

Creativity:

A Philosophical Exploration

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Abstract

This dissertation explores new frontiers of creativity. Currently, the concept of creativity is limited, restricting us to a narrow view of the phenomenon. To remedy this, I investigate new cases of behaviour, entities and systems. To do so, I construct a definition of creativity that can be applied outside the domain of human activity, and examine a broad array of examples that are entirely new to studies of creativity. In doing so, limitations owing to our ability to recognize creativity are made apparent. I argue that a new way of approaching creativity is required to overcome these limitations, and propose a diachronic definition of creativity based on a general systems law. Using the diachronic definition of creative behaviour, I discover a number of creative systems at different organizational scales, including prion adaptation and biogenesis. I argue that these newfound examples of creativity, and the new definition that explores them, have significant implications for how we understand creativity.

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Introduction

The current concept of creativity is narrow, and needs to be expanded if it is to encompass what I will demonstrate to be the full spectrum of creative behaviours, entities, and systems. My research explores new frontiers, investigating new cases that lie well beyond the limited view afforded by the standard model of creativity. My research produces three important results. First, it amends the standard conception of creativity to make it more inclusive, and thus more comprehensive. Second, it produces a new definition that enables a unified, systems based approach to creativity research. Third, it lays the foundations for a new discipline dedicated to the study of creative systems to be established. Let me explain why each of these are important.

The concept of creativity

An incomplete or narrow view of creativity stifles important and potentially enlightening discourse on the subject. In their review of the field of creativity research, Sternberg and Lubart highlight this as one of the major roadblocks historically faced by studies of creativity:

Unidisciplinary approaches to creativity that have tended to view a part of creativity as the whole phenomenon, often resulting in what we believe is a narrow vision of creativity and a perception that creativity is not as encompassing as it truly is. (Sternberg & Lubart, 1999, p. 4)

The discipline of creativity research is still young, with serious psychological inquiry beginning early in the 20th century with the likes of Wallas and Guilford (Glăveanu, 2010). These early studies focused on the creative individual, and constructed psychological models of the creative process. The concept of creativity at this time was that of the lone genius, an individualistic and exclusive notion with roots reaching back to Greek antiquity and the idea of divine inspiration (Sternberg, 2003). Since then, the study of creativity has progressed, and the concept of creativity has broadened.

The number of disciplines involved in the study of creativity have also increased. In addition to psychology and social psychology, research is being done in the fields of sociology, education, economics, philosophy, art history, and aesthetics (Magyari-Beck, 1999). Although these various disciplines are all involved in creativity research, the studies of creativity undertaken in the various fields are essentially isolated. So while the study of creativity is multi-disciplinary, in that there are several disciplines that are involved in

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creativity research, there is no truly interdisciplinary study of creativity: as these studies are not joined together under a single banner to comprise a common enterprise. The result of this being that although the concept of creativity has become broader and more inclusive, it is not obvious that there exists a single, shared concept of creativity (amongst the various disciplines). Although the various disciplines involved in creativity research each have their own specialized concept of creativity, it would be accurate to say that there is a shared notion of creativity: a loose idea of creativity that accurately captures common intuitions.

The expansion of the study of creativity into new fields of study has been beneficial for our understanding of creativity. The conception of creativity and creative behaviour has broadened considerably. Despite the concept of creativity becoming more inclusive, and the various disciplines undertaking studies of creativity, the focus of creativity research has remained fixed. The subject of creativity research in each field is humans and human activity. The focus of creativity research must be expanded. A synoptic view of creativity requires that we include non-human entities and behaviour.

The focus of creativity research needs to be more comprehensive. To illustrate this, I present examples of animal behaviour which I argue should be classified as creative. Research into creativity and creative behaviour has, for the most part, focused solely on humans and excluded other animals. One explanation for this is that the majority of creativity research is done by psychologists, not biologists (Kaufman & Kaufman, 2004). Whatever the reasons, the result is that animals are not typically seen as being creative. Apes and dolphins are a possible exception; although their behaviour is often used as evidence for what is referred to as “animal intelligence” and not “animal creativity”.

The study of creativity does not need to be restricted to human behaviour. Although the products of human creativity are clearly distinct; no other terrestrial species have built cell phones, skyscrapers, or spaceships, this does not mean that other species are not creative. Human beings are the only species that do the butterfly stroke or the crawl, but this does not mean that we are the only species that swims. The fact that the products of human creativity are distinct does not provide sufficient reason to restrict an investigation of creativity to the domain of human activity.

My examples are not exclusive to the domain of animal behaviour, I will show that groups, evolution, and inorganic systems are capable of creativity. To argue that these new cases are creative, it must first be established what I mean by “creative” and “creativity”.

Essentially, a definition of creativity is required before the investigation of new cases of creative behaviour can begin.

The creation of a new definition

“Creativity” is a subject that is familiar to common parlance and discourse. We are comfortable using the word creativity to describe things like movies, standup comedians, and advertising campaigns. However, our familiarity with the term is no guarantee that our mundane use of creativity has any claim to precision. In fact, the opposite may be true. Buchanan argues that in our common usage: “There is no consensus, just considerable ambiguity, about what we call creative behavior or what is involved in this behavior” (2001, p.1) Before beginning an exploration, it is best to be clear about what is actually being sought after. Our mundane notion of “creativity” is arguably vague and imprecise; hence, some clarification is in order.

As it is well regarded in the field of creativity research, I begin with Boden's definition of creativity. In the course of the discussion and modification of the criteria that Boden includes in her definition, I produce my own definition of creativity, which is essentially a modified version of Boden's definition. I then apply this definition to animal and group behaviour, and demonstrate that they are creative. I use these newfound cases of creative behaviour to illustrate two points. First, that the singular focus on human creativity omits a great deal in terms of who and what can be creative. Second, that an exploration of non-human creativity will have limitations owing to our inability to recognize creativity in many organisms, collectives, and organic and inorganic systems. To overcome these limits requires a novel approach based on a new definition.

This new definition of creativity is framed in terms of general systems theory, and applies to creativity *over time* rather than instances *at a time*. To create this new definition, I essentially “translate” the criteria for my modified version of Boden's definition of creativity into a systems theory framework, which highlights an unmistakable pattern produced by creativity. This pattern is sufficient to identify creative systems, and forms the basis for my new diachronic definition of creativity: which is well suited to an investigation of non-human creativity. This new definition, and the systems that it defines as creative, have implications for our understanding of human creativity, as well as the study of creativity in general. I examine these implications in depth throughout the third part of the dissertation, and propose the establishment of a new domain of creativity research.

Establishing a new discipline

As I will argue, the conception of creativity, and the focus of creativity research, must be expanded. To do so, I present a collection of cases of non-human creative behaviour, and a new way to approach and understand creativity. Essentially, this constructs the framework for an account of creativity within systems theory, and lays the foundations for a new field of creativity research; the study of creative systems.

As much of the discussion rests on points that will be made throughout my dissertation, I will not present the full argument for establishing a discipline devoted to the study of creative systems here. This is not the only time that I have proposed that systems theory be used to study and investigate creativity (Ferguson, 2007), and I am not alone in taking this view. Takashi Iba recently made a similar, yet distinct argument for the existence of creative systems, and for the establishment of a new discipline dedicated to the investigation of creativity using systems theory as well (Iba, 2010).

Part One

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Defining Creativity: Boden and Beyond

Chapter One

The Criterion of Novelty

The beginning of wisdom is to call things by their right names -Socrates

1. Introducing Boden's definition

A definition is a set of necessary and sufficient conditions. To produce a definition of a term, one determines the limits within which the term is properly and correctly employed. This is achieved by elucidating both the general context within which the term is employed, as well as highlighting the important differences which separate the term being defined from cognate terms and associated concepts (Götz, 1981). The result is a specialized or *strict* definition for a term with greater precision than popular or mundane parlance.

In her book, *The Creative Mind*, Margaret Boden discusses creativity at length, and proposes a definition of creativity. My discussion begins with the definition of creativity that Boden presents in *The Creative Mind*, where: “Creativity is the ability to come up with ideas or artefacts that are *new, surprising, and valuable.*” (Boden, 2004, p. 1)

Boden is important in the field of creativity research. This chapter analyzes and modifies Boden’s definition of creativity as presented in her book, *The Creative Mind: myths and mechanisms*. The reason I have chosen her definition, and why I will spend a considerable amount of space here on an exposition of that definition, is that her work on creativity, including her definition and associated concepts, such as the distinction she draws between historical and psychological novelty, are widely recognized and utilized by others in the field (Perkins, 1995; Maher, 2008; Rickards *et al.*, 2008). Since it is current and well recognized, Boden's definition of creativity is an ideal starting point. Some exposition is required for my exploration of Boden's definition. This exposition will familiarize the reader with Boden's arguments regarding her definition, and couch the topics covered in this discussion within the creativity literature. For instance, to properly outline her use of the criterion of “surprise” requires an exposition of several hypothetical methods for the production of creative ideas. This exposition is necessary to outline the role that Boden intends “surprise” to play.

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I have two goals that will be achieved through my analysis and modification of Boden's definition of creativity. First, the analysis of Boden's definition will shed light upon what creativity *is*, by way of a discussion of the three criteria that comprise her definition. This chapter highlights and investigates ideas that are necessary for an understanding and appreciation of creativity. This involves the introduction and perustration of several of the subtle and thorny concepts and associated problems. Second, through a critical analysis of Boden's definition, I will modify Boden's definition to construct my own definition of creativity.

The purpose of this section is to identify the essential aspects of creativity, by way of an exposition of the criteria in Boden's definition. Boden's definition of creativity is clear, intuitive and insightful. This is not to say that her definition of creativity is without problems. I do not endorse every criterion that Boden includes in her definition, especially without modification.

The exploration begins with a discussion of the first of Boden's criteria for creativity: namely novelty. The discussion of novelty addresses the various types of novelty that Boden identifies and the role that novelty plays in her definition of creativity. The discussion will consider differences that separate novelty, creativity, madness and randomness. This discussion involves an examination of various types of novelty, in particular Boden's concepts of Historical novelty and Psychological novelty. I will also outline a third kind of novelty, Situational novelty, in addition to the kinds of novelty that Boden proposes.

The discussion of novelty will then address various novelty-producing mechanisms. This introduces the second chapter, which is an investigation of Boden's second criterion for creativity, "surprise": wherein various interpretations of "surprise" are proposed and examined. The chapter on surprise of examines generative rules, the related issues of exploration versus transformation, and analogy as they relate to differing types of creativity. The second chapter concludes with a study of the possible roles that Boden's concept of "surprise" could potentially play in a definition of creativity; and whether surprise belongs in a definition of creativity.

The third chapter examines the last criterion in Boden's definition of creativity: value. I argue that the value which we assign to ideas and artifacts is not fixed. The value of an idea or artifact is contextual, interdependent upon or inter-affiliated with a set of conditions. The chapter concludes by presenting my definition of creativity that emerges from my discussion

of Boden's definition. My proposed definition is essentially a modified version of Boden's definition.

2. Novelty and Creativity

"The very essence of the creative is its novelty..." -Carl Rogers

Creativity involves novelty. Creative ideas are new ideas. Creative inventions are new to the world. When we see something creative we might exclaim "Oh my, how creative! How did someone manage to come up with that?" or "I have never seen anything like that before, how creative!". We do not say "Oh my, how creative! That is totally derivative." nor "I can easily see where they copied or lifted that idea from, there is nothing new about it. Very creative!" Creative things are novel. We use the terms "Creativity" and "Creative" in the general context of popular parlance to refer to things that display novelty and originality. If we want a definition that describes what we understand to be creative, that definition must include novelty as a criterion. This is reflected in the definition Boden gives for creativity:

Creativity in general is the ability to come up with new ideas that are surprising yet intelligible, and also valuable in some way. (Boden, 2001, p. 95)

The necessity for novelty is illustrated in the picture of creativity provided by philosophical treatments (like Boden's), as well as psychological studies. "At the heart of most psychological studies of creativity is the notion of novelty or originality" (Wales & Thornton, 1994, p. 93) Novelty is the first criterion in the definition of creativity that Sternberg and Lubart provide: "Creativity is the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints). (Sternberg & Lubart, 1999, p. 1)

To be creative is to be (at least) novel, yet there are those who make a stronger claim. It is possible to overstate the importance of novelty. For instance, Hayes argues that novelty is so important (in regards to creativity), that it trumps skill and technique when determining whether a work is creative. Essentially, Hayes views novelty as the primary constituent of creativity: "No matter how well executed a work may be, it will not be considered creative unless it incorporates substantial new ideas not easily derived from earlier work." (Hayes, 1989, p. 135) . Brinsjord can be seen to be making a similar point, but this conception of novelty is tied in with radical causal autonomy (Brinsjord & Ferrucci, 2001).

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It is not necessary to go so far as Hayes, and claim that novelty is the *most important* aspect of creativity. It is possible to overstate the importance of novelty for creativity. To do so is to risk confusing the issue, and results in sloppy thinking and imprecise word use. Hausman says as much, and claims that imprecise word use was common in creativity research literature: “the terms “originality,” “original,” and their variants are often used interchangeably with “creative”” (Hausman, 1985, p. 29). Götz made a similar claim, stating that: “Most views of creativity currently in vogue fail to differentiate creativity from related words within the class” (Götz, 1981, p. 1). Götz criticized definitions for failing to “distinguish adequately between creativity and originality...” (1981, p. 1). To avoid making this mistake, creativity should not be viewed in terms of its novelty alone, to the exclusion of all else. There is more to creativity than novelty, and a balance must be struck. It is enough to acknowledge that creativity requires novelty, therefore a definition of creativity must include novelty as a necessary criterion.

Beyond the initial point that creativity *requires* novelty, there are two further claims that I will make in this section: (1) Novelty is necessary, but not sufficient for creativity: not everything that is novel is creative, and (2) Novelty is complex, as there are different kinds of novelty. I will address (1) first. In doing so, I will outline the issue of “madness and creativity” and show how it is relevant to our discussion. Although the point is first raised here, the issue of “madness and creativity” will not be resolved until later in the discussion of Value. I will then move on to examine (2): wherein I will illustrate various ways in which something can be novel. There are multiple ways in which something can be novel, which for convenience, I will refer to as different *kinds* of novelty. I will begin by examining the two different kinds of novelty that Boden identifies; historical and psychological novelty. This will be followed by an exploration of situational novelty. Each of these kinds of novelty correspond to a different comparative context.

“Comparative context” is my own phrase for the context within which, or in regards to, something can be determined to be novel. The relative nature of novelty, as well as comparative context will be explained in greater detail throughout this discussion. Now, let me begin with an illustration of the issue of differentiating creativity from madness.

3. Differentiating Creativity from Madness

Novelty is necessary for creativity, but it is not sufficient. Other things are novel without being creative. Novelty is sufficient to distinguish what is creative from what is derivative, but more needs to be said to distinguish creativity from various other “flavours” of novelty.

There is novelty (and unpredictability) in randomness: so is chaos *as such* creative? There is novelty in madness too; what is the distinction between creativity and madness? (Boden, 2004, p. 13)

There are novel ideas that are inane or trite, insane, random, and vandalistic or detrimental. For example, an individual committed to a psychiatric hospital might think, say and do some very novel things: things that no one has thought, said or done before. However, we should not intuitively assume that the thoughts, utterances, and actions of an individual confined within a psychiatric hospital are necessarily creative based solely on the novelty of those thoughts and actions. Of course, madness does not guarantee the absence of creativity, the novel ideas, utterances and actions of the mental patient are not necessarily uncreative. The fact that an idea is novel can inform us as to whether it is potentially creative, but it cannot settle the issue. More must be said to be able to differentiate creativity from other novelty.

A working definition of creativity must be able to separate creative ideas and artifacts from those that are novel but not creative. Hence, an appreciation of uncreative novelty is relevant to our discussion of a definition of creativity. This issue presents a problem that a definition of creativity must address. For Boden, the distinction between creativity and other novelties is *value* (Boden, 1992). A creative idea has both novelty and value. I will address this distinction in full later, in the section dedicated to value.

4. The Relative Nature of Novelty

Novelty is complex and contextual. There are several different *kinds* of novelty, which equate to differences in comparative context. Novelty is relative, and as such, cannot exist in isolation. An idea or object can only be novel in relation to other things, within a context. In order to find out if something is novel, you compare it to what has come before. For example, suppose you paint a picture and you want to know if it is novel. To find out, you would compare it to other paintings. If it is different, it is novel. However, there are several different ways in which you could compare your painting with others. You might compare your painting to others in terms of subject matter. Your painting could be novel, in that it is

the first painting that depicts *Jesus taking a break from making a chair leg on a wood lathe to eat an overflowing bowl of beef stroganoff topped with strawberries and sprigs of mint* ever produced. Alternatively, you might compare your painting to others in terms of technique or style. For instance, you might be using a new method of applying the paint to the canvas. Your painting could be novel as it is the first painting produced by building little egg-cup trebuchets and catapults to hurl paint at the canvas.

You could also make comparisons whereby your painting will not be novel. For instance, your painting is not the first to consist of paint on a canvas, and is also not the first to be made by a human. The painting of Jesus making a chair leg would not be the first representational painting. If you used brushes to paint, that would not be novel; and if your use of the little catapults to apply paint to the canvas is novel, you would not be the first not to use brushes to paint.

There are many ways in which your painting might be novel, depending on the manner in which it is compared with other paintings. I refer to the manner of comparison as the “comparative context”.

5. Novelty Within a Comparative Context

When one asks “Is Y novel?” it should be read as “Compared to, or in relation to X, is Y novel?” In this case, Y is a particular idea or object, and X is the context of the comparison. X can be very small and specific. For instance, X could cover a particular person at a specific point in their life, such as Thomas Edison at thirty years old. X can have a broader scope. X could be the Catholic Church, Pre-Socratic philosophers, the Soviet space program, or the Ramones. Broader still, X could stand for whole cultures or societies. X could be the Ming Dynasty, the Roman Empire, or the population of the Americas. At the broadest, X can be taken to mean *everything and everyone from the present back to the dawn of time*.

Comparative context is limited. The scope of X is temporally limited to the past and immediate present. Boden addresses the variable scope of X and the relative nature of novelty by creating a distinction between psychological and historical creativity.

...we must note two different senses of ‘creative’. Both are common in conversations and writings about creativity, and (although the context often supports one or the other) they are sometimes confused. One sense is psychological (I call it P-creative, for short), the other historical (H-creative). Both are initially defined with respect to *ideas*, either concepts or styles of thinking. But they are then used to define

corresponding senses of ‘creative’ (and ‘creativity’) which describe *people*. (Boden, 2004, p. 43)

Although Boden uses the terms “Psychological-creative” and “Historical-creative” (“P-creative” and “H-creative” from here), what is really being discussed here is novelty. The distinction that P and H-creativity highlights is the *novelty* of the creative idea in question; an idea is P creative if it is novel to a particular mind, or H creative if it is novel to all of human history. Since the relative novelty of the idea is the only variable in the situation, the word ‘creative’ in P and H-creative can be more accurately substituted with ‘novelty’. Here is Boden’s description of P and H creativity:

The psychological sense concerns ideas (whether in science, needle-work, music, painting, literature...) that are surprising, or perhaps even fundamentally novel, with respect to *the individual mind* which had the idea. If Mary Smith combines ideas in a way she’s never done before, or if she has an idea she could not have had before, her idea is P-creative – no matter how many people have had the same idea already. The historical sense applies to ideas that are novel with respect to *the whole of human history*. Mary Smith’s surprising idea is H-creative only if no one has ever had that idea before her. (Boden, 2004, p. 43)

The distinction between psychological and historical creativity is formed on the basis of comparative context, hence p- and h-creativity *really* differentiate between kinds of novelty. To establish novelty, an idea is compared with other ideas that have occurred in a given context. To be P-novel, an idea is compared with the previous thoughts in an individual mind. An idea is H-novel when compared with all the previous ideas in human history. The “comparative context” is the context within which the idea is compared; differences in comparative context equate to different kinds of novelty (in this case, H- and P-novelty).

The P and H distinction is an example of difference or variation in novelty. The P and H distinction highlights the connection between different kinds of novelty and differences in comparative context. Novelty is fundamentally relative; and the recognition of this is required for proper understanding of the concept itself. Novelty cannot be understood in isolation. To provide an accurate reply to the question “Is Y novel?” one must first determine X, the comparative context, or scope of comparison, that Y is to be evaluated within. To reuse Boden’s P- and H- novelty as an example, the answer to “Is Y novel?” where Y is Mary Smith’s idea, depends on whether we are limiting the scope of X to the thoughts that Mary Smith has had so far, or whether we are including the whole of human history.

6. Situational Novelty

There is more to novelty than new ideas or new artifacts. A significant portion of novelty occurs in the re-use of the old and familiar. We are constantly finding new ways to use and apply what is old and familiar. Just think of the number of uses that we have found for duct tape; there is novelty, and sometimes creativity, in this. There is novelty in new musical covers of old songs. It is common for bands to cover an earlier song. In fact, there are tribute or cover bands that do not compose their own songs, and instead play nothing but covers. When a band covers a song, musicians sometimes produce a version of the song that “stays true” to the original, and sometimes musicians will put their own spin on it. The “new spin” can be quite a radical difference. A band might cover a song using different instruments, or play at a different tempo. For example, the band, “Me First and the Gimme Gimme's”, play punk covers of the songs “Country Roads” and “Don't Cry for Me, Argentina” that sound wildly different from the original performances of those songs. The band “Apocalyptica” is composed of classically trained cellists who play symphonic covers of thrash metal songs. The cover versions of the songs may sound different, they are essentially a faithful reproduction of the song. These are not new songs, but *there is novelty here!* There is novelty in musical covers, but it is a different kind of novelty than composing an original song. One could say that a new *version* of the song has been produced, but it is not a new song.

The same can be said for virtuosos. Joshua Bell's rendition of *Chaconne* from Bach's Partita in D minor for violin is distinct to Maxim Vengerov's. Vengerov and Bell differ in their interpretation of a familiar composition. The singers Luciano Pavarotti and Enrico Caruso have both performed “Serenata”, yet the two performances are not identical. The vocal timbre of the two singers is distinct. Both singers differ on the tone and emphasis they put on certain notes. Although Bell, Pavarotti and Caruso are all performing songs that are not novel, there is a kind of novelty here. To deny this kind of novelty is to deny the creativity of symphony musicians, conductors, soloists, and opera singers. There is novelty (and creativity) in the performance of familiar works. However, this kind of novelty is different to the production of new ideas or artifacts. They are not composing new songs, symphonies or operas.

To address the novelty of cover music, performance of classical works, jerry-rigging, and others cases of novel reinterpretation, or re-use, I propose a third kind of novelty; Situational-novelty or S-novelty. S-novelty broadens the focus to show that the use or

implementation of the idea or artifact can be novel. The comparative context of S-type novelty is the set of previous uses or implementations of an idea or artifact.

The important question for S-novelty is not “Is this particular idea or object novel?” but rather “Is the use or implementation of this idea or object novel?” For example, imagine a chess master. During the course of her life she has entertained the thought “knight to rook 3” countless times. Today, she is at a tournament and in the middle of a championship game. In this particular game, her opponent has set up a familiar but cunningly different defense. In all of her years of playing, she has never encountered this particular arrangement of pieces before. Then, in a flash, she sees a brilliant and elegant opening in her opponent’s defense. The idea she has, as it turns out, is “knight to rook 3”. This idea is not H-novel, as doubtlessly someone else has entertained this idea before her. The idea is not P-novel either, as she herself has thought “knight to rook 3” countless times before in her life (she is a chess master after all, and a knight taking a rook is a mundane move). In this example however, “knight to rook 3” is a novel use or application of an old idea: She has not produced a P-novel or H-novel idea.

Another example of situational novelty involves the use of an object. I was staying at a friend's beach house, and noticed that the screws that held the gate on the fence at the front of the property were loose, causing the gate to lean downwards at an angle that prevented it from closing properly. I searched through the house looking for a flathead screwdriver, and was unable to locate one. Instead, in my search for the screwdriver I had looked through the cutlery drawer. I noticed that one of the butter knives had a rounded tip that looked as though it might be made to fit into the heads of the screws out front, and that the metal was thick and the edge dull enough that the stress of turning a screw would not cause it to chip or fracture. I took the butter knife outside, and it worked well enough as a make-shift screwdriver to that the gate was now able to be shut. In doing so, I did not invent a new screwdriver. After all, I did not produce the butter knife, I found it. This is not an example of a novel artifact, it is an example of a new use for a familiar artifact. The butter knife is not novel. The use of the butter knife is S-novel.

The focus for S-novelty is not entirely dependent upon the state of affairs, or situation itself. Otherwise, it would simply be a trivial sense of novelty, where every situation is chronologically and physically novel. If that were the idea, then *everything* would be S-novel. Rather than trading on the old saying that “one can never step into the same river twice”, S-

novelty is intended to capture the scenario of an old, un-original idea or artifact used in novel manner. To return to the chess example, supposing that instead of having the idea “knight to rook 3” in response to a challenging and original defense in her championship game, our chess master has the thought “knight to rook 3” in response to a boring defense she has encountered countless times before. In that case, “knight to rook 3” is not S-novel. The thought “knight to rook 3” is not a new idea. The punk cover of “Country Roads” is not a new song, the butter knife used to tighten screws is not a new artifact. However, there is still novelty in the punk cover, the use of the butter knife, and the implementation of the thought about the chess move. An old idea or artifact that is used in a novel way counts as S-novel: while an old idea or artifact whose molecular composition or spatial location is novel, does not.

Situational novelty does not contradict Boden's classification of novelty. Instances of situational novelty are either H or P-novel. The S-novel use or implementation of a familiar idea or artifact will be the first time for a certain person (P-novel), or the first time that anyone has ever done so (H-novel).

7. Novelty as a Criterion for Creativity

Exploring novelty, particularly the H, P, and S distinction, is the first step in solving the puzzle of creativity. My aim in proposing S-novelty is to shift some of the importance or focus from the Y (idea or object) and onto the X (the comparative context) when calculating novelty. One should not view novelty as a property of a particular idea or object. A more accurate conception of novelty is that it involves an interrelation between ideas/objects within a comparative context. S-novelty highlights this interrelationship by essentially ignoring the properties of Y (the idea or object itself does not have to be novel for S-novelty), and focusing instead on the relationship (the use or implementation of Y) of Y and X.

There are three claims that I have made about novelty in this section, (1.) that creativity requires novelty, (2.) that creativity does not have a monopoly on novelty, and, (3.) that novelty is complex and contextual: there are different kinds of novelty which equate to different comparative contexts.

Creativity requires novelty. Intuitively, we know that creativity involves novelty. The words “creativity” and “creative” are used to refer to artifacts or ideas that are new and different. Novelty is in the etymological roots of the word 'creativity'. 'Creativity' and

'creative' come from the English 'create', from the Latin *creatio* and *creō*: meaning “to create, make or produce”¹. To create is to *bring something new* into existence. Our intuitions about, common use of, and the etymological roots of the word “creativity” all show that to be creative is to be novel.

A strict definition of creativity can be expected to differ from the way the word is understood within the context of popular usage. Researchers studying creativity might use a more specialized (strict) definition of *creativity*. For the sake of precision, this specialized definition could differ in meaning and use from the use of *creativity* within the familiar or mundane parlance. Hence, a strict definition of creativity might not necessarily include novelty, despite the meaning and use of the term in the general context of popular parlance. However, in regards to the inclusion of novelty as a criterion in strict or specialized definitions of creativity produced and used by researchers, this is not the case. Within the research literature on creativity, definitions of creativity that include novelty as a criterion are ubiquitous (Boden, 1992, 1994; Amabile, 1996; Sternberg, 1998; Lubart, 1990; Eysenck, 1993; De Bono 1992; Rogers, 1954; Margolis, 1998; Runco, 2006; Sawyer, 2006). This is not to say that definitions of creativity do not differ, or that all definitions of creativity are identical. Rather, that definitions of creativity that include novelty as a criterion are in the majority. Hence, in terms of general context, etymology, popular parlance, and strict or specialized usage, creativity involves novelty; to the extent that novelty is necessary for creativity.

I have briefly sketched out the justification for my second claim, that creativity does not have a monopoly on novelty. If something is creative, then it must be novel: however, if something is novel it is not necessarily creative. In the earlier section on differentiating madness from creativity, I stated that madness can produce novelty without necessarily being creative. This is not to claim that it is impossible for those who are mad to also be creative. However, insanity is different from creativity, and our definition of creativity must be able to differentiate madness from creativity. In doing so, I have outlined a problem that a definition of creativity must address. Beyond identifying it, there is nothing more to be said about this problem within a discussion of novelty. To recognize and illustrate the problem requires an appreciation of novelty, however, to solve the problem requires more than novelty. The

1 From the Oxford Latin Dictionary, (ed) P.G.W Glare, 1983

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solution to the problem involves value. Therefore, further discussion is postponed, and the issue is addressed in the later section on value.

In regards to my third claim, that novelty is complex (there are several kinds of novelty) and contextual; I have highlighted different kinds of novelty that equate to differences in comparative context. There are discernable differences in the manner in which something can be novel (as evidenced by the H, P and S distinctions) which can appropriately be called different *kinds* or *types* of novelty. The H, P, and S distinctions support my claim, as they demonstrate that there are various kinds of novelty. Hence, novelty is complex. The H, P, and S distinctions also support the claim that novelty is contextual, as H, P, and S-novelty differ in terms of *comparative context*. This is not the end of the story, more remains to be said about novelty.

In addition to different kinds of novelty, Boden discusses differing degrees of novelty, and thereby introduces the second criterion in her definition of creativity: Surprise. To understand how there can be different degrees of novelty, as well as why Boden includes *surprise* as a criterion in her definition of creativity, let us now explore “Surprise”.

Chapter Two

The Criterion of Surprise

1. A Brief Outline of Boden's Use of Surprise

In this section I will discuss the second criterion in Boden's definition of creativity, *surprise*. As was the case with *novelty*, there is an intuitive association between creativity and surprise. We know that creative ideas and artifacts can be surprising. This association can be based on personal experience; where it is likely that you may have had a creative idea, constructed a creative artifact, or even encountered an example of someone else's creativity that surprised you. Creative ideas and artifacts can be surprising in a variety of ways. For instance, one could be surprised by how new or different a creative artifact is, or by the cleverness or elegance of a creative solution to a problem.

The power of creative ideas or artifacts to cause surprise is reflected in popular culture. A clichéd example would be the familiar literary trope of the new invention covered in a white sheet: Wherein, the new invention, covered in a white sheet, is wheeled out before an expectant audience. The white sheet is whipped away to reveal the invention beneath (the prototype submarine car, high powered laser cannon death-ray, or machine that converts ordinary household cats into gold) and the audience let out a surprised *gasp* en masse. The association with surprise also has a basis in famous stories about people being creative, and descriptions of the creative process (Hadamard, 1954; Poincare', 1913). In these stories, a moment of creative insight has surprised or alarmed the person who experienced them such that they cried out exclamations like “Eureka” or “Aha!”. First person accounts of producing creative ideas have described the results as sudden, shocking, and surprising (Boden, 2004; Hadamard, 1954; Poincare', 1913). Together, these personal experiences, social tropes, famous stories, and descriptions all act as evidence for the idea that creativity can be surprising.

Creativity can be surprising. However, this does not necessarily mean that creativity *must* be surprising. We know that creative ideas and artifacts can surprise us, but does something have to surprise us in order for it to be considered creative? To put it another way, *Does surprise belong in a definition of creativity?* Boden argues that all creative ideas are

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surprising, and includes surprise as the second criterion in her definition of creativity (1996, 2004). The reasons that she gives for the inclusion of surprise in her definition pertain in part to the general understanding that creativity can be surprising, but the crux of Boden's argument rests on a specialized role that surprise plays in Boden's definition of creativity. In this section, I will examine Boden's reasons for including surprise as a criterion in a definition of creativity. I will also discuss surprise in a more general sense, and determine whether or not surprise (in either sense) belongs in a definition of creativity. I will begin by providing a quick sketch of Boden's treatment of surprise.

In *The Creative Mind*, Boden is not only engaged in producing a definition of creativity, she also discusses the ways in which creative ideas are produced (2004). Boden proposes and outlines three mechanisms capable of producing creativity (creative ideas), and associates them with different *sorts* of surprise. "Creativity can happen in three main ways, which correspond to the three sorts of surprise." (Boden, 2004, p.3)

The different mechanisms that Boden describes are capable of producing different degrees of creativity. The criterion of surprise in her definition of creativity relates directly to her discussion of these mechanisms, and acts as an measure of creativity. This is to say, that unlike the other two criteria in Boden's definition (novelty or value), the role of surprise is to differentiate between different *levels or degrees* of creativity, rather than delineating what is creative from what is not creative. Boden claims that surprise is informative about creativity in two ways. First, Boden proposes that the more creative an idea is, the more surprising it is.

All creative ideas *are* unusual, and they *are* surprising – not least, to their originators. They may come to seem glaringly obvious ('Ah, what a foolish bird I have been!'), but they often announce themselves with a shock of surprise. Moreover, some are more surprising than others. Surely, the ideas which are 'more creative' are those which are more unusual? (Boden, 2004, p. 41)

Surprise informs us about *how creative* an idea is, as it acts as a measure of the degree of creativity exhibited by an idea. Second, the degree of creativity exhibited by an idea tells us which creative mechanism was responsible for producing that idea, as the different creative mechanisms produce ideas that correspond to three sorts of surprise.

To identify the different *degrees* or *sorts* of surprise, Boden introduces improbable and impossible creative ideas. An improbable creative idea, is an idea that is statistically unlikely, in other words, it is against the odds that someone would ever entertain such an

idea.² The explanation of a impossible creative idea is more complicated, and requires an appreciation of, as Boden puts it, the different *ways in which creativity can happen*. Improbable and impossible creative ideas are produced in different ways, and they (the ideas) produce different degrees of surprise (Boden, 2004).

Boden states that there is a distinct kind of surprise that accompanies improbable ideas, which is different than the degree of surprise which we experience when we entertain impossible ideas. The surprise that accompanies an improbable idea is weaker, shallow, or otherwise “less surprising” than the surprise that accompanies an impossible idea.

Many creative ideas, however, are surprising in a deeper way. They concern novel ideas that not only *did not* happen before, but that – in a sense to be clarified below – *could not* have happened before. (Boden 1996, p.76)

Surprise is a phenomenological sensation, and Boden refers to it as such in her discussion. The surprise that accompanies or announces a creative idea is described using phenomenological terms. “they (creative ideas) often announce themselves with the *shock* of surprise.” (Boden, 2004, p. 43) and “But what is crucial is the sort of surprise – indeed, the shock – involved.” (*ibid*, p. 41)

The shock of surprise corroborates with a common feature of several famous first-person reports of creativity. Authors who have described their creative experience have reported that the creative idea arrives suddenly, as if “out of the blue”. Hadamard was impressed by the sudden arrival of creative ideas, and commented on it in *The Psychology of Invention in the Mathematical Field* (1954). Other authors have discussed the *suddenness* of the formation or arrival of creative ideas, as well as that they (creative ideas) are often incongruent or seemingly unconnected to the conscious thoughts that precede them. Henri Poincaré's description of “a moment of creative mathematical insight”, given in his lecture on *Mathematical Creation*, fits the model of the sudden and unheralded (even surprising) arrival of creative ideas³.

Having reached Coutances, we entered an omnibus to go some place or other. At the moment when I put my foot on the step, the idea came to me, without anything in my former thoughts seeming to have paved the way for it, that the transformations I had

2 The statistical rarity of an idea is quantified in “creativity tests”, in particular the Torrance tests of creative thinking measure the Originality of a “divergent” idea in terms of its statistical likelihood.

3 “Mathematical Creation” in *The Foundations of science*. Trans. G. Bruce Halsted, New York, 1913

used to define the Fuchsian functions were identical with those of non-Euclidian geometry. (Poincare', 1913, p. 387)

Perhaps more famous is the story of Archimedes. The story goes that after puzzling over a perplexing problem proposed by King Hiero,⁴ Archimedes was relaxing at the baths when he hit upon the solution. Such was his surprise, that forgot to put his clothes back on and he rushed home naked, shouting “Eureka!”.

The phenomenal or experiential element of surprise has implications for its viability as a criterion in a definition. Including surprise in a definition of creativity has the potential to impose overly-strict limitations on who or what can be considered capable of producing creative ideas. This will be addressed at the end of the discussion.

The discussion of surprise proceeds as follows: First, I will examine Boden's more specialized use of *surprise*, starting with an illustration of the three ways of producing creativity that Boden proposes: combinational creativity, exploratory creativity, and transformative creativity. This involves an explanation of the role that surprise is to play in differentiating improbable novelty from impossible novelty. After examining Boden's proposed treatment of surprise, I will discuss surprise as it relates to creativity in a more general sense. It is here that I will address the phenomenal aspect of *surprise*, and how that affects the viability of surprise as a criterion in a definition of creativity.

2. Combination-theory creativity

In *The Creative Mind*, Boden proposes and outlines three ways that creativity can happen. One method of producing novel ideas involves combining old ideas together to produce new ones (ideas). Boden refers to this as the *Combination-theory* of creativity.

The first involves making unfamiliar combinations of familiar ideas. Examples include poetic imagery, collage in painting or textile art, and analogies. These new combinations can be generated either deliberately or, often, unconsciously. Think of a physicist comparing an atom to the solar system, for instance, or a journalist comparing a politician with a decidedly non-cuddly animal. Or call to mind some examples of creative associations in poetry or visual art. (Boden, 2004, p. 3)

Boden states that the combination-theory of creativity has two points to recommend it (Boden, 2004). Combination theories of creativity, like Koestler's theory,⁵ offers a

4 The problem posed by the king was for anyone to devise a test to find out if the king's crown was made of pure gold, without damaging the crown, i.e. cutting into it, in the course of the test

5 For an exposition of this theory, see Koestler (1975)

psychological, rather than romantic or mystical explanation of the creative process (Boden, 2004, p. 15). Second, the combination-theory provides an explanation of the production a broad array of creative ideas. However, the combination-theory of creativity also has limitations and problems. I will address each of these in turn, starting with the positive aspects and finishing with the limitations and problems.

The combination-theory of creativity eschews any romantic or spiritual explanation of the creative process. Combination-theories describe creativity in terms of strictly psychological operations (Poincaré, 1952; Guilford, 1967; Hadamard, 1954). Boden states that couching the creative process in the psychological schema appeals to people with “a scientific cast of mind”, who would prefer to see creativity as removed from romantic notions (such as inspiration from the *Muses*).

People of a scientific cast of mind, anxious to avoid romanticism and obscurantism, generally define creativity in terms of “novel combinations of old ideas.” Accordingly, the surprise caused by a “creative” idea is said to be due to the improbability of the combination. Many psychometric tests designed to measure creativity work on this principle. (Boden, 1996, p. 75)

The combination-theory of creativity fits with first-person accounts of thinking creative thoughts. In his narration of coming up with creative ideas late at night, Poincaré explicitly uses the word 'combination' to describe the experience of being creative:

One evening, contrary to my custom, I drank black coffee and could not sleep. Ideas rose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. (Hadamard, 1954, p. 54)

The underlying idea here is that being creative is something that produces a particular experience, as well as producing a creative idea. In other words, there is a phenomenal experience that is reliably associated with producing a creative idea which is somehow informative about the production of the creative idea itself. If this is the case, then a theory which described the experience of being creative in a way that is wildly different from our own experiences (as well as reports from others) of being creative is in trouble. If the experience of being creative is informative about the process itself, then providing an accurate account of the associated experience is important for a theory of creativity.

These include examples of poetic and scientific creativity that are surprising in their juxtaposition of familiar ideas, or in their use of analogy to connect particularly disparate concepts/ideas.

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Boden claims that the range of creative ideas that can be produced by combination is extensive, including poetic descriptions and scientific insight:

Many examples of poetic imagery fit the combination-theory account: think of Manly Hopkin's description of thrushes' eggs as 'little low heavens' or of Coleridge's description of water-snakes as shedding 'elfish' light. Scientific insights, too, often involve the unusual juxtaposition of ideas: remember the analogy Kekulé noticed between 'long rows', 'snakes', and molecules. (Boden, 2004, p. 41)

The combination-theory of creativity might plausibly account for the production of poetic metaphor and juxtaposition (as is the case with Hopkins and Coleridge), and scientific insight (Kekulé's combination of Ouroboros and the molecular structure of benzene), as in Boden's example. Combination theory can account for some artistic creations (such as "The Death of Socra-toad"),⁶ as well as being able to account for a number of technological innovations. Several familiar technological inventions might well be the result of combination-theory creativity, whereby a novel invention is created via the combination of two pre-existing artifacts. For example, one might justifiably present the clock radio as the result of combination-theory creativity (the clock combined with a radio), or as Grandpa Simpson quipped, "*the fax machine is nothing but a waffle iron with a phone attached!*"⁷.

According to the combination-theory of creativity, creative ideas are produced by combining familiar ideas. Boden states the some of these creative ideas will be the result of unlikely, and therefore unexpected, intersections of ideas. For Boden, this is where surprise enters into the story: Boden proposes that these unlikely ideas surprise us when we encounter them (Boden, 1996; 2004).

To be surprised is to find that some of one's previous expectations do not fit the case. Combination-theories claim that the relevant expectations are statistical ones. If so, our surprise on encountering an original idea must be a mere marveling at the improbable, as when a steeple-chase is won by a rank outsider. (Boden, 2004, p. 41)

Boden claims that we are surprised by these unlikely combinations of ideas because they are unexpected (Boden, 1996; 2004). However, Boden also claims that a creative idea produced by combination theory creativity is less surprising than a creative idea produced by one of the other two methods of producing creative ideas that she proposes. The combination-theory of creativity is limited in terms of the type of novelty it can produce (Boden, 2004).

6 "The Death of Socratoad", watercolour on paper, painted by the Author – An example of Combination-theory creativity. Created by combining two familiar ideas, "Socrates" and "Toad".

7 The Simpsons, episode 22, season 4, *Krusty gets Kancelled*

The limitations of the combination-theory of creativity are an issue that relates directly to the larger discussion of the three creative mechanisms proposed by Boden. She claims that the inability to produce ideas with a high degree of novelty means that combination-theory creativity cannot tell the whole story, or in other words, combination-theory does not offer a complete account of creativity.

The major drawback of combination-theories, whether as definitions of creativity or explanations of it, is that they fail to capture the *fundamental* novelty that is distinctive of the most puzzling cases of creative thought. (*ibid*, p. 41)

Explaining the production of creative ideas *purely* in terms of a combination mechanism is an oversimplification. Unlikely combinations of old ideas are enough to provide novelty, but they are not enough to guarantee creativity. If all that was required to produce creativity was the combination of typically unrelated ideas, then a creative machine or computer program could easily be constructed. All that would be required of such machine/program would be that it contained an extensive list of words from diverse fields, and a selection algorithm that produced statistically unlikely associations. To be creative, the machine would select two typically unassociated words and combine them to produce a creative output. We know that there is more to creativity than this. With no concept of usefulness or value, the combinations produced by our computer program could just as easily be insane or inane, as creative. Boden recognizes this, and addresses the problem by explicitly incorporating value, in addition to (surprising) novelty, as a necessary requirement for ideas produced via combination-theory to be considered creative. Boden states:

The concept of creativity is value-laden. A creative idea must be useful, illuminating, or challenging in some way. But an unusual combination of ideas is often of no interest at all. Strictly, then, the criterion of value (to be discussed in later chapters) should be explicitly stated by combination-theories, not merely tacitly understood (Boden, 2004, p. 41)

The explicit requirement of value keeps the combination-theory of creativity from producing insane rather than creative combinations. However, Boden states that people have creative ideas that are beyond the capabilities of combination-theory creativity (1996; 2004). The creative ideas produced by combination-theory creativity are “improbable-creative”, yet Boden argues that we are capable of producing ideas that are “impossible-creative” (Boden, 2004). To produce “impossible-creative” ideas, a different mechanism or “way that creativity happens” is required. Boden argues that impossible-creative ideas are produced in a different

way, and produce a different level of surprise when we encounter them. Having examined combination-theory creativity and improbable-creative ideas, let us now move on to explore impossible-creative ideas and the mechanisms that produce them.

