to stay focussed and get the work done. I just wish I could do more to help, I really do,” He said soothingly.

She took a moment and when she removed herself from Mordecai’s arms her tear-streaked face was set in determined resolve. She looked along the partially built wall and with her calmer point of view she could see that they were almost finished. Many of the r-RNAs we atop the vast shoulders of t-RNAs, filling in the last gaps to the outside world.

Tuhoi was making his way up and down the wall with words of encouragement for everyone. He created an inspired resilience in everybody he spoke to and had an intuition for who needed support and when.

As he walked past Reva she called out to him, “Hey Tuhoi! Feel like giving me a boost?”

He obliged, lifting her short little frame atop his shoulders with ease. Mordecai viewed the two of them working together guardedly and couldn’t help noticing that despite their feisty introduction and Reva’s anti-t-RNA ranting, they had become very friendly. Tuhoi tripped on an amino on his way over, sending Reva into a fit of giggles. Mordecai felt a knot tighten in his stomach, a nervousness that would not subside. He removed himself silently and made his way to the other side of the cave where Morley was taking a break with her friend Tilly of the t-RNA tribe.

“Oh yeah. I’ll try.” he said distractedly still looking at Reva and Tuhoi across the cave.

The two young women continued their conversation as Mordecai sat down; “Yeah it was amazing. They surrounded him and formed this – well it looked like a protective barrier around him and took him off.”
“Oh yes. They are very protective at times, and swift. They must have taken your friend to be one of their own,” replied Tilly, clearly intrigued.

“Wait, are you talking about Meeko?” Mordecai perked up, becoming immediately interested in the girl’s chatting.

“Yeah, I was just telling Tilly about Meeko and she asked where he was.” Morley confirmed, “It was bizarre how those lipid creatures formed that dome around him when Tuhoi threatened him.”

The mention of Tuhoi prickled Mordecai but he attempted to not let it show, “Seems crazy now that you guys took us captive not so long ago!” he said to Tilly amiably.

Blushing she said apologetically, “Yeah we t-RNAs are famous for our hoarding and I guess after all that work collecting them we are protective of our aminoes.”

“Hey, we understand! If you work hard for something, you don’t want someone else to get it for nothing, do you?” Morley interjected, quickly making Tilly feel better.

“Oh yeah, definitely!” agreed Mordecai, “but you have to admit its pretty amazing what we can achieve with a little teamwork. I recon in just two days the r-RNAs have achieved the same amount of work as back at the r-RNA settlement, and they’ve been working on it there for almost a month!”

“The r-RNAs sure know what to do with these aminoes,” said Tilly admiringly. “Well I’d better go and do my bit. We don’t have much longer and we’ve still got to help you guys out too.” she said and returned to the growing wall.

“She’s lovely!” Morley said as soon as Tilly was out of earshot.

“Yeah, there are a lot of RNAs I’m going to miss once this is all over.” said Mordecai sadly, “If we make it through, of course.”

“Ahhh. I bet there is one RNA in particular, isn’t there,” Morley said making wild gestations towards Reva.

Mordecai leapt onto her, struggling to stop her from being seen, “Stop it, Morley! Stop it! I mean it!”
“Oh calm down, Morde! Half the cave knows you like her, anyway.” she said and walked off smirking.

As she was sauntering away the land moved under them again and shook her off her feet, sending Mordecai into hysterics. Morley retorted by drawing a love heart and making kissing noises at him, causing him to recoil in embarrassment.

He was too caught up in this mortifying episode to realise that something within the cave had changed. It was like someone had covered up the sun; the cave had darkened, and not slowly, like it did in the evenings. There was an awful sucking, gurgling sound from outside the cave and the aminoes were rattling quietly in their bonds.

Nobody within the cave moved. They waited. For what, they didn’t know. It was as soon as the sucking sound ceased and the roaring sound swelled did Mordecai realise what was upon them. There was no erasing that noise from his memory.

“Everybody get back from the wall!” he shouted, “Get back. The wave! The giant wave is coming!”

An outbreak of panic occurred as everybody rushed towards the back of the cave; the t-RNAs bumping each other out of the way with their large shoulders while the Ms and Rs desperately avoided being trampled.

The very nearly completed amino-wall shook more and more as time drew on. The growling from the water outside was growing and all eyes were on the, now flimsy-looking, protective wall. Horrified whispers wound their way throughout the cave, all wondering if it was going to stand up to the destructive wave.

Reva was shrieking, “What about my family, what about my family?” while the other r-RNAs whimpered.

Mordecai wanted to go comfort Reva but upon listening to her complaint, Meeko flashed into his brain and he couldn’t move. He was paralysed with the thought of Meeko, out there and alone. His whole tribe had little protection and the disaster was here!