3. A Brief Clarification of "Impossible" Creativity

Boden states that combinatorial creativity is capable of producing ideas with the degree of novelty required for improbable creativity, but not *impossible creativity*. Combinatorial creativity is only able to produce the unusual, uncommon, and statistically unlikely combinations of ideas that Boden refers to as the *improbable* kind of creativity. Ideas with the high degree of novelty required for impossible creativity are produced by a different kind of “creativity-producing” mechanism. I will introduce that mechanism here, but first, we need to appreciate how Boden utilizes the term “impossible” before we proceed any further.

For Boden, “impossible” means something like “Impossible to think within a particular paradigm” or more precisely, “Impossible to produce using to particular generative rules” (1996, 2004). To appreciate this special meaning of impossible requires an understanding of generative rules. To that end, I will now explore generative rules and conceptual domains.

4. An Explanation of Generative Rule Sets

Generative rule sets can be understood in terms of possibilities and limitations. Generative rules define what is possible by way of limitation or constraint. By limiting possibility, generative rules delineate what is possible from what is impossible. Hence, generative rules produce what can be understood as “domains” of possibility. One example of this is chess. The rules of chess, including board size, legal moves, and end-game conditions, create a domain of possible chess games. As long as you follow the rules, any game of chess that you play will be contained within that domain of possible games. Boden uses mathematics as an example of generative rules (2004). The example involves a sequence of seven numbers, 1, 4, 9, 16, 25, 36, and 49. These seven numbers are the squares of the first seven natural numbers. This particular sequence of numbers can be described by the rule ‘ S_n is the square of n (for $n = 1, 2, 3, \dots, 7$). On the other hand, the sequence can also be described by the rule ‘ S_n is the sum of the first n odd numbers’. When stated operationally, these rules are easier to comprehend.

Rule A:

Take the first number and square it, add one to the first number, square that, repeat.

Rule B:

Add the first number to itself, add the next odd number to that sum, take the total and add the next odd number to that. Continue to add the next odd number to the sum.

Boden says:

These two rules are called ‘generative’ by mathematicians, because they can produce, or generate, the series in question. They define timeless mappings, from an abstract schema to actual numbers. In mathematical terms, they are equivalent, since each can generate the numbers given above. (2004, p. 56)

Generative rules are not limited to mathematics. Language is another arena where generative rules exist; as is music, problem solving, painting, poetry, physiology, and many others. Each of these arenas contains a set of generative rules, which can be called a generative system. Generative systems have limitations and boundaries based on the generative rules that constitute them. If you take the total potential outputs and operations of the full set of included generative rules, then you have defined the generative system entirely.

Boden likens this procedure to exploration.

The creative mathematician explores a given generative system, or set of rules, to see what it can and cannot do. For instance: ‘Can it do addition?’ ‘Can it do subtraction?’ ‘Can it produce only odd numbers?’ ‘Could it have generated “ $365 + 1 = 366$ ”?’ ‘Could it have done “ $5 + 7 = 12$ ”?’ ‘Could it go on producing new numbers for ever?’ (Boden, 2004, p. 57)

The limitations of a generative system define a range of possibilities. Boden claims that thinking itself, in terms of possibilities and limitations is in some sense governed by generative rules (1996, 2004). The ‘impossible’ creative idea is an idea that is not possible (i.e it is unthinkable) within a particular generative system (defined by generative rules).

Boden uses Kekulé’s creation of aromatic chemistry as an example:

Kekulé created the possibility of a whole new science: aromatic chemistry (the study of the benzene derivatives). Indeed, he made possible also those areas of chemistry which deal with molecules based on rings made up of different numbers of atoms, and/or atoms of different elements. (Boden, 2004, p. 71)

Before Kekulé solved the benzene ring puzzle, the rules in the generative system of chemistry could not possibly create an output in the realm of aromatic chemistry. In other words, before the invention of aromatic chemistry, any idea about benzene rings (including

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Kekulé's initial discovery) would have been unthinkable, i.e. *impossible* rather than *improbable*. The distinction between improbable and impossible creativity should now be clear. However, if thinking is constrained by generative rules, then how could anyone ever think an impossible idea? Kekulé's thinking was constrained by the generative rules of chemistry which precluded the possibility of a benzene ring; and yet somehow he was able to entertain the idea. If the rules of a particular generative system limit the potential output of an individual's thinking, then how does one manage to create an idea that is impossible within that generative system? If thinking is constrained by the rules of a generative system, then an 'impossible' idea is still impossible: which is to say that it negates the possibility of its own existence.

Boden proposes two solutions to the problem of creative impossibility; which are exploration/transformation and analogy. Boden spends a good deal of time on the exploration/transformation solution. Her attention to detail and lucid discussion here is helpful, as there are some subtle and difficult questions that arise. In the following section, I will examine two questions that relate to the generation of impossible ideas. First, precisely what is being explored and transformed? Second, how does said exploration and transformation occur?

5. Explorers and Maps of Conceptual Domains

"In short, nothing is more natural than 'playing around' to gauge the potential – and the limits – of a given way of thinking." (Boden, 2004, p .56)

The exploration of a way of thinking is a testing of mental or conceptual constraints. The potential of a given way of thinking is defined by the possibilities and constraints of the generative rules that it consists of. The potential output of a given way of thinking about, or in accordance with, the possibilities delineated by a generative system is called a conceptual domain, or idea space.

A conceptual space defines a style of thinking: baroque fugue, modern jazz, chess, number theory, sonnet form, architectural styles, aromatic chemistry – not forgetting culture and cartoons. Conceptual spaces underly creative thinking and make it possible. (Boden, 1995, p. 1)

There are diverse reasons for exploring a conceptual domain, such as the gaining of technical expertise, mental exercise, conditions of employment, and natural curiosity: to name a few.

Exploration can even be motivated by boredom, as Martindale argues in *The Clockwork Muse* (1990). The motivations for exploration are varied, as are the methods of exploration:

Sometimes, mental exploration has a specific goal: doing subtraction by necklace, paying less tax, finding the structure of the benzene molecule. Often it does not. In this, as in other ways, creativity has much in common with play. Poincaré described the first phase of creativity – ‘preparation’ – as consisting of conscious attempts to solve the problem by using or explicitly adapting familiar methods. But what if there is no ‘problem’? ... Like much play, creativity is often open-ended, with no particular goal or aim. (Boden, 2004, p. 59)

Boden suggests that those who explore a generative system are simultaneously mapping it, or perhaps that the act of exploring a conceptual domain results in creation of a map of that domain. Here Boden discusses explorers of both the conventional and mental variety and maps:

Explorers usually make a map, and if possible they take some ready-made map with them in the first place. Some even set out with the specific intention of map-making, as Captain Cook circumnavigated Australia in order to chart its coastline. Maps do not merely offer isolated items of information (‘Here be mermaids’), but guide the traveler in various ways. (*ibid*, p. 59)

And specifically about maps of conceptual domains:

In short, the map is used to generate an indefinite number of very useful ‘coulds’ and ‘cannots’ (A list of landmarks is less useful: like the parroting of the first seven square numbers, it does not generate any new notions.)...., the maps in question are maps of the mind. These maps of the mind, which are themselves maps *in* the mind, are generative systems that guide thought and action into some paths but not others. (*ibid*, p. 59)

Boden presents a mental map of a conceptual domain or idea space as being identical with an understanding of the possibilities and limitations of a generative system (an indefinite number of very useful ‘coulds’ and ‘cannots’). This means that the exploration of a given style of thinking (generative system) is synonymous with the creation of a mental map of the possibilities and limitations of said generative system. Boden argues that the mapping of conceptual domains plays an important role in the production of impossible-creative ideas; in particular, mapping a conceptual domain is a necessary prerequisite step in the production of impossible-creative ideas *qua* analogy (2004).

The exploration of a conceptual domain does not produce impossible creative ideas, as the exploration of a conceptual domain is essentially a survey of what is *possible* within a

generative system. Impossible creative ideas result from where the exploration of a generative system naturally leads. The exploration or mental mapping of a given generative system plants the seeds for its own eventual destruction/transformation. By exploring a conceptual domain, we become acquainted with the generative rules which define the domain. Boden states that it is only a matter of time before we begin to test the generative rules, bending and transforming them.

Nothing is more natural than trying, successfully or not, to modify the current thinking-style so as to make thoughts possible which were not possible before. To put it another way, nothing is more natural than the progression from *exploring* a given style of thinking to *transforming* it, in some degree. (Boden, 2004, p. 58)

A thorough exploration of a style of thinking (generative system) that maps all of its possibilities and constraints makes it familiar. Familiarity with a generative system leads to boredom (Boden, 2004; Martindale, 1990). A well mapped conceptual domain provokes change, inspired by boredom and/or curiosity. Changing a conceptual domain is achieved by altering the generative rules that delineate the domain. Therefore, there is a natural progression from exploration to transformation, where exploration almost invariably leads to transformation (Boden, 2004).

6. Impossible-creativity via the Transformation of Generative Rules

“If you want to truly understand something, try to change it.” -Kurt Lewin

Boden provides several examples of the transformation of generative rules/systems. In this discussion I will examine just one of her examples in detail; that of the transition from tonal to atonal music. This transformation can be represented by a timeline, which would span several hundred years, charting a progression in musical composition that began during the Renaissance and continues today.

The ‘journey through musical space’ whose travelers included Bach, Brahms, Debussy, and Schoenberg was a journey which not only explored the relevant space but created it, too. And this creation, like all creation, was selectively constrained. (Indeed, controversial as it was while it was occurring, with hindsight it seems virtually inevitable.) (Boden, 2004, p. 61)

For Boden, the story of the transformation of tonal into atonal music begins with the creation of the generative rules of tonal music (2004). Essentially, the conceptual domain of tonal music was established by a set of rules regarding composition and, as the name implies,

tonality. Tonality is a system that based particular hierarchical pitch relationships on a central ‘home’ or ‘key’ note/tonic (Rameau, 1722). The listing of the generative rules that comprise the theory of tonal music is generally accredited to Jean-Philippe Rameau. Rameau describes the Minor-Major tonality, chord progressions, structure and cadence in his *Le traité de l'harmonie réduite à ses principes naturels*⁸ (Rameau, 1722).

The rules and resulting constraints of tonality were explored, mapped, tested and eventually transformed. Over time, composers and music theorists pushed the limits of tonality, bending and altering particular rules as they went, until the conceptual domain of tonality was transformed (Boden, 2004). The transformation of the generative rules of tonality, such as adherence to the home key, came to define the new conceptual domain of atonal music. Atonal music was created by composers such as C. Debussy, B. Bartók, A. Scriabin and A. Schoenberg, in particular Schoenberg's work produced after 1911 within the Second Viennese School (Baker, 1986; Griffiths, 2001). Atonal compositions broke the rules of tonality. Which is to say, *sensu* Boden, that within the system of tonality; Schoenberg's atonal compositions are impossible-creative. For Schoenberg (and the others) to produce their atonal compositions, the generative rules that constitute tonality had to be transformed.

It would be a mistake to view Schoenberg's creativity *purely* in terms of the transformation of generative rules. The exploration of the conceptual domain of tonal music that preceded the creation of atonal music is an important part of the equation as well. In other words, to understand the creativity of Schoenberg's compositions, we need to view them in relation to the creative explorations of tonality that preceded him.

The idea is not that if somehow, a composer in the sixteenth century produced an atonal piece, it would not have been considered creative. Whether or not people in the sixteenth century would have found atonal music creative is a matter open to debate. It is possible that atonal compositions would have been greeted at that time with rave reviews, and been generally seen as creative. It is also a possibility that atonal music would have been received poorly, and thought of as a cacophony rather than creative. However, regardless of whether people in the sixteenth century would have thought atonal music was creative, it would not have been creative *in the same way* as in the twentieth century. This is due to differences in the exploration conceptual domain of music at each period in time.

8 *Treatise on Harmony*

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If, by some miracle, a composer had written atonal music in the sixteenth century, it would not have been recognized as creative. To be appreciated as creative, a work of art or a scientific theory has to be understood in a specific relation to what preceded it (Boden, 2004, p. 74)

Since the conceptual domain of tonal music had not been as fully explored and mapped in the sixteenth century as they had been by the twentieth century, an atonal composition in the sixteenth century would not contrast so deeply with tonality. Atonal music required a full history of tonal compositions to transcend for the difference to have the same meaning:

Only someone who understood tonality could realize just what Schoenberg was doing in rejecting it, and why. Similarly, only someone who knew about string-molecules could appreciate Kekulé's insight. (Boden, 2004, p. 74)

The process of mapping the conceptual domain of tonal music was lengthy and gradual:

The conceptual space defined by tonality, its potential considered as a generative system, was so rich that mapping it would inevitably take a long time. In fact, it took several centuries. (Boden, 2004, p. 61)

The exploration of a generative system is typically a lengthy and gradual process, as it requires the development and application of skill and technique. For example, it would be impossible to explore the generative system of piano music, if one did not know how to play the piano. Exploration can also take a long time if the conceptual domain being explored is rich with possibility, as was the case with tonal music. Unlike exploration, transformation of a conceptual domain can occur suddenly. All that is required to drastically alter a conceptual domain is the transformation of a single generative rule. The question is, *how are generative rules transformed?*

Boden argues that the transformation of generative rules occurs through the implementation of heuristic rules (2004). Heuristic rules can be thought of as rules of thumb, rather than strict formal rules. For example, suppose you are interested in programming a computer to be able to play chess. You begin by programming in the rules of the game. A piece can only inhabit one square. A bishop is a piece that moves diagonally. A rook moves in straight lines. You continue on and on until you have exhausted the set of rules about the board, the pieces, and the conditions of the game. The computer program can now simulate the game of chess. However, this is not enough for the computer to be able to *play* chess. With the strict rules of chess, a program can only calculate the possible moves. To construct a

program that can actually play chess, it needs to be able to differentiate a good move from a bad move.

This is where heuristic rules are useful. For instance, the heuristic rule *Sacrifice a pawn to take a knight* would be a good addition to a chess playing program, as a pawn is considered to be a less powerful piece than a knight, in terms of movement and use. This means that trading a pawn for an opponent's knight is (usually) a good move. By *good move*, I mean one is one that is beneficial in terms of winning the game. As trading a pawn for a knight is typically a good move, this would be a helpful heuristic rule. With the addition of more helpful heuristic rules, the program would get better at chess. Of course, there are situations in which a generally helpful heuristic rule can be disastrous. Boden has this to say:

Most heuristics are pragmatic rules of thumb, not surefire methods of proof. Although there is a reasonable chance that they will help you solve your problem, they can sometimes prevent you from doing so. For example 'Protect your queen' is a very wise policy in chess, but will stop you from sacrificing your queen on the few occasions where this would be a winning move.(Boden, 2004, p. 65)

Heuristic rules can be very specific or broadly applicable. Heuristic rules about pawns, knights and queens will be useless for another game, like scrabble or roulette. Human beings are capable of thinking about a very wide range of subjects. Boden suggests that very general heuristic rules are used to transform or eliminate generative rules (2004). A general heuristic rule that Boden proposes is "Consider the negative":

...One way of getting a new slant on a problem is to negate some aspect of it, whether consciously or unconsciously. When this heuristic is applied to a structural aspect of the problem, as opposed to a mere superficial detail, it can change the conceptual geography in one step.(Boden, 2004, p. 66)

Boden continues on to explain the negation heuristic in some detail, as well as how it may have applied to specific cases such as Kekulé and the benzene ring. For our purposes however, the mystery of generative rule transformation has been solved. The story begins with the creation of a conceptual domain whose borders are defined by generative rules. The exploration of the conceptual domain occurs as curious individuals test the boundaries and constraints imposed by the generative system. Eventually, an individual tests a particular constraint using a general heuristic for constraint testing, the generative rule changes and the conceptual domain is transformed. With the transformation of the conceptual domain, what was previously impossible becomes possible. Hence, impossible-creativity can occur, and

when it does, Boden claims that we are more deeply or profoundly surprised by it than we were by the possible-creative novelties encountered during exploration. However, transformation of generative rules is not the only way that impossible creativity can occur.

7. Impossible-creativity via Analogy

The thinking of impossible creative thoughts, when it is not achieved through exploration leading to transformation, is achieved via analogy. Analogy begins in the same way as transformation, with the exploration and mapping of a conceptual domain. Producing impossible-creative ideas through analogy requires that the landscape of a conceptual domain is mapped. Instead of transforming particular generative rules using a general heuristic rule, an analogy is drawn between two or more conceptual domains. Through a mental comparison of two idea spaces, an individual can jump outside of the constraints imposed by a particular generative rule-set. This is achieved without needing to transform or eliminate any generative rules. One need only conceptualize the initial idea space as being shaped, or behaving according to a similar but different set of constraints. In other words, new ideas about what is possible within a given conceptual domain can occur by making a comparison with a separate conceptual domain that is similar but contains a distinctly different set of possibilities. Boden returns to Kekulé and the benzene ring/snake as an example of creative analogy:

No matter how it arose, Kekulé's snake-idea could have appeared *significant* only to someone with the relevant knowledge ('fortune favours the prepared mind.'). Like all of us, Kekulé was able to recognize analogies. Analogy is crucial to much creative thinking, in science and the arts, and later we shall ask what sorts of computational mechanisms might underlie it. Here we are interested in why Kekulé thought the analogy between snakes and molecules to be an exciting one. (Boden, 2004, p. 68)

A mind well acquainted a particular conceptual domain is able to turn playful abstractions and images into meaningful analogies. The idea-space interaction that is the result of analogy is not limited to only two conceptual domains, as three or more conceptual domains can come into play all at once. Take the example Boden gives of Kekulé; his insight involves the possible interplay of chemistry, mythology, herpetology, and topology.

His hunch, his feeling that this new idea was promising, was based on his chemical expertise. A tail-biting snake is surprising not only because it is rarely seen, but also because it is *an open curve that unexpectedly becomes a closed one*. It is the latter feature which proved so arresting, which awakened Kekulé 'as if by a flash of

lightning'. A snake which bites its tail thereby effects a topological change – the same change that is involved in passing from string-molecule to ring-molecule (Boden, 2004, p. 68)

The disassociated or *off-topic* connections required for analogy helps to explain why so many creative revelations occur in unlikely circumstances. Instead of staying true to the image of the tortured genius who is visited by revelation only when deep in thought at their desk and focused entirely on the matter at hand, creative thoughts manifest while day dreaming, lounging in the tub, during a fireside reverie, upon waking from a strange dream, up late drinking coffee, or just stepping onto the bus.

Recent studies on free association and the generation of creative ideas through brainstorming argue that wider-ranging or less constrained ideas are produced when constraints regarding the production of a correct answer are removed (Nemeth, 2005, 2007). The freedom of ideas that is possible while daydreaming is what allows the transformation of a conceptual domain via analogy to occur. When Kekulé was hard at work in his lab, thinking about the problem of the benzene molecule, his thoughts were constrained by the generative rules of chemistry. Boden argues that within those generative rules, molecular topology was restricted to strings, not rings (2004). Only later, when he was dozing and his mind was free to wander, was he able to make a connection, or draw an analogy, between Ouroboros and the potential topology of the benzene molecule. In other words, when he was hard at work in the lab, he would have been thinking about the problem and possible solutions in terms of chemistry: meaning that the generative rules of chemistry would have limited the ideas he was able to produce, or willing to entertain. Only later, when he was daydreaming by the fire and free to think about anything, even ideas that at first blush were totally irrelevant to chemistry, was analogy possible. Kekulé's relaxed mental state was required for the transformative analogy to occur, and that it also accounts for the surprise that accompanied the creative idea.

I propose that it was not a particular property (like impossible-novelty) of the creative idea itself that surprised Kekulé: rather, it was the fact that the solution to a vexing problem arrived *when he was not even thinking about chemistry* that was so surprising. That the solution came to him in a fireside reverie, rather than during the previous stretch of time when he was hard at work trying to solve the problem, more accurately accounts for his surprise. The necessity for a relaxing of the constraints of generative rules granted by letting

one's mind wander allows for the transformation of a conceptual domain to occur via analogy, and the fact that transformative analogy requires a relaxed, wandering mind accounts for the seemingly “out of the blue” arrival of creative insights, which explains why they are surprising.

My claim that Kekulé was surprised by the timing and circumstances of his idea does not necessarily contradict Boden's claim about the degree of surprise being indicative of the creative mechanism that produced it. It is consistent to claim that Kekulé was surprised both by the appearance of the solution to the problem in a dream, and by the “impossible-novelty” of the solution itself: the two are not mutually exclusive. In any case, this marks the end of the discussion of Boden's proposed mechanisms of creativity, and the illustration of her specialized role for surprise. I will now answer the question of whether surprise belongs in a definition of creativity: First in Boden's specialized use of “surprise”, and then in a more general sense.

8. Surprise in the Definition of Creativity

Boden lists surprise as a criterion in her definition of creativity. As we have seen, the role that surprise plays in Boden's definition of creativity is special. For Boden, surprise does not act as an indicator for whether an idea is creative or not; instead, the degree of surprise that accompanies a creative idea is informative about the way in which the creative idea was produced (Boden, 1996, 2004). According to Boden: Creative ideas that are produced by combining old ideas together to produce novel combinations are surprising. Creative ideas produced by exploring conceptual domains are surprising. Creative ideas that are produced by transforming generative rules are surprising, as are creative ideas produced by comparing analogous but distinct conceptual domains. Each of the creative ideas are surprising, but to different degrees. The different degrees of surprise correspond to different kinds of creative idea; improbable-creative and impossible-creative ideas. The combinational creative mechanism, and the exploration of conceptual domains are only capable of producing improbable-creative ideas. The ideas that produce a deeper level of surprise are impossible-creative, and they can only be produced by transformation of generative systems, or through analogy with other conceptual domains. Hence, Boden argues that surprise is informative about how a creative idea was produced, as well as how creative an idea is. “some are more surprising than others. Surely, the ideas which are ‘more creative’ are those which are more

unusual” (Boden, 2004, p. 41). This means that surprise may be useful in determining how a creative idea was produced, and the degree of creativity; but information about “production” and “degree” of creativity is too specialized to be useful in a general definition of creativity, whose intended use is to allow us to delineate what is creative from what is not. Boden's use of surprise does not help us discriminate what is creative from what is not. Surprise tells us *how creative* a creative idea is, it does not tell us whether an idea is creative.

Boden states that creative ideas are surprising (2004). However, no argument is made to show that *only* creative ideas are surprising, or that surprise is a distinct characteristic of creative ideas. For Boden, “surprise” is indicative of the mechanism that produced the idea, and the degree of creativity. Therefore, as Boden uses it, surprise does not belong in a general definition of creativity. More specifically, surprise does not belong in a definition of creativity whose intended function or purpose is to distinguish creative ideas or artifacts from uncreative ones.

Surprise in a General Sense

There is a more general sense in which surprise is associated with creativity. There are studies that provide compelling evidence for the ability of creative ideas to cause surprise. Psychological studies confirm that people who produce a creative solution to a problem, referred to as an “insight experience”, experience their solutions as “sudden and surprising” (Bowden & Jung-Beeman, 2003). The surprise that accompanies creative insight is well documented (Bowden, 1997, 2003; Davidson, 1995; Metcalfe, 1986; Schooler *et al*, 1993). Research into what has been called the *Aha! Moment* show that the phenomenal experience of surprise is often involved in creative problem solving. “The clearest defining characteristic of insight problem solving is the subjective “Aha!” or “Eureka!” experience that follows insight solutions” (Jung-Beeman *et al.*, 2004, p. 1).

Creative ideas can be surprising, but must an idea be surprising to be creative? If surprise is understood as the phenomenon of being shocked, then the statement that “creative ideas are surprising” is similar to the claim that “creative ideas tickle” or “creative ideas are painful”. Incorporating a phenomenological component into the definition of creativity is to require that everyone experience a particular phenomenon when they have a creative idea. In other words, if *surprise* is a necessary criterion in our definition of creativity, then an idea is not creative unless it is accompanied by the shock of surprise. It would be a mistake to

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include surprise in a definition of creativity, as to do so would severely restrict the definition, to the point of making it essentially useless.

Including a phenomenological criterion like surprise into our definition of creativity effectively negates our ability to evaluate the potential creativity of ideas that are produced by other minds. A definition with surprise as a necessary criterion automatically excludes any mind that may be potentially capable of creativity, yet incapable of experiencing the shock of surprise. This would potentially rule out computers, animals, aliens, and humans whose brains for whatever contingent reason (i.e. damage in the form of a lesion or tumor, stroke, or genetic mutation affecting brain structure), are not able to experience the shock of surprise. There is also the possibility that some people are just not easily surprised, or do not find ideas surprising. The fact that people are often surprised by creative ideas is not enough to deny the creativity of computers, animals, and people who for whatever reason are unable or unlikely to be surprised. To deny the creativity of agents who are incapable of surprise, it must be demonstrated that surprise is necessary for creativity, however, this has not been done.

The shock of surprise is a *reaction* to a creative idea. Therefore, it arrives too late, so to speak, to be an aspect or component of the creative idea itself. A creative idea that causes surprise is *already* creative, as the claim is that it is the *creativity* of the idea that causes the shock of surprise. To claim that creative ideas must be surprising is to confuse our phenomenal reaction to an idea, with the properties of the idea itself. To illustrate this confusion, suppose that we define “pepperoni pizza” roughly as “a flat dough base, covered in tomato sauce and slices of pepperoni”. After many clinical trials in which we feed pepperoni pizza to hungry grad students, we collect a mountain of data that shows that the smell and taste of pepperoni pizza causes grad students to salivate. Even if the data showed that pepperoni pizza caused salivation in an overwhelming majority of grad students, it would be a mistake to alter our definition of pepperoni pizza to include “makes grad students salivate” as a necessary criterion. To alter our definition to include “makes grad students salivate” would mean that the existence of pepperoni pizza would rely on the olfactory reactions of grad students. A consequence of this is that if we killed off all the grad students who salivated when they smelled or tasted pepperoni pizza, we would simultaneously eliminate all the pepperoni pizza in the world. There would still be flat dough bases covered in tomato sauce and slices of pepperoni, but it would not be pepperoni pizza, as it the only grad students left alive would be the ones who did not drool over pepperoni pizza. Hence, it

would be a mistake to include “causes grad students to drool” in our definition of pepperoni pizza; likewise, it is a mistake to include “causes surprise” in our definition of creative ideas.

The Temporal Problem

In addition to being overly restrictive in terms of limiting who or what is capable of being creative, surprise is also overly restrictive in regards to the kinds of thing that can be considered creative. We can easily imagine the arrival of a creative idea as being surprising, i.e. the sudden realization of a solution to a difficult problem. However, there are activities that we consider to be creative, or require that creativity, which take hours, days, weeks, months, or even years to complete. Painting a picture and writing a novel are two such activities. For example, Tolstoy's *War and Peace* is widely considered to be a masterpiece, a creative opus that stands out as one of the exemplars of fictional novels (Moser, 1992). It is safe to assume that *War and Peace* is an example of creativity.⁹ However, to write the novel, Tolstoy worked for years. The novel itself consists of four volumes, which contain elements from assorted shorter stories that Tolstoy had already written (Moser, 1992). As such, we know that *War and Peace* did not arrive suddenly, with a shock of surprise. Instead, it is the result of a long and sustained effort stretching over several years. Are we to deny Tolstoy's creativity because his book did not materialize in an instant? To do so would be ridiculous. A way to salvage the argument for surprise is to claim that although it took years for the book to be written, perhaps Tolstoy was visited by constant shocks of surprise as he wrote and edited his novel. In other words, each and every time he came up with an idea for the novel, that idea shocked him. However, rather than denying that Tolstoy was creative, or presenting an extended creative process as a continuum of constant shocks, a better option is to not include surprise as a necessary criterion for creativity. This does not require that we abandon or ignore the studies and first-person reports which associate surprise with creativity, there are other options available.

A weaker role that *surprise* can safely play is as a casual indicator to aid in the recognition of creativity. In this role, surprise is not necessary and so plays no part in the definition of creativity.

9 It makes little difference if you dispute the creativity of *War and Peace*. There will doubtlessly be an example of creativity that you can think of (i.e. a song, a poem, a painting, a book, or a sculpture) which took longer than an instant to produce. In which case my argument stands, with only a minor substitution.

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It would be a shame to ignore the apparent connection between the phenomenological sensation of surprise and the arrival of a creative idea. Used as a tool for recognition, the phenomenon of surprise is useful. Since surprise is known to often accompany the arrival of a creative idea, it is a salient topic in discussions of creativity. However, as I have shown, it is a mistake to incorporate the shock of surprise as a necessary criterion of a definition of creativity.

After examining “surprise”, both in Boden's specialized sense and in a more general sense, it is clear that “surprise” should not be included as a necessary criterion in a definition of creativity. The next section discusses the third and final criterion in Boden's definition of creativity: Value.

Chapter Three

The Criterion of Value

~Sozan, a Chinese Zen master, was asked by a student: “What is the most valuable thing in the world?”

The master replied: “The head of a dead cat.”

“Why is the head of a dead cat the most valuable thing in the world?” Inquired the student.

Sozan replied: “Because no one can name its price.”¹⁰

1. Introducing Axiotext

Value is the third criteria for Boden’s definition of creativity. The conceptual gulf that divides creativity from mere novelty is value. Value also separates creativity from madness or insanity.

In philosophy, ‘value’ is an expansive, fraught subject. A great deal of conceptual baggage, argument, and history is attached to ‘value’. A discussion of value is a philosophical quagmire, with the potential to arrest and derail our inquiry into creativity. We are only interested in value insofar that it pertains to creativity. To invoke (and engage with) ‘value’ here is not necessary. By creating a new term designed to do the same work, we can avoid entering into a discussion of value: effectively sidestepping the arduous process of identifying, selecting and arguing for a specialized conception of value as it pertains to creativity. To that end, I propose ‘Axiotext’, and the associated ‘Axiotextic’ and ‘Axiotextimorph’.

Axiotext is a portmanteau of the Latin words ‘axios’ and ‘context’. The word ‘Axios’ is Greek and means “worthy” or “having worth”. ‘Context’ is “the set of circumstances or facts that surround a particular event or situation.” Roughly, ‘axiotext’ means “Worth within a context”. Axiotextic is an adjective, an idea or object that possesses axiotext is axiotextic. Axiotextimorph is a form that is axiotextic. Axiotext does not distinguish between something with inherent worth or something that is recognized as having worth, and can refer to either. I am being intentionally ambiguous here.

10 Reys & Senzaki. *Zen Flesh, Zen Bones*, pg. 67

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For example, in the process of carving a wooden sculpture, a pile of wood chips is produced as well as the sculpture. For the sake of argument, assume that both the pile of wood chips and the sculpture are novel. The sculpture and the pile of wood chips have different levels of axiotext. The sculptor carefully places the statue upon a shelf, then sweeps up the wood chips and throws them into the trash. The actions of the sculptor are indicative of the axiotext of the two artifacts. The statue has axiotext; the pile of wood chips does not. The sculptor treats the statue differently than the discarded wood chips; it may be axiotextic within an economic context (i.e., the sculptor can sell or trade it), or perhaps the statue is axiotextic within an emotional context (it has a personal meaning or association for the sculptor). The wood chips have little or no axiotext for the sculptor (they have little or no worth within the given context), and they are tossed out in the trash.

The axiotext of an object or behaviour is not fixed, and is potentially different for different people, in different situations, or at different times. For instance, people differ in their appreciation of works of art. It is possible for some people to find a controversial piece of art axiotextic, and for others to view the same piece of art as worthless, uninspired, or vulgar; as was the case with Serrano's infamous "Piss Christ" (*See illustration below*). "Piss Christ" is a photograph of a plastic crucifix that has been placed within a glass of urine. The work was undeniably controversial, and created a scandal when Serrano first presented it for exhibition in 1989. Public reaction to Serrano's piece was mixed; it has been applauded as an successful, even iconic exploration of "the relation between the abject and the sacred" (Casey, 2004). On the other hand, "Piss Christ" has been called blasphemous and offensive, and the photograph itself was attacked twice at a museum exhibition in Australia.¹¹

¹¹ During an exhibition in 1997, the photograph was kicked, and later hit with a hammer. The attacks on the photograph prompted officials to close the exhibit.



Illustration 1: Andres Serrano's Piss Christ. 1987. Photo in Public Domain

The axiotext of a controversial piece of art like “Piss Christ” is different depending on who you ask. An object or behaviour does not have to be high profile and controversial for people to disagree over whether it is axiotextic. People disagree over the axiotext of putting anchovies on pizza, or the experience of travelling by airplane. It is possible for people to differ in terms of the level of axiotext which they assign to mundane objects and behaviour. This idea is expressed in the saying “One man's trash is another man's treasure” or the many variants on the same theme, such as “One man's heaven is another man's hell”.

The axiotext of a certain object or behaviour can change over time. Boden remarks on this, using beehive hairdos and bell-bottom trousers as examples of fashions that have come and gone (Boden, 2004). The “direction” of the change in axiotext is not limited to “axiotextic today, not axiotextic tomorrow”; objects and behaviours can be initially rejected and have their axiotext recognized later. Something can be said to be “before it's time”. This is the case with some movements in art, such as Impressionism, where it took some time before the axiotext of the paintings was generally recognized (Rewald, 1978). One instance in particular of this is the art of Vincent Van Gogh. During his lifetime, the artistic merit of Van Gogh's painting was essentially unrecognized while he lived, and he died as a pauper. Since his death, recognition of Van Gogh's brilliance has grown, his work influenced other notable artists, and his paintings are now among the most well known and recognized works of art (Metzger & Walther, 2008). The fall from grace of beehive hairdos, and the rise to recognition of Van Gogh's artwork are examples of the temporally shifting nature of axiotext. There is more to be said about axiotext itself, including a discussion of “neutral” and “negative” or “detrimental” axiotext.

2. Novelty With Neutral Axiotext

All creative ideas are novel. However, not all novel ideas are creative. We entertain numerous ideas that are novel but not necessarily creative in the course of a day. Suppose, for example, while working in an office, a pigeon alights outside your window. Arbitrarily, you decide to name the pigeon on a windowsill “Burt”. Seconds later, Burt the pigeon takes flight, you return to work, and the whole episode is forgotten. The idea of naming of Burt the pigeon is at least P-novel; presumably, you have never thought to name a pigeon “Burt” before. However, the naming of Burt the pigeon is not axiotextic or detrimental; one could say it has a neutral axiotext. There is no immediate axiotext (worth in the current context) in the act of

naming Burt the pigeon, and no future axiotext (you forget about the whole thing, and there are no repercussions) , as you then forget about the whole incident.

We can further illustrate the point; imagine a hardware error causes a computer program to assemble a string of characters, 50,000 characters long, and constituted by alternating ‘A’ and ‘Q’ characters, “AQAQAQAQAQA...” The string of characters is novel. For the sake of argument, let us assume that this is the first 50,000-character string of alternating A’s and Q’s. However, the string of characters is not creative; as in our example, it serves no purpose. The string is not used for anything, after running the program, the string of characters and the program is deleted, and the computer is turned off. If printed on paper or displayed on a screen, the long string of alternating A’s and Q’s would not cause someone to exclaim “Oh! How creative!” More likely, they would remark, “What is the point of that?” The string of characters is not axiotextic, it is only novel.

These two examples demonstrate novelty without axiotext. Axiotext differentiates creativity from plain novelty, yet creativity and plain novelty are not an all inclusive duality. An idea can be novel without being creative or only novel. The next examples illustrate the difference between a creative idea and an idea with negative axiotext.

3. Positive and Negative Axiotext

An idea may be novel and lack axiotext, as is the case with naming Burt the pigeon. A novel idea where the axiotext is absent is different from a novel idea that has negative axiotext. Axiotext is the difference between a creative idea, a merely novel idea, and (what Boden refers to as) a mad idea. However, ‘madness’ is not the ideal term to describe a novel idea that has negative axiotext. In common usage, ‘madness’ is not the antithesis of ‘creativity’. The opposite of madness is sanity, not creativity. Additionally, ‘madness’ is semantically ambiguous. Madness can mean a frenzy, intoxication, extreme folly, derangement, aberration, mania, and insanity. It is difficult to say what the antithesis of “creativity” is. At first blush, it would appear that “destruction” fits the part, yet sometimes destruction can be creative. For instance, there is a sense in which the artisan who carves the wood into a statue destroys the original piece of wood to do so. A more accurate term for the antithesis of creativity is “vandalism”. Vandalism here being anything which plays a vitiating role in the current context. However, vandalism is not necessarily novel. Therefore, I propose the rather unwieldy term “detrimental novelty”.

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To illustrate the difference between positive and negative axiotext, or creativity and detrimental novelty; imagine that you are a professional bicyclist. You are preparing for a big bicycle race, and are approached by a man named Albert. Albert claims that he has invented a new wheel that will revolutionize the sport of bicycle racing. As a professional in a highly competitive sport, you are intrigued by anything that might give you an advantage, and ask to see this new wheel. Albert says he has it with him, then reaches into a brown paper bag and produces a banana that he has painted with spots, like a giraffe. Albert then pokes a toothpick through the side of the painted banana and hands it to you. Albert's giraffe banana is almost certainly novel, for the sake of argument let us say that no one has thought to use a banana painted like a giraffe with a toothpick as a bicycle wheel before. There is good reason for this. Albert's idea is not creative, nor even merely novel, it is an example of detrimental novelty. Albert's giraffe banana wheel is not a case of neutral axiotext, as was the case with naming of Burt the pigeon and the AQ-string. Albert's painted banana is actually detrimental in the current context; it has negative axiotext as a wheel for a racing bike. Undoubtedly, swapping a bicycle wheel out for Albert's revolutionary painted banana would impair the performance of your bike, and by extension, the chances of winning the big bike race.

The same example can be modified slightly to illustrate creativity instead of detrimental novelty. All that is required is that Albert's invention is altered, so as to be axiotextic. For instance, instead of a painted banana and toothpick, suppose Albert has invented a novel bicycle wheel that is lighter and stronger than the wheels currently on your bike. Albert's lighter, stronger wheel improves the performance of the bike, and by extension, your chances of winning the big bike race. Of course, creativity is not limited to useful inventions, like wheels that increase the odds of winning a bike race.

4. The Minimum Axiotext for Creativity

“What is the minimum amount of axiotext required for an idea to be creative?”

Axiotext demarcates creativity from plain novelty (the inane or banal) and detrimental novel (insanity or vandalism). However, the width of the boundary between creativity, plain novelty and detrimental novelty has yet to be described. The boundary that separates creativity from other types of novelty is not a discrete dividing line. The difference between creativity and plain novelty is a continuum of axiotext. It is best to think of creativity not in terms of black and white, but in shades of grey.

Nor is it (creativity) an all-or-nothing affair. Rather than asking ‘Is that idea creative, yes or no?’ we should ask ‘Just how creative is it, and in just which way(s)?’ Asking that question will help us to appreciate the subtleties of the idea itself. (Boden, 2004, p. 2)

It can be helpful to view creativity, plain novelty and detrimental novelty as regions of a continuum of axiotext. As an element of a continuum, there is no denumerable quantity of axiotext that separates creativity from mere novelty. The reason for this is the variable and relational nature of axiotext.

they (*values*) change: who will proudly admit, today, to having worn a beehive hairdo or flared trousers in the 1960’s? They vary across cultures. And even within a given ‘culture’, they are often disputed: different subcultures or peer groups value different types of dress, jewellery [sic] or music. And where transformational creativity is concerned, the shock of the new may be so great that even fellow artists find it difficult to see value in the novel idea. (Boden, 2004, p. 10)

Similar to the values discussed in the quote above, axiotext is contingent and variable. Since axiotext is contextual (worth *within a context*), there is no particular example that can serve as an inveterate, perpetual example of the minimum axiotext for creativity in all contexts. As the context changes, so to does the axiotext. Therefore, it is impossible to produce an example of minimal creativity that will serve as an enduring boundary within a given context that will continue to demarcate minimum creativity from novelty as context changes. The same is true for finding an enduring example of “the most axiotextic” idea or product. As context changes, the axiotext of a given idea or artifact can change as well: meaning that while it is arguably possible to identify an idea or artifact that is the most axiotextic at a particular time and therefore, within a given context, there is no guarantee that it will retain the same degree of axiotext at another time, and in another context.

5. Axiotext in a Definition of Creativity

Axiotext is necessary for creativity. Like novelty, and unlike surprise, axiotext is required to differentiate what is creative from what is not. In particular, axiotext serves to delineate creativity from both mere novelty, and detrimental novelty. Therefore, a definition of creativity must include axiotext as a necessary criterion.

The criterion of axiotext differentiates what is creative from what is not creative. It does not inform us about degrees of creativity.¹² Examining Boden's criteria for creativity has resulted in some modifications being made to her definition. By this point, I have explored each of the criteria in Boden's definition. The exploration introduced the three criteria, novelty, surprise and value; and discussed whether they were necessary or sufficient for creativity. A modified definition emerged from the discussion of Boden's criteria. The modified definition kept “novelty” essentially un-changed, discarded “surprise”, and framed “value” in terms of “axiotext”.

My modified definition of creativity has two criteria, novelty and axiotext. Both novelty and axiotext are necessary, and together they are sufficient for creativity. To demonstrate that this definition works, here are two examples of creativity where both novelty and axiotext are apparent. These two examples are relatively easy targets, by which I mean that they are obvious examples of creativity. The reason I chose such easy targets is to clearly demonstrate that my definition succeeds where we can be sure that the example is creative, before setting out on an exploration of creativity that includes examples that have never been discussed in creativity research or identified as creative. My definition will

¹² One might suppose that greater axiotext equates to greater creativity. Certainly, we might be more impressed with a creative idea or object that has a greater axiotext than another creative idea or object. For instance, assume that the axiotext of a joke is how funny it is, or how well it causes laughter. In which case, a highly axiotextic creative joke will be funnier and cause us to laugh more than a minimally axiotextic creative joke. Since the joke with the higher axiotext was funnier, one might argue that it follows that it is more creative. However, the argument is problematic. The variable nature of axiotext over time creates any number of difficult counterexamples. For instance, a great many artists die unappreciated in their own time, only to become famous and adored posthumously. As the artist, and by extension their work, is unappreciated in their own time; the axiotext of their work is low at that time as well. The axiotext of Van Gogh's *Starry Night* was relatively low when it was painted, and later increased prodigiously. If a greater axiotext equates to greater creativity, then *Starry Night* has been increasing in creativity over time. One might claim that Van Gogh, and other unappreciated artists were simply ahead of their time. In other words, Van Gogh was in fact very creative, it just took some time before people came to realize it. In which case, the problem transforms to become “What makes today a more reliable indicator of axiotext than yesterday?” To my knowledge, there is no satisfactory answer to that question. The consequence of this being that as context (and thereby axiotext as well) can change over time, hence any measurement of how creative an idea or artifact is which is based upon axiotext can make no claim to being a permanent or objective standard.

identify particular instances of animal, and group behaviour as creative. Therefore, it is important to demonstrate that my definition correctly identifies creativity. To do so, I will show that it correctly identifies two examples that are clearly creative, taken from different fields of creative endeavor: technical innovation and the arts.

Example One: The Electro-pneumatic Paintball Marker

The invention of electro-pneumatic paintball markers is an example of creativity in technological innovation. To understand the creativity of the electro-pneumatic paintball marker requires an appreciation of why it was novel and why it was axiotextic. In 1996, two paintball companies released electro-pneumatic paintball markers. The companies WDP and Smart Parts, released the Angel and the Shocker (*See illustration below*), respectively. The Angel and the Shocker both differed significantly from the paintball markers that had been produced by paintball companies previously. The new markers incorporated a solenoid valve into their firing systems, although in different ways. The WDP Angel used a stacked tube design, where a hammer-valve was linked to the bolt, allowing a single solenoid valve to actuate the entire firing sequence. The Shocker, released by Smart Parts, used two solenoid valves, effectively replacing the hammer and valve with a solenoid. The addition of pneumatic solenoid valves to the firing mechanisms of these markers gave them two important advantages over other paintball markers that were on the market. First, it allowed for the markers to fire more paintballs per second. The Shocker was able to fire 12-13 paintballs per second. Second, the firing mechanism was actuated by a micro-switch, which allowed for a much lighter trigger pull. The lighter trigger pull meant that players were able to take advantage of the marker's ability to rapidly fire paintballs.