Time slowed down, making everything clear. As the immense load of furling water hit the entrance of the cave, it ripped apart the aminoes in chunks.
They were pushed into the cave along with the churning water, sending everybody turning around and round, within the cave.

Many were being battered against the walls and ceiling of the cave, while others were being pounded by the swirling debris. The large aminoes, some in single units, others in large blocks, were being hurled at the cave dwellers.

When the swirling, powerful surge had subsided the damage was severe. Many were dazed and confused; everybody defeated.

Mordecai’s protective instinct snapped into gear and forgetting any of his own ailments, he began to search through the rubble for his friends.

He found Maddox trapped under a piece of jagged rock that had been dislodged from the cave structure. Maverick was lying bewildered not far from the spot, with Marcella trying to rouse him.

“Marcella! Get over here and help me!” Mordecai called out to her frantically.

As soon as he’d yelled for help the large rock began to move. It was lifted up and off Maddox by what Mordecai recognised, could only be a t-RNA. As the
t-RNA put down the rock safely, Tuhoi revealed himself. Mordecai nodded at him gratefully and Marcella arrived with a still pretty out-of-it Maverick.

“Where’s Morley?” she asked Mordecai, worriedly.

He searched the scene and still saw nothing. Dashing around the perimeter of the cave, he scanned the area for her. Still nothing. He made his way to the wrecked wall to check she wasn’t under the shattered wall, but to no avail. His heart was pounding faster and faster, his face hot and his eyes watering.

*Where are you, Morley??*

A small, weak noise came from just outside the cave and Mordecai quickly shoved his long body over the edge. There she was; hanging from the cave opening, her arm lodged between the cave floor and a remnant amino.

“Morley! Thank goodness!” Mordecai spluttered.

He grabbed at her waist while shoving against the amino that trapped her. She winced in pain. He felt added pressure on the amino from somebody else but did not trust himself to look away from Morley. The amino finally gave way releasing Morley from its clutches. Mordecai swung her up and back onto the cave plinth with great effort. Rolling back in exhaustion, Reva’s alarmed face came into view.

“It didn’t work! It didn’t work!” Reva said, and crumpled down next to them, stroking the sobbing Morley, gently.

From their position at the mouth of the underwater cave they could see the expanse outside. Out of the corner of Mordecai’s eye, he saw something moving on the horizon. It was then that he realised that the roaring hadn’t ceased.

He turned his head toward the horizon, “No. No. That wasn’t it. That wasn’t the tidal wave! It’s not over!” he uttered in disbelief, pointing shakily towards the colossal frothing mass forming in the distance.
CHAPTER NINE
MEEKO’S RETURN

It took a few minutes before Mordecai’s exhausted body could comprehend what the colossal swell would mean. He pointed, mouth open, gaping at the horizon that was rolling forward towards them. He managed to make a gurgling noise to get the attention of Reva and Morley, and they gasped in shock when they saw what was to come.

They weren’t the only ones that had seen the turbulent mass in the distance. Tuhoi was yelling hysterically and waving wildly toward the imminent danger. The entire cave gathered along the entrance and took in the savage wave with a defeated solemnness. There was nothing now, no hope to grasp to. There was nothing they could do to protect themselves.

Whispers began to spread throughout the cave. They were more resilient than it appeared. Those strong and determined RNAs were refusing to give up and let the wave take them, even if it was a futile effort. To no surprise, Reva was among them. She had risen from the ground, wiping her teary face forcefully.

With gritted teeth she shouted to the mass of RNAs, “We need to run! We’ve got to flee.” Then, when the response she received was weak, she added, “What other choice do we have? We can’t just give up. What kind of RNA does that? Just give up.” she said shaking her head, “No. I’m making a go of it - we might just outrun that hateful thing!”

“But Reva, what about the injured? We are all so weak?” Mordecai asked, looking furtively at Morley who was looking out at the tidal wave with tired acceptance.

“I don’t know. I don’t know.” she said confused and emotional, “All I know is that I’m not letting it take me down!” fury was flaming in her eyes.

Tuhoi had appeared beside Reva, his jaw set in determination. “I’m coming with you, Reva.” And then with a solemn look around the many hurt, “I don’t see any other option.”

He appealed to his tribe’s people with the aim to convince the able bodied to go. All the while the swell was approaching and growing, roaring tremendously in the background. The terrifying churning noise that it created made Tuhoi almost impossible to hear.
Mordecai found himself in turmoil. Deep down he knew that there was a very small chance of survival if he left, but then there was no chance if he stayed. He had the beautiful and incomparable Reva giving him pleading looks, willing him to come with her, but next to him, weak and in pain, he had his dearest and oldest friend unable to flee. Did he go with Reva and make an attempt at survival, or did he stay and be taken by the wave, comforting Morley? The decision was wrenching at his heart, impossibly hard to make.