The Shocker was a milestone in a trend towards higher rates of fire in paintball markers. Early paintball markers, like the Splatmaster, had a very low rate of fire and a very simplistic firing mechanism (*See illustrations below*): compared with later electro-pneumatic markers.

SHOCKERTM
Manufactured exclusively for SMART PARTS by pneuVentures

The **Shocker**TM is a well engineered, highly precise electropneumatic device. It has been engineered with very few moving parts, to give you many years of pleasure with relatively easy maintenance.

All New!

ULTRA LIGHT WEIGHT!

PATENTS PENDING

STANDARD 2 FINGER TRIGGER

The **SHOCKER**TM is an electronically timed, closed-bolt design which cocks automatically with the first trigger pull. There are no external moving parts. The firing sequence combines the logic of electronics with pneuForceTM control. The operating pressure of the **SHOCKER**TM is approximately 130 psi resulting in greatly reduced distortion of the paintball & an unusually flat trajectory. Accuracy is aided by a gradual application of propellant force which continuously accelerates the paintball as it travels down the barrel. The electronics are powered by four AA batteries contained in the gun body. The **Shocker**TM has very low recoil due to the low operating pressure and the elimination of springs in the firing sequence. Movement is minimized by the very light trigger pull. The **SHOCKER**TM is capable of operating on CO₂, compressed air & nitrogen. The gun will also perform well in both hot and cold weather extremes. The **SHOCKER**TM is designed to be set up in either on-gun or remote applications.

SMART PARTS

COMPETITION READY!

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Illustration 2: Smart parts advertisement for the Shocker. Picture from www.ody.ca

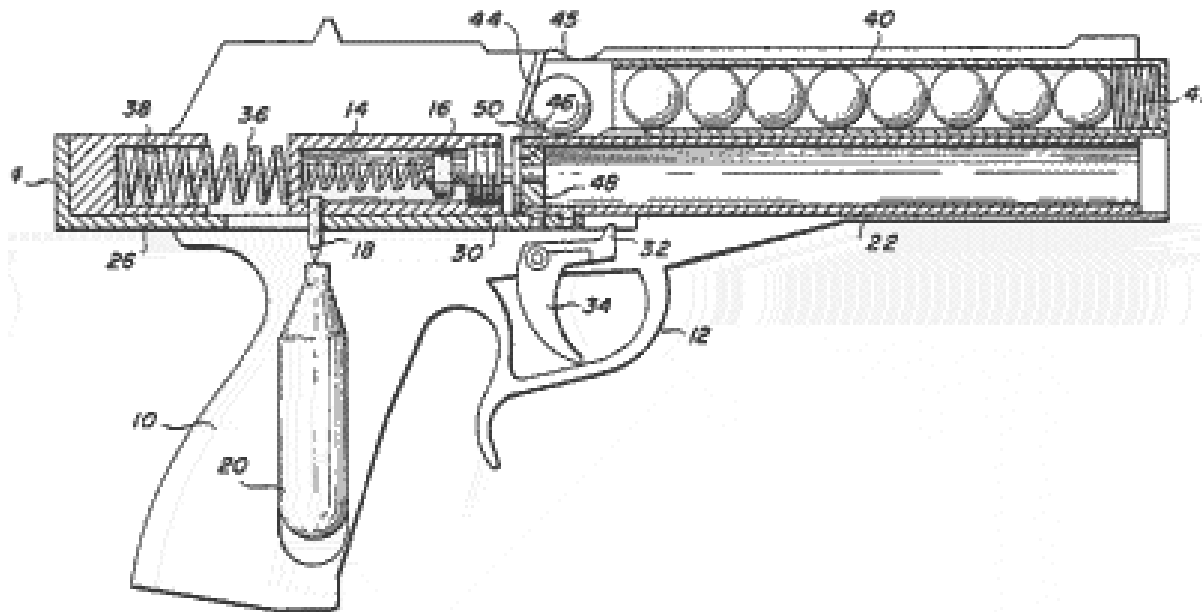


Illustration 3: Splatmaster internals. Pushing the button on the back (4) allows a ball to fall into the breech and "cocks" the marker: Pulling the trigger releases the hammer (16), that releases a charge of compressed gas from the gas cylinder (20) and fires the paintball down the barrel. Image from US. Patent Image



Illustration 4: Icon Splatmaster paintball marker. Manufactured by NSG. Photo from vintagerex.com

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The primary reason for the trend toward higher rates of fire is the idea of “accuracy through volume”. A paintball is round, and so the paintball marker firing a paintball faces the same problems with accuracy that early muskets did. A round projectile is vulnerable to shifts and changes in air pressure and wind direction during flight.

In theory spinning a projectile on the axis of flight adds gyroscopic stability as well as averages out any imperfections in the surface air flow. Paintballs leave a bad turbulence wake behind them that "walks around" the back of the ball as it flies through the air. This is the main cause of a paintballs inaccuracy as the turbulence tail drags the ball around sideways in flight. (Kaye, 2001, p. 1)

A paintball is made by injecting paint into a lightweight gelatin shell. Thus, the paint accounts for the majority of the paintball's mass. This restricts the efficiency of rifling the barrel and adding spin to the paintball to steady it during its flight. The liquid paint center of the paintball rapidly slows the rotation of the shell, effectively canceling out any benefit on trajectory (Kaye, 2001). Experiments with rifled barrels, and even motorized rotating barrels that put a spin on paintballs as they were fired, demonstrated no useful increase in accuracy (Kaye, 2001). At range, the accuracy of paintball projectiles is limited.

A paintball will reliably fly in a straight line, but only over relatively short distances. To hit targets at longer distances, paintball players subscribed to the theory of “accuracy through volume”. One paintball fired at a distant target might reasonably be expected to miss. By firing a lot of paintballs at a time, the odds increase that one will go the distance and hit the target. “Accuracy through volume” is not really an increase in the accuracy of the marker. In paintball, the goal is to eliminate other players by tagging them with a paintball. There is no competitive target shooting in the sport of paintball. The number of paintballs fired does not affect your score. So what is important is that a paintball makes contact with your target, not how many paintballs are fired in order to achieve that goal. This means that in paintball, “accuracy through volume” is a better method for producing long range eliminations than firing just one or two paintballs and hoping that they find their target. To achieve accuracy through volume, a paintball marker that is capable of firing more paintball per second is axiotextic. The Shocker is capable of firing 12-13 paintballs per second, whereas with the Splatmaster, it would be difficult to fire more than 2 paintballs per second.

The increased rate of fire afforded to electro-pneumatic paintball markers resulted in better odds of eliminating opposing players. In tournament paintball, as in any competitive sport, something that will give you an advantage over your opponent is appreciated. Electro-

pneumatic paintball markers provided an advantage, and they soon dominated the market for mid to high end tournament paintball markers. Now they are ubiquitous, every tournament paintball marker produced in 2009 is electro-pneumatic. Electro-pneumatic markers were influential in the further progression of the sport of paintball.¹³

The invention of the electro-pneumatic paintball marker produced a novel marker with an increased capacity for firing paintballs per second. Therefore, the invention of the electro-pneumatic marker was both novel (the new addition of the solenoid actuated firing mechanism) and axiotextic (capable of achieving greater accuracy through volume). Since it was both novel and axiotextic, according to my definition of creativity, the electro-pneumatic paintball marker was a creative invention.

Example Two: Impression, Sunrise

In 1872, Claude Monet painted “Impression, soleil levant”. The painting was done in oils on canvas, and depicted a cool sunrise over the Le Havre harbour in Paris, as seen from Monet's window (Forge et al., 1989). The painting is suggestive rather than strictly representative, with loose brush strokes. (*See Illustration below*). Monet's painting was creative, as it was both novel and axiotextic. The novelty and axiotext of the painting are interconnected, as in addition to the aesthetic qualities of the painting, it is the novelty of Monet's “Impression” that makes it axiotextic. Monet's painting “Impression, soleil levant” helped to create and name a radically different style of painting, making the novelty of the painting axiotextic in regards to establishing a vibrant new movement in art.

The painting, “Impression, soleil levant”, although being derided by critics at the time, was indicative of a new style called “Impressionism”.¹⁴ Impressionism was a radical departure from academic painting, employing new techniques (loose brush strokes, thickly applied paint, minimal mixing of colour on the canvas), as well as new ideas regarding content and composition (Rewald, 1978). Monet's painting was one of the original impressionist paintings, whose title inadvertently gave a name to the new movement. It was

13 The increased rate of fire of the electro-pneumatic paintball marker, as well as their popularity and prevalence affected other aspects of paintball. For instance, new loaders were designed that could feed paintballs into the marker fast enough to keep up with the higher rates of fire. Players shot more paint, which increased demand and brought the price of paintballs down. New technology was implemented in the markers themselves, such as “eyes” to detect the position of the paintball within the breech and reduce the chance of the paintball being “chopped” by the bolt.

14 Critic Louis Leroy wrote an article in the paper *Le Charivari* where he disparaged Monet's painting: making a play on the title of Monet's “Impression, soleil levant” Leroy's article was titled “The Exhibition of the Impressionists”.

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a novel painting, done in a novel style. “Impression, soleil levant” was axiotextic, not just for the role that it played in helping to launch and name a new movement in art, but as a beautiful and well composed work of art in its own right.

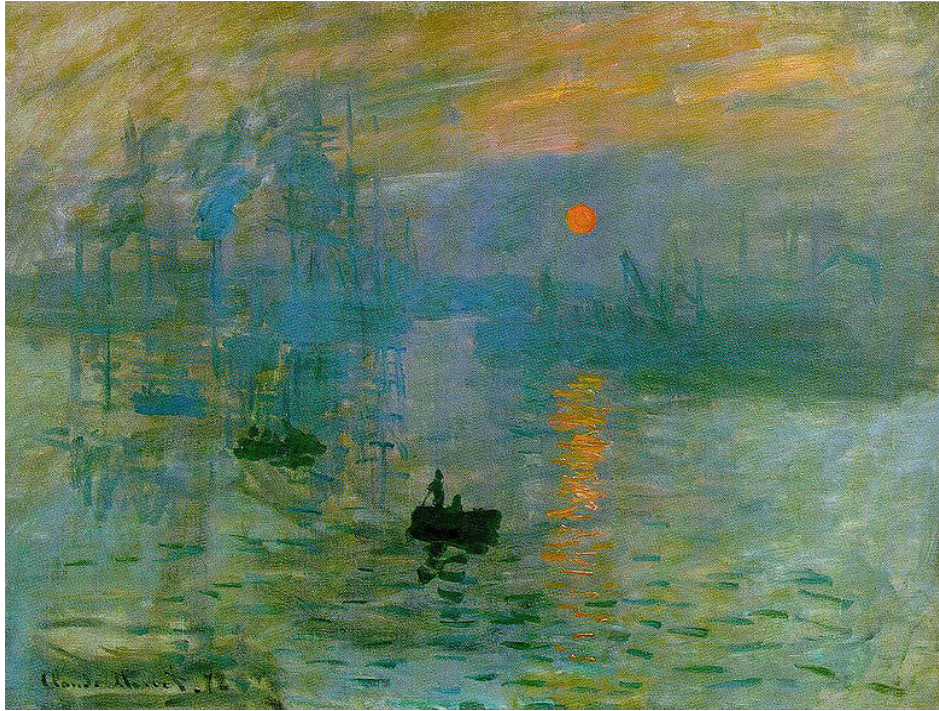


Illustration 5: Claude Monet. Impression, soleil levant (Sunrise). 1872. Image Public Domain

Monet was being creative when he painted “Impression, soleil levant”, as the product was both novel and axiotextic. The painting was novel, in that it broke with the traditions and practices of academic painting. The painting was axiotextic, not just for the aesthetic merits of Monet's work, but also in regards to the role it played in helping to create and establish Impressionism.

Having demonstrated that my definition of creativity works with the previous examples of creativity in technological innovation, and works of art, I will now use this definition to explore examples of animal creativity. The following examples are of animal behaviour where the novelty and axiotext, and therefore the creativity, is readily apparent.

Part Two

—

Widening the Focus: Animal and Group Creativity

Chapter Four

Animal Creativity

1. Introducing Animal Creativity

The application of my definition of creativity is not restricted to human behaviour: it is designed to be applicable to behaviour in general. For example, my definition can be applied to animal behaviour; wherein animal behaviour that is both novel and axiotextic qualifies as creative. A study of creative behaviour in general reveals that human creativity is just the tip of the iceberg. As I will show, the scope of creativity is considerably broader.

The creative behaviour of animals is different from creativity exhibited by humans. This is not to say that the goals of creative animal behaviour are utterly different from our own. Humans share similar goals with other animals, such as the acquisition of basic requirements for continued survival (food, water, and shelter), as well as goals relevant to sexual selection and procreation. However, the human capacity to invent, create and manufacture artifacts, when compared with the ability of any other species of animal, highlights the fact that human beings are unique in this regard. Airplanes, skyscrapers, ploughs, cell phones, oil paints, video games, pianos, and rain coats are all creative inventions unique to human beings. It is clear that human beings are exemplars of creativity, and exhibit creative behaviour unique to the species. However, the fact that humans are highly creative does not preclude the possibility that other species are also creative. The difference in creative capacity between humans and animals is significant: nevertheless, the difference is in degree rather than kind.

This discussion of animal creativity does not claim that non-human creativity is identical to human creativity. To the contrary, the aim of this discussion of animal creativity is to properly differentiate animal from human creativity. We tend to anthropomorphize cases of creative behaviour in animals, wherein we imagine something akin to our human experience transpiring within the animal in the scenario. An everyday example of this is when pet owners attribute human emotions or experiences to their pet's behaviour. As in "Fluffy is jealous of the attention we have been giving the new kitten. Fluffy thinks of herself as a person who is a part of the family, and doesn't understand why she should have to share her house with new a kitten." However, to anthropomorphize the behaviour of an animal is to

lose sight of the important differences between human and animal creativity. This has the effect of minimizing or *glossing over* the differences in physical makeup, perception, and psychology that makes animal creativity distinct. Exploring these differences can provide insights into human creativity, but more importantly, it facilitates a more pellucid apprehension of creativity in general.

The discussion of animal creativity consists of a series of brief case studies of creative animal behaviour. Animals exhibit creative behaviour, from the very large¹⁵, to the very small.¹⁶ This range of examples is intentionally expansive and varied, ranging from intelligent animals, like crows, to lower-level organisms, like slime moulds. The broad scope of examples is demonstrative of the equally broad range of creative behaviour. The discussion of animal creativity is essentially an investigation of the different kinds of thing that can be creative. The initial cases, such as tool use, are those which are most clearly creative and uncontroversial examples of creative animal behaviour, and bear the closest resemblance to human creative behaviour.

The species of animals included in the initial examples are all intelligent,¹⁷ and their actions are all clearly novel and axiotextic. The examples towards the end of the discussion are of group behaviour in what might be called “lower” organisms. In these examples, the animals are less intelligent, and their behaviour does not obviously resemble human creative behaviour. Hence, the creativity displayed by these animals is more contentious. These examples are especially important to the discussion for two reasons. First, the animals involved are sufficiently alien to human form and behaviour that they discourage anthropomorphizing. Second, they highlight key issues that are important to my discussion, in regards to what kinds of thing can be creative, as well as the mechanisms responsible for creativity.

The examples of behaviour in this section are not intended to constitute an exhaustive list of the creative behaviour of any of the species. While it is possible to compile a statistically significant record of creative behaviour in particularly intelligent species, like a

15 Elephants display creative behaviour, including constructing “canteens” during the dry season for regular access to water, and domestic elephants are known to plug up the bells they wear with mud so they can silently raid orchards at night without alerting their keepers. Elephants will also use sticks to assist in removing ticks from their forelegs, and will utilize palm fronds as fly swatters (Holdrege, 2001)

16 Microscopic organisms, such as amoeba, display creative behaviour – including constructing sealed “shelters” out of minute grains of silica sand or centric diatoms to protect themselves when their environment becomes inhospitable (Ford, 2004).

17 By intelligent, I mean “capable of grasping the essentials of a situation and responding appropriately”.

crow or chimpanzee; such a list would be huge, and would not suit the purpose here. The purpose of this discussion is to highlight a cross section of non-human creativity, to provide evidence that creative behaviour is not confined to a single species, and different species are creative in different ways. To illustrate the difference in creativity amongst different species requires an assortment of varied cases, rather than focusing on the behaviour a particular species.

2. Tool Use by New Caledonian Crows

Of the examples in this section, perhaps most striking is the tool-making behaviour of New Caledonian crows. In recent experiments, a captive female New Caledonian crow was confronted with a problem that could be solved by the use of a hook to retrieve a food-containing bucket from a vertical pipe (Weir et al., 2002). The crow spontaneously bent a piece of straight wire into a hooked shape to retrieve the food bucket from the pipe. The use of ‘spontaneous’ is justified, as although crows are known to employ natural materials (sticks and leaves) to access food in the wild; the crow in the test had no previous experience or training with pliant materials, like wire. The creation of the hook was not a one-off fluke, as the crow repeated the behaviour in nine out of ten subsequent trials (Weir et al., 2002).



Illustration 6: Crow using a stick to access food. Photo Gavin Hunt.



*Illustration 7: A crow tearing a strand of spikey material to use as a tool to get access to food.
Photo Gavin Hunt*

Video footage of the experiment shows the crow attempting to use the straight piece of wire to remove the food-containing bucket from the vertical pipe without success. After several attempts to snare the food bucket with the straight wire, the crow then pushed the wire into the duct tape that anchored the tube and bent the straight wire into a hook. (*See Illustration below*)



*Illustration 8: Crow with wire bent into a hook to retrieve food from tube.
Photo from Weir video via BBC*

With the wire bent into a hook, the crow then quickly succeeds in extracting the food-containing bucket from the pipe. Bending the wire into a hook was creative, as it was both novel and axiotextic. The crow's behaviour is novel. Although crows in the wild have been observed using sticks and spiky leaves to extract food from logs, the manipulation of the wire into a hook is novel. First, there is novelty in terms of material. The crow has no previous training or experience with pliant material. Second, turning the straight wire into a hook shape is novel. Crows in the wild use sticks to gain access to food. The crow in the experiment began by using the wire like a stick, but without success. The crow then bent the wire into a hook, a novel shape and material compared to stick use in the wild. Hence, bending wire into a hook to extract food from a pipe is novel. The crow's behaviour meets my first criteria for creativity, novelty. The crow's behaviour has worth within the given context. The crow directly benefits from making the wire into a hook, in that it gets the food which would otherwise be unavailable. Since it has worth within the given context, the crow's behaviour is axiotextic. Bending the wire into a hook is both novel and axiotextic, the crow is being creative.

The wire-hook is not the only creative behaviour exhibited by crows¹⁸: and the New Caledonian crow is not the only bird that exhibits creative behaviour. Novel foraging

¹⁸ Crows have also been shown to solve somewhat more complex problems, where they use a short stick to gain access to a longer stick, which in turn allows them to gain access to food down a deep hole (Taylor *et al.*, 2009). Furthermore, I have personally observed crows perching on the traffic light wires over a busy

behaviour in non-captive birds of various species has been documented. This includes the axiotextic use of puddles and other bodies of water to drown prey (Fitzpatrick, 1979; Grieg, 1979), and house sparrows triggering the opening mechanism of an automatic door to gain access to food indoors (Breitwisch & Breitwisch 1991). However, gaining access to food is not the only task in which birds display creative behaviour.

3. Creative Nest Construction by Bowerbirds

The Australian bowerbird is named for the elaborate and colourful bowers that they create. The building of a bower is essential to the success of a male bowerbird in luring females and mating with them. The male bowerbird builds a bower, and then decorates it using brightly coloured objects. These include natural objects like flowers, sea shells, berries; as well as thread, beads, glass, and foil. Studies show that more brightly coloured and elaborate bowers are more successful at attracting female bowerbirds (Borgia, 1985). (*See Illustration below*)



Illustration 9: A male Satin Bowerbird decorates his bower. Photographer unknown.

Male bowerbirds show a preference for rarity, and they selectively decorate their bowers with flowers that are uncommon in the immediate area (Borgia, Kaatz, & Condit,

intersection with live snakes in their beaks, waiting until cars were moving below and dropping the snakes, then flying down when the cars stop moving to eat the snakes that were run over by the cars.

1987). The bowers of different species of bowerbirds differ in size, shape and construction. There is also significant variation in the decoration of bowers among individuals of the same species (Griffin, 1992).

The construction and decoration of the bower is an example of creative behaviour. The bowerbird's nest is both novel and axiotextic. The result of the construction and selective decoration of a bower by a bowerbird is the creation of a unique nest. This fulfills the novelty criterion. As it plays an important role in attracting a mate, the creation of an elaborate and colourful bower is axiotextic for the male bowerbird. Since a well furnished bower is both novel and axiotextic, the construction and decoration of a bower qualifies as creative behaviour. The creativity of the bowerbird is discussed in research on animal creativity. J.C & A.B Kaufman provide examples of creative animal behaviour, including the nest-construction behaviour of the bowerbird (J.C & A.B Kaufman, 2004).

4. Creative Sweet-potato Washing by Koshima Island Monkeys

A famous example of creative animal behaviour is the sweet potato washing behaviour of the monkeys on Koshima Island, Japan. In September of 1953, a young one and a half year old female monkey named Imo washed a dirty sweet potato in fresh water (Kawai, 1962). This occurred as Imo was engaging in play behaviour with the sweet potato. That particular play behaviour typically utilized rocks, but in this case a sweet potato was substituted for the rocks (Kawai, 1962). The sweet potato became immersed in fresh water during the play behaviour, and was washed clean. The sweet potato washing behaviour was one of several newly-acquired behaviours that the troop of wild monkeys on Koshima displayed since becoming regularly provisioned.

The washing behaviour was acquired by Imo's mother and three other playmates by February 1954, and then by nearly half the troop towards the end of 1957. By August 1962, the entire troop of monkeys had acquired the behaviour (except for infants less than a year old, and adults older than 12 years) (Kawai, 1963). As the behaviour became more widely adopted, the technique has changed to include salt water washing. (*See Illustration below*)



*Illustration 10: Koshima Island monkey washing a sweet potato in the sea.
Photo Nature, international weekly journal of science*

The switch from fresh water washing to seawater washing may have something to do with the salt content of seawater, and with the flavor that salt contributes to the food.

At first the sweet potato washing was conducted in fresh water, but today the utilization of sea water has increased a great deal, and it is often observed that the young monkeys do not now eat sweet potatoes without having washed them in sea water several times beforehand, the act being similar to the ‘seasoning’ routine of human beings. They are also able to wash sweet potatoes very skillfully. (Kawai, 1963, p. 2)

Imo's sweet potato washing behaviour is creative, as it is both novel and axiotextic. The behaviour is novel, as no monkey on Koshima island was observed washing sweet potatoes before Imo began in 1953 (Kawai, 1963). The sweet potato washing behaviour is axiotextic, as it cleans the potato, which makes it easier to eat, and washing the potato in seawater also “seasons” it with salt, presumably making it more pleasant to eat. This makes washing the sweet potato an axiotextic behaviour. Since it is both novel and axiotextic, Imo's sweet potato washing is creative. This example does not end here, as there is more to this story than Imo's individual creativity.

Imo's creative sweet potato washing behaviour has become "a firmly established custom" (Kawai, 1963). The spread of sweet potato washing to the other monkeys in the troop has had consequences in terms of other activities. Since the creative sweet potato washing behaviour became an established routine, further creative behaviour has developed in the troop.

The sweet potato washing behaviour taught the monkeys not only the utility but also the accessibility of water. From 1954 onward they began to eat oppositional univalve shells on a rock near the beach. From the year 1959, the young monkeys began to play on the beach and then to walk voluntarily into the sea to swim and hunt for food naturally floating on the waves or thrown there by tourists. (Kawai, 1963, p. 2)

This meant that other monkeys were able to augment or modify Imo's potato washing behaviour, and developed creative behaviour of their own. Like Imo's potato washing, these newly developed creative behaviours spread to the rest of the troop (Kawai, 1963). One of these new creative behaviours is to use water as a kind of sieve to separate grains of wheat from grains of sand:

One of the foods given to the monkeys is wheat. When wheat is scattered over the beach it is so easily buried under the sand that it is difficult for them to find it. Until a couple of years ago they had been picking up the grains one by one, but recently they have begun to scoop them up with the sand and carry the mixture to the sea or to a stream of water. There they wash the sand away and then eat the wheat. This is called the 'Placer-Mining Selection Method' and 14 monkeys act it at present. It is interesting to note that their fear of water was overcome as a result of their becoming skillful in washing sweet potatoes. (Kawai, 1963, p. 3)

The transfer of an individual's behaviour to the whole troop, and the modification of that behaviour by other members of the troop introduces a new variable into my discussion of creativity; Groups.

This example demonstrates that given the right conditions, the creative behaviour of individuals can affect the behaviour of a group, and the behaviours adopted by the group can influence the creative behaviour of individuals in the group. In other words, there is a "two-way street" with group creativity: where individuals can influence the group, and the group can influence individuals. The creative behaviour of an individual (Imo's sweet potato washing) was adopted by the group, and resulted in other monkeys being creative. The troop of monkeys (excluding infants and adults over 12) all adopted the washing behaviour, which altered the way in which the monkeys interacted with water. As a result of the troop's

newfound familiarity with water through washing, they began to swim in the sea (Kawai, 1962). The newly acquired behaviours of hunting for food on the waves and extracting wheat from sand using Placer-Mining selection came about as a result of Imo's sweet potato washing behaviour spreading to the rest of the troop, and then influencing the production of creative behaviour by other monkeys.

In their paper on creativity and animal cognition, Kaufman & Kaufman refer to the Koshima monkey example (2004). They posit that the mechanism through which the changes in the group behaviour of the Koshima Island monkey troop occurs through *observational learning*. Observational learning occurs when one individual observes the behaviour another and mimics it to achieve the same outcome.

observational learning can act as both a mechanism for spreading innovative behaviour (as in the macaques), or as a mechanism to maintain traditional behaviour (Kaufman & Kaufman, 2004, p. 6)

Kaufman and Kaufman's discussion of observational learning highlights a mechanism through which individual behaviour can affect group behaviour. The mechanisms responsible for group behaviour are pertinent to our discussion here, as certain group behaviours are creative: in which case, an investigation of different mechanisms responsible for creative group behaviour is an investigation of mechanisms that produce creative behaviour. In the following examples, special attention will be paid to the mechanisms or organizing principles that are responsible for the group behaviour. The following examples of animal creativity differ from those presented thus far, in that it is the group itself, rather than an individual animal, that is being creative. These are examples of the creativity of animal groups: creative collective behaviour.

Group, or distributed creativity occurs when a number of individuals act together in a manner that is both novel and axiotextic *in regards to the group as a whole*. Group creativity is emergent, by which I mean "displaying properties or producing effects or outcomes that are different to the properties, effects or outcomes available to the individuals that comprise the group". To illustrate this, I have selected a varied cross-section of creative behaviour in groups of animals. In each example, I will illustrate the ways in which the behaviour of the group is novel and axiotextic, as well as the mechanisms responsible. The investigation of these examples, including mechanisms and axiotext, leads to a discussion of creative behaviour in groups of humans, and groups in general.

5. Creative Behaviour in Fish Schools

The schooling behaviour of fish is a basic, introductory example of group creativity. It is highly organized, producing collective movement and reactions to environmental stimulus.

Hundreds of small silver fish glide in unison, more like a single organism than a collection of individuals. The school idles along on a straight course, then wheels suddenly, not a single fish is lost from the group. A Barracuda darts from behind an outcropping of coral, and the members of the school flash out-ward in an expanding sphere. The flash expansion dissolves the school in a fraction of a second, yet none of the fish collide. Moments later the scattered individuals collect in small groups; ultimately the school re-forms and continues to feed, lacking perhaps a member or two. (Partridge, 1982, p. 1)

The quote above illustrates an important feature of group creativity; the group is considered to be a single organizational unit. The group is a whole that emerges from the individual constituent parts. A school of fish appears in form and movement to be more like a single organism than a collection of individuals. (*See Illustration below*) Group creativity is behaviour that is novel and axiotextic for the group as a whole. Let us examine what it means for group behaviour to be axiotextic.

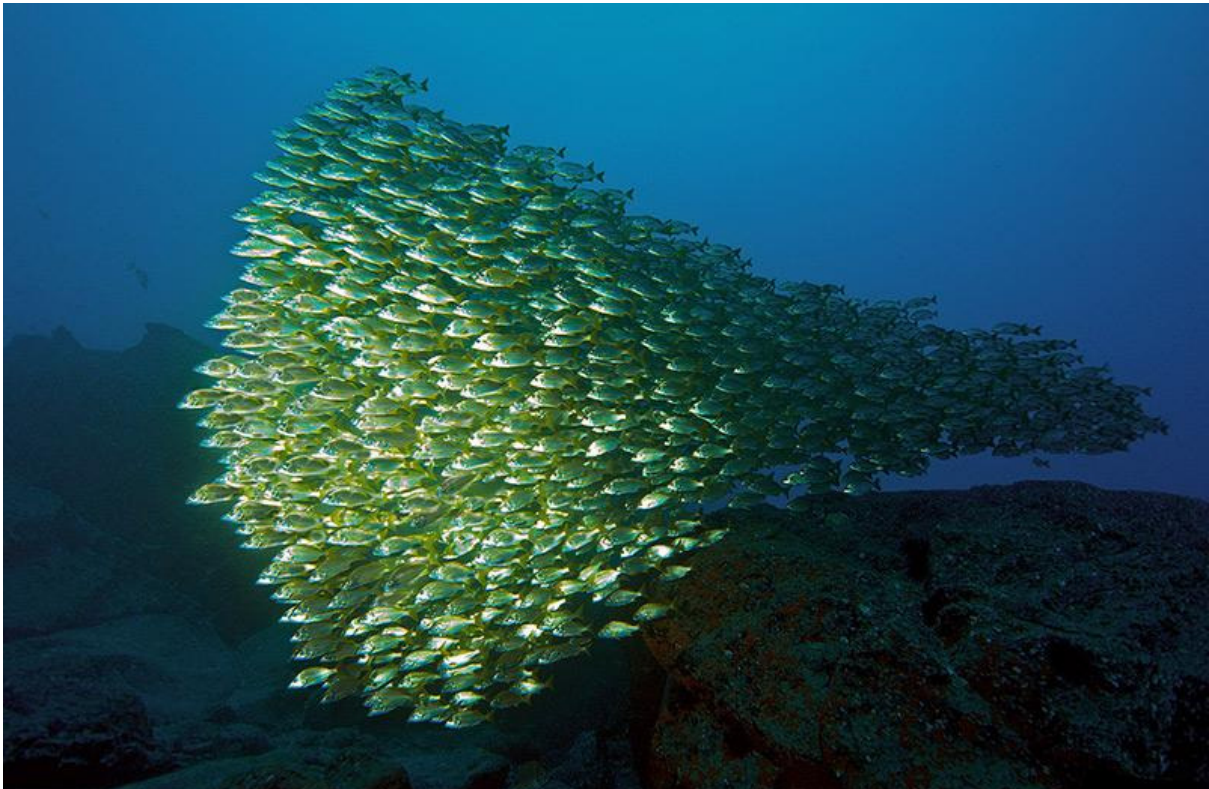


Illustration 11: Fish schooling together in unison resemble a larger, single “organism”.
Photo Pixdaus

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Group behaviour can be axiotextic for the individuals that constitute the group. The axiotext of schooling may not be immediately apparent. One might imagine that by congregating in large numbers the fish become easier to locate than they would be if they split up; that a group of hundreds or thousands of small fish would be more likely to be seen by an ocean predator. If it were the case that fish are easier to spot in a school, then schooling behaviour would not be axiotextic, and would not be creative. However, although it might seem otherwise, a big school is not significantly more likely to be seen. Schooling actually makes fish less likely to be located by a predator. This is due to the optical characteristics of the medium in which schooling occurs. Contrast is essential for visually distinguishing an object from its background, and ocean water rapidly reduces visual contrast over distance:

In a large body of water the scattering of light by suspended particles and the absorption of light by the water itself greatly reduces the contrast. As a result, even in water of exceptional clarity the greatest distance at which an object can be seen is about 200 meters, *and the distance does not depend on the size of the object*. In practice the maximum is usually much less....visibility from 30 to 50 meters is (considered to be) exceptionally good. (Partridge, 1982, p. 10).

The optical characteristics of large bodies of water create an environment within which schooling is axiotextic. The chance of being located by a predator in open water is decreased for each fish that joins a school. To illustrate this, imagine three fish swimming close together in a small school. The visibility in the water determines the range at which a fish can be seen by a predator. The fish are swimming in open water, so suppose that the fish can be spotted by a predator from above, below, or each side. The fish are not hiding behind anything, so no object interferes with the predator's chances of seeing them. Therefore, the area where a fish can be seen by a predator is a sphere, the radius of which is the maximum distance of visibility afforded by the optical characteristics of the water. Keep in mind that it is the optical characteristics of the ocean water that determines the distance of effective visibility; the size of an object has no bearing on the distance at which it can be seen.

Since the three fish are swimming close together, the spheres (the areas wherein they can be spotted by a predator) overlap to a large degree. Due to this overlapping, the chance of a predator locating the small school of three fish is only slightly higher than the chance of finding an individual fish. If the three fish were separated and occupied the same body of water, the chance of the predator spotting at least one of the fish would be much higher. The chance of a predator locating the small school of three fish is approximately one third the

chance of finding at least one of the three fish if they were swimming alone and separated in an area of the same size. The anti-predatory advantage of schooling is compounded by safety in numbers.

...in the open ocean a predator's chance of finding a school of 1,000 fish is only slightly greater than its chance of finding one fish. If the predator, on discovering the school, eats exactly one fish, then an individual fish's risk of being eaten is about a thousandth of what it would have been if the prey had been discovered on its own (Partridge, 1982, p. 10)

The benefit to individuals who engage in schooling behaviour is clear. Due to the optical characteristics of water, and since ocean predator prey-location is partly visual, schools of fish can be huge and yet be only marginally more likely to be located by a predator than a single fish. Not only that, but once located, the odds are better for an individual fish in a large school than alone: assuming the predator does not eat the whole school. If the predator only eats one or two fish, then the chances of an individual fish in a school of thousands getting killed is significantly lower than if they encountered the predator on their own. However, the benefit offered by schooling is not restricted to decreasing the odds that a predator will locate the school. Fish engage in schooling behaviour while being in the constant presence of predators. Several species of schooling fish live their entire lives within several meters of predators. For these fish, schooling behaviour is axiotextic; yet not for reduced risk of location by predators.

Many species of fish living on the coral reefs off the coast of Florida spend their entire lives within a few feet of predatory barracuda and groupers; nevertheless, schooling is common among the prey species. The notion of predators searching a limitless ocean for scarce prey cannot clearly explain such schools. (Partridge, 1982)

An individual fish in a school is less likely to be eaten by a predator than a solitary fish, and not just because it is able to "play the odds" (Godin & Morgan, 1985). There are other factors that increase the anti-predation benefits for fish which are due to the effects that schooling behaviour has on predators themselves, and "tactics" undertaken *en masse*. For instance, when facing a large school of closely aligned fish, a predator has increased difficulty in selecting a single fish to consume. Furthermore, a school of fish has a number of evasive behaviours, referred to from here on as "tactics", which they employ when a predator approaches. The tactic adopted by a school of fish depends on a number of different variables (Salvanes, *et al*, 2006). A primary variable in determining the tactic that a school adopts is

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the speed at which a predator is approaching; high velocity predator attacks elicit different school tactics than low velocity predator attacks. When a predator moves slowly towards a school, the fish in the school can back away while maintaining a general proximity or “cohesion”; creating a cavity in the school around the predator.



Illustration 12: Tactics: A school of Salema outmaneuver a Sea lion by creating a cavity in the school around the predator. Photo National Geographic

When confronted by a slowly approaching predator, a school can also adopt a tactic called the fountain effect; wherein:

the school splits into two parts in front of the predator. The halves of the school turn outward, swim around the (predator) and rejoin behind it. ...The result is that the predator is left with the school behind it. If the (predator) turns, the maneuver is repeated. By a succession of such movements the school can evade a predator it cannot outrun. (Partridge, 1982)

In situations when a predator is approaching rapidly, the tactics of the school are different. A high velocity approach by a predator is often an attack or a “strike”; meaning that the predator is not just reconnoitering or following the school, but is attempting to make

a kill. When a predator strikes, the school adopts the “explosion” tactic, where each fish simultaneously propels itself outward from the center of the school with a lightning fast single flip of its tail. This tactic causes the school to explode outward and away from the attacking predator, resembling the burst of sparks produced by an aerial firework. As it is a response to a high velocity attack, this tactic is triggered and occurs with incredible speed.

In as little as a fiftieth of a second each fish accelerates from a standing start to a velocity of between 10 and 20 body lengths per second. The entire expansion can take place in half a second. (Partridge, 1982)

Alternatively, when a school of fish is under attack by a rapidly approaching predator, the school also can adopt a tactic where it “constricts” and the fish swim very close to one another. This tactic does not get the fish out of harm's way, as the “explosion” tactic does; and so the axiotext of this tactic is not immediately obvious. The effectiveness of this tactic is due to something called the “Confusion effect” (Partridge, 1982). The exact causes of the confusion effect are still being studied, but it is thought to result from two different processes (Partridge, 1982). The first process takes place in the central nervous system, where the predator is faced with a large number of nearly identical potential prey and is unable to “decide on” which prey to attack. The second process takes place in the peripheral nervous system, where the collective movement of the prey would overwhelm the predator's senses. Let me sketch out both in greater detail here.

Many predators prefer to attack prey that are distinct from the rest of the school in appearance or behaviour (Partridge, 1982; Godin & Morgan, 1985). Differences in terms of appearance or behaviour can indicate that an individual animal is sick or injured, or otherwise impaired. Injured, weak, old or very young prey are selected for by predators, as they are at a disadvantage physically, and are thereby more easily caught. Although it only requires a tiny difference in appearance or behaviour between prey to overcome a predator’s inability to decide on which fish to attack: in many schools the fish are essentially identical in those regards. When tightly packed together and moving in unison, the similarity is magnified (Partridge, 1982). This makes it difficult for the predator to select a particular fish to strike, which is axiotextic for the fish in the school.

The second process behind the confusion effect stems from operations in the peripheral nervous system of the predator; the senses. In this case, the movement of an entire

school of fish may cause a kind of “sensory overload” or confusion resulting from a large quantity of prey moving around the predator as it attempts to strike (Partridge, 1982).

Sensory confusion would occur even if the predator was able to rapidly decide on a particular fish to attack. The movement of other fish in close proximity can be distracting to a predator attempting to strike. By fitting a greater number of fish into closer proximity, the school can compound the potential for sensory overload in an attacking predator. Instead of tracking a solitary fish against a contrasting background, the predator's optical senses must process a “shimmering wall” of tightly packed fish, that may “overload” its capacity to function at the speed necessary to make a successful strike. Therefore, although the tightly constricted tactic does not evade the predator like the explosion tactic does, it is nonetheless an effective anti-predation maneuver.

These tactics, in addition to other factors (such as flight reaction difference), means that a solitary fish (or a fish straying momentarily from a school) is more vulnerable to predation than an individual fish in a school (Godin & Morgan, 1985). The shapes and tactics available confer a greater anti-predatory benefit to fish in the school than would be available to a solitary fish trying to avoid a similar attack. The result of this is that even though schools mean that there are more prey present in a given area, a predator is less likely to make a successful strike.

This anti-predation benefit applies to every member of the school. It is a group-wide advantage within a specific context: the behaviour of schooling is axiotextic for the whole group. The axiotext results from the shape of the school (in that it lessens the odds of visual location by predators), and on the tactics employed by the school (cavity, fountain, the confusion effect and flight reaction differences afforded by schooling behaviour). In this example, our appreciation of the axiotext of the group behaviour emerges from or *piggy-backs* upon that behaviour being axiotextic for the individuals that constitute the group. We can appreciate the axiotext of the collective behaviour of the school of fish *in terms of* what is axiotextic for the individual fish involved. To put it another way, we understand the axiotext of schooling because we appreciate the axiotext of not being eaten by a predator. There is more to be said about group behaviour, individual behaviour, and axiotext, but that will wait until the discussion of group creativity in the next chapter. For now, the discussion continues with the mechanisms responsible for fish schooling behaviour and other examples of creative group behaviour.

Mechanisms of collective behaviour

Unlike the creative group behaviour displayed by the monkeys on Koshima Island, schooling behaviour in fish does not occur *via* the mechanism of observational learning. Fish do not need to be taught schooling behaviour, it is instinctual; schooling is a non-hierarchical behaviour, there is no leader fish responsible for issuing orders that direct the rest of the school (Salvanes *et al.*, 2006). Schooling is a collective behaviour that requires interaction between several individuals. Unlike the sweet potato washing behaviour which was “invented” by Imo the monkey and later spread to the whole troop, schooling behaviour is collective from the outset (a single fish is not a school). It is conceivable for Imo to have begun washing sweet potatoes as a solitary monkey who did not live within a troop; however, it is inconceivable for a solitary fish to engage in schooling. Group creativity (schooling) is different from individual creativity (sweet potato washing), at least in terms of mechanism. The implications of this, in regards to an understanding of creativity, will be discussed shortly. For now, to better appreciate the difference between the two, let us examine the mechanisms that produce schooling behaviour.

The school structure results from each fish following a few simple behavioural rules (Partridge, 1980). The first rule is that each individual maintains a given distance of empty space between itself and the next nearest fish. This is referred to as the minimum-approach distance.

The minimum-approach distance depends on the size of the fish, and is typically around three-tenths of the body length (Breder, 1954). In each species of fish there is a typical preferred distance to the nearest neighbor fish in a school, which is usually approximately one body length (Partridge *et al.*, 1980). In a school, fish tend to keep their nearest neighbor at a particular angle of alignment with their body axis. This angle can be referred to as the “preferred angle”. By each maintaining the minimum-approach distance, preferred angle, and other simple rules regarding school size and swimming speed, the fish in the school are able to maintain a collective spatial arrangement (Breder, 1954; Cullen *et al.*, 1965).

The minimum-approach distance and preferred angle are not hard and fast rules that must be maintained by every fish at all times. Both the preferred angle and preferred distance are statistical abstractions acquired by averaging the overall behaviour of the school over time: the spatial relationships between individual fish in a school change constantly as the

school moves and the fish adjust their direction and speed (Cullen *et al.*, 1965). At a given moment, only a few fish in the school may have their neighbor at the preferred angle and distance. However, averaged over a long period of time the preferred angle and preferred distance dominate. The fish maintain the preferred distance, minimum-approach distance, and preferred angle through use of their eyes and lateral line (Partridge, 1980, 1982; . The lateral line is composed of displacement-sensitive hair cells, similar to those found in the ears of terrestrial vertebrates. The hair cells are: “placed in canals laid out in a complicated way on the head of the fish and in a roughly linear arrangement between the head and tail.” (Partridge, 1982, p. 122)

Although the lateral line is unique to aquatic organisms (amongst which it is primarily present in fish), the mechanism of individuals following simple behavioural rules to produce collective behaviour is not. Other organisms engage in schooling behaviour, despite lacking a lateral line. “Workers have shown that schools of squid, frog tadpoles, and even flocks of certain birds are organized on the same principles.” (Partridge, 1982, p. 121) This, along with my next two examples, suggests that collective creative behaviour is not unique to fish. However, before we continue to my next example, I will address a potential concern.

Instinct and novelty

As I have demonstrated, a school of fish is a population of interacting individuals whose behaviour has the effect of optimizing a function or goal (not being eaten): hence, the school is collectively behaving in a manner that is axiotextic. However, some mention must be made of the fact that schooling behaviour in the individual fish is instinctual. To become a genetic instinct requires repetition, as generation after successive generation engage in and hones the genes responsible for the behaviour. One might assume that due to this repetition, instinctual behaviour cannot be novel, and therefore does not qualify as creative. This is a mistaken assumption. To demonstrate this, let me briefly re-state the different types of novelty presented in my earlier discussion of that topic and show how instinctual behaviour can be novel.

Earlier, I introduced and discussed three different types of novelty which are sufficient for creativity. These are historical novelty (H-novelty), psychological novelty (P-novelty), and situational novelty (S-novelty). To the best of our knowledge, repetition by generations of genetic ancestors is necessary, though perhaps not sufficient, for instinctual behaviour. However, while it is true that fish alive today who engage in schooling behaviour

are not the first to do so (generations of their ancestors already beat them to it); this only eliminates the possibility of historical novelty.

For a newborn fish who engages in schooling behaviour for the first time, such behaviour *is* novel; as it is not “just copying” or aping the behaviour of a leader fish. Hence, although it is not H-novel, it is possible for instinctual behaviour to be P-novel and S-novel. To illustrate that instinctual behaviour can be S-novel, studies show that instinctual behaviour can be altered or adapted in regards to environmental stimulus (Salvanes, *et al*, 2007; Braithwaite & Salvanes, 2005). This means that the same species of fish, reared in different environments, display novel schooling behaviours (Salvanes & Braithwaite, 2005). The novelty of (adapted) instinctual behaviour is recognized in studies of animal creativity. Kaufman & Kaufman specifically identify adapted instinctual behaviour as one their examples of creative animal behaviour.

...innovative behaviour may also be useful in defending one's home; feigning injury to lure a predator away from the nest is a common strategy in plovers. Even if feigning injury can be considered to be an innate behaviour, plovers have been observed to adapt their displays according to the predator they are trying to distract. (Kaufman & Kaufman, 2004, p. 147)

Finally, although the behaviours in these examples are not H-novel themselves, they are examples of behaviour that was *H-novel at an earlier time*. The fish in schools today may not be engaging in H-novel behaviour, but schooling behaviour was once H-novel. The fact that fish school today can be taken as a kind of record of earlier novel behaviour. As that earlier behaviour was both axiotextic (anti-predation benefits), and H-novel (the first time fish ever schooled), it is creative. This does not only apply to fish schooling, but can be carried over into the other examples of creative instinctual behaviour.

Of course, to show that instinctual behaviour can be novel will not suffice to answer all potential worries about such behaviour being creative. For instance, it will be no comfort to those who object to the idea that instinctual behaviour qualifies as creative, not specifically on the basis that it lacks novelty, but simply on principle. However, this is not the place to address such concerns. To qualify as creative, group behaviour must be both axiotextic and novel. During the discussion of schooling, I highlighted the ways in which that instinctual behaviour is axiotextic, and explained how it can be P- or S-novel (and was at one time H-novel). The question of whether instinctual behaviour necessarily precludes creativity on principle will be postponed until the end of these final two examples of creative behaviour in

groups of animals. I will now continue with my investigation of examples of creative group behaviour.

6. Creative Behaviour in Ant Colonies

An example of creative group behaviour occurs via the “swarm intelligence” displayed by colonies of ants. Swarm intelligence occurs when two or more individuals independently collect information that is processed through social interaction and provides a solution to a cognitive problem that is not available to single individuals (Krause, *et al*, 2009). Examples of the swarm intelligence of ants make for lucid illustrations of creative *collective* behaviour, as there is a clear distinction between the capacities of the individual ant, and the capacities of the collective colony. Although an individual ant is limited to very simple cognition and is restricted in what it can achieve, “the group collectively is capable of astonishing feats” (Krause, *et al*, 2009, p. 1) Like the schooling behaviour in fish, swarm intelligence (S.I.) is the result of individuals following simple rules. Although the colony has a queen, the name is misleading, as the queen ant does not actually “run the whole show” (Sumpter, 2006). The collective SI behaviour of the colony is non-hierarchical. It emerges from the bottom up, through the relatively simple interactions of the individual ants (Sumpter, 2006).

Production of food trails

The production of food trails is an example of swarm intelligence. Ants communicate using touch and smell. Several species of ants lay down chemical scent trails, called pheromones, to indicate a trail leading to food from the colony. These chemical scent trails are created initially by forager ants that have discovered an external source of food, and have left a string of pheromone marks along the way as they returned to the colony. Like Hansel and Gretel's breadcrumbs, the pheromones mark the forager's route from the newly discovered food and back to the colony. By marking the route, the forager ants are able to inform other ants at the nest of the presence of food and its location. Worker ants at the nest will encounter the pheromone trail and follow it, collect some of the food, and return to the nest (Sumpter, 2006).

Having found and collected food from the source, the worker ants that followed the trail from the nest will also leave pheromone markings along the route they take as they return to the nest with food. After depositing the food at the nest, the ants return to the pheromone trail and repeat the whole procedure. Other worker ants join in the procession as

they encounter the pheromone markers at the colony, and soon there is a constant stream of ants carrying the food back to the nest. In this way, a workforce of ants assembles to locate and transport food to the nest (Goldstone & Gureckis, 2009). However, the pheromone trail mechanism is not limited to locating and transporting food; the ant colony can determine which of several food sources is closer, and allocate more workers to transporting food from that source, resulting in more food being gathered in less time.

Pheromone trail formation occurs through local information. A trail is started by a single individual or a small group of forager ants in response to the presence of food, and is reinforced by other worker ants who encounter and follow the trail. The reinforcement pheromones laid down by worker ants following the same trail does more than clearly mark the route; it is also the mechanism by which more workers are “assigned” to transport food from the closest sources.

The simple behaviour of following a trail of pheromones and then applying more pheromone markers on the return to the nest creates a form of positive feedback; more ants lay more pheromone markers, which in turn attracts more ants. Although the mechanism is simple, pheromone trail forming behaviour allows the colony of ants to solve the problem of resource allocation. Given a choice between two food sources at different distances from the nest, concentrating on transporting food from the nearest source results in more food transported over a given amount of time; as ants are able to make more trips back and forth on a trail between the colony and a nearby food source than a more distant food source. The simple behaviour that produces pheromone trails provides a mechanism through which the colony can send more ants to the nearest food source, and gather more food.

To illustrate how this works in greater detail, let us examine a recent laboratory experiment. Researchers provided a colony of ants with two food sources. The food was placed across two bridges of different lengths, so that one food source was significantly closer to the colony than the other. The experiment showed that a colony of black garden ants (*Lasius niger*) that had been starved of food solved the problem of resource allocation by sending more ants to the closer food source across the shorter bridge (Beckers *et al*, 1992).

Half an hour after the first forager ants located the food sources the researchers measured the number of ants following pheromone trails across the two bridges. When one of the bridges was 40% longer than the other, over 80% of the ants took the shorter bridge in the

majority of experimental trials¹⁹ (Beckers *et al*, 1992). This difference in division of labor was not due to judgements or calculations made by the individual ants regarding the distance to food sources, or the guidance of an “overseer” or ant foreman; it is the result of pheromone concentration on the two trails:

Individual ants make little or no comparison of the two bridges, instead the slightly longer trip time means that pheromone is laid less rapidly on the longer bridge. Thus, when trail following ants make the choice between the two bridges they detect a higher concentration of pheromone on one of the bridges, the shorter one. The shorter bridge is thus chosen with a higher probability by the follower ants and when these ants return home they further reinforce the shortest path. Since pheromone continually evaporates on both paths but is more strongly reinforced only on the shortest path, the ants rapidly concentrate their trail on the shorter path. (Sumpter, 2009, p. 7)

Discriminating between paths of different lengths is axiotextic for the colony; not just for transporting more food back to the nest over a given period of time, but in terms of anti-predation benefits as well.

Selecting the shortest path between two points can be important to any animal, and this is certainly true for ant colonies that use chemical recruitment trails to exploit large sources. During the construction of such trails, there are many occasions in which a large stone or other obstacle gives the ants the choice of going round it on the left or on the right, especially for subterranean ants whose freedom of movement is limited. The corresponding savings in time, effort or exposure to predation, multiplied by the importance of the traffic during a mass recruitment, are potentially of great adaptive value. (Beckers *et al.*, 1992)

The ability to find the shortest path to a food source, and discriminate between food sources at different distances from the nest is axiotextic for the colony. There will have been a first time that an ant colony engaged in this behaviour, which would have been novel. As such, that would have been an instance of novel and axiotextic collective behaviour, and is an example of creative collective behaviour.

The mechanism of collective behaviour

The mechanism through which the axiotextic behaviour occurs is several ants following simple rules. No individual ant measures the distance between the various food sources, or is responsible for selecting how many ants should be recruited to transport food on a particular trail. The axiotextic behaviour emerges from the collective behaviour of the ants. As was the case with the school of fish, the creative behaviour of the group is not due to the behaviour of a single individual, but emerges from the group as a whole.

¹⁹ In the 20 trials that were run, the ants took the shorter bridge 16 times.

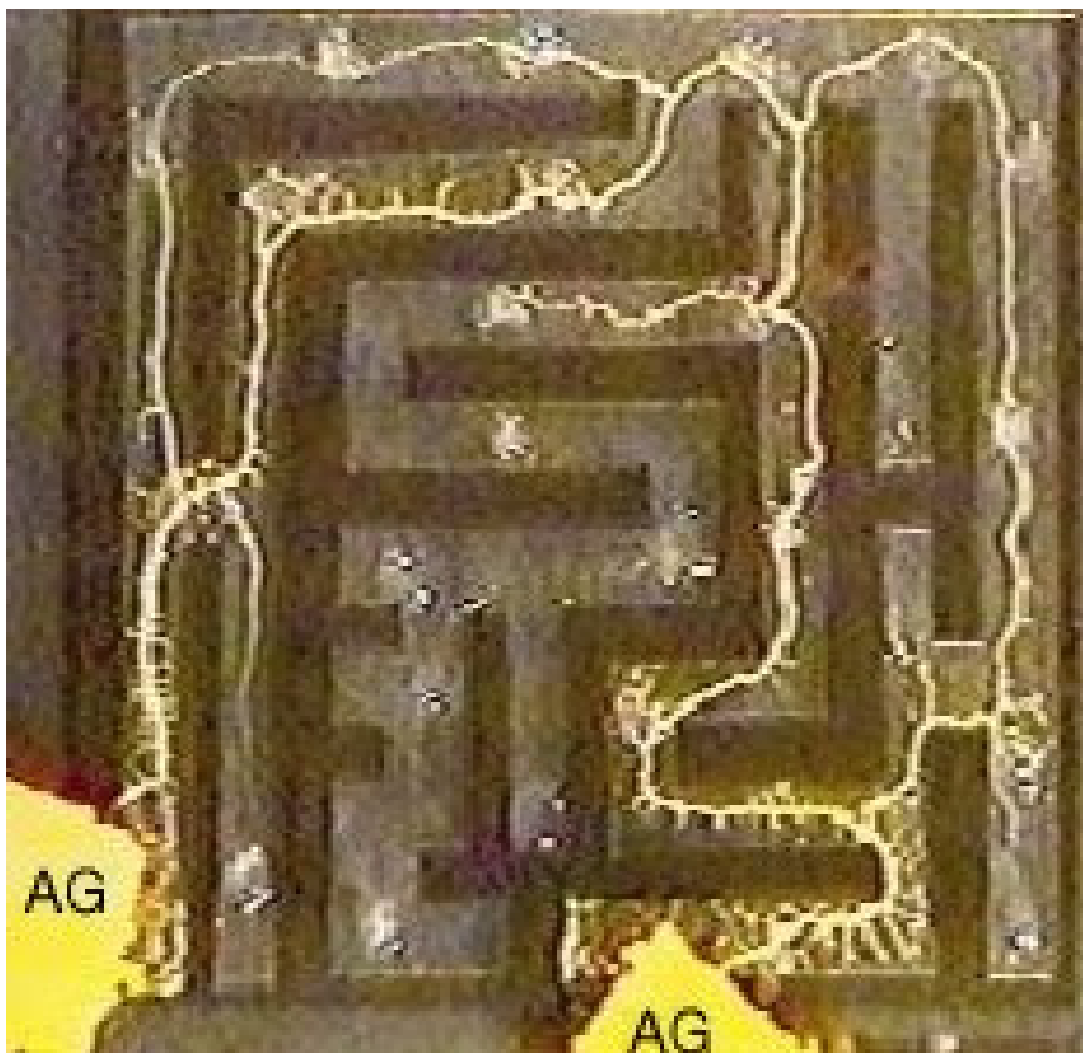
By following trails that have a higher concentration of pheromones to food sources, and continuing to lay markers on their return to the colony, the ants incorporate a form of *positive feedback* into the production of food trails. The result of this positive feedback is collective creative behaviour, therefore positive feedback is a mechanism that can produce creativity. Examples of positive feedback in nature are not limited to the production of pheromone food trails by ants; as it is observed in the recruitment dance of honey bees, the construction of mounds by termites, and cemetery building by *Messor sancta* ants (Sumpter, 2009). Although the specifics for each of these species is different – i.e the recruitment of worker bees occurs through the use of a “waggle dance” rather than through the laying of a pheromone trail - the same kind of collective behaviour is produced. There is some initial event (in the case of the ants, a forager ant finds food) which then creates a positive feedback loop that displays a pattern of rapid amplification. Positive feedback is not unique to social insects such as honey bees, ants and termites:

(positive feedback) is also observed within groups of unrelated animals. For example, cockroaches rest for longer periods under shelters with more cockroaches leading to aggregation and solitary locusts are excited through multiple contacts with other solitary locusts leading to gregarization and collective migration. (Sumpter, 2009, p. 7)

Although the specific mechanisms are different (pheromone trails, waggle dances), there are identifiable patterns that manifest within group behaviour that utilizes positive feedback loops. The idea that different mechanisms can produce similar behaviour will be important later in the dissertation. For now, let us examine the last example of creative group behaviour.

7. Creativity in Slime Mould Aggregates

A recent study shows that a slime mould plasmodium is capable of creative behaviour. There are several species of slime mould with different traits and characteristics. The slime mould in this example is the “many-headed slime” *Physarum polycephalum*, which is an amoeba-like organism, typically coloured yellow and found living in rotting plant matter, such as leaves and logs. Research demonstrates that a *P. polycephalum* plasmodium is capable of “solving” a maze containing two food sources, and implies that the microorganism possesses a kind of primitive intelligence (Nakagaki, 2001). (*See illustration below*)



*Illustration 13: The Slime mould finds and utilizes the path to the food. (in yellow)
Photo: Nature*

In the slime mould maze experiment, researchers created a maze by cutting a negative pattern of the maze into a sheet of plastic film to form a template, and then placing it onto a plate of agar. Slime mould plasmodium tends to avoid the dry plastic surface of the plastic film, restricting the plasmodium to the wet surface of agar not covered by plastic (Nakagaki, 2001). At each end of the maze, what one might call the “start” and “finish” points, the researchers placed food.

The researchers began by placing pieces of slime mould throughout the maze. One can cut pieces off from a larger slime mould plasmodium, and those pieces of slime mould will regenerate and become another slime mould organism. When two slime mould plasmodia come into contact, coalesce into a single organism. To grow and expand, the slime mould throws out tube-like structures called pseudopodia. As a plasmodium, *P.*

polycephalum is large, multinuclear and unicellular. The body of the plasmodium is a branching laminar network of tubes, similar in appearance to the arterial network in lungs, or veins in a leaf. As the pieces of slime mould expanded and joined together, they eventually coalesced into a branching plasmodia that filled the entire maze.

There were four routes through the maze, four available options to get from one food source to the other. After a period of eight hours, the slime mould had shrunk down to the point where it filled only the parts of the maze that provided a route connecting the two food sources.

The mechanism responsible for the slime mould “solving” the maze consists of two parts or phases. To fill the maze, the distributed pieces of *Physarum polycephalum* expanded and joined together. The expansion behaviour utilizes a mechanism related to wave propagation of rhythmic contraction.

When the contractile activity propagates like a wave through the plasmodium, the tube structure develops and grows along the propagation direction of the waves. On the other hand, along the direction perpendicular to the propagation direction, the tube is retracted and disappears. Waves of the rhythmic contraction mediate formation of the tube network (Nakagaki, 2001, p. 3)

The waves of rhythmic contraction propagated in a widening circle or arc, causing the distributed pieces of slime mould to expand outwards, connect with one another, and form a single plasmodium that filled the entirety of the maze.

The parts of the plasmodium that come into contact with food contract more often than those areas of the plasmodium which do not. The frequent contractions have the effect of propagating waves to other areas of the plasmodium. The waves caused by the more frequent contractions in the areas in contact with food act as feedback signals, which inform the local cells on whether to grow further or contract.

...the contraction waves propagate between two food sources: the wave source is switched from one food source to another every several waves. Parts of the plasmodium in dead ends of the maze contract rather synchronously. This contraction pattern means that dead-end parts of the plasmodium shrink and that the tubes which connect the food sources grow. (Nakagaki, 2001, p. 3)

The plasmodium body contracts into several thick tubes that snake through the maze via all viable routes available. The plasmodium “solves” the maze, and in doing so it optimizes foraging ability, body size efficiency and behaviour according to contingent, contextual

circumstances. This makes the slime mould plasmodium's behaviour creative, as it is both novel and axiotextic.

The slime mould acts in a way that solves a novel problem, i.e. “What is the most efficient way to utilize both sources of food located in a maze?” For the slime mould, the circumstance is novel (this is the first time it has been in a plastic maze set in agar), and that situation creates a particular problem “How to best take advantage of food source location?” (What is the most efficient plasmodium body shape to adopt given the situation?) which requires a novel solution.

By finding the routes through the maze to the food deposited at each exit, the slime mould creates the most efficient plasmodium shape for the circumstances. The slime mould plasmodium's behaviour is axiotextic, as foraging for food, and efficient body (tubule network) shape and size is important for continued survival. As the behaviour of the slime mould plasmodium is both novel and axiotextic, it is creative.

The creative behaviour of the slime mould plasmodium is non-hierarchical; it does not depend upon the behaviour of an individual slime mould. The “maze-solving” is another example of swarm intelligence, where the cognitive capacity of the collective is greater than that of an individual. An individual slime mould bacterium is incapable of “solving” a maze, yet a collective plasmodium is capable of doing so (Nakagaki, 2001).

Anthropomorphic resistance

Unlike the examples involving animal creativity, it is difficult to anthropomorphize the actions of the slime mould. Slime moulds are sufficiently alien in their physical makeup and actions that it is extremely difficult to imagine something resembling human experience occurring within them. This is beneficial, as we are not in any danger of marginalizing their creativity as something resembling a less developed or lower level instance of human creativity, which is a risk we run when examining some cases of animal creativity. It is easy to imagine something loosely akin to human thoughts or experience occurring in the New Caledonian crow as it solves the problem of how to gain access to the food bucket. If faced with the same problem, it is likely that we would arrive at the same solution. The slime mould plasmodium, with its network of branching tubules and expanding waves of rhythmic contraction do not invite such imaginings as readily, if at all. In other words, we might make a wire hook to get at food, however, we would not solve a maze by expanding our body to fill the maze and then contracting ourselves into a network of thick, fluid filled tubes. However,

it would be a mistake to assume the alien appearance and behaviour of the slime mould plasmodium make it less a relevant example than the earlier examples of creative animal behaviour. The creative achievement of the slime mould may seem relatively unimpressive, especially when compared with the achievements of human creativity. However, the slime mould plasmodium and the other examples of group creative behaviour are equally informative about creativity as the examples of creative behaviour in individual animals.

8. Objections and Replies

There are potential objections that can be raised against my examples of animal creativity, particularly the claim that the examples of group behaviour qualify as creative. One might claim that although the behaviour in the examples is both novel and axiotextic, nonetheless, they do not count as being creative because things like ant colonies and slime moulds simply are not the kind of things that can be creative. This claim can be defended two ways. First, one might claim that only brains are capable of creativity. Therefore, anything that is not made of the same material as a brain is incapable of being creative. I shall refer to this as the “wrong material” argument. Second, one might claim that the groups of animals in the examples were acting according to instinct, and that purely instinctual behaviour cannot be creative. I will refer to this argument as the “instinct” argument. Let me begin by examining the wrong material argument.

The wrong material argument

The wrong material argument is based upon the claim that only neurons are capable of creativity. Boden addresses a similar argument in her discussion of creativity in machines. In her version of the argument, she addresses the claim that the inorganic matter of which computers are comprised is incapable of intelligence and creativity (Boden, 2004). Although slime mould plasmodium and ant colonies are both composed of organic material and not silicon, the “wrong material” argument applies in both cases – as neither slime moulds nor computers are composed of the same material as brains (neuroprotein). The claim that neuroprotein is the only material that can support or produce creativity may well turn out to be true: it may be the case that ant colonies or slime mould plasmodiums are made of the wrong *stuff* to ever be creative. In which case, the fact that they behave in ways that are both novel and axiotextic is beside the point. Ant colonies and computers might only *appear* to be

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creative. This may be true, but the “wrong material” argument provides no reason to accept it.

As Boden writes:

(that neuroprotein is unique in its capacity to support creativity) is not obvious at all. Certainly, neuroprotein does support intelligence, meaning, and creativity. But we understand almost nothing of how it does so, *qua* neuroprotein – as opposed to some other chemical stuff. Indeed, insofar as we do understand this, we focus on the neurochemistry of certain basic *computational functions* embodied in neurones: message passing, facilitation, inhibition, and the like. (Boden, 2004, p. 288)

If the ability of groups of neurons to produce creativity is mysterious and currently it is, then it is not clear what basis there is to the claim that neurons are unique in that ability. Without knowing what gives neuroprotein the ability to produce creativity, we are “in the dark” about whether other materials can have the same ability. Hence, the “wrong material” argument does not show that ant colonies or slime moulds are incapable of being creative.

The claim that ant colonies are able to produce creative behaviour may be counter-intuitive, and it may be difficult to believe that a slime mould plasmodium could be capable of creativity. However, there is a long history of intuitions being mistaken. For instance, the capacity of neurons to support intelligence is not intuitive.

...intuitively speaking, we cannot see how neuroprotein – that grey mushy stuff inside our skulls – can do so either. *No* mind-matter dependencies are intuitively plausible. Nobody who was puzzled about intelligence (as opposed to electrical activity in neurones) ever exclaimed ‘Sodium – Of Course!’ Sodium pumps are no less ‘obviously’ absurd than silicon chips...Even though the mind-matter roles of sodium pumps and electrical polarities are scientifically compelling, they are not intuitively intelligible. On the contrary, they are highly counter-intuitive. (Boden, 2004, p. 289)

It is certainly the case that people may find the idea of creative ant colonies or slime moulds to be counter-intuitive. However, this in itself is not enough to show that an ant colony or slime mould plasmodium is incapable of creativity. We know that neuroprotein is capable of producing creativity, but the fact that brains can be creative does not necessarily mean that *only* brains can be creative. More needs to be done to show that things that are not made up of neuroprotein are thereby incapable of creativity. Baldly stating that only neuroprotein is capable of producing creativity does nothing to prove the accuracy of the claim. Our intuitions may be that ant colonies or schools of fish cannot be creative; however, our intuitions may be mistaken.

The instinct argument

One might find the actions of the aggregate slime mould plasmodium, school of fish, and ant colony astounding and yet disagree with the claim that they are creative. The axiotextic and novel behaviour in the examples of group creative behaviour is, to the best of our understanding, instinctual (Krause *et al.*, 2009; Partridge, 1980; Sumpter, 2009). Instinctual behaviour is unlearned and inherited. Fish engage in schooling behaviour instinctually. A newborn fish does not need to observe the actions of older fish in order to learn how to engage in schooling behaviour. When individual fish join together to create a school, they do so not because they all got together the night before, had a brainstorming session and came up with the idea as a creative solution to a shared concern about predation: instead, the formation of a school is an instinctual behaviour. The instinctual nature of the fish's behaviour might make their role appear to be more akin to a cog in a machine, rather than a creative participant. I will reply to this objection in two ways. First, just because a behaviour is instinctual is no guarantee that it cannot be creative. Second, this objection misconstrues the example. I *do not* make the claim that the individual fish are being creative, but rather that the *school* of fish is being creative collectively.

Although the behaviour of the fish is instinctual, the outcome is still novel and axiotextic. As was established in chapter one, there are several kinds of novelty that are sufficient for creativity.²⁰ There are two ways to appreciate the novelty of the fish schooling behaviour. (1) There was a first instance of fish schooling, where such behaviour had never been done by fish before. In this case, the fish schooling behaviour was both H-novel (as it had never been done before) and axiotextic, as it provided a anti-predatory benefit to the fish. In which case, as it was both novel and axiotextic, the schooling behaviour was creative. (2) There is a current case of newborn fish engaging in schooling behaviour, which is the first time that these particular fish have ever participated in a school. In this case, schooling behaviour is not H-novel, as countless generations of fish have previously schooled. However, in this case, the behaviour still counts as P-novel, and the behaviour is axiotextic as it continues to provide an anti-predatory advantage; hence, it is creative. In both cases the schooling behaviour, though instinctual, is creative.

In my examples of creative collective behaviour, I do not claim that the individuals in the group are being creative; instead, I claim that the behaviour of the group *as a whole* is

20 These are historical novelty, psychological novelty, and situational novelty.

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creative. This means that through various underlying mechanisms, a group of interacting individuals produces collective behaviour that is both novel and axiotextic. The creative status of the group's behaviour is to be assessed independently of whether the individual members of the group are being creative, or are even capable of comprehending the properties or outcomes of the collective behaviour in which they are engaged. To assess the creative status of a group requires that we are able to determine whether the collective behaviour is axiotextic and novel. This presents a number of challenges, although the primary obstacle concerns our ability (or inability) to recognize axiotext at the group level.

There is more to be said about the creativity of groups, particularly on the topics of axiotext, interaction, and mechanism. There are also issues that need to be addressed regarding the various organizational scales, hierarchal "layers" of useful abstraction that comprise collective behaviour. To address these and other issues, the discussion turns now to address the topic of "Group Creativity".

Chapter Five

Group Creativity

1. The State of Current Research

Let me begin by establishing the importance of group creativity in terms of its relevance to the aims of this dissertation. As I have stated previously, the goal of this thesis is to explore the range of creativity. The investigation of group creativity is salient to the overall goal of this thesis for two reasons: Firstly, it opens the door on a whole domain of creative behaviour that would otherwise be ignored. Secondly, it shifts the perceived locus of creative behaviour away from the individual (the lone genius). Given that much of human creativity occurs at the group level, it is important that those interested in creativity to recognize the creativity of groups. It is not uncommon for problems to be tackled and creatively solved by groups, such as brainstorming sessions, research collectives, and think tanks. Interaction and collaboration draws upon the resources and abilities of several group members, and produces creative outcomes that would otherwise be unavailable to a solitary individual.²¹ I will show that group creativity, by which I mean collective creative behaviour, is distinct from individual creativity.

Group creativity deserves to be recognized as different to individual creativity (at least in terms of mechanism), and groups themselves should be acknowledged as capable of producing creative behaviour. However, this is not the case. Studies of group creativity are studies of creative individuals within groups, primarily focusing on group norms or cultural influences as factors that govern, limit, or otherwise affect the creativity of individual group members (Sawyer & DeZutter, 2009, Glăveanu, 2010). The range of group factors and individual members studied by research into group creativity is broad: they include the influence of wartime inspired political ideologies (Simonton, 2003), historical zeitgeists, interpersonal processes affecting individual motivation (Hennessey, 2003) family variables and history, and the interaction and interconnection between *person/field/domain* (Csikszentmihalyi, 1999). In each case, the individual is considered to be the locus or source of creativity. The result of this is that although there is much research being done in the field

²¹ For an intensive discussion of the differences (particularly in terms of mechanism) between collective and individual cognition and behaviour, see (Krause et al., 2009, Sumpter, 2006)

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of group creativity, the focus is fixed firmly on the individual: there is effectively no discussion of groups as being creative.

My discussion of group creativity is different to typical studies of group creativity. The examples I provide in the following discussion demonstrate that collective creativity differs from individual creativity in terms of mechanism and context. These differences demand that the idea that *groups are creative* be taken seriously. The discussion also reveals a problem that bedevils not only the investigation of group creativity, but an exploration of creativity in general.

My purpose here is not to lessen, detract from, or malign the undeniable and exemplary creativity of individuals, such as Bach and Einstein. It is possible to maintain a reverence and respect for creative individuals, while also recognizing other sources of creativity and creative behaviour, such as animals and groups. The investigation of group creativity provides examples of behaviour that is recognizable as both distinctly collective, as well as creative (in that it is both novel and axiotextic). The discussion of group creativity challenges a naive assumption about creativity, namely that creativity is restricted to the thoughts and actions of individuals. The discussion of group creativity effectively broadens our concept of creativity, by providing examples of collective creative behaviour. Group creativity is not a rare phenomenon; and this is reflected in the examples given, where the subjects are mundane, and their behaviour familiar. These examples of group creativity include sports teams, and armies. They demonstrate the existence and prevalence of creative groups, as well as highlight the differences between group creativity and the creativity of individuals.

The investigation of group creativity necessarily ventures beyond the domain of individual creative behaviour: and in so doing faces a serious difficulty. For reasons that I will make clear, the investigation of group creativity illustrates the limitations of my definition of creativity.²² More specifically, I will demonstrate that any investigation of creativity that uses a similar definition will be unable to address the full range of creative group behaviour due to the difficulty of determining axiotext for groups and collective behaviour.

²² The limitation is not due to a fault with my definition of creativity in particular. The limitation stems from our limited capacity to determine axiotext in the behaviour of others. The criteria of axiotext (or near analogues like value and appropriateness) is included in every modern definition of creativity, which means that any current definition of creativity suffers from the same limitations for the same reason.

The first half of this discussion is an examination of the mechanisms of group creativity; it serves to establish the existence of group creativity by exploring examples of collective creative behaviour. The aim of the first half of the discussion is to both establish the existence of group creativity, and to highlight the differences between individual and group creativity in terms of mechanism. This involves an example of collective creative behaviour in a sports team.

The second half of the discussion concerns the difficulties inherent in studying and assessing group creativity using a definition. These difficulties primarily concern our ability to recognize the axiotext of collective behaviour, and to a lesser extent the scale and complexity of the collective behaviour of large groups. These difficulties are discussed, and afterwards I provide a solution to these problems.

During the discussion of group creativity I will make common use of the two terms, “organizational unit” and “organizational scale”. I would like to explain these two terms. An “organizational unit” is roughly synonymous with “complex unit” or “whole group”. It refers to an organized set of parts as though they were a single unit or entity. An example of an organizational unit is a molecule, which is composed of several atoms. Together, these atoms form a group or “organizational unit”, which is referred to as a single molecule. This example can also be used to illustrate the term “organizational scale”.

An organizational unit is a complex unit, composed of parts. An organizational unit can be described as a whole, or in terms of its constituent parts. One can understand “organizational scale” as referring to levels or layers of useful description. For instance, depending on the organizational scale used, the behaviour of a molecule can be described as a single unit or decomposed into a collection of atoms. The molecule can be described on two organizational scales: the molecular organizational scale, where collections of atoms are described as single organizational units called molecules, and the atomic organizational scale, where collections of sub-atomic particles are described as single organizational units called atoms.

Organizational scale is useful for describing complex systems or collectives. Complexity - quantified in terms of behaviour, interactions, and objects/agents - decreases as one ascends the levels of organizational scale, and increases as one descends. A description of the behaviour of a molecule as a single unit is far less complex than the behaviour of a

molecule described in terms of the behaviour of several atoms. In the first case, the description consists of one object (the molecule); the latter describes several.

In this section on group creativity, the examples of creative behaviour are considerably higher on the organizational scale than the atomic or molecular. The examples in this section are at the organizational scale where organizational units are collectives of multi-cellular organisms. The fact that the examples in this section are all at the same organizational scale does not mean that this is the only organizational scale at which creativity occurs, or can occur. This is demonstrated by the continued investigation of creative behaviour, which includes examples of creative behaviour that occur lower on the organizational scale.

A new study of group creativity

The focus of my discussion is groups, and not individuals in groups, thus making my discussion of collective or group creativity different from the majority of research on the subject. Research into group creativity has (almost) exclusively been interested in the individual members who comprise the group, and the effects that group membership has on their creativity or creative potential.²³ Unlike previous studies that have focused on psychological or biological attributes of creative individuals, research into group creativity aims to distinguish and explore the effects of social and cultural factors on the creative process (Amabile, 1996). In other words, group creativity research aims to produce a theory of creativity that acknowledges the role of social factors and to illustrate that “creativity takes place within, is constituted and influenced by, and has consequences for, a social context” (Westwood & Low, 2003, p. 184). This push for the recognition of the social influences and roots of creativity is in stark contrast to earlier theories of creativity, which take a strong individualist stance and view creativity in terms of individuality, ability, genius, and insight (Amabile, 1996; Mason, 2003; Simonton, 2003). This move away from a strictly individualistic view of creativity - the “We-paradigm” of creativity - is relatively recent. The We-paradigm attempts to couch the creative process within a broader framework, provided by social or cultural psychology (Glăveanu, 2010). Although the We-paradigm represents a

23 With the rare exception (Sawyer & DeZutter, 2009), research on group creativity has focused on the individuals within the group. See, (Wagner, 1995; Wink, 1997; Sternberg, Kaufman & Pretz, 2002; Amabile, 1996; Nemeth & Kwan, 1985; Oyserman, Coon & Kimmelmeier, 2002; Diehl & Stroebe, 1987; Larey & Paulus, 1999; Nemeth, 1997)

step away from a strictly individualistic appreciation of creativity, it still focuses on the individual as the locus and source of creativity.

My research into and discussion of, group creativity is different, insofar as it focuses on the group itself. I propose that groups themselves are capable of producing creative behaviour. To support my view, I will make use of studies of collective behaviour and swarm intelligence.

While there has been little research done on the creativity of groups, much has been done on the topic of collective behaviour in general. Research into collective behaviour and cognition (swarm intelligence) demonstrates that there are important differences between individual and collective cognition. However, the results and subsequent implications that research into collective behaviour and cognition has for our appreciation of creativity (especially in terms of creative groups) has yet to be properly recognized within the field of creativity research (Sawyer & DeZutter, 2009). In this chapter, I use research into collective behaviour and cognition to demonstrate that group creativity is distinct from individual-within-a-group creativity, and that groups are capable of being creative. This approach breaks new ground, as this is the first time that the creativity of these groups (sports teams, the army) has been discussed in creativity literature. As I will show, a full exploration of the creativity of groups requires a radical departure from current methods of assessing creativity and the creation of a *new and different kind* of definition of creativity, based on a unique way of approaching and understanding creative behaviour.

2. Examples of Creative Groups

Human beings are social animals, and the formation of groups, from families to nations, is ubiquitous. People form groups of various kinds, for various reasons. People join together in groups of families, tribes, companies, teams, religious groups, political parties, communities, and military forces. Through collective action, groups have capabilities that are beyond the scope of the individual. Individuals acting in concert bring about social and political change, wage wars, fight crime, produce new research, and create and establish new directions in art.

People join together into groups to perform actions or achieve outcomes that would be difficult or impossible to achieve as a solitary individual. These collective actions or outcomes can be creative. An example of this is exhibited by sports teams, where individuals must act collectively to achieve certain goals or results. These goals relate to winning the

game and are typically along the lines of “scoring points” and “preventing the other team from scoring points”. Sports teams are often creative when they achieve these goals. I have played competitive paintball for nearly a decade, and as I am well acquainted with the sport, I have chosen paintball to be my first example of group creativity.

3. Creative Behaviour in Paintball Teams

A common game format for competitive paintball is “Center flag”, where a flag is placed in the center of a rectangular field of play. Two teams begin the game located at the two far ends of the field. (*See Illustration below*)

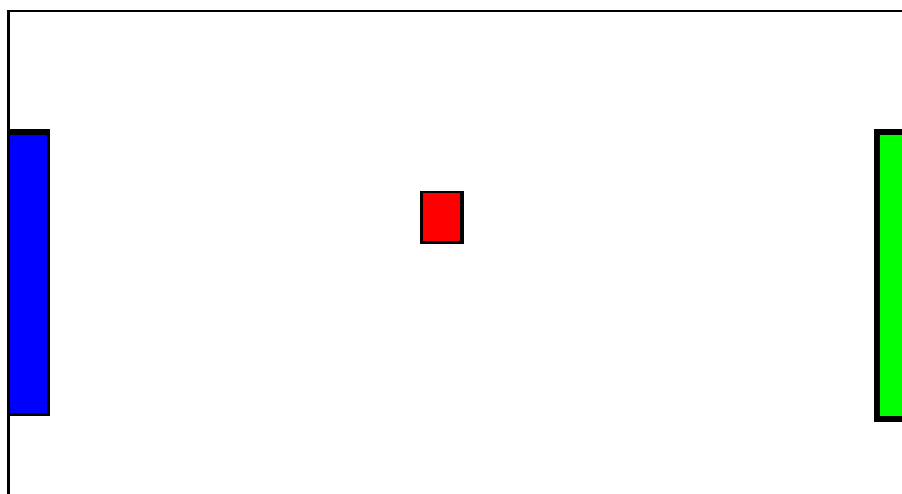


Illustration 14: Blue is Team A starting position, Red is the flag, Green is Team B starting position.

The goal of center flag is to capture the flag and take it to the opposing team’s starting position. As paintball is a non-contact sport, a team does not force the flag to the goal by physically overwhelming or out-running the other team. Each member of each team is equipped with a paintball “marker”, which fires paintballs. An individual player is eliminated if a paintball breaks on them. Therefore, each team attempts to eliminate enough (typically all) of the opposing team so that they can get the flag to the opposing team’s starting position without being eliminated themselves.

The paintball field contains a number of objects, referred to as “bunkers”, for the players to hide behind to avoid being hit with paintballs. In the past, these objects have included trees, hay bales, and piles of tires. Now the majority of competition level paintball is played using inflatable objects, called “sup air bunkers”; these are made of a soft, bouncy poly-urethane shell, that is inflated with air, like a balloon. These bunkers have become

ubiquitous in tournament paintball as they are lightweight for their size, and can be more easily arranged so that fields are “mirrored”. A field is “mirrored” if the bunkers are set up thus that if the field is divided by a vertical line down the center, the objects on both sides of the dividing line are identically arranged; hence, each side is like a mirror reflection of the other. Mirrored fields are the norm in competitive paintball, as it provides a level playing field; where neither team has an advantage or disadvantage depending on which side they start from.

In a game of center flag, a team will have a plan or strategy for how they will start the game. This plan consists of which bunker each player will initially attempt to get to, and which bunkers they will try and stop the other team from getting to. This plan is called the “breakout”, and it dictates the actions of the team for the start of the round of play.

After the breakout, the team must continually *assess* the unfolding game situation and rapidly *respond* to changes, which is referred to as “reading the field”. Reading the field is dynamic interactive process, that involves taking stock of which players on your own team have been eliminated, which players have been eliminated on the opposing team, the location of your team mates and the players on the opposing team, and using that information to produce and execute a game plan. The team must continually collect, process, respond to, and act on the information gathered as the game progresses. Doing so allows the team to coordinate players' actions to achieve goals, such as gaining better positions on the field, preventing the other team from gaining superior positions, eliminating members of the other team, keeping their own players from being eliminated, and setting up planned plays to attempt to force an outcome. A paintball team reading the field responds collectively to in-game situations. For instance, if a player on the opposing team has moved too far up the field to be effectively protected by his teammates, a paintball team will often work together and make moves so as to further isolate and surround that far-forward player for an easy elimination. Reading the field is a collective behaviour, and is often creative.

Collective mechanisms produce creative behaviour

Reading the field, and collectively coming up with a strategy for the remainder of the game, requires cooperation and communication among the players. Reading the field is analogous to the behaviour of basketball teams, as described in recent studies.

Players respond almost instantaneously to each other and their opponents, taking into account not only their teammates' positions but also their projected intentions,

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abilities, and roles. Coaches do provide strategic direction, but much more important are the in-the-moment negotiations and communications between players (Goldstone & Gureckis, 2009, p. 18)

Like the players in a basketball team, the players in a paintball team respond instantaneously to in-game changes. The negotiations and communication amongst players are interactive, and non-hierarchical.

Every (non-eliminated) member on a paintball team is involved in reading the field. There is typically no single on-field “decision maker” who is in charge. This is due to the fact that it is possible for any player on the field to be eliminated during a given game. If a paintball team elected one player to make the plans and decisions, and that player was eliminated before the other players on their team, then the team would lose their ability to read the field. Furthermore, if other teams were to discover that only one member of a team was responsible for, or capable of reading the field, they would target that player for early elimination. Therefore, it is important for every member of a paintball team to be able to read the field. Reading the field requires the coordination and communication between players to overcome the limitations imposed by individual perception.

Due to the size and positioning of the objects on a paintball field, it is typically impossible for a player in a single location to see the whole field. Sup air bunkers are large enough for grown men to hide behind, and they often create “blind-spots”, where whole areas of the field can be hidden from sight. *(See Illustration below)*



Illustration 15: A portion of a competition paintball field including sup air bunkers. Notice the blind-spot produced from this vantage point by the large triangular sup air bunker in the foreground. Author's photo.

To combat this limited perception, as a paintball team spreads out across a field, the players communicate with one another to relay the location of the opposing team players. The result is that instead of each player only knowing the location of one or two opposing players, the whole team knows the location of every opposing player. (See Illustration below) This communication continues throughout the duration of the game, constantly updating information about the number of opposing players and their position on field, as well as which players in your own team are still in play. Knowing the numbers and location of the opposing team is vital to being able to “read the field”. To “read the field” is to collect and process information about player location and eliminations, and then to produce a game plan or strategy which is based on that information.



Illustration 16: Three paintball players spread out and communicating, engaged in "reading the field" from their respective positions. Author's Photo

Creative collective behaviour

Reading the field is a potentially creative activity, in that it can produce novel and axiotextic strategies. As it requires cooperation and communication between players, reading the field is a collective behaviour. Competitive paintball fields change with each tournament.

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The layout of the sup air bunkers on the field at a given tournament will be different from the layout used at other tournaments. A strategy that worked on a particular field configuration might be disastrous on a different configuration. Hence, a paintball team reading the field has to produce a novel strategy to account for the new configuration of bunkers.

Field configuration is not the only source of novelty in a paintball game. As players on both teams are eliminated, and those remaining move from bunker to bunker, the players on a paintball team can find themselves in a previously un-encountered position. Different field layouts, player locations, as well as varying numbers of teammates and opponents eliminated, provide a wellspring of novel in-game situations. The differences of in-game situations are not trivial, as each variable (field layout, player numbers, and location) is important in regards to setting up and executing moves and set-plays. Paintball teams must be able to communicate and cooperate to produce strategies in response to novel in-game situations. The novelty of the in-game situations necessitate the spontaneous production of novel strategies that are “custom made” or specifically tailored for the current match.

The differences in field layout, player numbers and position all combine to create novel in-game situations that require the production of novel strategies. The strategies must be novel to be effective, as old game plans will have been based on previous in-game situations that - given the number of variables in a game of tournament paintball - will almost certainly be different from the current match. An effective team strategy is axiotextic, as it has worth or value within the given context of tournament paintball (i.e winning is good). In a game of center-flag: an effective strategy that leads to victory is axiotextic. Therefore, since reading the field is a collective behaviour that produces novel and axiotextic results, it is a collective creative behaviour which is *produced by the team as a whole*. Given that the creative behaviour is produced collectively through interaction and communication, it is a mistake to view it as a case of individual creativity.²⁴

Reading the field *as a team* involves cooperation and communication between players: it is not individual behaviour. This is not to say that a single player cannot read the field. If the rest of her teammates are eliminated, the last remaining player must read the field

24 This is similar to the conclusions drawn by Sawyer & DeZutter regarding creativity and collaboration in theater groups. “(in a group creative process) that generates a creative product, but one in which no single participant's contribution determines the result...in cases of creativity such as this, it is inaccurate to describe creativity as a purely mental process; rather, this case represents a nonindividualistic creative process” (2009, p. 81)

alone. A single player is capable of reading the field and coming up with a creative strategy on their own. However, reading the field as a team and reading the field as a single player are different. Although both involve the same information, and both result in the production of strategies, reading the field as a team involves communication, cooperation, and other interactions between players. This is not the case for the solitary individual.