Tuhoi and Reva had recruited an able bodied group. None of the m-RNA’s had decided to join. Maddox was too hurt to leave; the rock that had crushed him rendered him unable to make the move. Marcella was refusing to leave him and Morley, concentrating all her efforts on making them comfortable and savagely ignoring the oncoming disaster. Maverick sat silently near the three others, his face stony with acceptance.

Reva turned to look questioningly at Mordecai, the group was about to leave; they had little time to spare. He met her gaze with regret; his decision had been made, he couldn’t leave Morley and Maddox. Reva gave him one last confused and disappointed look, and turned to leave. Mordecai was left with the sight of Tuhoi and Reva disappearing through the mouth of the cave.

With the troop making their move, Morley had a moment of clarity, realising the sacrifice Mordecai and Marcella had made. Seeing his anguished expression, she shouted at him, “What are you doing? Why are you still here?”

“What do you mean? Of course I’m still here. I wouldn’t leave you for anything.” he said soothingly.

“Your crazy!” she continued to yell, “Go. You have the chance to get away! Leave!” she desperately appealed to Mordecai, Marcella and Maverick.

“Do it. Quickly, you can catch them up. We don’t need you here.” Maddox added soberly.

The capable m-RNAs gave each other meaningful and anguished looks.

Just as they got to their feet to leave, shouts and cheers could be heard from those that had fled. Hurriedly, the m-RNAs scrambled to see what the fuss was about. They saw that the scene was unchanged, the great tidal wave was still charging on, however, there was a large, dynamic globe approaching them in great leaping movements. It had a jelly-like texture, and as it reached
the small group of escapees it swooped down, a slit rapidly opening in its side. In one foul plunge it engulfed them all.

Mordecai was horrified! He had just witnessed a creature, larger than he could have ever thought possible, swallow up the few RNA that had a chance of survival. Reva was gone. Tuhoi too. It had taken them all, and now, to Mordecai’s horror, the mammoth monster was heading straight for them.

Marcella began screaming, uncontrollably. Mordecai had given into despair. The rest of the cave gave way to a mixture of the two responses.

Mordecai got up and began pulling at Morley and Maddox. He had to get them away from the cave opening, and away from the approaching monster.

“Hold on,” said Morley to the struggling Mordecai, “Wait a minute... look at that thing! It’s made up of many tiny parts.” she said, peering at the creature intently.

“Morley, come on! We don’t have time to study the thing!” Mordecai screeched.

“No, really. Look!” she insisted, “It’s lipids! The thing is made up of lipids!” a small smile crept over her face.

Mordecai stopped what he was doing, his eyes scanning the huge globe. It was shimmering with the movement of a billion tiny creatures. Their two-pronged tails propelling the great swarm forward, through the turbulent water, in synchronisation. Morley was right; it was billions of the little lipids that had taken Meeko! They had made a dome, quite like the form that they had made, in protection of him, when they had first taken him away.

The swarm was almost upon them now and as the orb of lipids pulled up in front of the cave, it split again to reveal a hollow, cavernous interior. That was not all that was revealed. There, standing within the lipid-dome, was a sight to make the m-RNA hearts soar; Meeko appeared before them.

“Jump in, guys!” Meeko yelled at them over the roaring of the tidal wave and the beating of lipid tails, “Quickly, we don’t have much time! Everybody get in!”
From within the rippling orb, the t-RNA and r-RNAs that had been gobbled up, spilled out. They followed instruction from Meeko, quickly helping the injured on-board the lipid vessel. Marcella and Mordecai gathered Morley and Maddox, and clambered inside.

“Meeko! You absolute hero!” Marcella exclaimed, throwing herself around him in a suffocating embrace.

“Yes. Yes, Marcella. Good to see you too. Now get off! We have to go and get the others!” he said soberly, then shot them a classic Meeko grin, “To the r-RNA settlement!” he yelled out to the dome of teeming lipids, instructing them through abstract gestures.

Everybody within the hollow lipid globe was jolted backwards as the lipids began to propel through the water.

Through a few tiny gaps in the lipid globe, the world outside was exposed and zooming by at high speed. Inside the domed room, it was spacious and
calm; the roaring of the wave quieter, though never-the-less growing in volume.

It was clear that Meeko had bonded with the lipids in his time away, and could now influence them to do his bidding. He was steering them towards the r-RNA encampment that they had left long ago.

The growling and roaring of the great tidal wave was increasing rapidly. It seemed as though, even at the accelerated rate of the lipids encasing them, they would be swallowed up by the wave anyway – and who knew what would happen then.

Mordecai and Marcella, along with a sore Morley, joined Meeko at the forefront of the moving lipid capsule. Through a tiny gap made by the lipids, Meeko could see where they were headed and guide them all accordingly. As they m-RNAs joined him, he gave the team of lipids the message to veer off the current course. The message was relayed through the flickering lipids and throughout the sphere; quick as anything, they all veered off at the same time.