Collective creative behaviour is similar to swarm intelligence. Swarm intelligence is a term that refers to the ability of groups of animals to solve problems that are unavailable to, or beyond the cognitive capacity of, individual animals. Swarm intelligence is different from individual intelligence, in that it involves cooperation and interaction:

whenever SI (swarm intelligence) enables grouping individuals to solve a cognitive problem, then the way in which this is done (information processing through interaction) is unique to grouping and cannot be implemented by singletons (even if they are capable of solving the problem in other ways). (Krause *et al.* 2009, p. 2)

The creative collective behaviour which results from the interaction of individuals is unique to group creativity. Group creativity involves interaction, which like swarm intelligence, “cannot be implemented by singletons”.²⁵ This difference in mechanism (interaction, communication) between group creativity and individual creativity is one reason to take the idea of creative groups seriously. Since the creative behaviour produced by a group (like reading the field) involves mechanisms that are *unavailable* to singletons: a move to reduce the collective behaviour down to the individuals that comprise the group should be resisted.

I would like to address a worry about this example of group creativity. The worry is that despite demonstrating that reading the field is a collective behaviour, one might still be thinking about this example of group creativity, and about group creativity in general, in terms of the individuals involved. In other words, I worry that it appears that this example does not demand that idea of *creative groups* (as opposed to creative individuals *in groups*) be taken seriously. I believe that the reason for this is the similarity between what is understood to be axiotextic for the group as a whole, and what is understood to be axiotextic for the individuals members of the group. To put it another way, what is “good” for the group is also what is “good” for the individuals within the group. Winning the paintball game is good (axiotextic) for the paintball players, and it is also good (axiotextic) for the

25 (ibid, 2009)

paintball team. This similarity in axiotext at different levels of organizational scale (individual players and the team) can make it difficult to differentiate between the creativity of the *group itself* and the creativity of the individual members. To remedy this, the next example of group creativity involves a group whose behaviour is axiotextic for the group itself, but detrimental for the individual members of the group. This illustrates an important difference between individual and group creativity, and provides further reason to take the idea that the *group itself is being creative* seriously.

The group in this next example (an international military coalition) differs from the groups in the earlier examples (a sports team, school of fish, ant colony); in terms of the size of the group, the scale of organization, and the fact that the axiotext is clearly different at the individual and group level. Afterwards, I discuss the idea of different axiotext at different organizational scales (individual and group level), and examine the implications that this has for our understanding and investigation of creativity in general.

4. Collective Benefit and Individual Detriment

Military history is replete with examples of creativity on both the individual and group scale. I do not argue that *all* military actions or innovations are creative. Creative advances have repeatedly revolutionized the practice of combat. For instance, guerilla tactics and gunpowder are two innovations that, when introduced, changed the way people fought. The history of warfare, including new tactics, vehicles, weapons and armour is essentially a catalogue or “fossil record” of creativity.

In the Second World War, the world’s nations allied themselves together into two opposing military organizations, the Axis and the Allies. The size and scale of this war was incredible. During the conflict more than one hundred million military personnel were mobilized to fight (Gilbert, 1989). As the armies of the Axis and the Allies engaged each other, their actions were sometimes creative. Operation Overlord was one of those creative actions.

During the Second World War, the Allied forces undertook a series of beach landings, referred to as “Operation Overlord” and “Operation Neptune”. These landings commenced on the 6th of June, 1944, otherwise known as “D-Day”. Operation Overlord involved the combined efforts of American, British, Canadian, and Free French military personnel, and to this date, Operation Overlord remains the largest amphibious invasion ever undertaken

(Gilbert, 1989). Five thousand Allied navy ships and over one hundred and ninety five thousand Allied navy personnel took part in the operation, with over one hundred and seventy five thousand troops actually landing on the beaches. Due to what happened to the soldiers who landed on the beaches, and the result of the undertaking in terms of the Allied war effort, Operation Overlord is an example of group creativity that is split or divided along the lines of organizational scale. By one measure, Operation Overlord was creative; by another, it was not. I will start by demonstrating how Operation Overlord was creative.

To be creative, the behaviour of an army must be both novel and axiotextic. In regards to military maneuvers, novelty can be very important. One reason that novelty is important is that it avoids predictability. When one is at war, the ability to predict the opponent's actions is a tremendous boon. Being able to accurately predict your opponent's actions and reactions allows for certain tactics to be effectively employed against them. For instance, if you can predict that your opponent will be at a certain place at a certain time, then you can use that information to ambush them. By ambushing your opponent you gain the element of surprise and can take time to prepare for the engagement beforehand, thus giving you valuable advantages in combat.

Without novelty, the behaviour of an army would be predictable as the army would act and react in the same manner time and time again. By acting in novel and unpredictable ways, an army can keep it's enemies "on their toes". An unpredictable attack possesses the potential of catching an opponent at a vulnerable moment. If an opponent expects that an attack will come later, an earlier "surprise" attack may catch them off-guard when they are not properly prepared to defend. Additionally, an army can make novel use of weapons or technology (which may themselves be novel). An attack can be novel in terms of size as well. A huge offensive might be launched in hopes of quickly overpowering an enemy, or a tiny attack might be used to draw out or distract enemy forces. Novel implementations of weapons and technology can change the offensive, defensive, and other (communications, transport) capabilities of an army. Essentially, novelty is an important aspect of successful military operations.

The novelty of Operation Overlord

Operation Overlord was a novel maneuver in terms of its size; no amphibious military operation as large had ever been performed. Operation Overlord was also novel in the use of newly-developed weapons and technology, including amphibious tanks (Ambrose, 1994).

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Duplex-Drive, or DD tanks were utilized to support infantry during the beach landing and subsequent invasion. DD tanks had a propeller drive to move the tank underwater, and a large water-proofed canvass floatation screen. (*See Illustration below*). Using the propeller and floatation screen allowed the tanks to “swim” ashore after being launched from ships. Duplex-drive tanks were launched and landed on all of the beaches targeted by Operation Overlord (Ambrose, 1994).



*Illustration 17: DD Sherman tank with floatation screen lowered.
Photo from the Imperial War Museum collection. Public domain.*

Operation Overlord was the first time that DD Sherman tanks had been used in combat. Therefore, due to the size of the operation, and use of new technology, Operation Overlord was novel. However, it is not the novelty of Operation Overlord that makes it such a special example of group creativity; it is the axiotext. The axiotext of Operation Overlord is “special”, because it is different at different organizational scales.

The axiotext of Operation Overlord

There are two ways that one can assess the axiotext of a military action like Operation Overlord. On the one hand, the outcome of Operation Overlord (the taking and establishing of beach heads in Nazi-occupied France) was clearly beneficial to the Allied war effort. Operation Overlord was axiotextic for the Allied forces achieving victory in the European theater: victory that directly contributed to winning the war (Ambrose, 1994). On the other hand, the casualty rates of soldiers involved in the operation, especially at the landing sites on Omaha beach, were very high. This means that Operation Overlord was not axiotextic, but was instead detrimental for many of the soldiers involved.

Viewed as a whole, a military operation can be axiotextic in ways that are not necessarily shared by the component “parts” of that military unit. Behaviour that is axiotextic for the military as a whole is often detrimental to the individual soldiers. For instance, soldiers may be assigned to undertake a “suicide mission”, a risky maneuver that carries a high probability that the soldiers will be killed while performing it. For the individual soldiers, participation in such a risky maneuver is not axiotextic; participation on their part is detrimental (as they will likely be maimed or killed). This was the case with the first wave of soldiers who, early in the morning on June 6th, 1944, landed on Omaha beach and suffered heavy casualties.

Operation Overlord was axiotextic for the Allied armies, in that it helped secure a victory in the Second World War. For the multitude of soldiers who were maimed, psychologically damaged, or lost their lives, Operation Overlord was not axiotextic. Unlike the earlier examples of group creativity, there is a clear distinction in what is axiotextic for the individual members of the group, and for the group itself.

5. Creativity at Different Organizational Scales

The fact that Operation Overlord was axiotextic on one level (for the Allied armies) and detrimental on another (for the individual soldiers) means that it satisfies the criteria for creativity at the group level, but not at the individual level. This means that Operation Overlord was simultaneously creative, and not creative. I will examine this claim in detail, and then discuss the implications.

Operation Overlord was axiotextic for the Allied armies; it had value for the Allied armies within the context of achieving victory in Europe. As a historical event, the strategic importance of Operation Overlord is a matter for debate. The Allied armies achieved victory, yet the question can be raised “Was victory achieved because of Operation Overlord, or in spite of it?” Operation Overlord and the subsequent Normandy campaign have been criticized both in terms of use of resources that might have been put to better use elsewhere, and the duration of combat (Gilbert, 1989). In spite of these criticisms, Operation Overlord is considered to have been a decisive strategic victory for the Allied forces, and is seen as a landmark in the history of the war which signaled the beginning of the end for Nazi Germany (Ambrose, 1994).

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The Allied armies achieved victory over the Axis in the Second World War. To that end, at least some of the operations undertaken by the Allied armies must have been axiotextic (instrumental in achieving that larger victory). Those operations resulted in the casualties of the soldiers involved. Therefore, even if current historical opinion is mistaken, and Operation Overlord was not axiotextic for the Allied war effort, there are other examples of military action that are axiotextic at the group level and not axiotextic at the individual level.

Individual detriment

The claim that Operation Overlord was not axiotextic for the individual soldiers involved is self-evident. To be killed in combat was not axiotextic for the casualties of Operation Overlord. People do not typically pursue their own demise; those who do are suicidal. As being killed is contrary to their goals and interests, it is not axiotextic.

One might agree that Operation Overlord was not axiotextic for the soldiers who died or were injured, but argue that it was axiotextic for those soldiers who survived the beach landings without serious physical injury. After all, their actions contributed to the success of the operation and they survived without serious injury. However, first-hand accounts of what it was like to be a soldier involved in the beach landings on D-Day describe it as “hellish”; accounts of the soldiers who undertook the beach landings describe the terror, confusion, and anguish of the troops who went ashore and survived (Ryan, 1959). Therefore, due to the hellish experience involved, even for the soldiers who survived, Operation Overlord was not axiotextic.

Noble sacrifice

A potential objection to my claim regarding different levels of axiotext is that the soldiers who undertook Operation Overlord could view the eventuality of their own death and suffering as an honorable sacrifice for the good of their military unit, friends and family, or nation. Viewed in this way, the terrible physical and psychological casualties suffered by the individual soldiers are actually axiotextic. Let us refer to this as the “noble sacrifice” claim.

The noble sacrifice claim is guilty of a confusion of group axiotext and individual axiotext, and actually reinforces, rather than refutes the claim that the axiotext of Operation Overlord is different at the individual and group levels. Put simply, the noble sacrifice claim is the idea that “the individual is willing to accept suffering and even death, for the good of the many”. This does not show that suffering and death are axiotextic for the individual. To

make the noble sacrifice claim, one acknowledges that the situation for the individual is bad, but insists that bad individual circumstance is an acceptable price to pay for an outcome that benefits the group. Noble sacrifice does not show that Operation Overlord was axiotextic on both the group (Allied forces) and individual (soldiers) level. Instead, it acknowledges that the axiotext was different at the two levels, but argues that the axiotext at the group level *trumps* the suffering on the individual level.

In essence, Operation Overlord is an instance where “What is good for the group is not necessarily good for individual members of the group”. I take this idea to be uncontroversial, with many ready examples to be made from corporations laying-off employees to avoid financial collapse, the incarceration of violent criminals for the safety of others, and the sacrifices made by martyrs to progress or give voice to a larger cause. An explanation of the potential difference between “good for the group” and “good for the individual” is that the context (and therefore axiotext) can differ for groups and individual members of the group. This is an obvious and important point, as it highlights an aspect of group creativity that is not addressed in the literature (Sawyer & DeZutter, 2009). The point is simple, but it is not trivial. If collective behaviour is detrimental for the individual, then the individual cannot be the “who or what” that is being creative. Creativity requires novelty and axiotext, no axiotext for the individual means no creativity at the individual level.

For Operation Overlord to be axiotextic it is necessary that it be evaluated in the context of the group, in terms of the Allied war effort, rather than in the context of the individual soldiers. As axiotext is a criterion for creativity, the result of Operation Overlord being evaluated at different organizational scales is that it is both creative and not creative, depending on which organizational scale (and the associated context) you view it in. The difference in axiotext at different organizational scales has consequences for my discussion, and for the study of creative behaviour in general. I will address those consequences, but before doing so, I would like to discuss an important difference between the group in the Operation Overlord example and the groups in my previous examples of collective creativity.

6. Objections and Replies

All armies have a hierarchical structure, where the movements of troops and war machines (tanks, fighter-planes, bombers, destroyers, battleships) follow the orders issued through chain of command. This means that, to a certain extent, the events that took place during

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Operation Overlord were planned and orchestrated by the Allied High Command. The hierarchal structure of the army means that one might make the mistake of assuming that it was the Generals, or planning committee responsible for planning Operation Overlord who were being creative, rather than the whole army. One might disagree with my claims that Operation Overlord is an example of group creativity, requiring collaboration and interaction. Instead, one might think that the creativity of Operation Overlord is an example of individual creativity of the highest ranking officer, rather than the collective behaviour of the army as a whole.

The earlier examples of group creativity in collective animal behaviour provide a clear contrast between individual behaviour and collective behaviour. As a collective, the ant colony is capable of solving problems regarding food location and worker allocation based on food source distance. The individual ants do not measure the distance between the food sources and the hive itself to decide which food source is closest. The ant colony does not have a single ant, or small group of ants who are in charge of planning the number of workers to allocate to a particular food trail. The problem of worker allocation is solved by the colony through collective behaviour; and unlike the Allied army, an ant colony is non-hierarchical. However, it is the difference in mechanism, the interaction of multiple members, rather than the hierarchical or non-hierarchical structure, that is the relevant difference between individual and collective creativity. Interaction, whether organized from the top down (hierarchal) or from the bottom up (non-hierarchal), produces distinctly collective behaviour. The communication, negotiation and actions of the soldiers involved make Operation Overlord an example of a group whose collective behaviour was creative.

The collective processing of information occurred through radio communication between those soldiers at the front, those on other beaches, those yet to land, and those stationed on the ships which were providing artillery fire. This allowed for the successful allocation of reinforcements, covering fire, and supplies, and required cooperation and interaction, thus it is an example of problem solving that is “unique to grouping”. Even if the operation could have been carried out by a single individual -- Superman singlehandedly invades the beaches of Normandy -- the creative behaviour of the group is distinct from the creative behaviour of the singleton. The Allied invasion of the beaches of Normandy is different from Superman's invasion of the same beaches, in that the Allied invasion involved

interaction. Regardless of whether Operation Overlord was planned by an individual General in High Command, (and it was not),²⁶ the undertaking of the operation was collective.

I have presented examples of collective behaviour that is both novel and axiotextic (creative), in groups that have hierarchical structures (armies) and non-hierarchical structures (sports teams, schools of fish, ant colonies). These examples demonstrate that both hierarchical and non-hierarchical groups are capable of collective creative behaviour, and therefore the hierarchal/non-hierarchal organization of a group is not sufficient to determine whether that group is capable of creativity.

To summarize the discussion of group creativity thus far, the examples of group creativity highlight two differences between group creativity and individual creativity: namely, “group level axiotext” and “interaction”. Group axiotext can be different to individual axiotext, the result being that behaviour that is axiotextic for the group is not necessarily axiotextic for the individuals. Furthermore, group creativity involves interaction between individuals. In terms of context and the underlying “mechanism” of interaction, group creativity differs from individual creativity. These differences are enough to encourage one to view not just the collective behaviour, but the group itself, as creative.

As I stated earlier, the potential for different axiotext at different organizational scales has implications for my investigation of creative behaviour, and for the study of creativity in general. The differences between collective creative behaviour and individual creative behaviour direct us to view the creativity of groups as meaningfully distinct from individual creativity. The difference in axiotext that helped to highlight the differences between group creativity and individual creativity raises problems for the study of creative behaviour that must be addressed. In particular, the potential for different axiotext at different organizational scales means that a given behaviour can be simultaneously creative and non-creative.

Evaluating axiotext at different organizational scales

Differences in applicable contexts and their importance in evaluating creativity have been established and discussed in several studies (Advares-Yorno et al., 2006; Amabile, 1983, 1996; Csikszentmihalyi, 1998, Howe, 1999, Wetherell, 1987). These studies are primarily concerned with the potential conflict or opposition between the individual and the

²⁶ Operation Overlord was not planned by an individual, but by a collection of high ranking individuals including Frederick Morgan and Ray Barker, as well as other members of the COSSAC staff (Gilbert, 1989).

group in terms of evaluating potentially creative behaviour. Studies, in particular the work of Adarves-Yorno *et al.*, have shown that there are differences in the production of creative products, and the evaluation of potentially creative behaviour as an individual and as a group. Groups and individuals differ in terms of the artifacts and behaviours that they produce and determine to be creative. A given behaviour might be determined to be creative by a solitary individual and not recognized as creative by a group. An individual artist might view their work as clearly creative, and at the same time that artist's work might be regarded as uncreative by art critics or by society in general.

The existence of different and potentially opposing axiotext at the individual and group level has repercussions for the study of creativity. The idea that a particular behaviour can be both creative and non-creative raises problems for research on creative behaviour:

One limitation of nearly all creativity research – on individuals as well as groups – is the prevailing assumption that the researcher can decide what is creative and what is not. The problem with this assumption is that it disguises the fact that in non-research settings “creativity” is a social judgement, not an objective property of the creation that can be assessed independently of its social context (Adarves-Yorno *et al.*, 2006, p. 1)

The potential for difference in the creative status of a given behaviour or object does not contradict my claim about group creativity, rather, it supports my argument. My claim about axiotext being different at the individual and group level is supported by research that highlights the existence of *different levels at which the creative status of a given behaviour can be assessed*. This has consequences for the study of creativity in general, as well as the overall goal of this dissertation: an investigation of the full range of creative behaviour.

If a given behaviour can be both creative and non-creative, depending on the organizational scale it is assessed at, then an investigation intended to explore the full range of creativity might mistake a great deal of creative behaviour as un-creative simply because it is unable to be assessed on the organizational scale at which it is axiotextic. Thus, an investigation of the range of creativity is limited by our ability to assess axiotext. To properly appreciate this limitation, and what can be done to overcome it, the next section is a discussion of our ability to assess axiotext.

Chapter Six

Applying Systems Theory to Creativity

1. Recognizing Creativity

Group creativity, specifically creative groups, are examples of creative behaviour where it is not clear if the question is “who is being creative?” or “what is being creative?” The difference in group-level axiotext and individual axiotext and the collaborative, interactive mechanisms of creative group behaviour are differences which illustrate the fact that the group itself is creative. This is important in terms of our understanding of the *kinds of things* that can be creative, as were the examples of the creative behaviour of individual animals (like the crow). Both have helped to expand our appreciation of the kinds of organisms that can be creative. However, a hive of ants, school of fish, or the Allied Armies in the Second World War are not organisms: at least, they are not single- or multi-cellular organisms. The groups in my examples are collections of organisms, and hence a hive or an army is more of a “what” than a “who”. The idea that groups can be creative has implications for our study and understanding of creativity, and it opens the door to a systems based account of creativity.

The Operation Overlord example demonstrates that organisms which are part of a larger group may behave in ways that is not creative when evaluated in terms of that individual’s context (storming the beaches of Normandy was not axiotextic for the soldiers). Nevertheless, the behaviour of those individuals can be creative when viewed in aggregate, and evaluated within the group-level context. By accepting that groups can be creative, we dramatically increase the set of things that are potentially creative, as we are now able to consider the creative status of collectives and behaviour on several organizational scales.

The examples of animal and group creativity provide evidence for the claim that a full investigation of novel and axiotextic behaviour cannot be limited only to the domain of human behaviour, individual organisms, or to a single organizational scale. However, our ability to fully investigate the range of creative behaviour faces a serious obstacle, as our ability to assess axiotext in the behaviour of others is limited. This limitation is not restricted to the behaviour of groups of organisms, but applies to the behaviour of other organisms, other possible minds, and behaviour at lower organizational scales as well. Following a discussion of this problem, I will propose a solution that allows us to overcome the limits

imposed by our ability to assess axiotext, and to undertake an unrestricted exploration of creativity through an application of systems theory.

2. Assessing Axiotext

There was no discussion of context in the examples of creative animal behaviour. We are able to automatically assess axiotext in the behaviour of others. Although this ability is limited. The limitations of our ability to assess axiotext has consequences for our appreciation of creativity. Here now are some examples that present our ability to assess axiotext in the behaviour of others in greater detail, followed by a discussion of the limits of that ability. The limitation of our ability to assess axiotext is a major hurdle that must be overcome by an investigation of creativity.

I have three points that I will argue for here. The first is that we have the ability to assess axiotext in the behaviour of others. The second is that this ability is limited. The third is that the investigation of creativity has been restricted by our limited ability to assess axiotext. We have the ability to recognize axiotext in the behaviour of others, we do it automatically, without requiring volitional action, or having to “think about it”. This ability is related to the concept of “mindreading” as it is used in philosophical discussions about the theory of mind (Baron-Cohen, 1995). Essentially, mindreading is the application of a theory of mind to the behaviour of others, and has three functions:

1. To comprehend and explain the behaviour of others.
2. To predict the behaviour of others
3. To manipulate the behaviour of others, based on our ability to comprehend and predict their behaviour.

Our ability to assess axiotext in the behaviour of others is predicated on our ability to understand the behaviour of others. By recognizing the axiotext in a particular behaviour, we understand why someone would undertake that behaviour. That we have the ability to comprehend the motivations (and by extension, axiotext) of others is well established and recognized in the theory of mind literature (Baron-Cohen, 1995; Churchland, 1991; Gordon, 1995 & 1996). This is sufficient endorsement for my claim that we have the ability to assess axiotext in the behaviour of others.

I will now illustrate my second point, that our ability to assess axiotext in the behaviour of others is limited. To do so, I describe our ability to assess axiotext using

terminology and examples that are similar to simulation theory. This should not be taken as an endorsement of simulation theory over theory theory, or endorsement of any other explanatory apparatus or schema regarding the theory of mind. I make no claims about the simulation theory being superior or inferior to the theory theory as a theory of mind. The following examples are intended to highlight that we have the ability to assess axiotext, and that our ability to do so is limited.

Examples of the limitations in our ability to assess axiotext

One way to explain our ability to assess the axiotext in the behaviour of others is that we are able to relate or empathize with them. We assess the axiotext of behaviour of other people by “putting ourselves in their shoes”. I enjoy the adrenaline thrill I get from riding on roller-coasters and snowboarding. I have never been skydiving, but because I enjoy the thrill of adrenaline, I can understand why people go skydiving. There are relevant similarities between behaviour that I personally find axiotextic -such as riding roller-coasters and snowboarding- and skydiving; based on that similarity, I can recognize the axiotext of the different thrill-seeking behaviours that others engage in.

There are limits to our ability to assess the axiotext of other people's behaviour. If we are unable to find any relevant similarities between our own experience and the behaviour of others, then we will find it difficult or impossible to recognize the axiotext of that behaviour. For instance, suppose that I have a mild palate or have a sensitive stomach, and spicy food causes me physical discomfort. I also have a friend who loves to eat hot and spicy food. This friend slathers hot sauce on steaks, eats raw chili peppers, and generally pursues food that causes her to sweat profusely and turns her face red. Since my mild palate and sensitive stomach have made every encounter with spicy food a painful and uncomfortable episode, I have no idea why my friend goes out of her way to eat spicy food. I am unable to recognize the axiotext of her behaviour. I am unable to “put myself in her shoes”, as what she likes about hot food is a mystery to me.

Our ability to assess axiotext extends to the behaviour of animals and other organisms. An example of this is provided by the behaviour of a pet. My father had a border collie named Zap, and some of Zap's behaviour was recognizably axiotextic. For instance, it was obvious from his behaviour that Zap loved to play fetch. Given any opportunity, Zap would find an object that could be thrown and retrieved: sticks, balls, frisbees, stuffed toys, and an array of other small, throwable objects. Given his apparent love of playing fetch, I

can recognize his throwable-object finding behaviour as axiotextic. I am able to “put myself in his shoes” as it were, and I can appreciate the connection between loving to play fetch and behaviour that enables the game of fetch to be played.

Our ability to assess axiotext in the behaviour of animals has also been demonstrated in the examples of animal creativity given earlier in this dissertation. In the discussion of animal creativity, the behaviour of the New Caledonian crow (bending a piece of wire into a hook to retrieve food from a pipe) was clearly axiotextic. It was not necessary to provide an explanation of why gaining access to food was axiotextic; neither did I discuss why not being eaten by predators was axiotextic for the fish in the school, nor why a monkey would find a clean and sea-salted sweet potato preferable to a dirty one. It was not necessary to discuss the reasons why the animal behaviour in the examples is axiotextic, as gaining access to food and not being eaten by predators is apparent, without the need for explanation.

Our ability to assess axiotext in the behaviour of animals is limited. In addition to those behaviours that were recognizably axiotextic, Zap would also behave in ways that from a human perspective were just plain odd. Whether these behaviours were axiotextic, or in what way they could be axiotextic, was mysterious. For instance, Zap would often sit down in front of a glass door or window and spend several minutes intently licking the glass. There was no food or drink that had been spilt on the glass, so he was not eating anything. Several theories were put forward about why he licked the glass. One was that he saw his reflection in the glass and was trying to lick either himself or the “other dog”. Another idea was that the glass was cold, and that maybe he liked the way it felt on his tongue. I was never sure why Zap licked the glass windows and doors. The possible axiotext of his glass licking behaviour was a mystery to me.

Zap behaved in ways that I could recognize as axiotextic, and also exhibited behaviour that I could not recognize as axiotextic. My ability to assess the axiotext of his behaviour was limited. I could emphasize with his love of playing games, but whatever benefit licking the glass door provided him was opaque. The limits of our ability become even more pronounced when we attempt to assess axiotext in the collective behaviour of groups.

Assessing axiotext in group behaviour

Our ability to assess axiotext in collective behaviour is essentially limited to those behaviours where there group level axiotext can be “cashed out” in terms of axiotext for individual group members. This explains our ability to recognize the axiotext of survival and economic gain for the members of the group. However, the range of group behaviour that is axiotextic in that way is limited. Axiotext may exist at the group level that we are unable to recognize. Groups are not necessarily comprised of organisms, and so the common ground that we as organisms can establish with groups at higher and lower organizational scales is limited, and often non-existent. For example, I can recognize the axiotext in the Bowerbird constructing a nest to attract a mate, or the New Caledonian Crow making a wire hook to get food. However, it is difficult to recognize the axiotext of the behaviour of groups, such as multi-national corporations, ant colonies, or immune systems. With other organisms, there is common ground; I can “put myself in the shoes” of other people, and even animals like dogs, birds, or monkeys. I can imagine that people who work for a corporation get hungry, perhaps ants do as well. However, to view the corporation or the colony *purely* in terms of the employees or individual ants is to miss the point, or to not take the concept of the organizational unit seriously. If we are to honestly evaluate the axiotext of *collective* behaviour, then we are looking for common ground with the *group itself*. It is not clear how to do so, as groups (ant colonies, corporations) do not appear to be the sorts of things that can get hungry, feel pain, or want to attract a mate. This brings me to my third point, that the limits of our ability to assess axiotext restrict an exploration of creativity. This means that any exploration of creativity that relies upon our ability to assess axiotext will be in danger of being incomplete, as creative behaviour may occur which is beyond our ability to assess axiotext.

3. The Cell in Picasso's Arm

To illustrate this point, imagine a remarkably intelligent and long-lived cell in a human body. The cell is a part of the bicep muscle in the upper arm. The cell is curious about the actions of the body as a whole (the collective action of it and the rest of the cells), and it wants to find out if the collective behaviour in which it takes part is creative. Through careful observation, the cell charts the behaviour of the body over a month-long period.

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It turns out that the cell is able to recognize the acts of eating, procreating, and evading danger in the collective behaviour of the body as a whole, and is able to recognize the axiotext in those collective behaviours. The cell itself engages in similar behaviours, as it “eats” glucose molecules for energy, reproduces by division, and having observed the cells in the immune system battling viruses and bacteria, understands the benefit of avoiding dangerous pathogens. The cell's collected data shows that the body as a whole engages in behaviour that it recognizes as eating, reproducing, and avoiding danger; since its own behaviour gives it some common ground, it recognizes the axiotext of these collective behaviours. However, those behaviours occur only some of the time, and account for only a portion of the body's overall behaviour. In addition to this, the body also engages in other behaviours, which are not obviously axiotextic.

Using my definition of creativity (novelty and axiotext), the cell concludes that although the collective behaviour of the body can be creative, only those actions that it is able to recognize as axiotextic (eating, reproducing, and avoiding danger) are creative. The other collective behaviour has no apparent axiotext, and so it must not be creative. However, to draw this conclusion could be a mistake. It might be the case that the collective behaviour is axiotextic in ways that the cell is not aware of.

Suppose that the cell in our example is in the body of Picasso; and that a portion of the unrecognizable collective behaviour that Picasso engages in is the painting of a picture. Let us also take it for granted that Picasso is being creative when he paints the picture. Since cells have no common ground (similar behaviour that is axiotextic), the cell cannot recognize the axiotext of Picasso painting. In this case, the collective behaviour of painting is actually creative, despite the fact that such behaviour is not obviously axiotextic at the cellular level.

The situation faced by the cell is analogous to our own. Like the cell in Picasso's arm, we can take part in collective behaviour that is only axiotextic (and therefore only creative) *at the group level*.²⁷ Given that this is the case, it is possible that we take part in collective creative behaviour, where the group level axiotext is not apparent. As was the case in the example of the cell in Picasso's arm, it is a mistake for us to assume that creativity is wholly limited to behaviour that is *apparently* axiotextic.

²⁷ This was the case with Operation Overlord. The beach landings were axiotextic for the Allied army, but not for the individuals involved.

To apprehend the full range of creative behaviour requires the ability to determine context beyond the limitations imposed by our ability to assess axiotext. Returning to the cell example, the problem for the cell was that it has no common ground with the various aesthetic, technical, social, and economic contexts in which Picasso's painting are examples of creativity. If it did, then it would be able to assess the axiotext, and therefore the creativity of Picasso's painting. The cell has no way in which to recognize axiotext at the group level, and it is entirely likely that it never will. However, the story does not have to end here.

I propose that there is an observable aspect of behaviour, collective or otherwise, that is indicative of axiotext. Roughly put, axiotextic behaviour is markedly distinct from non-axiotextic behaviour, and once you know how to spot the difference, it is possible to determine axiotextic behaviour *even in the absence of apparent axiotext*. To illustrate this, I will utilize general systems theory.

General systems theory is designed to address groups and behaviour (Bertalanffy, 1950). If a system is adaptive, axiotext can be extrapolated from the trajectory of the system through state space over time. Let me begin with an introduction to systems and systems theory, before explaining what I mean by "adaptive" systems, trajectory, and state space.

4. An Overview of Systems Theory

Systems theory is a theoretical framework through which one can investigate and describe any set of related parts. Systems theory aims for the development of systematic theoretical constructs that discuss or model the general relationships and interactions of groups. Systems theory grew out of the General Systems Theory, proposed by Ludwig Von Bertalanffy.

There exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or "forces" between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general. (Bertalanffy, 1950, p. 1)

A system is a group of interacting parts. A part of a system can be a single object or another system. A system acting as a part in a larger system is called a sub-system. A system can consist of single objects and sub-systems. Since a system can include sub-systems, a system that contains sub-systems can be a sub-system in a larger system. Systems have states; a state is a particular configuration of the parts of the system. For an example of system states, imagine a jigsaw puzzle where all the parts are scattered randomly across a table. With the

pieces in a jumble, we can say the jigsaw puzzle system is in a state called S1. Suppose we arrange the pieces (parts) to solve the puzzle (system), we could call that state S2. The parts of the system are the same, but the configuration of the pieces in state S1 is different from S2. In some cases, the parts of a system can change as well as the configuration of those parts. In those cases, the states of the system refer not only to the configuration of the parts, but to the identity of the parts as well.

In addition to parts and sub-systems, systems have “wholeness”.²⁸ Roughly defined, “wholeness” is the idea that a system is more than the sum of its parts. A system cannot be fully explained by reducing it to its elementary parts. For an example of wholeness, imagine a painting of a sailboat. The painting consists of nothing but coloured paint and canvas. The canvas and the paint, if isolated and examined, cannot explain the representative property of the painting. When viewed as a whole the painting looks like a sailboat. However, neither the paint nor the canvas has the property of “looking like a sailboat”.

System theory is a useful tool for the investigation of creative behaviour. Systems theory is a very general field of inquiry. Systems theory can illuminate the important similarities that identify creativity and creative behaviour in a wide assortment of disparate systems.

5. Systems Laws

A systems law describes the behaviour of systems. Systems laws are general; they describe different systems that are not necessarily physically identical, or even physical. An example of a general systems law is Pareto’s law; after the Italian economist and philosopher Vilfredo Pareto, who introduced and discussed it in *Cours de l’Economie Politique*. Pareto’s law is a power law, which is also known as the law of the vital few and the principle of factor sparsity. Pareto noted that his law described certain economic systems and certain biological systems.²⁹

What is known in national economy as Pareto’s law of the distribution of income within a nation, represents, in biology, the law of allometric growth, describing the relative increase of organs, chemical compounds, or physiological activities with respect to body size. (Bertalanffy, 1950, p. 1)

²⁸ *An Outline of Systems Theory*, Bertalanffy, pp. 134

²⁹ Pareto noticed that 80% of the wealth in Italy was controlled by 20% of the population. He then found the same distribution in his own backyard, where 20% of the pea pods in his garden produced 80% of the peas.

Bertalanffy presents further systems laws which describe the behaviour of biological systems, economic systems, environmental or ecological systems, various social systems, and chemical systems. The laws that Bertalanffy presents describe the behaviour of systems using mathematics, typically formulas which describe parabolic or sigmoid curves. Not all systems laws are parabolic or sigmoid formulas. Recent research into critical and near-critical system states has investigated a wide assortment of systems whose behaviour can be described using power laws (Bak, (1996); Buchanan, (2001)).³⁰

I will utilize the logarithmic spiral as an example of a general systems law that describes the behaviour of different systems. As it appears in a broad array of natural systems with radically different underlying mechanisms, the logarithmic spiral is an ideal example to demonstrate the universal reach of systems laws. First I will define the logarithmic spiral. Next I explore different mechanisms that produce the logarithmic spiral in two distinct systems (a B-Z reaction and a colony of *D. discoideum*), to demonstrate how different mechanisms can produce the same pattern. This is followed by presenting pictures of the logarithmic spiral as it appears in other systems with heterogenous underlying mechanisms. The purpose of this is to illustrate the general application of systems laws, regardless of system type (biological, chemical, economic, social) and underlying mechanism.

The logarithmic spiral

The logarithmic spiral is a spiral curve with a history. The properties of the logarithmic spiral and its common appearance in the natural world intrigued early mathematicians (Bernoulli, Torricelli) and natural philosophers (Descartes, Cook, Thompson). The logarithmic spiral is self-similar, meaning that although the size of the spiral changes, the shape of the curve remains the same. This means that the logarithmic spiral can manifest at the microscopic, as well as the cosmic scale.

The polar equation for the logarithmic spiral is:

$$r = ae^{b\theta}$$

where r is the distance from the origin, θ is the angle from the x-axis, and a and b are arbitrary constants. This produces a spiral curve that looks like this:

³⁰ For a broad assortment of examples of critical and near-critical systems whose trajectories can be described by a power law, see *Ubiquity*, Buchanan (2001).

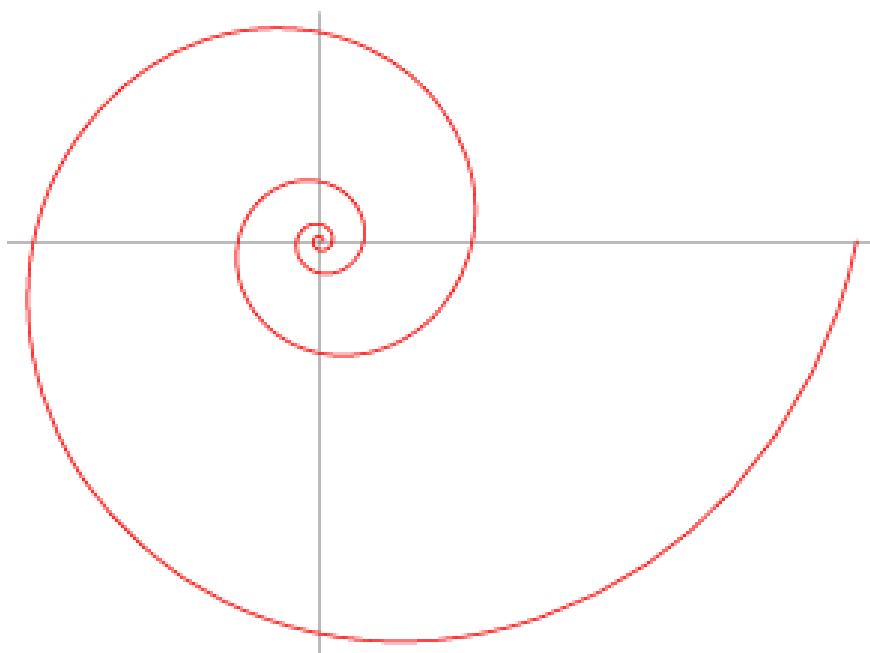


Illustration 18: Image from MathWorld, WolframMathematica.

The logarithmic spiral, which is produced by heterogeneous mechanisms, appears in many disparate systems. First I will explore two distinct mechanisms that produce the logarithmic spiral, and then I will present a number of examples of the logarithmic spiral as it appears in various systems without engaging in an exposition of the underlying mechanisms responsible. Together, these examples will demonstrate the broad range and general applicability of a systems law.

6. Heterogenous Mechanisms Producing the Logarithmic Spiral

The Belousov-Zhabotinsky reaction is an example of a nonlinear reaction, and serves as an example of nonlinear thermodynamics. Nonlinear thermodynamics is the study of time dependent thermodynamic systems, irreversible transformations, and open systems. The Belousov-Zhabotinsky reaction is a nonlinear chemical oscillator reaction. The Belousov-Zhabotinsky reaction is excitable, which leads to the formation of patterns which would not normally form in a quiescent medium (a state of equilibrium). A chemical oscillator reaction, like the Belousov-Zhabotinsky reaction, can be thought of like a room with two thermostats set to different temperatures; the two thermostats *oppose* each other, one set keep the room at 100° F and the other set to 0° F. Imagine that the two thermostats are attached to a very powerful air conditioning unit, which can quickly heat or cool the room. Suppose we start with the room being very cold, at 0° F. Since the room is at 0°, the thermostat set to cool the

room will not make any demands on the air conditioning unit. For the other thermostat set to 100°, the room is too cold and must be heated. The thermostat makes the air conditioning unit blow hot air into the room. As the room gets hot, the thermostat set to 100° will make fewer demands on the air conditioning unit. While at the same time, the thermostat set to 0° will make more demands on the air conditioning unit for cold air to bring the temperature back down again. Of course, as soon as the room cools the thermostat set to 100° will kick in and the cycle will continue. Eventually the room will reach a precarious middle ground between hot and cold.

The oscillating reaction is similar to a room with two thermostats. the Belousov-Zhabotinsky reaction is a system that contains two chemical reactions which can be seen to *oppose or respond to* each other. Each chemical reaction uses and produces chemicals. Picture a beaker or jar full of liquid. The liquid contains a mix of chemicals in which two different chemical reactions occur; reaction A and reaction B. The fluid contains, among others, chemical 1 and chemical 2. Reaction A uses chemical 2 and produces chemical 1, or in other words it converts chemical 2 into chemical 1. Reaction A occurs rapidly in high concentrations of chemical 2. Reaction B converts chemical 1 into chemical 2 and occurs rapidly in high concentrations of chemical 1.

For simplicity, the two reactions are:

Reaction A: converts chem. 2 to chem. 1

And

Reaction B: converts chem. 1 to chem. 2

In a Belousov-Zhabotinsky reaction, the concentration of chemical 1 and 2 throughout the medium is not uniform. That means that throughout the fluid in which the two reactions take place, there are *pockets* or local concentrations of either chemical 1 or 2. The chemical composition of the pockets determines which reaction will predominantly occur. Chemical 2 can be seen as a kind of fuel for reaction A, since reaction A converts chemical 2 into chemical 1. Chemical 1 can similarly be seen as the fuel for reaction B. Thus, high concentrations of chemical 1 will cause reaction B and vice versa.

Therefore,

Pockets where the concentration of Chem. 2 > Chem. 1 “fuels” Reaction A

And

Pockets where the concentration of Chem. 1 > Chem. 2 “fuels” Reaction B

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Since both reactions convert their own fuel into the fuel for the opposing reaction, each pocket of chemical concentration can be seen as a tiny instance of the room with two thermostats. The concentration of chemical 1 or 2 in each pocket creates cycles of reactions A and B, converting chemical 1 to 2, then 2 back into 1, and so on. The cycling of reaction A and B propagates waves of ions. When marking chemicals are added to the fluid medium, these waves of ions can clearly be seen. The cycling of reaction A and B creates two distinct wave shapes, spiral waves and concentric waves. When chemical markers are added, the concentric waves look like the bull's eye on an archer's target, and spiral waves look like spirals. The combination of spiral and concentric waves creates some striking patterns.

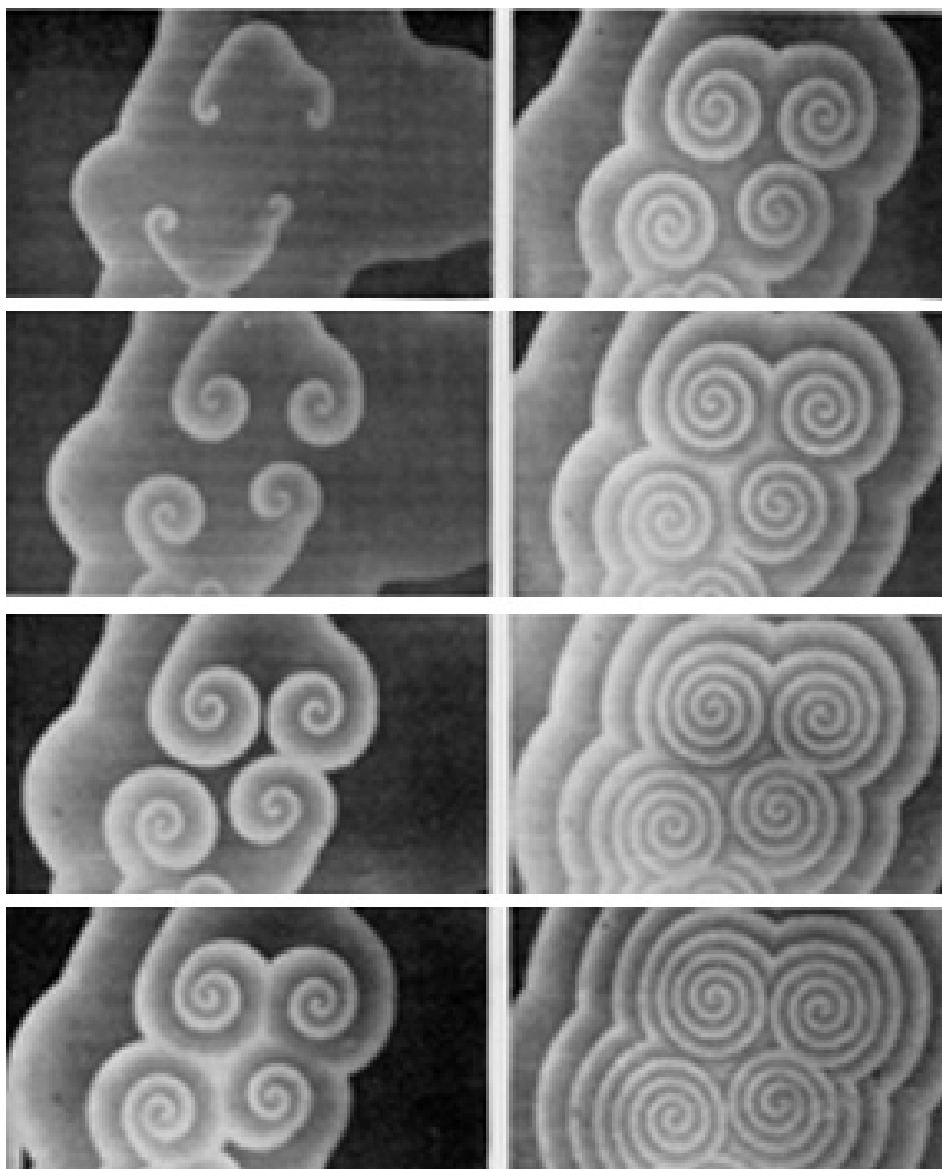


Illustration 19: Formation of spiral wave patterns in B-Z reaction. Public Domain, orig. Zhabotinsky and Zaikin, 1971.

Spiral wave pattern in D. discoideum colony

The spiral wave patterns evident in the Belousov-Zhabotinsky reaction also appear in living systems. The systems law which describes the patterns in the Belousov-Zhabotinsky reaction also describes the propagation of chemical waves in populations of *Dictyostelium discoideum* (slime moulds).

Dictyostelium discoideum is a species of slime mould, which is a member of the dictyostelid (social amoebae) group. When food (bacteria) is readily available they take the form of individual amoebae, which feed and divide under normal conditions. Then, when the supply of food is exhausted, the colony of amoeba aggregate to form a multi-cellular assembly, called a pseudo-plasmodium or slug (not to be confused with the gastropod, which is commonly referred to as a slug). The *D. discoideum* slug displays properties and behaviours that are not shared by the constituent amoebae, such as a definite anterior and posterior, the capacity to respond to light and temperature gradients, and the ability to migrate.

The slime mould aggregation occurs via amoebic chemo taxis (motility) up concentration gradients of cyclic adenosine monophosphate (cAMP). The formation of the aggregate slug begins when a single amoeba - the colony founding amoeba- releases a chemical signal of cAMP. The onset of starvation is what causes the cell to produce and secrete the chemical signal. Surrounding amoebae detect the signal and react in two ways.

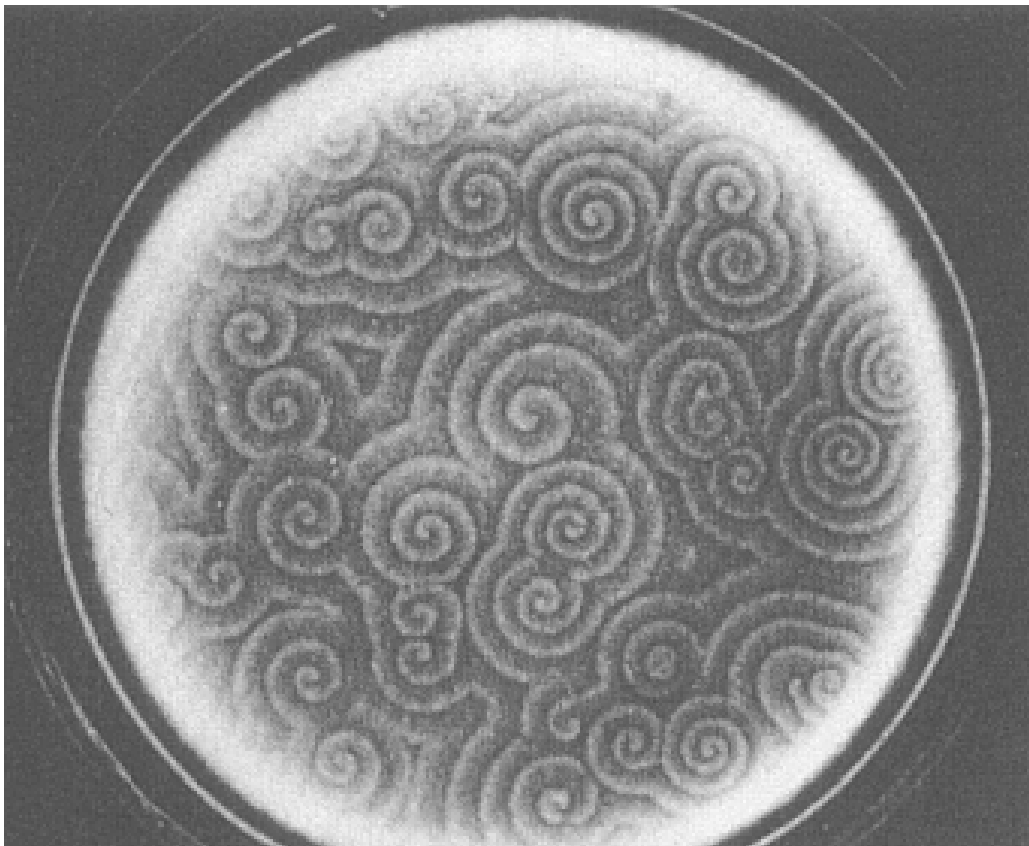
The first, and faster, process activates the adenylate cyclase enzyme which stimulates the amoebae to produce the chemical signal (cAMP). As the chemical signal is secreted from the amoebae, it can bind to the same cell, stimulating the production of more cAMP. The secreted chemical signal spreads to other nearby cells, which causes them to produce cAMP as well. In this way, the chemical signal travels across the cells, like a ripple in a lake.

The second process is slower to take effect, and leads to inhibition of the production of adenylate cyclase; the enzyme which triggers the production and secretion of cAMP. This stops the autocatalytic production of the chemical wave of cAMP, as further secretion of the chemical signal stops and the already-secreted, extra-cellular chemical signal is diffused and eventually degraded by phosphodiesterase: a chemical which is secreted by the slime mould cells. Once the concentration of extra-cellular cAMP reaches a low threshold, the second process stops and the cells slowly regain the ability to produce cAMP. This allows the first process to begin again, and for the production and propagation of the chemical signal.

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The alternating cycles of autocatalytic production/secretion and inhibition produce a chemical wave that travels through the colony of slime mould amoebae. As the chemical signal is diffused and degraded, the lower cAMP concentration excites amoebae that then relay the wave by producing more cAMP. When the amoebae become refractory (inhibiting further cAMP production), the chemical wave “moves on”. The chemical waves produced by the alternating cycles of production and inhibition form patterns like those observed in Belousov-Zhabotinsky reactions (Spiral and concentric wave patterns).

The oscillations create striking patterns of spiral and concentric waves in the colony during the morphogenesis of the aggregate slug. The patterns of spiral and concentric waves are described by the same systems law that describes the wave patterns in the Belousov-Zhabotinsky reaction (*See illustration below*).



*Illustration 20: Spiral wave formations in a colony of D. discoideum.
Photo from Ball, 1994*

The general systems laws that describe concentric and spiral waves illustrate shared behaviour in disparate systems. In addition to Belousov-Zhabotinsky reactions and *D. discoideum* colonies, spiral waves describe the form of hurricanes, the nautilus shell, and galaxies (*See illustrations below*).



Illustration 21: Satellite photograph of Hurricane Fran. Photo by NASA.



Illustration 22: M74: The Perfect Spiral Galaxy. Photo from Nasa, Gemini Observatory.



Illustration 23: Logarithmic spiral in a bisected nautilus shell.

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The mechanisms responsible for the spiral forms in hurricanes, shells, galaxies, chemical reactions and slime mould cultures are heterogenous. Despite the differences in mechanism, the same systems law describes the shared form in varied systems.

General systems laws can apply to any system, regardless of mechanism or composition. Hence, a general systems law has a tremendously broad range. I will argue that the scope of systems and phenomena available to a definition of creativity which is based upon a general systems law is far wider than is available to definitions of creativity currently in use. The latter are limited in their range by our ability to assess axiotext (as we cannot assess the axiotext of a significant portion of group or animal behaviour); and therefore, in terms of investigating the full scope of creative behaviour, using a general systems law is superior. The question is *what kind of systems law could be formulated to define creative behaviour?* I will provide an answer to that question shortly, but before doing so; I will examine an example of a systems law which was used to describe creativity, but falls short of my requirements.

I am not the first to think of using general systems laws to describe creativity. Kauffman makes use of systems laws to describe creativity in his discussion of self-organized, near-critical systems (1995). Kauffman's discussion of near-critical systems includes two examples that are salient to our discussion here, namely technological innovation and evolution:

Might the same general laws govern major aspects of biological and technological evolution? Both organisms and artifacts confront conflicting design constraints....We explore the landscapes of technological opportunity with intention, under the selective pressure of market forces. But if the underlying design problems result in similar rugged landscapes of conflicting constraints, it would not be surprising if the same laws governed both biological and technological evolution. Tissue and terracotta may evolve by deeply similar laws. (Kauffman, 1995, p. 191)

In his investigation of self-organizing systems, Stuart Kauffman proposes that the evolution of organisms and the “evolutionary” changes in artifacts might be governed by the same, or “deeply similar”, laws. As evidence for his claim, Kauffman provides descriptive examples of both innovation and evolution, in which both display a pattern of rapid experimentation followed by slow modification (Kauffman, 1995). To better illustrate this pattern, I will now examine the two examples Kauffman provides. The first example describes the evolution of biological forms that occurred during the Cambrian explosion.

Kauffman's description of the flourishing of biological forms does follow a pattern of “exuberant” novelty, followed by the extinction or the gradual modification of the surviving life forms:

Soon after multi-celled life forms were invented, a grand burst of evolutionary novelty thrust itself outward...in a kind of wild dance of heedless exploration. As though filling in the Linnean chart from the top down, from the general to the specific, species harboring the different major body plans rapidly spring into existence in a burst of experimentation, then diversify further. The Major variations arise swiftly, founding phyla, followed by even finer tinkering to form the so-called lower taxa: the classes, orders, families, and genera. Later, after the initial burst, the frenzied party, many of the initial forms became extinct, many of the new phyla failed, and life settled down to the dominant designs, the remaining 30 or so phyla, Vertebrates, Arthropods, and so forth, which captured and dominated the biosphere. (Kauffman, 1995, p. 191)

Kauffman's description of the profusion of biological novelty is not just wild speculation about what may have happened earlier to produce the broad variety of body plans that life has today. There is evidence of the “grand burst of evolutionary novelty” of the Cambrian explosion, specifically the fossilized remains of organisms that have been found in Burgess shale formation, and other fossil sites (Erwin, 2007). Kauffman compares his description of the Cambrian explosion and the pattern of “heedless novelty, followed by fine tinkering”, with a more general description of human invention:

Here human artificers make fundamental inventions. Here, too, one witnesses, time after time, an early explosion of diverse forms as the human tinkerers try out the plethora of new possibilities opened up by the basic innovation. Here, too, is an almost gleeful exploration of possibilities. And, after the party, we settle down to finer and finer tinkering among a few dominant designs that command the technological landscape for some time -- (Kauffman, 1995, p. 192)

Kauffman's pattern of wild novelty followed by fine tuning is intriguing, and may accurately describe the trajectory of *some examples of* biological and technological “evolution”. More importantly, it demonstrates that systems laws can potentially be used to describe creative behaviour. In other words, general laws can be formulated which describe the behaviour of various systems despite differences in physical make-up and underlying mechanism, including biological and technological systems: an idea which is central to the current discussion. However, Kauffman's discussion does not actually provide me with a systems law that describes creative behaviour, and the pattern of “heedless novelty, followed by tinkering” that he describes is poorly suited for an exploration of creativity in general.

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For my purposes (a general systems law that describes the pattern produced by creative behaviour over time), the pattern proposed by Kauffman is a poor candidate. The primary reason for this is that it requires that we have a clear picture of the full history of a potentially creative system. To discern the pattern of wild novelty followed by slow tinkering in biological evolution requires the capacity to look back to around 530 million years ago, otherwise we would not be aware of the heedless novelty and tinkering that (probably) occurred during the Cambrian explosion. Even with the fossil record, looking that far back into the past is difficult. The early history of other potentially creative systems may be even more difficult to ascertain, such as an ancient culture who only maintained an oral history. The “access to full history” requirement of Kauffman's pattern means that an exploration of creative behaviour using that pattern will be limited, since there will be a considerable number of systems where we may never know their complete history. This is not ideal, as the lack of limitations is central to my argument for the use of systems laws as an exploratory method or tool. There is another problem with Kauffman's pattern as well.

The pattern of wild novelty, followed by slow tinkering may not be an accurate description of the biological diversification during the Cambrian explosion. The fossil record remains incomplete, and the Cambrian explosion is still a topic of scientific debate. Just how “wild a dance” it was in terms of novelty is still a puzzling question (Erwin, 2007). It may turn out that Kauffman's pattern did not appear in the Cambrian explosion, and furthermore, one can imagine examples of technological innovation which do not follow that pattern either. For instance, one would not describe the invention of the modern drinking straw, patented in 1888 by M. Stone, as being heralded by a wild dance of novelty, followed by slow tinkering towards perfection. Straws would eventually be made from plastic rather than the original paper, and later incorporated an accordion-hinge, but these two changes hardly constitute a “wild dance of novelty”. An “explosion of novelty” was unnecessary in this case, as they essentially “hit the nail on the head” with the initial form of the straw.

There is a sense in which my criticisms here are unfair, as it was not Kauffman's aim to identify a pattern that could be used to explore creativity. Therefore, pointing out the ways in which Kauffman's pattern fails in this regard is roughly akin to arguing that a guitar makes for a lousy can-opener. I will now discuss a pattern that is designed for that purpose. Like the logarithmic spiral, this is a pattern that is manifested by various assorted systems, and produced by disparate underlying mechanisms. I will argue that this pattern is produced by

creative behaviour over time, and that it is indicative of creativity (i.e. if a system displays this pattern, then that system is creative). The pattern, which I shall refer to as the “AN pattern”, incorporates novelty and adaptation. Of the two, adaptation is the more technical aspect, and this is where my discussion of the AN-pattern begins.

7. Adaptive Systems

The term adaptation is used in different ways in different fields of study. For instance, “adaptation” is commonly used in the biological sciences in relation to natural selection. In biology, “adaption” or “adaptation” has an established meaning.

a biological adaptation is an anatomic structure, a physiological process or a behaviour's trait of an organism that has been selected (for by natural selection in) that such traits increase (an organism's) probability of reproduction (Martin, Lope, Maravall; 2009, p. 3)

The meaning of “adaption” in biology is too restricted for my purposes here. The biological meaning of “adaption” is limited in terms of mechanism (natural selection) and scope (organisms and traits). Instead, I will utilize the meaning of the terms “adaption” and “adaptive” as they are used in control theory and cybernetics. In control theory, the term “adaption” is defined in terms of a conceptual generalization of the principles of homeostasis observed in physiological systems (Cannon, 1932; Wiener, 1963). Wiener outlines the concept and operations of a simple adaptive system from within the “Control theory paradigm”:

The objective in this control paradigm is to maintain or guide the environment to a desired state by means of the control actions emitted by the control system. The interaction between these two components is represented by the circular flow of information between the environmental state and the control actions emitted by the control system. (Wiener, 1963, p. 1)

A system's behaviour is adaptive if it responds to changes in its environment and constituent parts in a consistent manner or “direction(s)”.³¹ Adaptive behaviour in a system provides a context over time through consistent responses to changes in the environment, and changes in the system itself. In this way, the behaviour of an adaptive system can be understood to have “direction” or a “goal”. An example of behaviour with a consistent “goal” is a thermostat set to regulate room temperature. External influences can cause the ambient temperature in the

31 A formal rule that describes adaptive systems is given in (*José Antonio Martín H., Javier de Lope and Darío Maravall, 2008*), and included in this dissertation as an endnote.

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room to change. These changes mean that the room temperature can shift above or below the temperature that the thermostat is set to maintain. When these changes occur, the thermostat responds by heating or cooling the room. Viewed over time, the system consistently responds to changes in the environment. The behaviour of the thermostat over time can be used to determine a context within which axiotext can be assessed. For instance, if the temperature of the room drops, then heating the room would be axiotextic, while further cooling would be detrimental.

An example of adaptive behaviour in an organic system is chemotaxis, which is the process by which cellular organisms (body cells, bacterium) move through their environment in response to chemical triggers. This includes following, or “swimming up” a glucose gradient for food (attractants), or “swimming away” from toxins (repellants). Bacteria move through their environment with a combination of spinning and stopping.

Bacteria swim by rotating semirigid, left-handed helical flagellar filaments; counterclockwise rotation produces straight swims, known as “runs,” and clockwise rotation generates abrupt changes in direction, known as 'tumbles'. (Manson, 1990, p. 2)

As a bacterium tumbles and runs through its environment, it detects and responds to chemical concentrations. The bacterium continually makes comparisons of these chemical concentrations in its surroundings. Attractants and repellants bind to chemical receptors in the cell wall which modulate the activity of signal transducers; these transducers are proteins that run through the bacterium's cytoplasmic membrane (Manson, 1990). The protein transducers produce signals that control the motion of the flagella (the “hairs” that aid in swimming). These signals in turn produce behaviours that propel the bacterium towards or “up” attractor gradients, and away from “down” repellant gradients:

(a bacterium) responds to spatial gradients of attractant by extending the length of a run in the favorable direction – up an attractant gradient or down a repellant gradient...Spatial gradients are sensed by comparing chemoeffector concentrations in time as the cell swims. In effect, cells are able to compare the instantaneous chemoeffector concentration, measured by receptor occupancy, with concentrations over the last few seconds. (Manson, 1990, p. 2)

The behaviour that results from chemotaxis is consistent in response to changes in the cell's environment. A bacterium will swim towards higher concentrations of food, and away from poisons. This allows us to determine a context for the bacterium's behaviour. Roughly, this context would be “get food, avoid poison”. Within this context, it is possible to determine the

axiotext of the cell's behaviour. Behaviour that moves the cell to greater concentrations of food, and away from higher concentrations of poisons, is axiotextic (within the context established by adaptive behaviour).

8. Using Adaptive Behaviour to Determine Axiotext

Adaptive behaviour over time provides a means to assess axiotext. This is important, as it means that the axiotext of adaptive behaviour can be established independently of our ability to recognize whether that behaviour is axiotextic. Adaptive behaviour can reveal axiotext in any system, provided that system's behaviour is adaptive. This applies to systems that are well beyond the boundaries set by our limited ability to assess axiotext (the behaviour of animals and organizational units at different organizational scales). The result is that axiotext manifests in a number of unexpected systems and behaviours. Adaptive behaviour can reveal axiotext in systems where it may seem to be counter-intuitive, absurd, or inconsistent to attribute axiotext. As an example, adaptive behaviour reveals axiotextic behaviour in systems that do not include organisms or organic chemistry, such as machines or complex chemical reactions.

Adaptive behaviour can provide a context when observed over time. I will refer to this context as “adaptive-context” (AC). I will demonstrate that the adaptive-context can be used to ascertain axiotextic and non-axiotextic behaviour within systems that we already recognize as creative. Doing so provides evidence for the ability of AC to be used to accurately determine axiotextic behaviour; and additionally it provides evidence for the fact that the behaviours that AC identifies as axiotextic do not conflict with our ability to assess axiotext. I argue that since AC identifies the axiotext in behaviour that we are able to recognize as creative, it will also accurately identify axiotextic behaviour in systems which are beyond the limits of our ability to assess axiotext by “putting ourselves in someone else’s shoes”.

Adaptive behaviour is sufficient to determine adaptive-context, and adaptive context is enough to assess the potential axiotext of behaviour. However, axiotext alone is not sufficient to define a system as creative. To be creative, a system must be more than axiotextic (adaptive); it must also produce novelty. After all, a thermostat that controls room temperature is adaptive, and although the behaviour of the thermostat can be axiotextic (within AC), it is not creative. In addition to being adaptive, a system must also be novelty-

producing to be creative. To illustrate this point, I will briefly discuss what constitutes a novelty-producing system, I will also discuss how novelty can be described in terms of system trajectory and state space. This is followed by a discussion of the AN-pattern, and examples of adaptive novelty (the AN-pattern) in various systems.

9. Novelty-producing Systems

A novelty-producing system exhibits novelty in its form and/or behaviour over time. An example of a novelty-producing system is the Earth's weather system. The weather system produces changes in temperature and precipitation through a complex and chaotic set of interacting forces. The novelty produced by the weather system can be observed in the multiform shape, size and colour of clouds, or in the shape of snowflakes. Novelty producing systems are not necessarily as complex as the weather system. Two simpler examples of novelty-producing systems include a computer program that randomly combines words to produce novel sentences and a catapult that fires buckets of paint at a wall to produce novel splatters of paint.

In systems terms, novelty can be described in terms of trajectory and state space. A novelty producing system will display novelty in its trajectory, or produce a novel state space. To illustrate this, here is a brief overview of system trajectory and state space, followed by examples of creativity framed in terms of novel trajectory and state space.

State space can be understood as a set of possibilities. Specifically, it refers to the full set of possible states for a given system. A system is a collection of parts. Those parts can be in different configurations or states. Imagine a system composed of a string of light bulbs, like the ones used to decorate a Christmas tree. For simplicity, let us say that there are only three lightbulbs in this system. When the light bulb system is plugged in, the three lights flash on and off. At any time, the system is in a particular state. We can define the different states in terms of the three lightbulbs being on or off. There are a total of nine possible states for the system to be in.

Possible states for the three bulb system are as follows:

XXX

XXO

XOX

XOO

OXO

OOX

OOX

OXX

OOO

*where x and o represent lightbulbs being off (x) and on (o).

These nine states comprise the state space of the light bulb system, and contain every possible state of that system. The trajectory of the system describes the states of the system over time. When we plug in the string of lights, they blink on and off in a particular pattern. To start with, suppose that this pattern is very simple and repetitive, only alternating between two states. All the lights turning on simultaneously (ooo), and then turn off (xxx). This pattern repeats indefinitely. By following this simple pattern, the light bulb system alternates between two states: thereby producing a trajectory through state space.

The trajectory of a system through state space can be used to assess whether a system is novelty-producing. For example, an examination of the trajectory of the light bulb system following the simple pattern reveals that the system does not produce novelty, as it simply alternates between xxx and ooo. A novelty producing system creates novelty in its own trajectory and/or state space. To qualify as a novelty producing system, the light bulb system could produce a novel trajectory by altering the pattern to incorporate a different state (or states). A novel state space can be produced in several ways, such as by adding extra lightbulbs to the system, or altering the system such that the bulbs vary in brightness or are able to change colour. These extra bulbs or added variables would create more potential states for the system. Adding another bulb to the system would increase the state space from 9 to 16 states. Novelty in terms of state space and system trajectory through state space can be understood as the production and population of new areas of possibility. The light bulb system is a particularly simple example, intended to clearly illustrate the concepts of system trajectory and state space. To demonstrate how these concepts are related to creativity, I present two examples of creativity where the novelty is described in terms of system trajectory and state space, respectively.

My first example involves the invention of the curveball pitch in the game of baseball. The curveball was creative as it was both novel (a new style of pitch) and axiotextic (it is a hard pitch for a batter to hit). To throw a curveball, a pitcher must move their arm in a

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different way than throwing a fastball. To get the ball to curve, the pitcher must put a “forward” spin on the ball; it is the curving arc of the ball's flight that gives the pitch its name, and makes it so difficult for a batter to hit it (Alaways *et al.*, 2001).

The curveball pitch is an example of novelty in a system's trajectory through state space (the population of possibility), but not the creation of new states (the production of possibility). The human arm has a range of possible movement that is determined by the physical makeup of the assorted muscles, ligaments, tendons and joints which compose the arm and the shoulder. These parts can be taken together as a single system which I will refer to as the “arm system”. Like the light bulb system, the arm system has a state space. The state space of the arm system consists of the set of spatial positions that the arm can occupy within its possible range of movement.

To pitch a fastball, the pitcher's arm goes through a particular range of motions, that is, the arm system follows a specific trajectory through state space. Essentially, the arm system follows a particular “pattern” of spatial states to produce the motion required to pitch a fastball. The same is true for the arm system when pitching a curveball. The “curveball” trajectory is different from the “fastball” trajectory, but both trajectories are contained within the state space of the arm system. No alteration needs to be made to the arm system itself to pitch either a fastball or a curveball. Hence, the invention of the curveball pitch is an example of novelty in system trajectory, rather than state space.

My second example is the invention of oil paints. Unlike the creation of the curveball, which is an example of a novel system trajectory, the invention of oil paints and oil painting techniques is an example of a new state space. The invention of oil paints created new possibilities. Here Watson describes these possibilities, as afforded by the newly invented medium:

“The most important point about oil painting is that, unlike fresco – the most popular medium to that point – it dries slowly. Fresco dried so quickly that painters had to work very fast and their chances of changing what they had done was minimal. But pigments mixed with oil do not dry for weeks, meaning that alterations could be made, painters could improve weak patches, or change their minds completely if a new idea occurred to them. This made painters more thoughtful, more reflective, and also enabled them to take their time over mixing colours, to achieve more subtle effects. This was in evidence early on with the van Eycks, whose detailed rendering of objects and surfaces (next to impossible in fresco) meant that form and space were now much more developed and realistic.” (Watson, 2005, p. 407)

The invention of oil paints was creative, in that it was both novel and axiotextic. Described in systems terms, the novelty of oil paints was an alteration of the system that produced a new state space. The invention of oil paints for the painting system was similar to the addition of more bulbs or varying luminosity in the lightbulb system. Oil paints changed what was possible in terms of painting, and thereby increased the state space of the painting system.

The novelty of a creative idea, artifact, or behaviour can be described by new trajectory and new state space. Systems theory can also describe the adaptive behaviour of a system. Therefore, systems that produce novel and axiotextic behaviour can be identified using systems laws. This would provide a general and objective means of identifying creative systems: in other words, a way to extend the search for creative behaviour well beyond our limited ability to assess axiotext. I propose that there is a pattern generated over time by creative behaviour, and that the presence of that pattern is indicative of creativity.

10. Creative Systems

Creativity is distinct. Creative behaviour is unique in being both novel and axiotextic. I argue that since creative behaviour is unique in being novel and axiotextic, it produces a distinct pattern of adaptive novelty. I will refer to this pattern of adaptive novelty as the “AN-pattern”. I will argue that it is possible to use the AN-pattern to identify creative systems. Specifically, a system is creative if the AN-pattern manifests in the form or behaviour of that system over time.

In a creative system, novelty and adaption combine, resulting in various novel forms and/or behaviours that are axiotextic within the established adaptive-context. When viewed over time, the novel forms and behaviours that are axiotextic within the adaptive-context endure or influence the further behaviour of the system. The consequence of this is that creative systems produce novel forms and behaviour, that when viewed diachronically, are adaptive. As an example, consider again the thermostat that controls room temperature. It is not creative, since it is merely adaptive and does not produce a novel trajectory or novel state space. However, if the thermostat was to produce a novel method of heating and cooling the room, which made it more effective at controlling the temperature, that would be both novel and axiotextic, and hence creative.

The ability to define creative systems using the AN-pattern broadens the range of potentially creative behaviour and “entities” that we are able to investigate. The AN-pattern

does not challenge my definition of creativity, as it reveals the telltale signs produced by the production of novel and axiotextic ideas, artifacts and behaviour over time.

To provide evidence for this claim, I will now examine a number of systems that we recognize as clearly creative, and demonstrate that these creative systems are adaptive and novelty-producing in terms of both trajectory and state space. This illustrates that the production of the AN-pattern is sufficient to identify that system as creative. The claim that the AN-pattern is necessary for creativity is too strong; I am not claiming that a system needs to display this pattern to be creative. However, the AN-pattern is sufficient to define a system as creative. Hence, while a system can potentially be creative and not display this pattern, a system must be creative if it exhibits the AN-pattern over time.

The AN-pattern defines creative systems, but one might wonder “What exactly is a creative system?” or “What is it for a system to be creative?” Let us start with the simple answer. A system is a set of interacting parts. A creative system is a set of interacting parts that produces a novel trajectory or new state space, and is adaptive. That answers the first question, but the second question is somewhat more difficult. This question is essentially asking, *Does the diachronic definition inform us about “who or what” is being creative?* In other words, when I use the AN-pattern to claim that a system is creative, it is not clear that by doing so I am also claiming that *something* (perhaps like a collective *someone*) is being creative, or many things are “pitching in” to be creative together, or if there is a third option (i.e. all of the above or none of the above). Let me clear up any confusion about this now.

When I define a particular system as creative, I am making the claim that a set of interacting parts is following a trajectory or altering its state space in a manner that is that is both novel and adaptive. As for who or what is being creative, the diachronic definition does not inform us about the source or sources of the creativity. According to the diachronic definition, a system is creative if it displays the AN-pattern. Who or what is actually being creative is a separate question. In other words, the diachronic definition is only concerned with the system and the AN-pattern; it has nothing to say about whether it is the whole system, particular parts of the system, certain underlying mechanisms, processes, or interactions which are responsible for producing the AN-pattern.

**Part Three – Adaptive-Novelty (AN): The signature of
creative systems**

Chapter Seven

The AN-pattern in Artifacts

1. Applying Systems Theory to the Evolution of the Automobile

The first example of the AN-pattern in a creative system is the progression of the automobile headlight. The technologies, shape, design and production of the automobile have changed over time. The following example examines a sub-section of these changes; specifically the changes in headlight designs. I will use the headlight example to argue that the automobile system, the parameters of which I will define shortly, is a creative system that is novelty-producing and adaptive, and thereby exhibits the AN-pattern (adaptive novelty).

To understand the changes that occur in the automobile over time, one must couch the automobile itself in terms of a larger system. I will refer to this as the automobile system. The automobile system is huge, containing numerous heterogeneous parts. It consists of the automobiles themselves, as well as automobile manufacturing companies (such as Ford and Toyota), consumers who purchase automobiles, and automobile organizations (such as Formula One racing, and the World Rally Championship). The automobile manufacturing companies (car companies) are systems themselves, with several sub-systems including manufacturing, research-design, and marketing departments.

These assorted and varied parts are all constituents of the automobile system as they are all meaningfully related in terms of the production, purchasing, and use of the automobile. The elements of the automobile system affect and influence the changing form of the automobile over time. A car does not materialize in a vacuum. It is constructed by a corporation, which itself has goals and limitations, and form a context within which the form of the automobile is evaluated. Associated organizations, and consumers, also provide a context for the designs of cars. For instance, a car can be judged on profit margin, how well it sells in a particular country, or how successful it is at winning races. The aspects of an automobile's design can affect how a given car will perform in those contexts. A more powerful engine or improved suspension can increase a car's chances of success in racing, or a more fuel efficient engine could be a factor in higher sales numbers. Success and failure in these various contexts influence further changes in automobile design. Successful designs and innovations will typically be selected for, detrimental designs or aspects will not.

The large size of the automobile system, the various contexts, and the different functions of assorted cars and car parts constitutes a very complicated system. Even if it were restricted to a single year, to chart and explain the changes in every production automobile design would be a monumental task. Thankfully, to appreciate the adaptive and novelty producing nature of the automobile system, we need only to concentrate on the changes that occur in a single part. The adaptive changes that occur in the headlight over time are easily illustrated, and the reasons why one change replaced another are pellucid. I will examine three major changes that occurred in the headlight; in doing so, I will argue that each change was creative, in that it was axiotextic and novel, and that these creative changes when viewed over time produce a pattern of adaptive novelty (the AN-pattern).

2. The AN-pattern in the Progressive Development of the Headlight

The first automobiles closely resembled horse-drawn carriages, only instead of being pulled by horses they were propelled by internal-combustion engines. The first headlight design to be used in an automobile was a carry-over from horse-drawn wagons. These headlights were glass lanterns, lit with candles, and they performed two functions, acting as both headlights and tail-lights. The headlight was a glass box. The forward and side facing glass was clear, while the backward facing glass was tinted red to serve as a tail-light. (*See Illustration below*) Since the headlight also served as a tail-light, it had to be visible from the front as well as the back of the automobile. Hence, these early headlights were mounted on each side of the automobile, rather than on the front; otherwise the light would be obscured by the chassis when viewed from behind.

Compared to later headlight designs, the candle in the headlight lantern was not very bright, and did very little to illuminate the road ahead. These headlights did more to alert other road users to the presence and direction of the automobile in the dark than to illuminate the surroundings. As the form of the headlight changed, its abilities and function changed as well.



Illustration 24: Early Candle Headlight. Photo taken by the Author at the Southward Auto Museum.

The headlight changed from being a dual-purpose headlight/tail-light. As the design of the headlight changed, its ability to illuminate the road ahead increased. The candle was replaced with a brighter gas lamp. The rear-facing red tinted glass was replaced with forward-facing mirrors, to reflect additional light forwards. As automobiles were capable of reaching higher speeds, the ability to see further ahead became more important. At low speeds, a driver had more time to react to obstacles or sharp turns in the road. As the speeds that automobiles were capable of increased, so too did the forward illumination produced by headlights. Travelling at higher speeds meant greater air movement. Gas lamp designs were produced, which were less likely to be blown out at speed than candles. When travelling at high speed at night, a sudden loss of visibility would be disastrous.

The change to uni-directional light meant that the headlight's location on the chassis could shift. When the headlight had to fulfill both the headlight and tail-light functions it

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needed to be located so that it could be seen from both the front and back of the vehicle. Being located on the side of the vehicle meant that the headlight could be damaged by common roadside dangers, like tree limbs. A scrape or a tight squeeze could easily damage the delicate glass box. New lamp headlights were constructed using a more robust metal frame, as they were located at the front of the vehicle, they were less likely to be damaged by roadside dangers. Moving the headlight to the front of the automobile was axiotextic.



Illustration 25: Lamps and mirrors incorporated into headlights. Uni-directional forward facing illumination. Location changed to the front of the vehicle. Photo taken by the Author at the Southward Auto Museum.

Further changes in the headlight saw the lamp replaced by the electric light bulb, which is brighter than a lamp, and provides greater illumination. The location of the headlight and the use of mirrors were unchanged. *(See Illustration below).*

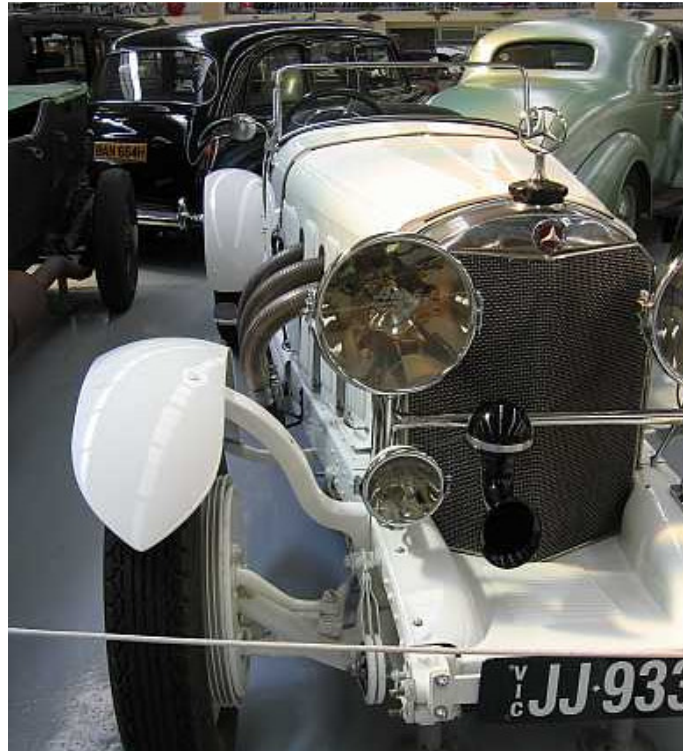


Illustration 26: Electric light bulb headlight. Photo by the Author, Southward Auto Museum.

The changes in the automobile headlight were axiotextic. Replacing the candle with a lamp was an axiotextic change, as was the addition of mirrors. Lamps and mirrors resulted in an improved luminosity. Increased forward illumination improved a driver's ability to see the road at night, as well as increasing the driver's visual range and hence increasing the speed at which it was safe to travel. Both the lamp and light bulb were both more reliable than their predecessors. The migration of the headlight from the side of the vehicle, to the front, and eventual incorporation into the body of the vehicle was axiotextic. The changes made to the headlight that were axiotextic, in terms of illumination and location, were incorporated into later headlight designs, effectively replacing the earlier designs. This creates a pattern in the changes of form and location of the automobile headlight over time.

There is a pattern in the changes in the headlight that shows a tendency towards, or sensitivity to, axiotext in regards to improved forward illumination. Creativity on the part of clever designers and inventors produced new and different kinds of headlights. The changes that improved forward illumination were implemented in subsequent headlight designs, the less-effective headlight designs disappeared over time. The direction of the adaptive behaviour in the example is fixed; where changes in form that increase forward illumination

are implemented. Ford and Toyota no longer design headlights which use candles as light sources. However, the goal of increased forward illumination is balanced with other considerations. Headlight designs have changed over time, so that they are brighter today than they were previously, but forward illumination is not the only goal of headlight design. It is an oversimplification to suppose that greater forward illumination *equals* axiotext.

The brightness of a headlight must take into consideration the fact that there are other drivers on the road. A light that is bright enough to blind other road users, especially oncoming traffic, would be a poor headlight design. Attaching the equivalent of stadium floodlights to the front of your car would easily outperform stock headlights in terms of raw candlepower, but for other drivers on the road driving towards those headlights at night would be like staring into the sun, and the chances of blinded drivers accidentally crossing the center line and crashing headlong into your car, or veering off the road to their own demise would be greatly increased.

The heightened odds of a head on collision would make the stadium floodlight a bad design for car headlights. Additionally, the power needed to illuminate your row of high output stadium floodlights would be much greater than stock headlights, and the cost of an electrical system capable of powering the floodlights would be much higher than the cost of the stock system. Safety and economic factors act to balance the trend towards greater forward illumination. This balancing means that although there is a trend towards greater forward illumination, that trend is kept somewhat in check. This is what makes the system adaptive, and the result of this is a diachronic adaptive trend in the form of headlights.

3. Function and Axiotext in Artifacts

This example of change in headlight design illustrates how creativity can affect the form of an artifact over time. This example illustrates two points; first, that the changes in the headlight are creative, and second, that changes in the automobile over time are adaptive and novel. Each change to the headlight in the example was novel, the gas lamp was a novel source of illumination, the addition of mirrors was a novel method of directing light. Each change in the example was also axiotextic. In terms of intended function, each new change produced a better headlight which was brighter and less prone to failure or damage. The changes to the headlight were novel and axiotextic, hence they were creative. The automobile system is sensitive to both axiotextic and detrimental changes within their relevant contexts.

Creative (axiotextic) changes in the form of the automobile are adopted over time, as is evidenced by the absence of candle-powered headlights produced today.

The automobile is not the only system of artifacts that manifests the AN-pattern. The progression of war machines and weapons also displays a pattern of adaptive novelty. Diachronic changes in the form of the tank and the rifle produce the same AN-pattern that is evident in the example of changes in the headlight. I will highlight the pattern of adaptive novelty in the tank, and then move on to the next chapter, where I will discuss the AN-pattern as it appears in evolution.

4. The AN-pattern in Tank Design

The tank is a tracked, armoured combat vehicle, with a large caliber main cannon mounted on a rotating platform. Modern tanks have increased capacity in terms of firepower, armour and mobility since the original tanks produced in the First World War. To illustrate this, I will now examine the “evolution” of the tank, from the Mark I tank to the M1A2 Abrams MBT. Although detailed, my examination of the changes in tank designs is not exhaustive. As I will demonstrate, these changes display a diachronic pattern of adaptive novelty.

Consecutive tank designs have steadily improved firepower, armour, and mobility; while maintaining a balance between all three. The following examination of tank designs clearly illustrates the pattern of steady and balanced improvement. The story begins with the Mark I, the world’s first combat tank, which was produced in 1916 (although prototypes existed in 1915³²), designed by W. Wilson for the British Landships Committee. (Fletcher, 2001) The tank itself was rhomboid shaped, with caterpillar tracks. It had a crew of 8 men, weighed 28 tons, and was just over 32 feet long (Bishop, 2006). The Mark I was powered by a 6 cylinder engine, capable of producing 105 hp which propelled the tank along at 4 miles per hour (Fletcher, 2001).

The armour of the Mark I tank varied on the front/back and sides, ranging between 6-12mm of steel plate (Bishop, 2006). This armour made the Mark I invulnerable to small arms fire, until the German military produced a specially designed armour piercing “K-bullet”, which was capable of penetrating the Mark I’s armour. Two versions of the Mark I, designated male and female, were produced; and both were heavily armed. The male variant

32 The Mark I design was developed directly from the early tank-prototype “Little Willy” which was built by Wilson and Tritton in 1915. The first Mark I prototype, named “Big Willy” or “Mother”, was built that same year.

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carried two 6 pounder cannons and four .303 caliber machine guns, while the female variant carried six .303 caliber machine guns (Fletcher, 2001). Both models of Mark I had their guns mounted in sponsons on the side of the tank. As it was the first tank, the design of the Mark I was understandably primitive, and it suffered from several design flaws. The crew shared the poorly ventilated internal compartment with an un-housed engine, which meant that the inside of the tank would quickly fill with choking exhaust fumes. The fuel tanks were also vulnerable to grenade and artillery strikes, and if ignited they would incinerate the crew of the tank before they had any chance to escape (Fletcher, 2001). As communication was limited, the first tank used runners and trained pigeons to relay messages with command.

The Mark V tank was designed and produced in 1917, weighed 29 tons, sported a maximum of 14 mm of armour, and had an engine that produced 150hp which propelled the tank at a maximum speed of five miles per hour (Hogg & Thurston, 1972). *See Illustration 4.* For its primary weapon, it had a pair of modified Ordnance QF 6 pounder Hotchkiss guns. These were mounted in sponsons on each side of the tank, rather than in a turret on the top as is familiar to modern tank designs. The modified 6 pounder guns were shortened specially for use on the tank, as the barrels of the longer standard variant would dig into the mud as the tank maneuvered through and over trenches (Hogg & Thurston, 1972).



Illustration 27: Mark V Tank. Photo from the Imperial War Collection, public domain.

The Mark V, and the subsequent Mark V* and V** (Mark five-star and Mark five-star star) designs were not really “new” tanks in their own right, but instead were heavily modified versions of the original Mark I. They had several advantages over the Mark I, including a new 6 cylinder engine capable of producing 150 hp, which was bored out in the later Mark V** to produce 225 hp. This was more than twice the horsepower available to the Mark I, and allowed the Mark V to move at a slightly faster 5 mph. The body of the tank had been lengthened by six feet, the internal compartment had been segregated, and a troop transport area had been added; making the Mark V the first armed and tracked armoured personnel carrier (APC) (Fletcher, 2001). The Mark V also had slightly thicker armour than the Mark I, with 14mm steel plate. These improvements to design made the Mark V (*&***) variants more successful on the battlefield than the Mark I, making the innovative alterations both novel and axiotextic. There is an obvious trend is towards improved mobility and armour, even in the differences between the early designs of the Mark I and the Mark V**. The next major innovation in tank design continued this trend of improved mobility and armour, and introduced a major offensive improvement as well. This occurred with the design and production of the French tank, the Renault FT-17.