“Do you think we’ll make it, Meeks?” Mordecai inquired worriedly.

“I’m going to do my best to try,” Meeko said, ever the optimist.

“And what happens if we don’t?” Mordecai asked hesitantly, almost not entirely wanting to hear the answer. The lipids had provided hope and he didn’t know if his heart could deal with yet another failure.

“The structure they’ve made to protect us should hold up. We - “ he said indicating to the mass of creatures, “Managed to stick together in the last wave, and I saw what that did to that amino-wall you guys were building!” Meeko said, a little smugly, “You’ll try your best to protect us though won’t you, my little friends?” he said to the tiny lipid creatures, and they wiggled their little tentacles in agreement. The whispering noise that propagated throughout the encasing was rather pleasant and Mordecai shoved his fear deeper within.

He could only hope that Meeko was right.

Finally, with the ferocious wave pressing in on them, the trench that contained the r-RNA settlement came into view. Everybody within the extraordinary, lipid-encased, compartment, was willing the lipids on. There
were shouts of encouragement from M, T and r-RNA alike; however, they were drowned out by the thrashing water outside.

They were almost upon the trench; sinking low to pick up the RNAs within, but the wave was upon them. The mighty lipids fought hard against the swirling mass but they were beginning to be tugged out of the r-RNA ravine. The struggling mass was the only thing sheltering the community below from the destructive wave, churning above.

“Get in. Get in!” everybody shrieked, from within the orb.

With the lipids writhing against the immense force of the tidal wave, its searing heat weakening the bonds between them, the population of m and r-RNAs began to move swiftly into the protective compartment with looks of awed relief upon their faces.

With the help of old Ruarc guiding them, everybody clambered on board; the leader refusing to get into the giant orb until he was sure everybody was safe. The suborn old man was about to get in, when the lipids could no longer fight against the wave. Reva hung out of the vessel to grab him, but they were flicked out of the trench that had secured them to the seafloor and madly tumbled over and over through the turbulent ocean.

The lipids began to close the gap that Reva was hanging out of; fighting to stay together as the water whipped around them in all sorts of directions.

Thinking fast, Mordecai grabbed onto her, heaving hard to get her back into the dome. It was a futile effort; she was slipping out and pulling Mordecai with her.

Others had noticed the commotion, and despite their weary state, joined in the struggle, but not before her entire body, along with Mordecai’s head, had slipped out of the gap. He immediately saw what was pulling her out; she was holding on to Ruarc, desperately.

“Let go of me, Reva!” Ruarc was yelling up at her. “Save yourself!”

She stubbornly held on; “I’m not letting you go!”

Mordecai could feel more and more RNAs joining the fight to save them. The strain on his body was excessive and almost too much to bear but he also stubbornly refused to let go of her.
For what seemed an eternity fighting against the raging, hot water, a huge heaving force came from within the lipid dome and with a loud popping noise, the three distressed RNA’s slipped back through to join their tribes within. The lipids closed the gap quickly.

Attached to Mordecai’s lower half was Tuhoi, along with much of his tribe members. He thanked them all with sincere gratitude and embraced Tuhoi like a brother. This man was a good one, and Mordecai could no longer pretend otherwise.

The lipid globe was spinning and turning aggressively in the turbulent water but within, it was relatively calm. They seemed to have cracked it. Meeko was right; the protective lipids were holding up to the challenge and Mordecai could not have been happier.

He searched for Reva within the domed room; he found her fussing over Ruarc. The old man shook her off, and she turned to find Mordecai at her side. When their gaze met, admiration and gratitude beamed from her. She rushed at him, planting a kiss on his cheek, which flared red as the entire community began to cheer. He had been wrong; now, he could not be any happier.
Many, many years later, with Mordecai’s generation long past, the landscape of the world had changed drastically. The RNA beings, of this story, had made a home within their lipid-dome saviour; the lipids happy to provide them protection from the elements.

With all three tribes living in such close quarters, they were forced to interact with one another. Through joining together aminoes, the resident RNAs began to build. At first, what they produced did little for the community, but before long, the amino creations that would later be deemed proteins, began to make up a more complex and efficient place to live.

Eventually, with the structures they built, a miniscule civilisation was crafted within. The complex structure was later named by humans ‘the cell’. The RNA civilisation, within the cell, had created a power plant (the mitochondria), a postal system (the Golgi), rubbish collection (lysosomes), and for it all to run smoothly, a library full of instructions (DNA, held within the nucleus). These ‘cells’ became the first living things of this Earth and went on to become the animals of today – but that is another story entirely.
As for this story, like most, it will vary from teller to teller. It is an ever-changing tale, with new scientific information leading us closer and closer to the truth.