The Renault FT-17 was designed and produced in 1917. In terms of shape, crew size and tonnage, the FT-17 was a radical departure from the British Mark I-V** tanks. Weighing in at around 7 tons, the FT-17 was a lightweight compared to the 29 ton Mark V. The FT-17 had a crew of only two men, a commander/gunner and a driver, and was powered by a smaller 4 cylinder engine that produced only 39 hp (Bishop, 2006). The smaller size and lighter weight of the FT-17 meant that although it had significantly less horsepower than the Mark V** (39 hp compared to 225 hp), it was able to move at roughly the same speed (4.3 mph compared to the Mark V**'s 5 mph), while also packing thicker armour – the FT-17 had 22mm of steel plate (Bishop, 2006). While the decrease in size and increase in armour thickness was a boon, arguably the most important difference in design between the FT-17 and the Mark V** was the invention of a top-mounted, 360° rotating turret. (*See Illustration below*)

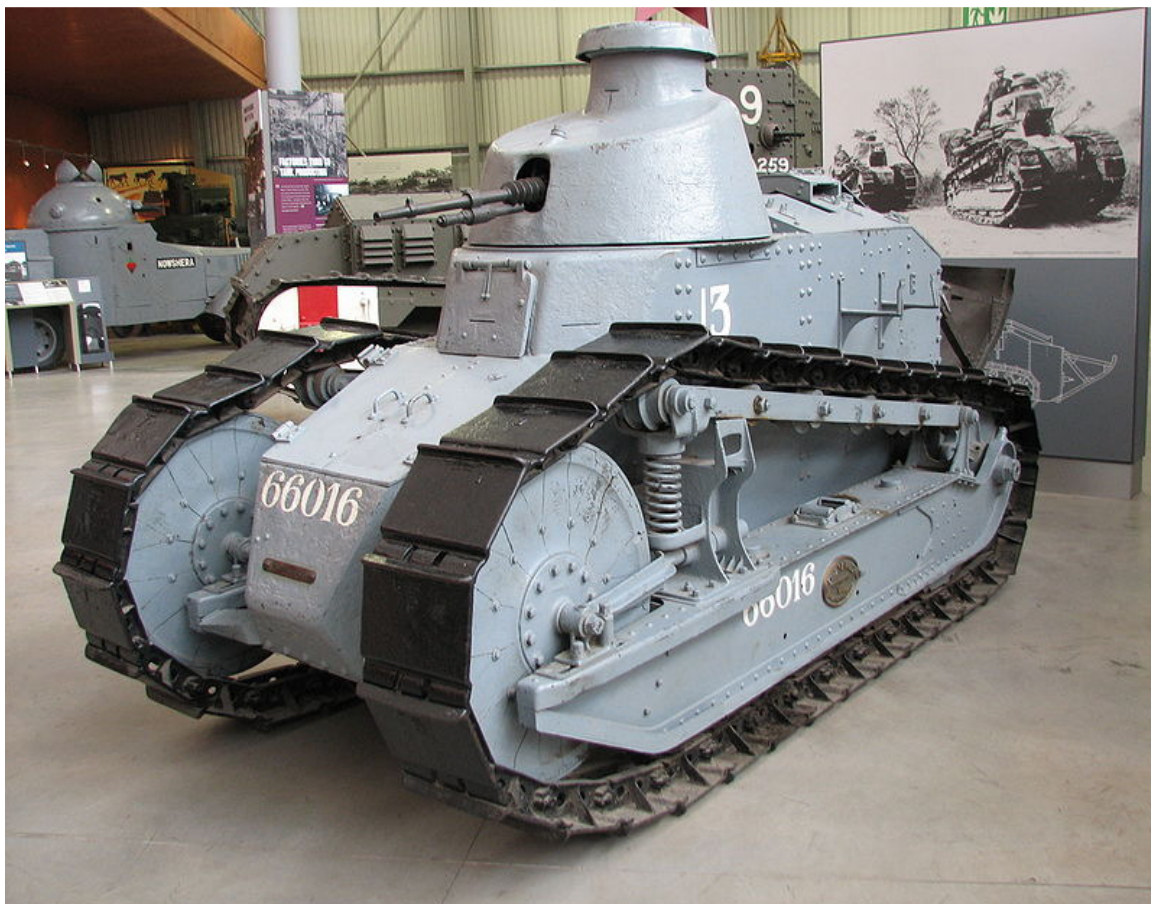


Illustration 28: Renault FT-17 in the Bovington tank museum with turret mounted 7.92mm machine gun. Photo: Hohum in Public Domain

The FT-17 could mount either a 37mm cannon or a 7.92mm machine gun in the top turret. The gun on the FT-17 was mounted on a rotating turret, which gave the gun a 360° firing circle, and therefore a significant advantage in terms of offensive capability. The side-mounted sponsons that housed the 6 pounders on the Mark V were only able to provide a 90° field of fire, to the front and side of the tank. A full 360° field of fire allows the tank to bring its gun to bear on a target by rotating the turret, which is a faster way to acquire a target than rotating the tank itself (Kelly, 1989). A rotating turret also meant that a moving tank could bring its gun to bear on a target, the result of this being that the tank could spend less time as a stationary target or “sitting duck”. The advantages of the rotating turret were obvious; they became ubiquitous in subsequent tank designs, up to and including present-day tanks.

The M1A2 Abrams MBT is a current variant of the M1 Abrams MBT, first produced in 1980. The M1 Abrams weighs just over 61 tons is protected by Chobham RH armour (steel encased depleted uranium mesh plating). The engine of the M1 is a multi-fuel turbine jet engine, producing 1,500hp and propelling the tank at 42 miles per hour on-road and 30 miles

per hour off-road. The primary armament for the M1A2 is a 120mm smoothbore M256 cannon (Foss, 2002). The M1A2 Abrams bears a “family resemblance“ to earlier tanks like the FT-17 (see figure 5), however there are important differences.



Illustration 29: M1 Abrams MBT. Photo from Army Recognition Magazine.

The firepower of the M1A2 Abrams is vastly superior to earlier tanks. The 120mm smoothbore gun on the Abrams is superior to the 6 pounder Hotchkiss gun on the Mark V in terms of effective range³³, accuracy, and firepower. In addition to firing shells, the M256 is capable of firing anti-tank missiles like the LAHAT (Laser Homing Anti-Tank) missile. The firing system of the M1A2 Abrams incorporates a laser range-finder and targeting computer, which is capable of rapidly calculating the correct firing angle in terms of range-to-target. The main gun is gyroscopically stabilized to maintain a steady firing platform even while moving over unsteady or bumpy terrain (Kelly, 1989).

The M1A2 is superior to the Mark V in terms of armour and mobility as well. The jet turbine in the M1A2 Abrams produces ten times the power of the six-cylinder petrol engine that the Mark V employed (1,120 kW compared with 110 kW). Consequently, the top speed of the M1A2 is six times the speed of the Mark V (30mph off-road compared with 5mph). The Mark V tank was armoured with 14mm of steel. The Chobham armour that protects the

33 8,700 yards (Abrams) compared to 7,300 yards (Mark V)

M1A2 Abrams is equivalent to 960-980mm of steel³⁴. The fact that the M1A2 Abrams is superior to the Mark V is not surprising, as a great deal of progress has occurred during the 63 years between the production of these tanks. Advances in materials science have produced lighter and stronger materials, allowing for better armour. Advances in engine design, weapons technology, communications technology, and production techniques have all contributed to today's tanks being superior to earlier designs. It was not just these advancements in the various fields mentioned that resulted in the M1A2 Abrams tank being superior to the Mark V tank. Adaptive changes in the design of the tank over time in terms of firepower, armour, and mobility are responsible for the superiority of current tanks.

5. The AN-pattern Emerges From Competitive Design

The form of the tank over time has changed to increase offensive and defensive capabilities, as well as superior mobility. In terms of firepower, armour and mobility, these changes have been both novel, and axiotextic. Like the changes in the headlight over time, the changes to the tank display the AN-pattern. Diachronic adaptive changes in the form of the tank follow a trend of *increased and balanced* ability in terms of firepower, armour and mobility. The mechanism that produced the adaptive changes will be roughly outlined here. The changes in the tank over time which lead from early tanks like the Mark V to the M1A2 Abrams can be understood as being driven by competition.

During the 63 years between the Mark V and the M1A2, different countries have been involved in tank design and production. An axiotextic change in the design of a tank in one country, prompted change in other tanks (Ogorkiewicz, 1989). If someone developed a new design that boasted an increase in armour thickness, this would prompt other tank designers to produce tanks with higher caliber guns capable of penetrating that new armour. There were several adaptive changes in the form of tanks during the first and second World Wars, as well as the proxy-wars and inter-war period of the Cold War. During this time, changes that offered an improvement in terms of protection, such as better armour, prompted a corresponding change in firepower.

The armour, engine and primary armament of the M1A2 Abrams is a result of the competitive co-evolution of tank design that was a part of the larger “arms race”, a consequence of Cold War tension between Warsaw pact countries and Nato (North Atlantic

34 Chobham armour is rated here in terms of rolled homogeneous steel armour (RHAE).

Treaty Organization) countries (Ogorkiewicz, 1989; Kelly, 1989). During the arms race, both sides produced advancements in weapons, armour and engines as each sought to develop superior tanks. This meant that the novel changes in the tank that were axiotextic in terms of firepower, armour, and mobility were adopted; producing a diachronic pattern of adaptive novelty. This explains the steady increase in firepower, armour, and mobility between early tanks (like the Mark V) and current tanks.

The adaptive pattern in tank design was not one of blind, unchecked improvement. The arms race in tank design resulted in the balancing of firepower, armour and mobility. Each of these three elements are important to the success of a tank in combat. To be effective on the battlefield, a tank could not afford to be underpowered in any of these three aspects. If a given tank design was “behind the curve” in terms of firepower, then it would have difficulty penetrating the armour of enemy tanks and would be at a severe disadvantage in combat. A tank's armour and mobility are also important in terms of combat effectiveness. Tanks are not armed with the biggest guns available, or the thickest armour that it is possible to produce, or the biggest engines with the highest output. Although tank guns are big and their armour is thick, they are lightly armed with thin armour when compared with other military vehicles, like battleships and destroyers. In theory, it would be possible to mount a navy artillery gun on a tank. A tank armed with an 18 inch gun would have an tremendous advantage over other tanks in terms of firepower.³⁵ The reason that we do not see tanks being produced with 18 in (or similar) guns on their turrets is that such a giant gun would ruin the balance of firepower with the other important aspects of tank design. The British 18 inch navy artillery gun weighed roughly 151 tons, with each round weighing over 3,000 lb. Because of the size and weight of the gun, one would have to build a tank that was large and heavy enough not to tip over when moving or firing such a massive gun. The size of such a tank would require a great deal of power just to move, let alone moving quickly.

The same is true of building a tank with armour as thick as battleship armour. The weight of huge guns or super-thick armour quickly adds up, and reduces the mobility and range of the tank. A tank that is too slow is at a disadvantage in terms of combat effectiveness as it will be outmaneuvered by enemy tanks, and makes for an easier target; as well as being a potential liability in terms of tactical considerations, as very slow tanks will

³⁵ An 18in (460mm) gun was mounted on Japanese Yamato Battleships, which fired a massive 3,200 lb round to a max range of around 46,000 yards. This is roughly 5x the max range of modern tank guns.

hold up an armies' rate of advance, or ability to retreat. Hence, it is important that the firepower, armour, and mobility of a tank be balanced.

The tank and the automobile are not unique in their manifestation of the AN-pattern. Other artifacts that undergo successive creative changes over time also produce the AN-pattern. Without going into detail, computers, cell phones, and airplanes have all changed adaptively over time. Computers have become smaller and faster, cell phones have become smaller and more powerful, and airplanes have become larger and faster. One could attempt to provide an exhaustive set of the changes in various artifacts that manifest the AN-pattern. However, the size of such a set of examples would be monumental, and largely repetitive. The examples of the headlight and the tank illustrate what I mean by changes in artifacts that display the AN-pattern, as well as how creativity over time produces a pattern of adaptive novelty.

6. Objections and Replies

Before moving on, I will answer possible objections to the claims I have made in this section. One might object to my claim that the changes in the headlight and the tank over time were axiotextic (in terms of forward illumination for the headlight, and firepower, armour and mobility for the tank). For instance, one might assume that it is my claim that *ALL* changes in the form of the artifacts over time were axiotextic in their associated contexts (illumination and firepower *etc.*). The objection would be that this claim is too strong, and that some of the changes that occurred in the headlight and tank over time were detrimental. In other words, a close examination of every single change that occurred in the headlight and tank would reveal some poor designs that were not axiotextic. After all, human beings are fallible, we make mistakes. However, I do not claim that *all* changes in the form of the artifacts discussed have been axiotextic.

The behaviour that the AN-pattern identifies as creative can include mistakes, failures, and poor designs. The assumption being that a mistake or failure is not axiotextic, and therefore is not creative according to the monochronic definition of creativity. The diachronic definition applies to the behavior of a system over time. This includes the mistakes and failures as well as the successes that all contribute to produce the AN-pattern. Therefore, it appears that the diachronic definition of creativity is not accurate, as it identifies mistakes and failures as creative behaviour.

I argued that there is a pattern of adaptive novelty in tank designs over time, such that modern tanks are superior to earlier tanks in terms of firepower, armour, and mobility. I claim that the AN-pattern was produced by a series of creative design innovations that were adopted into successive tank designs. However, during that time, there would have been tank designs that were failures or mistakes. These would be tank designs that were underpowered, under-armed, or under-armoured, and were thus unable to effectively compete with other tanks on the battlefield. Since the diachronic definition does not discriminate between these individual successes and failures, and only looks at the system as a whole, it appears that these non-creative failures are included along with the creative successes. Therefore, it appears that the diachronic definition of creativity wrongly identifies non-creative behaviour (failed designs) as creative behaviour (part of an overall pattern of adaptive novelty). However, to do so would be to confuse the subject of the diachronic definition of creativity with the subject of the monochronic definition of creativity. The diachronic definition of creativity makes no claim regarding the creativity of the individual changes, which when taken together, produce a pattern of adaptive novelty. Therefore, although the mistakes and failures do get included as a part of the system's behaviour, they are not identified as being creative.

The changes in the headlight and tank systems are adaptive; in other words, they can be understood to have a direction or goal, such as better forward illumination, and greater firepower, armour and mobility. This should not be confused with the claim that *every* change has been axiotextic. Adaption only requires that the majority of changes that are axiotextic are adopted over time. If axiotextic changes are adopted over time, the result will be a trend of axiotextic change. That trend is precisely what we find in my examples, as headlights have become demonstrably better at providing forward illumination, and modern tanks are superior to earlier tanks in terms of firepower, armour and mobility.

The Broken Machine Objection

The broken machine objection would argue that not all adaptive behaviours are axiotextic. The objection begins by describing a machine that is slowly breaking down. As time passes, the machine becomes more and more broken. If viewed over time, the machine would display a tendency towards a total lack of operation. As the machine is malfunctioning, it also produces a novel trajectory, as the malfunctioning control mechanism produces new and erratic patterns of behaviour. The argument is that given the tendency of

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the machine towards total operational failure, and the novel behaviour that it produces as it continues to break down, the behaviour of the machine displays the AN-pattern of adaptive novelty. This is presented as a problem for my diachronic definition of creativity, as it is counter-intuitive to claim that this machine is being creative as it gets progressively less able to function, and yet if it displays the AN-pattern it is defined as a creative system. There are two points in this objection that I need to address. First is the idea that a machine breaking down could not be creative; and second is a distinction between a trend and adaptive behaviour.

While it may be counter-intuitive to think of a broken machine as being creative, there is no reason to accept that it is necessarily the case that a broken machine could not be creative. In fact, one could imagine machines specially designed to break down in new ways with the “goal” of finding as many different ways of malfunctioning as possible without actually breaking down completely. In which case, I would have no quarrel with defining the behaviour of those machines as creative. However, I do not have to make the claim that the machine in the broken machine objection is creative, since the trajectory of the machine in the example does not actually display the AN-pattern. The reason that it appears to display the AN-pattern is due to the apparent similarity between a trend and an adaptive trend. However, not all trends are adaptive.

As the machine breaks down, there is a measurable trend towards no longer working. However, this trend is not the same as adaptive behaviour. To see the difference between a trend and an adaptive trend, let me return to the example of the thermostat. A thermostat is an adaptive system, in that it regulates the temperature of a room. When a thermostat is set to a given temperature, if the room is below that temperature, the thermostat will heat the room. Conversely, if the room temperature is too hot, it will cool the room. The thermostat is adaptive. On the other hand, a heater produces a trend, but is not adaptive. When switched on, a heater will heat up a room. As time progresses, the heater simply heats, it does not cool. The same is true of the machine that is progressively breaking down: it displays a definite trend towards operational failure over time, but the system is not adaptive.

The trajectory of the broken machine is novel, in that in the course of breaking down it behaves in ways that it did not, or could not during normal operation. However, the machine is not adaptive, as the trend is not balanced. The machine only trends toward

operational failure, so it does not display the AN-pattern. Therefore, the broken machine is not a creative system, and the objection fails.

The Narrow Focus Objection

One might raise the objection that the examples in my discussion are too narrowly focused to support my claims. The examples I use are concerned with changes in artifacts. While creativity is clearly involved in the invention and modification of artifacts, it may appear that by focusing on technological changes in artifacts, I am ignoring the changes that occur in other areas of creative human endeavor: such as the domains of art and science. The creative changes that occur in scientific theories or artistic movements over time might differ significantly from the changes that occur in artifacts; meaning that the conclusions that I draw regarding the AN-pattern in technological evolution does not necessarily apply broadly to human creativity.

The reason I chose to use examples of creative changes in artifacts exclusively is that the axiotext for artifacts is simple and pellucid. For instance, it is easier to appreciate “what makes a good headlight” than the more nebulous “what makes a good work of art”. Comparisons based on instrumental or functional axiotext can be made between iterations of artifacts like the headlight (e.g. which design provides better forward illumination); these comparisons make the evolution of adaptive changes in headlight design over time obvious. The same is true for the tank. Things are not so clear cut in the domain of art or science. However, this does not mean that the diachronic definition of creativity has any difficulty with the domains of art or science, or that the AN-pattern does not occur in those domains.³⁶

The manner in which a piece of art is evaluated is not as straightforward as that in which a headlight or a tank can be evaluated. The axiotext of an artifact like a headlight can be clearly illustrated in instrumental or functional terms; the axiotext of a headlight can be understood in the sense that it illuminates the road ahead. It is not as simple to explain or illustrate “what makes a piece of art axiotextic?” To address the axiotext of art involves venturing into discussions of aesthetics, advancement of technique, and artistic merit. These are complex discussions, and in many respects the jury is still out. The instrumental axiotext of artifacts is easy to demonstrate and requires no accompanying discussion of topics within

³⁶ The AN-pattern is apparent in the history of art, and is particularly evident in the progression in various artistic movements, such as realism, impressionism, cubism.

the philosophy of art; and therefore, the progression in headlight and tank design are ideal examples.³⁷ My reasons are similar for not including examples of adaptive changes in science.

The manner in which the axiotext of a scientific theory can be evaluated is less obvious, or at least more highly contested, than the axiotext of a headlight or tank. As such, examples of the pattern of adaptive novelty in changing scientific theories are more complex than examples involving changes in headlights or tanks. For the purposes of my current discussion, presenting clear cases of the manifestation of the AN-pattern, an example of adaptive change in scientific theories is not ideal. As is also the case with art, this is not an admission that the AN-pattern does not manifest itself in the changing of scientific theories. There is an adaptive trend in the changes in scientific theories over time. The changes in existing theories and production of new theories in general can be viewed as being directed towards a goal. Roughly stated, that goal is “to produce an accurate description of physical phenomena”. This adaptive trend, along with novel changes to existing theories and the creation of new theories, produces a pattern of adaptive novelty.

Of course, to offer a complete reply to the narrow focus objection, I would need to present examples from not just science and art, but every sphere of human activity where creativity is present. To do so would require an exhaustive, encyclopedic set of examples; requiring far more space than is available to me here. My other option is to reiterate why it is that creativity produces the AN-pattern, and argue again for this being general to human activity. The monochronic definition informs us that creativity is unique in that it is both novel and axiotextic. Creativity in any domain of human activity will produce novel and axiotextic ideas, behaviours, or artifacts, be they new accounting procedures, theories about space-time, paintings, sculptures, cell phones, tanks, houses, pedagogical practices, or medicines. Unless they are entirely new, as a part of determining their axiotext, they will be compared to the previous relevant ideas, behaviours, and artifacts. A new theory about space-time will be compared to already existing theories about space-time and a new toaster will be compared with other toasters. For a new theory to be axiotextic it must be better in some way, or offer some advantage over other theories about space-time; the same goes for the new toaster. If they are creative, they will likely be adopted, since they are better in some

³⁷ The progression in design is illustrated by the fact that the forward illumination capacity of today's headlights is superior to earlier designs, and that the tanks of today easily outperform earlier tank designs.

way than the current crop of theories and toasters. Indeed, this is exactly what we see, as each new generation of computers gets faster and more powerful, new scientific theories are adopted, advances occur in medicine and medical procedures, and new schools or forms of expression are explored in art. There is no reason to assume that the comparison, adoption, and implementation of creative ideas, behaviours, and artifacts are limited to particular domains of human endeavor.

Using the examples of the headlight and the tank, I have argued that creativity produces the AN-pattern over time in the progression of artifacts. These are examples of the AN-pattern in human activity. When introducing the diachronic definition, I claimed that creativity produces the AN-pattern universally: in any system. To illustrate this, I will now present examples of the AN-pattern as it appears in both non-human and non-living systems, beginning with an exploration of the AN-pattern as it appears in the evolution of biological organisms.

Chapter Eight

The AN-pattern in Evolution

1. An Outline of the Discussion

The AN-pattern appears in the changes in the physical traits and behaviours produced by evolution. By “evolution” I refer to the adaptive changes in the genotype and associated phenotype of organisms that occur via the process of natural selection.³⁸ The aim of this discussion is to demonstrate the existence of the AN-pattern in the evolution of organisms, which indicates that evolution is a creative system. To do so, I will show that the changes in organisms display a pattern of adaptive novelty over time, which, as was the case with artifacts, is produced by creativity. As this discussion draws heavily from the claims and arguments made in chapter seven (the AN-pattern in technological innovation), I will highlight important similarities between organisms and artifacts, and discuss the implications of those similarities.

The discussion begins with an outline of evolution which lays out the process of evolution in broad strokes. At the conclusion of the outline, I present examples of the AN-pattern in the evolution of phenotypes. The first of these examples is an exploration of the differences in beak morphology in Galápagos finches. This illustrates the AN-pattern as it appears in evolution. Next I discuss the set of pharyngeal jaws in the moray eel. This serves as an example of an evolved form that provides a creative solution to a problem. This, in particular, is used to highlight the similarities between an organism and an artifact.

The discussion moves on to investigate the relevant similarities between biological and technological change, beginning with a perustration of William Paley's watch argument. I use Paley's argument not as a proposal that we ought to view the changes in organic form as evidence for the influence of a divine creator; rather, I wish to re-appropriate Paley's argument as an elegant and well-worded support for my argument that the AN-pattern displayed in the changes in both artifact and organism is indicative of creativity in both - or as Kaufman put it: “Tissue and terracotta may evolve by deeply similar laws” (1995, p. 192). I conclude the discussion of evolution and creativity by answering potential objections.

38 Genotype is the genetic material or information, and Phenotype is the expressed traits and behaviour.

2. A Brief Overview of Evolution

Biological evolution is the modification of heritable traits over generations, or as the changes in the inherited traits of a population of organisms through successive generations. The specific details, mechanisms and operations of evolution are complex. A complete explanation of evolution is too involved to be included in the space available here. My interest is not so much with the mechanisms of evolution, but rather with the changes in physical traits and behaviours (phenotypes) that are produced through evolutionary mechanisms. Hence, I will briefly sketch out the underlying mechanisms of evolution before moving on to examples of the AN-pattern in the evolved phenotypes of organisms.

Evolution can be understood as the product of two processes: variation and selection. Differences in genetic sequence produce variance in the traits expressed in a population of organisms. These traits will affect the likelihood of survival and reproduction for the individual organisms. Those organisms whose traits increase their odds to survive and reproduce will have more offspring. This results in a natural mechanism that selects for those traits which increase the likelihood of survival and reproduction over time. This is a very simplistic and generalized outline of evolution. For my purposes here, a slightly more in-depth portrayal of evolution is required, to illuminate the mechanism that produces variance and the concept of fitness.

Variation of traits

Variation in traits occurs through genetic recombination and mutation. Mutations are changes that occur in the genetic sequence of a cell's DNA. There are several reasons why mutations occur. The genetic sequence may be affected by viruses, radiation, chemicals, or cellular processes. However, for the process of evolution, the primary source of variation is the result of mutations in the genetic sequence caused by genetic recombination (Carroll *et al.*, 2005). In organisms which reproduce sexually, genetic recombination occurs via a process called 'meiosis'. This produces changes in the genetic sequence of the nucleic molecule (DNA or RNA) by mixing up the genetic sequences of the parentally contributed genes to form a new nucleic molecule. The result is a novel genetic mosaic consisting of assorted parts of the parental genotypes. This alone is enough to produce variation in an offspring's traits, as the new genetic sequence produced by meiosis is a *novel* combination of the two parental genetic sequences. However, in addition to the variance produced by genetic recombination, other mutations can occur. This adds further novelty to the genetic sequence.

The shuffling of heritable parental traits which occurs through both genetic recombination, and mutations, create nucleic molecules with novel genetic sequences. These changes produce variation in terms of expressed traits. These traits will affect the likelihood of an organism surviving in a given environment, finding or attracting a mate, and therefore, reproductive success.

Selection of traits

As organisms evolve, they change to become better suited to their environment. This is called “adaptation”. Adaptation occurs when there is a consistent difference in survival and reproduction between different phenotypes in terms of reproductive success. Adaptation is produced by a mechanism called “natural selection”.

Natural selection winnows those heritable traits which increase the chances of an individual organism surviving and reproducing. If an organism has a trait that increases its chances of surviving and reproducing, then it is more likely to reproduce than those who do not share that trait, and whose chances of survival and reproduction are therefore less. As that individual is more likely to produce offspring than others in the same population, the result will be a greater likelihood of that organism's genetic material being passed on to the next generation of organisms within that population. The likelihood of an organism surviving and reproducing in a given environment is called “fitness”. Although the concept appears simple, the fitness of an organism is complex with many components involved.

Consider a species that has a simple life cycle. Zygotes are produced and either survive to adulthood or do not. If they do, adults attempt to court and mate. If all goes well, these adults produce some number of offspring and the cycle begins anew. Differences in fitness among individuals can arise from differences in “performance” at any of these stages. Each of these “fitness components”— in this case, viability, mating success, fecundity— can contribute to differences in total fitness among individuals, i.e., can cause different individuals to leave different numbers of progeny. (Orr, 2009, p. 3)

A given trait will not provide a general fitness benefit. The environment provides a context within which an organism's traits are evaluated. A change of context can make a trait that was previously beneficial become detrimental for survival or reproductive success, and vice-versa. For instance, a trait like green skin colour would increase an organism's fitness in a forest, as it would camouflage the organism and help to keep it safe from predation. However, the same trait would not be effective in an environment where green stands out, like the snow and ice of the tundra. As fitness is a measure of success in a given context, it is

very similar to axiotext. In fact, as I will argue the axiotext of a given change in phenotype can be understood in terms of fitness.

3. The AN-pattern in Evolution

Variation and selection are the two processes that drive evolution. Variation produces novelty in form, and natural selection winnows out those varied forms according to their fitness. Adaptive changes in form over time provide us with an AC context, and therefore the capability to determine axiotext.³⁹ Natural selection provides a context, within which increased fitness is axiotextic. Genetic variation produces novel expressed traits with differing levels of fitness. The new traits which offer increased fitness are selected, and this produces a pattern of adaptive novelty within populations of organisms.

The evolution of biological organisms displays the AN-pattern; hence, evolution is a creative system. This is a contentious claim, and there are several ways in which it might be misinterpreted. To avoid any confusion, my argument can be summed up in three simple points. One, evolution produces a pattern of adaptive novelty. Two, evolution produces traits that are novel and axiotextic, and would be classified as creative if they were produced by human innovation rather than evolution. Three, a comparison drawn between those traits produced by evolution and artifacts produced by people demonstrates the creativity of evolution. This is followed by an investigation of the pertinent differences between evolutionary and human creativity.

Let me begin by demonstrating the manifestation of the AN-pattern in evolved phenotypes with an example of an evolved trait: the beak morphology of the Galápagos finch. These changes, which occurred as the species adapted to different environments, displays a pattern of adaptive novelty: the AN-pattern.

4. The AN-pattern in the Speciation of the Galápagos Finch

Through variation and natural selection, evolution has produced a stunning profusion of organic forms. Although the world is filled with appropriate examples to demonstrate the evolution of biological form, I have selected the finches of the Galápagos, which are perhaps *the* textbook example of evolution. Charles Darwin visited the Galápagos islands, and wrote about the species he encountered there in “The Voyage of the Beagle”. The differences in

³⁹ The manner in which the AC or Adaptive Context can be used to determine axiotext was outlined in chapter six.

beak size and shape which he observed in the Galápagos finches provided grist for his theories on natural selection. (Darwin, 1839) The changes in the form (morphology) of the beak display the AN-pattern of adaptive novelty:

High above the cliffs of the Darwin Bay on Isla Genovésa (Tower Island), one of the Galápagos archipelago islands in the Pacific Ocean, jumping around the sharp lava rocks on the ground, perched on the branches of the yellow geiger and croton bushes and flying around large yellow flowers of prickly pear cactuses, are small black and brown birds. These birds look similar to each other in plumage and song, yet closer observation reveals that they all differ from one another in how their beaks look and work. (Abzhanov, 2010, p. 1)

The size and shape of the beaks of the Galápagos finches differs among populations endemic to different islands. The finches on Isla Genovésa have beaks that have adapted to their environment, and become “specialized” to particular functions:

One of them is called a warbler finch (*Certhidea fusca*) and, as its name suggests, it looks and behaves like a warbler from the mainland. It has a very thin and pointed beak, which is used to probe leaves of the palo santo trees to catch small insects and their larvae. Another species feeding nearby on a small bush is the sharp-beaked finch (*Geospiza difficilis*), which has a slightly larger and more cone-shaped beak that is used to collect a more varied diet of both insects and small seeds. (Abzhanov, 2010, p. 3)

The different islands in the Galápagos archipelago have distinct environments, weather conditions, and ecology. The ecological conditions vary from one island to the next, additionally on the larger islands there is variation in the array of vegetation zones at different altitudes (Tebich et al, 2010). The diverse environments present distinct ecological opportunities and pressures for the birds. For instance, the seeds and insects that are prolific on Isla Genovésa are absent on nearby Wolf island. The distinct cone-shaped beak of *G. difficilis* is an endemic morphology, present in the Isla Genovésa population and absent in the Wolf island population. The changes to beak morphology and behaviour of the populations of *G. difficilis* living on Tower and Wolf island display a pattern of adaptive novelty.

On the neighbouring small island of Wolf, members of the same species (*G. difficilis septentrionalis*) use their sharp arrowhead-shaped beaks to cut wounds on large sea birds, such as the Nazca and blue-footed boobies, and drink their blood. These same populations also feed on booby eggs by pushing and rolling them into rocks until they break, revealing remarkable behavioural adaptations that match their beak morphology. (Abzhanov, 2010, p. 1)

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The adaptive beak morphologies of the Galápagos finches do not only differ from island to island. Populations of birds on the same island have adapted to take advantage of different aspects of the same ecology. The beaks of the finches on Isla Genovésa have various forms, which provide access to food sources that for some reason are unavailable to competitors. The finches on Isla Genovésa have adapted novel forms and behaviours to take advantage of “pockets of ecological opportunity”.

Two larger species of finches on Genovésa feed and nest in close proximity to the warbler and sharp-beaked finches. One of them, the large ground finch (*G. magnirostris*), has a massive, extremely deep and broad bullfinch-shaped beak that can be deployed to crush the large and hard seeds that no other bird on the island can handle...there is the large cactus finch (*G. conirostris*) that has a more elongated yet still robust beak adapted for penetrating the firm covers of cactus fruits and closed cactus flower buds that contain protein- and sugar-rich parts inside. (Abzhanov, 2010, p. 2)

The differences in biological form (in this case, beak morphology), are striking. (*See Illustration below*).

There are various natural explanations given for the difference in traits amongst Galápagos finch populations, which are all variations on a given theme or idea. The central idea for the various explanations is, essentially, the Galápagos finch adapted to the disparate endemic ecological conditions of the islands through natural selection (Tebich, 2010).

All these species and 10 more across other islands of the Galápagos archipelago and Cocos Island do not belong to different families, as their extreme differences in beak morphology and specializations would suggest, but are all part of a tightly linked and relatively recent group that diverged within the last 2–3 Myr called Darwin's finches (formerly known as the Galápagos finches) (Abzhanov, 2010, p. 5)

From a common ancestor, finches adapted to the distinct environments on the various islands in the Galápagos archipelago, evolving novel beak shapes in response to endemic ecological scenarios. To suit the assorted endemic ecologies, the finch beak morphology changed over time, producing a pattern of adaptive novelty (AN-pattern). This is similar to the earlier example involving changes in artifacts over time. The automobile headlight changed over time to increase forward illumination. The beak of the finch changed over time to increase fitness. This similarity is more than coincidence.

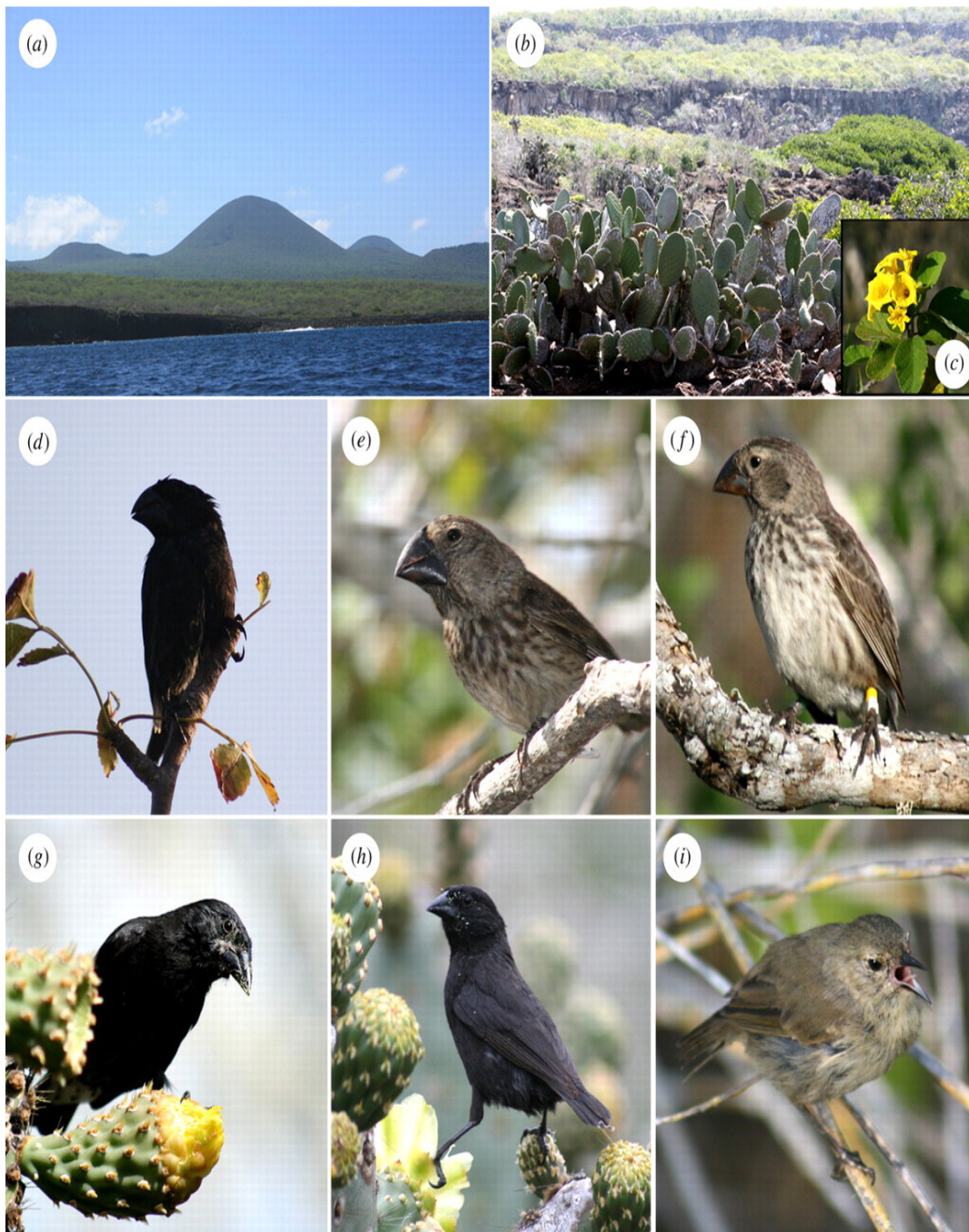


Illustration 30: (a) Galápagos Islands, such as Isla Floreana, are volcanic islands visited by Charles Darwin in 1835; (b) bushes of the prickly pear cactuses (Opuntia helleri) on Isla Genovesa (Tower Island); (c) flowers of the yellow geiger (Cordia lutea); (d) male of the large ground finch (Geospiza magnirostris) singing during the rainy season; (e) female of the large ground finch (G. magnirostris) on Isla Genovesa; (f) female of the medium ground finch (G. fortis) on Isla Santa Cruz; (g) male large cactus finch (G. conirostris); (h) male sharp-beaked finch (G. difficilis) feeding on cactus flowers on Isla Genovesa; (i) male warbler finch (Certhidea fusca) singing next to its nest. Photographs and Legend with permission from Abzhanov, 2010

Novel and adaptive changes in beak morphology

The changes that lead from a single common beak morphology to several specialized beak morphologies display a pattern of adaptive novelty. The presence of the AN-pattern in the evolution of Galápagos finch beak morphology is unmistakable. These changes in beak and behaviour were adaptive, since the changes were axiotextic in terms of increased fitness. The variations in beak morphology and behaviour were also novel, including new beak shapes (e.g. strong conical beaks to crush strong seeds, sharp pointed beaks to draw blood), and new feeding behaviours (e.g. drinking blood from seabirds, and piercing cactus fruits). The novel beak morphologies and feeding behaviours populated new areas of possibility, in terms of form and behaviour. Hence, the changes in the Galápagos finch populations over time exhibit the AN-pattern of adaptive novelty.

Evolution of biological forms is driven by variation and adaptation. The adaptation of traits through natural selection produces adaptive changes in a population over time. Variation in traits, which is the result of mutations in genetic sequence, produces novel biological forms and behaviour. Thus evolution produces a pattern of adaptive novelty. The combination of variation and adaptation that effectuate evolution guarantees that evolutionary changes in biological form will exhibit the AN-pattern diachronically. Hence, any system with a state-space trajectory generated by the adaptation/variation evolution mechanism will produce the AN-pattern; thereby identifying that system as creative. Therefore, any further investigation of the AN-pattern in examples of evolved traits is redundant. To demonstrate that the AN-pattern correctly identifies evolution as a creative system, I will now argue that a particular evolved biological mechanism is creative. This mechanism is novel and axiotextic, and had it been invented by a human, it would be undeniably creative.

5. The Jaw of the Moray Eel as an Example of Evolutionary Creativity

The jaws of the moray eel are an example of an evolved trait that “solves” a problem owing to the size of the eel, the size of the eel's prey, and the size of the space that the eel inhabits and hunts in. The jaws of the moray eel are a novel and axiotextic “solution” to that problem. To appreciate the novelty and axiotext of the jaws requires a description of both the problem and solution in greater detail. I will start with a detailed description the jaws of the moray, followed by an explanation of the problem and how the jaws solve that problem. I will then outline why the jaws of the moray eel are novel and axiotextic (creative).

In common with other fish in the Teleostei infraclass, the moray eel (*Muraena retifera*) has two sets of jaws: the oral jaw and pharyngeal jaw. The Pharyngeal jaw arose through the evolutionary modification of the gill arches, and is utilized in transporting food from the mouth into the throat.

In many teleost fishes, the upper pharyngeal jaws are broad plates. Both upper and lower pharyngeal jaws bear teeth. The lower pharyngeal jaws press against the upper pharyngeal jaws while the latter are moved posteriorly in a shearing motion to manipulate material that is transported into the throat, a function that is relatively conserved across bony fish. (Mehta & Wainwright, 2007, p. 1)

In moray eels, the upper and lower pharyngeal jaws are not bony plates. The jaws of *M. retifera* are long, thin bones which resemble pliers (See *Illustration below*).

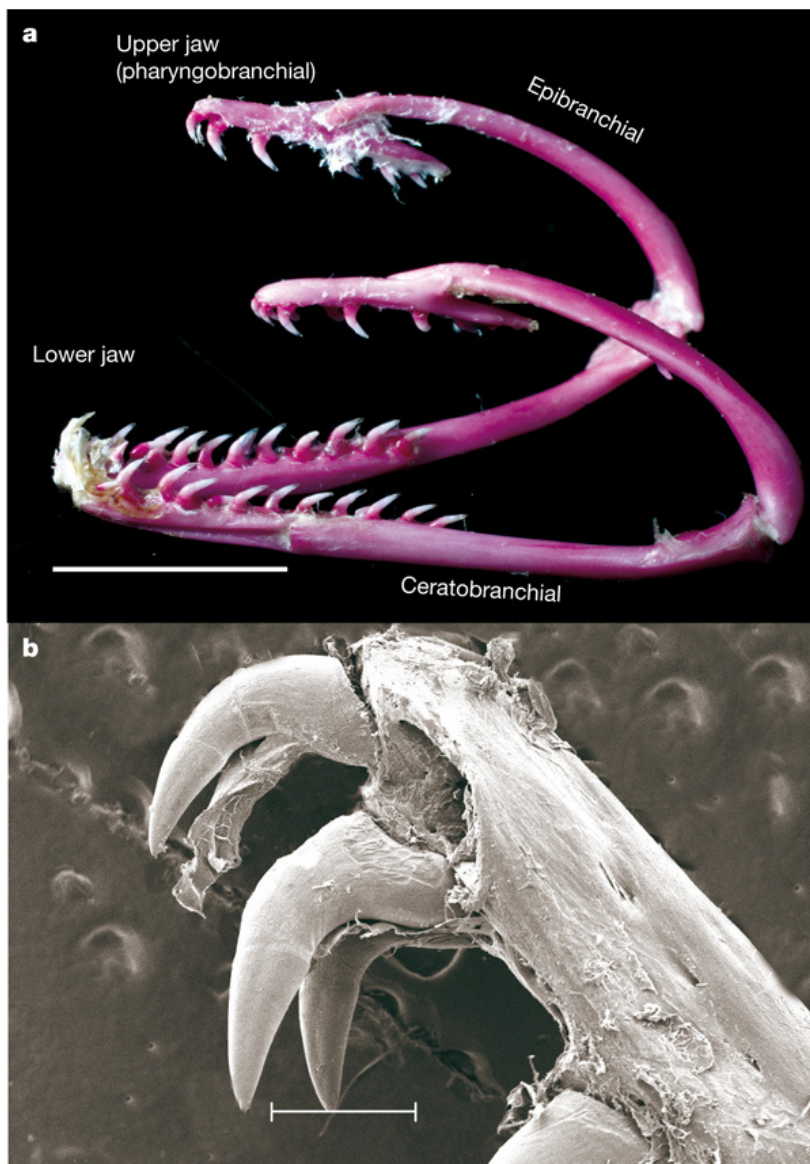


Illustration 31: a, Left lateral view of a cleared and alizarin red-stained pharyngeal jaw apparatus, illustrating the sharp, recurved teeth on the pharyngobranchials used to grasp prey. Scale bar, 1 cm. b, Left anterior upper pharyngobranchial revealing highly recurved teeth. Scale bar, 500 μ m. Photo and Legend from Mehta & Wainwright, 2007

The shape of the pharyngeal jaw reflects its function. The hinged, plier-like shape of the jaw, along with the sharp rear-facing teeth, effectively grasps and pulls prey into the throat.

The upper and lower jaws bear sharp recurved teeth, giving the impression of talons. A hinge, which attaches the upper pharyngobranchial to the epibranchial, enables the toothed pharyngobranchial to rotate dorsally. The upper jaws have slight independent anterior–posterior-directed movement and greater lateral movement. The left and right sides of the lower pharyngobranchials are joined anteriorly by a region of connective tissue fibres and are restricted to anterior–posterior-directed movement. The design of the moray pharyngeal jaw represents specialization for extreme transport movements to carry prey from the oral jaws into the oesophagus. (Mehta & Wainwright, 2007, p. 3)

The mechanism by which the pharyngeal jaw retracts back into the throat is muscular-skeletal. The jaw protracts into the oral cavity to grasp prey. To achieve this, the moray eel tilts its head forward, shortening the distance between the oral jaw and the esophagus where the pharyngeal jaw is positioned. The pharyngeal jaw then comes forward and ensnares the prey, then retracts *qua* a dorsal retractor and the pharyngocleithralis. The dorsal retractor is a muscle that is attached to the vertebral column behind the skull, and the pharyngocleithralis is attached low on the cleithrum (Mehta & Wainwright, 2007). (*See illustration*) The pharyngeal jaw and the associated musculoskeletal protraction/retraction system in the moray eel is complex, with several parts which interact to perform a particular function.

The recurved teeth on the lower pharyngeal jaw ensnare prey during retraction rather than protraction. During retraction, the pharyngeal arms adduct so that the upper and lower teeth securely bite down on the prey. With a firm grip on the prey, the pharyngeal jaws travel back to their resting position behind the skull. The prey is further transported into the oesophagus by contraction of the oesophageal sphincter followed by bilateral compression of the body, resulting in posterior-directed waves....Once the prey had completely entered the oral cavity and could not be grasped by the oral jaws, only pharyngeal and cervical vertebral movements were used to swallow prey. (Mehta & Wainwright, 2007, p. 3)

The pharyngeal jaw mechanism in the moray eel is well suited to the environmental conditions in which moray eels live and hunt. To understand why the moray eel possesses a complex retracting pharyngeal jaw, instead of the simpler hydraulic/bony plate mechanism to transport prey, one must appreciate the relationship the organism has with its environment. Moray eels live and hunt within reefs, therefore much of their time is spent within crevices, holes, and other confined spaces. The size and shape of the Moray eel are important parts of the equation as well.

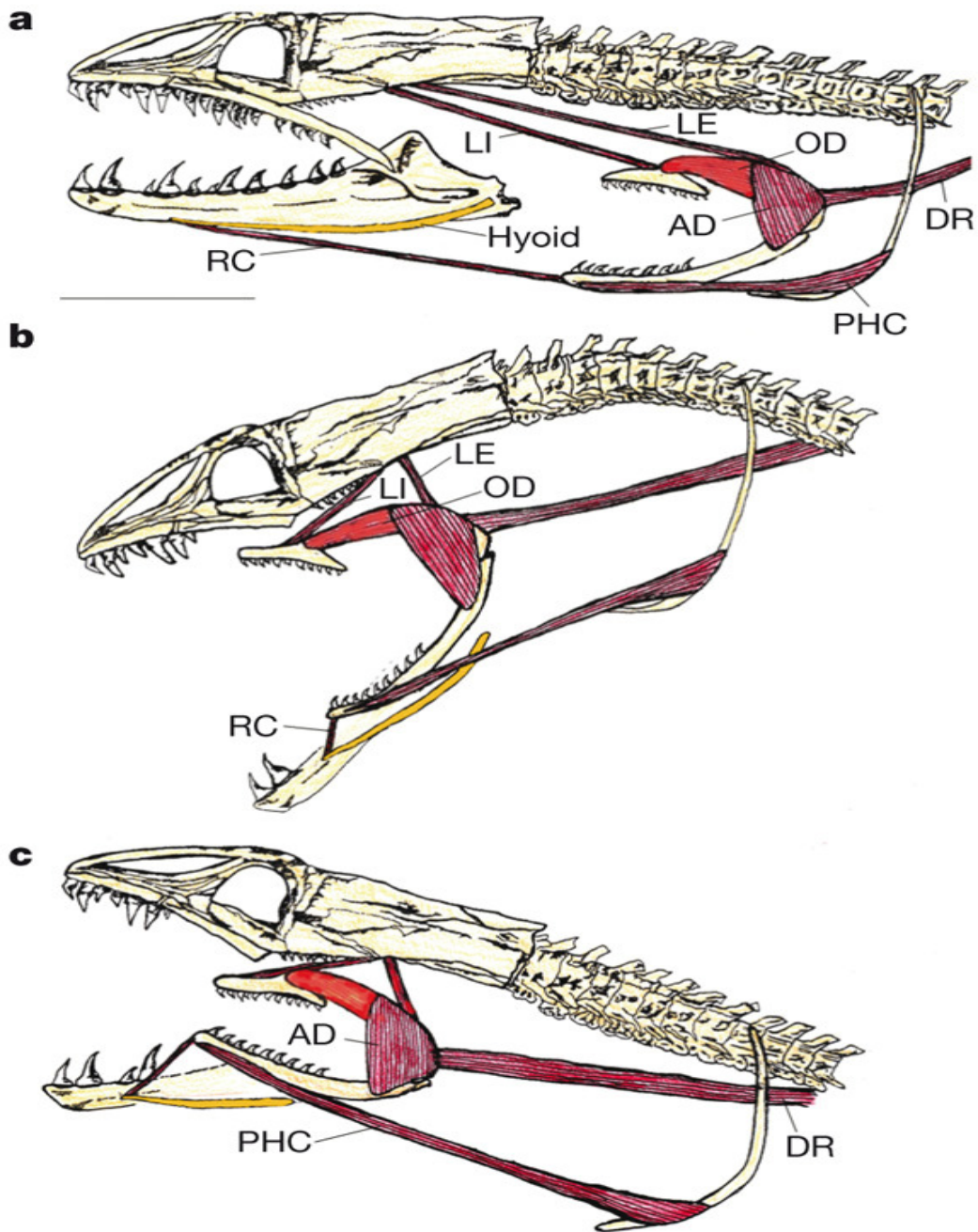


Illustration 32: The left dentary has been removed in a–c, and the left maxilla has been removed in b and c. a, Pharyngeal jaw apparatus at rest. b, Pharyngeal jaw protracted: the levator internus (LI) and levator externus (LE) protract the upper jaw into the oral cavity, whereas the rectus communis (RC) protracts the lower jaw. During protraction, the upper pharyngobranchial is dorsally rotated by contraction of the LI and the obliquus dorsalis (OD). c, After prey contact, the adductor (AD) contracts to bring the upper and lower jaws together to deliver a second bite. The dorsal retractor (DR) and pharyngocleitheralis (PHC) retract the pharyngeal jaws back to their resting position behind the skull. Scale bar, 1 cm. Illustration and legend from Mehta and Wainwright, 2007.

The moray eel is a large reef predator that occupies and feeds in confined spaces. The hydraulic transport mechanism employed by other Teleostei fish requires the capacity for the head to “balloon up” to draw in a surge of water, which is used to pull the prey into the oral cavity and down the esophagus (Mehta & Wainwright, 2007). In open water there is no external physical constraint imposed on a large head expanding to draw in water. However, in the tight confines of the coral reef, there simply may not be room for a large predator like *M. retifera* to “balloon up” to swallow prey. Given the size of the eel and the environment it lives and hunts in, the musculoskeletal prey transport mechanism is advantageous:

Morays hunt in rocky crevices and these confined spaces may limit the cranial expansion required to generate intra-oral water movement. Both suction feeding and hydraulic transport mechanisms require rapid rotation and abduction of many cranial elements. The angular excursion of cranial movements scales with body size, and maximum excursion velocities and overall timing of mouth opening increases during suction feeding. Thus, cranial movements may be limited and less effective for large predatory fish hunting in the confines of coral crevices. (Mehta & Wainwright, 2007, p. 2)

The pharyngeal jaw mechanism of *M. retifera* is an example of an evolved biological mechanism that fulfill my criteria for creativity, and so by my account of creativity, it is creative. It is a complex system with several interacting parts, which act in concert to achieve the function of gripping prey and transporting it from the oral cavity to the esophagus. The mechanism is highly effective, and well suited to the set of constraints imposed by the environment on the organism (Mehta & Wainwright, 2007). The musculoskeletal transport mechanism is novel, as it is not shared by the other Teleostei fish which employ a hydraulic transport mechanism. The pharyngeal jaw of *M. retifera* is both novel (compared with other transport mechanisms) and axiotextic. Therefore, the pharyngeal jaw of the Moray eel is creative.

To further illustrate this point, imagine that instead of being an organism, the Moray eel is a machine. Suppose that we have asked an engineer to design a fish trap that could be placed in coral reefs, in confined spaces. Suppose that we already have a functioning trap that we can use in open water, which utilizes a hydraulic transport system, but this trap is ineffective at catching larger fish within confined spaces. The engineer says that she has produced a new design that utilizes a new transport system and gives us a presentation wherein she outlines a mechanized version of the prey transport system utilized by the moray eel. The function and mechanism (grasping and transporting, and how it is achieved) of her

trap and the moray eel are identical. This is not because she has seen or studied moray eels and copied their pharyngeal jaw. In fact, let us imagine that in this example, *M. retifera* does not exist. The engineer came up with the design all by herself. The new trap is highly effective at trapping fish, and works well within the confined areas of coral reefs.

The new trap is novel, it is a new transport system that is not hydraulic. The new trap is also highly effective, and works within the confined spaces of a coral reef; hence, it is axiotextic. As it is both novel and axiotextic, we would have no reason to deny that her newly invented fish trap is creative. The transport mechanism of the trap and the Moray eel are identical. Both the trap and the jaw are novel and axiotextic (creative). If the invention of the fish trap is creative, then the evolution of the pharyngeal jaw is creative.

One might object to the claim that the pharyngeal jaw should be classified as creative, on the grounds that there is no human agent involved. I will refer to this as the “Poor Comparison” objection. The objection would be framed along the lines that “The jaw cannot be creative, because evolution does not produce phenotypes in the same way that humans invent artifacts” Essentially, the Poor Comparison objection argues that in addition to “novelty” and “axiotext, a definition of creativity must include a third criterion; that of human agency or genesis. This would be an element that is unique to human creativity (such as a specific mechanism for the production of human creativity), or a more general criterion along the lines of “Creativity can only be produced by intentional agents”.

The Poor Comparison objection is actually an attack on my monochronic definition of creativity. I will address this objection by examining arguments for introducing a third criterion that limits creativity to the products of human agents. Before that however, I will briefly explore a historical comparison that was made between evolved traits and creativity, which is directly relevant to the point raised by the Poor Comparison objection. By examining a previous comparison, highlighting its strengths as well as where it went wrong, I am able to clear up any confusion about my own comparison.

6. A Historical Comparison

Above all, in things both great and small, the naturalist is rightfully impressed and finally engrossed by the peculiar beauty which is manifested in apparent fitness or 'adaptation' – the flower for the bee, the berry for the bird. -D'Arcy Thompson, 1961

One might appreciate the serene beauty of an ancient oak, or marvel at the complex workings of the human heart. Evolved traits and organisms are remarkable in their form, function, and fitness. The similarities between evolved phenotypes and artifacts are obvious, and arguments based on these similarities are not rare.

Before Darwin published “On the Origin of Species”, thereby setting the foundation for evolutionary theory and providing an explanation of the adaptive changes in biological forms via a natural mechanism; adapted biological forms were taken as evidence for a divine creator. One of the more famous and elegant examples of this is the Watch argument presented by William Paley in *Natural Theology*. Paley's argument draws upon similarities between artifacts (in this case, a watch) and organisms. I will present a slightly abridged overview of his argument here, as it succeeds in illuminating the deep similarities between artifact and organism, and affirms a historical precedent of intuition regarding nature and creativity. It is also an example of a mistaken conclusion drawn from a comparison between evolved traits and artifacts. Therefore, this discussion of Paley's watches argument will highlight the claims that I am *not* making, and should thereby preempt the objection that I am “making the same mistake that Paley did”. To illustrate this point clearly, I will outline Paley's argument, then briefly examine the conclusions he draws from the comparison, and show how these conclusions differ from mine.

7. Paley's Watch

In crossing a heath, suppose I pitched my foot against a stone, and were asked how the stone came to be there; I might possibly answer, that, for anything I knew to the contrary, it had lain there forever: nor would it perhaps be very easy to show the absurdity of this answer. But suppose I had found a watch upon the ground, and it should be inquired how the watch happened to be in that place; I should hardly think of the answer which I had before given, that, for anything I knew, the watch might have always been there. Yet why should not this answer serve for the watch as well as the stone? Why is it not as admissible in the second sense, as in the first? (Paley, 1802, p. 5)

Paley draws a distinction between a stone and a watch, and claims that nothing about the stone requires us to give a special story about whence it came. On the other hand, he proposes

that the watch (by being complex and through its own form possessing the means to perform a given function), demands a different answer regarding its origin. Paley highlights the complex workings of the watch, and claims that the fact that those workings fulfill the function of telling time implies that the watch is an artifact – created through technique by an artist:

...when we come to inspect the watch, we perceive (what we could not discover in the stone) that its several parts are framed and put together for a purpose, e.g. that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that if the different parts had been differently shaped from what they are, of a manner, or in any other order, than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use that is now served by it. (Paley, 1802, p. 6)

The fact that the internal mechanisms of the watch work together in a specific way to fulfill the function of telling time is important for Paley's argument. A particular configuration of the parts is needed for the watch to be able to accurately tell time. One does not just put a haphazard collection of wheels, springs, cogs and glue together in a box and shake it to produce a watch that can accurately tell time. To produce a mechanical watch that tells time is a complicated and intricate process, requiring skill and ability. Knowing this, if we were to come across a watch while "crossing a heath", Paley argues that we should think that the watch was constructed; rather than the result of accidental collisions between its constituent parts:

The mechanism being observed (it requires indeed an examination of the instrument, and perhaps some previous knowledge on the subject, to perceive and understand it; but once, as we have said, observed and understood) the inference, we think, is inevitable; that the watch must have had a maker; that there must have existed, at some time, and at some place or other, an artificer or artificers, who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use. (Paley, 1802, p. 7)

From this, Paley makes further claims regarding what is implied by the form and function of the watch. Roughly stated, even with the caveats, we did not understand or know the method by which the watch was made, or if the watch does not work perfectly, Paley argues that there is no difference to the strength of the conclusion that "The watch must have been constructed".

The self-replicating watch

The next step in Paley's argument is to introduce a hypothetical watch, which has the ability to produce other watches. This watch is identical to a normal watch, except that it:

possessed the unexpected property of producing, in the course of its movement, another watch like itself, (the thing is conceivable;) that it contained within it a mechanism, a system of parts, a mould for instance, or a complex adjustment of lathes, files, and other tools, evidently and separately calculated for this purpose; (Paley, 1802, p. 8)

In other words, in addition to the gears and springs that provide the function of telling time, the watch contains a little toolbox or workshop that allows it to mechanically reproduce itself. The addition of the ability to self-replicate transforms the watch into a kind of clockwork pseudo-organism. Paley proposes four effects that the addition of the ability to replicate itself should have on our former conclusions about the watch. All four address the same point, roughly that “the fact that the watch can make other watches like itself does not show that a watchmaker was not required to make the first self-replicating watch”.⁴⁰ Paley compares the watch with biological organisms, and argues that the similarities between the two in terms of form and function mean that we must draw the same conclusion for both: that they were created. Paley’s watch is an argument for the existence of God.⁴¹

8. Re-appropriating Paley's Watch

I do not agree with Paley's conclusions. I do not present his argument here as evidence for the interfering hand of a deity in the evolution of natural form. The problem with Paley's argument is not due to any dissimilarity between the output of human creativity with which

40 1. Our admiration of the watch itself should increase, as well as our admiration of the skill of the watchmaker. It would obviously require greater skill and ability to make a watch that in addition to being able to tell time, was capable of self-replication. 2. We should draw a distinction between the watch as a maker of watches, and the watchmaker as maker of watches. When the watch makes another watch, 'makes' for the watch is in a different sense than “from that in which a carpenter is the maker of a chair; the author of its contrivance, the cause of the relation of its parts to their use. With respect to these, the first watch was no cause at all to the second: in no such sense as this was it the author of the constitution and order, either of the parts which the new watch contained, or of the parts by the aid and instrumentality of which it was produced. 3. The watch found in the example, since it has the capacity to self-replicate, is not necessarily the first replicating watch. More likely, it is one of many “offspring” watches. However, this does not affect the original inference, that “an artificer had been originally employed and concerned in the production 4. Our original inference about the watch being the product of an artificer (or artificers) is not affected by “running the difficulty farther back, i.e. by supposing the watch before us to have been produced from another watch, that from a former, and so on indefinitely. Our going back ever so far brings us no nearer to the least degree of satisfaction upon the subject.” (Paley, 1802, p. 9)

41 By God, I mean an omniscient entity who created the universe. I take Paley to be arguing for the existence of God as is known in the Judaic Christian tradition.

we are familiar (like artifacts) and the output of evolution in terms of biological forms (organisms with adapted traits). The problem is not with the comparison between evolution and “the work of an artificer”, the problem is that one has to be very careful about the claims that such a comparison will support.

Paley's watch argument is based on the inescapable similarities between artifacts and organisms in terms of complexity and apparent function. The examples I give to illustrate the creativity of evolution (finch beak, eel jaw) essentially trade upon the same similarity. Paley's argument arrives at an erroneous conclusion regarding the necessity of a divine artificer, as the mechanism of evolution adequately explains Nature's rich tapestry of complex and adapted forms and behaviour. However, I do not need to spill further ink to argue this point. If it turns out that a divine artificer has designed and created the forms of Nature, then the essence of my argument remains unchanged. The forms of Nature, so well-suited to their various environments, are creative (the result of a creative mechanism). This point stands, regardless of whether Nature's forms are brought about through evolution, or by a deity.

My position would be improved if the natural world *was* created by God. It is trivial to argue for the creativity of an omnipotent artificer. After all, we know humans are capable of creativity: and a deity who designed and *created* the universe would be far beyond human capacities in that regard. If the world was created by such a deity, I would not have to reply to the Poor Comparison objection; as it would no longer apply.

Both Paley and I argue that the similarities between evolved forms and artifacts (the AN-pattern) should be taken as evidence that both are creative. Where we differ is in what we attribute to creativity, and what we mean by “creative”.

9. Seeing Nature as Creative

Let me begin with two pertinent quotes:

...the contrivances of nature surpass the contrivances of art, in the complexity, subtilty, and curiosity of the mechanism; and still more, if possible, do they go beyond them in number and variety: yet, in a multitude of cases, are not less evidently mechanical, not less evidently contrivances, not less evidently accommodated to their end, or suited to their office, than are the most perfect productions of human ingenuity. (Paley, 1802, p.13)

And:

Nothing at first can appear more difficult to believe than that the more complex organs and instincts should have been perfected, not by means superior to, though analogous with human reason, but by the accumulation of innumerable slight variations, each good for the individual possessor. (Darwin, 1859)

The similarities that Darwin and Paley draw between artifact and organism are informative. Unlike Paley, I do not argue that the similarities between the two are so striking that the processes or mechanisms responsible must be similar as well. The mechanisms which drive evolution - genetic variation and natural selection - are different to those mechanisms which produce change in artifacts. The design teams, factories, prototypes, market researchers, and others involved in the production of new automobiles are worlds apart from the processes of cellular meiosis, nucleic acid molecules, embryo morphogenesis and other aspects of evolution. Automobiles do not have DNA, and finch beaks are not produced in factories in Japan. Clearly, the claim that human creativity and evolution are identical is too strong. However, I am not making the claim that human creativity is identical with evolution, only that both are creative; as both display the AN-pattern.

The mechanisms responsible for changes in artifacts and changes in organisms are different. However, this is not a problem for my diachronic definition of creativity. The AN-pattern, upon which the diachronic definition is based, is a general systems law. General systems laws apply across systems, regardless of differences in their physical makeup. A general systems law has the capacity to capture the important similarities between artifacts and organisms, without making claims regarding the underlying mechanisms responsible. After all, as we saw in chapter six, the same general systems law describes the form of hurricanes, nautilus shells, and auto-catalytic chemical reactions, despite their underlying mechanisms being different.

10. Objections and Replies

The Poor Comparison objection stems from the idea that creativity must be produced by some mechanism unique to human cognition or, in more general terms, by intentional agents. If either of these is the case, it is a mistake to attribute the creativity to evolution. I will address the objection from mechanism first and intentional agents second.

The Mechanism objection

It is uncontentious that some kind of cognitive mechanism or mechanisms produce human creativity (Boden, 2004). However, the Poor Comparison objection is not just making

the claim that there is a particular cognitive mechanism that produces human creativity, rather, that a particular cognitive mechanism is a *necessary* requirement for *all* creativity. This claim underpins the “mechanism” version of the Poor Comparison objection, which argues that it is a mistake to define evolution as creative, as it occurs *via* a different underlying mechanism than human creativity. In other words, evolution cannot be genuinely creative because it occurs *via* natural selection, produced by variations in genetic molecules; rather than “true” creativity which occurs *via* some cognitive mechanism produced by firings of neural fibers. There are two reasons to not accept this claim, first is that it is not clear that it is accurate, that the mechanisms that produce human creativity and evolution are actually different; second is that even if the mechanisms that underlie evolution and human creativity are different, it would be a mistake to conclude that creativity can only be produced by a particular mechanism. Let me begin by examining the idea that the mechanisms that underlie evolution and human creativity are different.

At first blush, the mechanisms that produce the evolution of biological traits and those that produce creative ideas could not be more different. In terms of timescale, evolution involves the replication of organisms over countless generations, while the production of a creative solution to a problem can appear nearly instantaneous. The “basic components” are different as well. However, despite these apparent differences in physical makeup and timescale, there is the possibility of a formal equivalence between the two. It may be the case that the mechanisms that produce human creativity are actually analogous to natural selection. We currently make use of evolutionary or genetic algorithms to produce solutions to problems, as Becker points out:

Evolutionary strategies and genetic algorithms have conquered many areas in (human) problem solving such as optimization problems, inverse problems, and image processing. There are even problem classes for which no other methods (for quickly generating solutions) are known...Evolution turns out to be very creative and efficient. (Becker, 1999, p. 1)

There are well known models within creativity research literature that claim that human creativity operates according to mechanisms analogous to natural selection (Simonton, 1999; Campbell, 1974; Finke *et al.*, 1992; Calvin, 1987). Essentially, these accounts take natural selection as the manifest inspiration for a “generic” model according to which we can subsume not just the evolution of biological forms, but also learning, problem solving, and creativity (Campbell, 1974). These models of creativity argue that despite the ontological

differences between neuroprotein and genetic molecules (RNA and DNA), the mechanisms that underlie evolution and human creativity are analogous. If this is the case - it is not clear that these models are inaccurate – then there is no basis for the claim that evolution cannot be creative due to a difference in mechanism. However, it is possible that these models are inaccurate, and that human creativity occurs via mechanisms that are significantly distinct to biological evolution. If this is the case, it would still be a mistake to deny the creativity of biological evolution based on a difference in mechanism.

There are behaviours and artifacts that were created by people who we recognize as creative. For an example, I will use the play *Hamlet*, written by William Shakespeare. We recognize *Hamlet* as creative, and that Shakespeare was being creative when he wrote it.

While we recognize that *Hamlet* is creative, we have no record or knowledge of Shakespeare's mental processes when he wrote *Hamlet*.

We can imagine that Shakespeare was a robot whose CPU “brain” operated via mechanisms that are totally alien to our brains. This lifelike robot Shakespeare still wrote *Hamlet*, as well as all of his other plays and poems. Now, imagine that the fact that Shakespeare was a robot comes to light. Furthermore, his robot “brain” is exhumed and it is revealed that Shakespeare's brain operated via radically different underlying mechanisms than a human brain.⁴² These alien mechanisms were responsible for producing *Hamlet*. The question is, are the works of robot Shakespeare still creative?

It would be a mistake to deny the creativity of *Hamlet* simply because we discovered that Shakespeare's robot brain operated differently to ours. Our recognition of *Hamlet* as being creative cannot be based on facts about Shakespeare's mental processes (those mechanisms that produced the creative output), as we have no knowledge of said processes or mechanisms. Perhaps if we had some certainty about the mental processes or mechanisms in our own brains that produced creativity, then we might be able to include that mechanism (or set of mechanisms) as a necessary criterion in a definition of creativity. However, the actual mechanisms by which creativity is produced in the human brain are still mysterious; and even if we eventually are able to identify those mechanisms, it would be a mistake to include them as necessary criteria in a definition of creativity.

The inclusion of a particular cognitive mechanism as a necessary criterion in our definition of creativity has repercussions in the area of non-human creativity, specifically

42 Perhaps they were a highly developed robotic version of a genetic algorithm

artificial intelligence. Our capacity to determine whether a being is creative would depend on our ability to discern whether that being possessed a mind capable of producing novel and axiotextic behaviour *via* underlying mechanisms that are identical to those that we have identified as being responsible for producing creativity in the human brain. This is setting the bar too high for non-human creativity, considering that we do not make these judgments with certainty about other humans. It would be unfair to deny the creative status of other beings (or potential minds) by holding them to a standard of certainty that we do not require for ourselves.

The intentional agent objection

One might agree that it would be a mistake to include a particular cognitive mechanism as criteria in a definition of creativity, yet still object to my claim that evolution is creative. One could argue that although I have not relaxed the criteria for creativity (novelty and axiotext), I have used my definition of creativity in a way that conflicts with a requirement for creativity that is implicitly included in what could be called the “standard model” of creativity employed by researchers. Creativity research has almost exclusively focused on the domain of human behaviour (Kaufman & Kaufman, 2004). Consequently, one might argue that although it is never explicitly stated, there is an *implicit assumption* that creativity is produced by intentional agents, and is therefore restricted to the sphere of human cognition and behaviour. The objection would be that novelty and axiotext are enough to define creativity in terms of human behaviour, but that it is a mistake to extend that definition to apply to non-human behaviour. To claim that evolution is creative contradicts an implicit assumption, which although it is never explicitly stated, is important nonetheless. Therefore, the intentional agent variant of the Poor Comparison objection argues that although I have shown that the evolution of organisms is novel and axiotextic, evolution does not count as creative because it is not produced by intentional agents.

The nature of the relationship between intentional agents and creativity is a matter for debate. On one hand, there is no question that intentional agents are involved in some instances of creativity. However, it would be a mistake to equate “involved in some instances of creativity”, or even “involved in almost all instances of creativity”, with “necessary for creativity”.

One could baldly state that intentional agents are required for creativity. However, one could just as easily make the opposite claim, that intentional agents are not required for

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creativity. To move past this impasse requires a convincing story about why creativity is impossible without intentional agents. The fact that intentional agents are involved or associated with familiar instances of creativity is not enough; nor is the fact that nearly all research into creativity focuses on the behaviour of intentional agents. This is sufficient to demonstrate that creativity often involves intentional agents, but it does not demonstrate that creativity *necessarily* involves intentional agents (that creativity is impossible without them).

It is not obvious that intentional agents are required to produce creativity. As the current discussion of evolution and creativity shows, the mechanism of evolution is capable of producing novel and axiotextic forms and behaviour without intentional agency. In other words, the question is not “Are intentional agents required to produce output that is both novel and axiotextic?”, since the answer to that question is demonstrably “No, they are not - evolution produces physical traits and behaviours that are both novel and axiotextic”. Instead, the question is “How does the absence of intentional agents affect the creative status of forms and behaviour that would otherwise be considered creative?” or “How does the absence of intentional agents make creativity impossible?” Rather than address that question here, I propose that a distinction be made in terms of creativity.

The objection arises because my definition deviates significantly from the standard model of creativity, and explores creativity beyond the domain of human behaviour. By making a distinction between different kinds of creativity, and explicitly addressing the involvement of intentional agents, the objection can be avoided. The distinction is drawn along the lines of the inclusion of intentional agents; on one side we have agent-creativity (a-creativity), which is creativity that necessarily includes intentional agents, and on the other is broad-creativity (b-creativity), which is creativity that does not necessarily include intentional agents. As the necessity of intentional agents is at best - without additional argument - an *untested implicit assumption*; both a- and b-creativity are genuinely creative. The distinction between a- and b-creativity is not made in order to show that one is any more or less creative, or that one is *really* creative while the other is only superficially creative. The distinction is intended to introduce a greater level of precision into discussions of creativity and creative behaviour, and to highlight (and also sidestep) a potential issue regarding the involvement of intentional agents. For the remainder of this dissertation, I will use “creativity” as shorthand for “b-creativity”, unless otherwise noted.

There are differences between evolution and human creativity. The involvement of intentional agents is one of those differences, and underlying mechanism is another. There are deep similarities between evolution and human creativity as well. These similarities are striking and profound, as is illustrated by arguments like Paley's watch. One may disagree with my definition of creativity in terms of the range of systems that it identifies as creative. The idea of extending a definition of creativity beyond the domain of human cognition and action may conflict with some intuitions. However, limiting the range of creativity requires that we willfully ignore or overlook instances that would be undeniably creative if they were produced by a human.⁴³ A definition of creativity limited to human behaviour is a poor notion of creativity. Here is Margolis on what a notion of creativity should include:

The question is one rather of what we should mean by the notion (of creativity), with due respect to the sense in which it is a scarce commodity and also an ubiquitous one, a distinctly human trait and also a trait that must have its moorings in the animate and inanimate world at large. It is a matter of proposing a paradigm or a strategic clue for organizing a great motley of experience and musings in a way that will illuminate certain salient and undeniable instances at least. We all begin, in this effort, with God's creation *ex nihilo*, with the birth of new infants, with the evolution of new species, with the first appearance of living forms from organic but inanimate substances, with the invention of the wheel and the plow, with the masterpieces of the world of art, with an Einstein or a Darwin. (Margolis, 1985, p. 12)

By adopting a definition of creativity that is able to be applied to a wide range of systems and behaviour, we are able to undertake an exploration of creativity in general; an exploration that couches human creativity within a much larger phenomenon. The alternative is to isolate creativity within human behaviour, despite obvious similarities in the behaviour of other systems, to preserve our intuitions regarding the status of human behaviour as unique amongst the rest of nature.

The origins of creative behaviour suggest that evolution is creative. If human creativity evolved, then to deny the creativity of evolution is to deny that the process that produced creativity was creative. As I argued in chapter four, the nest building behaviour of the Bowerbird is creative: the construction of a well-decorated bower is both novel and axiotextic. A male Bowerbird who constructs a bower that succeeds in attracting females will be more likely to reproduce. The Bowerbird's reproductive success directly affects an underlying mechanism of biological evolution, sexual selection. This produces the AN-

⁴³ An engineer who produced an artifact that was equivalent to the human heart, or brain in terms of efficiency and function would be undeniably creative.

pattern in evolution; hence the creative behaviour of the Bowerbird affects the production of the AN-pattern in evolution. This is not restricted to the Bowerbird; for any organism, creative behaviour that affects their reproductive success will affect the mechanism of sexual selection. There is reason to suspect that this may work “in reverse” as well, where natural selection would influence the mechanisms that produce creative behaviour in the individual organisms. If individual creativity results in greater reproductive success (i.e. well decorated bowers successfully attract females), then individual creativity affects natural selection, which in turn might result in the evolution of organisms with an increased capacity for individual creativity.

For this to be the case, we must assume that the capacity for individual creativity is (or is in some sense related to) a phenotype that can be selected for. Carruthers argues that as creativity is indicative of intelligence, and central to the ability to solve problems, creative capacity would have been selected for by both natural and sexual selection mechanisms (2002). Other research suggests that early forms of art, such as song and dance, could have become a fitness indicator in addition to their original “functions” as art (Dissanayake, 1992). Other research has focused on the evolutionary origins of particular creative artifacts, such as Paleolithic cave paintings (Lewis-Williams, 2002). There has been much research done recently on the evolution of the human cognition – not all listed here – that argues that the genesis and blossoming of our capacity for creativity is a story told by evolution (Miller, 2000; Mithen, 1996, 1998; Orians, 2001; Falk, 2000; Brown, 2000; Dutton, 2009). These studies suggest that human creativity evolved (and that creative human behaviour was directly involved in the evolution of the human capacity for creativity), which I take to further illustrate the creativity of biological evolution.⁴⁴ To accept that human creativity evolved, and yet deny the creativity of evolution, is to claim that the system that produced creativity was not itself creative.

⁴⁴ If evolution generated, expanded, and augmented human creativity, and creative behaviour (music, painting, and other arts) was directly involved in the evolution of an greater capacity for creativity; then it both the origin and flourishing of creativity (evolution) and the creative human behaviour are obviously creative.

Chapter Nine

The AN-pattern in Protein Systems

1. Nested Creativity

Creative behaviour occurs in collectives at levels of organization higher than individual organisms: armies, multi-national corporations, ecosystems, and the evolution of species all display diachronic creativity.⁴⁵ However, group and collective behaviour does not only occur at higher levels, but lower on the organizational scale as well:

Nature is hierarchical in its organization. For example, cells arrange into organs that make an organism, organisms in turn add up to an ecosystem and ecosystems total the global biosphere. The nested pattern is also found when descending downward in scale. For example, a eukaryotic cell houses cellular organelles that contain molecular complexes assembled from molecules that are, in turn, composed of atoms and so on. (Annala & Kuismanen, 2009, p. 1)

Creative behaviour at scales of organization above and below the level of individual organisms is difficult to assess using a definition of creativity that relies upon our (limited) ability to assess axiotext. It is difficult (if not impossible) to assess axiotext in the behaviour of groups higher on the organizational scale.⁴⁶ The same is true for creative behaviour below the level of individual organisms. The lower you get on the organizational scale, the harder it is to anthropomorphize the organizational units. Descend far enough down the organizational scale, and you are examining and describing the behaviour of chemical reactions.

We do not use a theory of mind to explain or predict the behaviour of the organizational units at lower organizational scales. We do not typically attribute mental states or processes to things like molecules or chemical reactions. Unlike the behaviour of people, or even other animals such as the New Caledonian crow, we do not interpret the behaviour of chemical reactions or molecules as being motivated by goals, beliefs, desires, or emotions. Behaviour at the sub-cellular molecular organizational scale involves contexts that we are unable to “connect with” or comprehend within an anthropomorphic context. I cannot imagine what it is like for something to be axiotextic or detrimental for a molecule or

45 Chapters seven and eight contain examples of diachronic creativity produced by car companies, military industries, and evolution. For a discussion of adaptive novelty expressed in ecosystems, see Jørgenson et al., 1998.

46 As I argued in chapters five and six, using an example of varied context at different organizational scales.

chemical reaction. As I will demonstrate, this does not mean that creativity does not occur at the lower organizational scales.

Although assessing axiotext is difficult at both higher and lower organizational scales, there is a practical advantage to examining behaviour at lower organizational scales. There is an added difficulty facing an investigation of collective behaviour at organizational scales above the level of individual organisms due to the physical size of those groups. The behaviour of a large collectives, such as a multi-national corporation, involves a system with an incredible number of parts.⁴⁷ These parts are not necessarily all local, and can be spread out in various locations across the globe, resulting in collective behaviour that is both highly complex and widespread. Hence, collective behaviour at high organizational scales is unable to be contained and studied within a laboratory.

This is not the case with behaviour at lower organizational scales. Although collectives at lower levels of organization can still be comprised of a great many parts, and the complexity of their behaviour can be akin to that of higher-level collectives; the physical size of lower-level systems is much smaller (molecules are much smaller than people). Collective behaviour at lower levels of organization is therefore more accessible to controlled, in-depth laboratory studies. Definitions of creativity have so far been unable to be applied to collective behaviour at low organizational scales. Consequently, low level group behaviour is a “new frontier” for creativity research into heretofore undiscovered creative systems. As evidence for this, I present the following two examples of diachronic creativity at a low organizational scale: Prion “evolution” and an account of biogenesis (the origins of life) involving lipid aggregate “evolution”.

2. The AN-pattern in prion and lipid systems

This section investigates examples of the pattern of adaptive novelty as it appears in prion and pre-biotic chemical systems. The discussion begins by exploring the composition of prions (folded protein molecules), as well as briefly explaining how prions replicate and adapt to their environment. This will be followed by a brief discussion of prions as non-living entities, which leads naturally into the discussion of biogenesis. In the section on biogenesis, I examine a hypothetical model for the origins of life on Earth. This model operates on the

⁴⁷ Operation Overlord involved over 190,000 military personel. As of 2008, Starbucks coffee listed over 170,000 employees worldwide (Fortune, 2010).

idea that prebiotic evolution led to the creation of proto-cells, which were precursors to the first living cells. Like the prions, the proto-cells are not considered to be alive. In both prions and biogenesis examples, the AN-pattern is produced by mechanisms that are distinct to those presented in earlier examples.

In both the prion and biogenesis examples, I will highlight the presence of the AN-pattern of adaptive novelty. The prion example is important for the following three reasons: **(a)** Prion populations are systems that are low on the organizational scale. This example shows that creativity occurs in systems at the molecular level on the organizational scale. **(b)** This example is distinct from previous examples of creativity, in that prions are not alive. **(c)** Prions adapt, yet they do so without DNA or RNA. This makes the mechanism(s) for prion adaptation distinct from my previous examples of adaptive behaviour.

Populations of prions adaptively respond to changes in their environment. Prion populations adapt to their environment through a process of variation and adaptation that is similar to the process of natural selection which drives evolutionary change in populations of organisms. However, the underlying mechanisms of the process of prion adaptation are different to those of natural selection in organisms. Variation in natural selection in the evolution of organisms is primarily produced by mutations in the genetic sequence of the DNA or RNA molecules that occur during recombination. Prions do not contain DNA or RNA, and are incapable of self-replication. Therefore, although the result of the processes (natural selection in organisms and the selection algorithm in prions) is similar (adaptation to environment), the mechanisms are distinct. To appreciate the differences, and their consequences, it is necessary to appreciate both in greater detail.

3. Prion Structure and Behaviour

Prions are composed of protein. A protein is an organic compound, composed of a chain of amino acids. Amino acids are molecules that are common and important in biological systems. Proteins are formed when amino acid molecules link together to form a linear chain, like a bead necklace. There are 20 standard amino acid molecules, each with a distinct size, shape and set of properties. Protein chains typically range in size, from 50 to 2,000 amino acid “beads” (NIGMS, 2007). There are many different potential combinations of amino acids that can form a chain. Consequently, there are many different proteins, and each has a distinct sequence of amino acid molecules linked together end to end. This sequence of

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amino acids is referred to as the “primary structure”, and is used as a chemical definition for the varied assortment of proteins.

The chains of amino acid molecules that compose a protein's primary structure do not stretch out in a straight line, but folds into a three-dimensional shape. This shape is referred to as the secondary structure of the protein:

amino acid chains do not remain straight and orderly. They twist and buckle, folding in upon themselves, the knobs of some amino acids nestling into grooves in others. This process is complete almost immediately after proteins are made. Most proteins fold in less than a second, although the largest and most complex proteins may require several seconds to fold. Most proteins need help from other proteins, called “chaperones,” to fold efficiently. (NIGMS, 2007, p. 5)

The primary structure and folded shape allow the protein to perform different functions. These functions are important and vital to the continued operations of the human body. Proteins can be understood as “worker molecules” which help undertake “virtually every activity in your body” (NIGMS, 2007). For instance, the protein haemoglobin in our blood attaches to oxygen molecules in the capillaries in the lungs, which allows the oxygen to be transported around the body. Enzymes are proteins that are present in our saliva, small intestines and stomach. These proteins break down the molecules of food that we ingest, assisting in the process of digestion (NIGMS, 2007). Antibody proteins “attack” pathogens, like bacteria and viruses, contributing to our bodies’ immune response against disease. Protein is a major component in our muscles, hair, and fingernails.

A small difference in the primary structure (the sequence of amino acids) of a protein can alter its shape and function. For instance, changing a single amino acid in the primary structure of haemoglobin affects the shape, and consequently the functional capacities of the protein.

Sickle cell disease...is caused by a single error in the gene for hemoglobin, the oxygen-carrying protein in red blood cells. This error, or mutation, results in an incorrect amino acid at one position in the molecule. Hemoglobin molecules with this incorrect amino acid stick together and distort the normally smooth, lozenge-shaped red blood cells into jagged sickle shapes. The most common symptom of the disease is unpredictable pain in any body organ or joint, caused when the distorted blood cells jam together, unable to pass through small blood vessels. These blockages prevent oxygen-carrying blood from getting to organs and tissues.. (NIGMS, 2007, p. 11)

Difference in primary structure is not the only manner in which proteins can change. There is a regularity to the way in which proteins fold to form the secondary structure, they do not

“randomly wad up into twisted masses” (NIGMS, 2007). Thus, a given amino acid chain will regularly fold into a characteristic secondary structure. This regularity is enough to suggest that some law or principle governs protein folding, and is a subject of inquiry in the field of bioinformatics called “protein structure” or “secondary structure” prediction (Luthy & Eisenberg, 1991). Currently, we do not possess a complete understanding of how a protein's primary structure determines the secondary structure. However, we do know that there is not necessarily a one-to-one correlation between primary structure and secondary structure (Luthy & Eisenberg, 1991). Proteins with identical primary structures can fold into different secondary structures. When a protein does not fold into the characteristic secondary structure, the result can be detrimental. As such, a protein with an uncharacteristic secondary structure is said to have been “incorrectly folded” or “mis-folded” (NIGMS, 2007).

Prion disease

A prion is a protein that is an infectious or “causative agent of transmissible spongiform encephalopathies (TSEs)” including bovine spongiform encephalopathy or “Mad Cow disease” in cows, Scrapie in sheep, and Creutzfeldt-Jacob disease and Kuru in people (Weissmann, 2005). The word 'prion' is a portmanteau of the words “protein” and “infectious”. Prions cause brain diseases in mammals. All mammalian prion diseases involve the damaging of neural tissue and are untreatable and universally fatal.

Mammalian cells normally produce cellular prion protein or PrPC. During infections, such as the human form of mad cow disease known as vCJD, abnormal or misfolded proteins convert the normal host prion protein into its toxic form by changing its conformation or shape...The prion protein is not a clone, it is a quasi-species that can create different protein strains even in the same animal. (Weissmann, 2010, p. 1)

Prion infection proceeds through four stages or “processes”. These are penetration, translocation, multiplication, and pathogenesis (Weissmann, 2005).

under “natural” circumstances mammalian prions are usually taken up orally. After penetrating the lining of the gastrointestinal tract they enter the lymphoreticular tissue of the gut, invade the peripheral nervous system, either directly or via lymph nodes and spleen, and ascend the central nervous system (CNS). Prions multiply to high titers in the brain and in some hosts in spleen, albeit to a lower level. Spongiform degeneration, astrogliosis, and neuronal cell death accompany prion multiplication in the CNS (Weissmann, 2005, p. 2)

As infectious agents, prions are similar to viruses. The prion diseases Kuru and Scrapie were both originally thought to be viral (Prusiner, 1998). We now know that these diseases are

caused by prions that infect a host, replicate through interaction with the host, and cause disease. The prion pathogens are similar to viruses, but they differ from viruses in two important ways. (1). Prions do not contain the genetic nucleic molecules RNA or DNA. Neither prion nor virus can self-replicate; both require the “help” of the host they have infected to propagate. All viruses contain a genetic sequence encoded in a DNA or RNA molecule. A virus propagates itself by infecting a host cell and “hi-jacking” the mechanisms for nucleic acid production. A prion is different, as “Prions are devoid of nucleic acid and seem to be composed exclusively of a modified isoform of PrP designated PrP^{Sc}” and hence do not propagate themselves using the machinery and metabolism of a host cell (Prusiner, 1998). (2). Prions can potentially be generated “de novo”, in a cell-free environment (Weissmann, 2005). Meaning that unlike viruses, which rely on pre-existing cellular machinery and therefore follow Pasteur's precept of “Omne vivum ex vivo”;⁴⁸ prions do not. Prions can self-generate in certain complex chemical solutions.

Prion structure classification

Prions were originally classified in terms of different strains. The various prion strains were classified using the vernacular of pathogenic disease, and were “originally characterized by the incubation time and neuropathology they elicit in a particular host” (Li *et al*, 2010). The theory was that different pathogenic symptoms in the host indicate a different strain (Bruce, *et al*, 1992). This method of classification was sufficient to identify the existence of different strains, but was imprecise. To discover the adaptive behaviour of prions, a different method of prion classification was required. To appreciate in what way prions are adaptive, and how we are able to demonstrate their adaptive behaviour, familiarity with the prion “protein-only” hypothesis is useful. To that end, I will now briefly discuss the “symptom” classification and the “protein-only” hypothesis. This discussion will highlight the important differences between “symptom” and “protein-only”, which explain why the adaptive behaviour of prions has only recently been discovered.

The problem with the “symptom” method of prion classification is that several (15 or more) different prion configurations can propagate within a host, while only producing a “single” set of symptoms (Li *et al*, 2010). The “symptom” method of classification for prion strains suffers from an ambiguity which stems from the lack of a one-to-one correlation

48 Trans. “all life from life”, or “no life without antecedent life” from Louis Pasteur, a phrase that summarized Pasteur's empirical studies on germ theory and spontaneous creation. (Pasteur, 1870)

between expressed pathogenic symptoms displayed by the host, and stable prion secondary structure configurations.⁴⁹ A more precise method of prion classification is provided by the “protein-only” hypothesis; which proposes that instead of identifying prion strains with incubation time and neuropathological effects, rather, various prion strains be “associated with a different conformer of PrP^{Sc}” (Li *et al*, 2010).⁵⁰ The protein-only classification focused on the secondary structure of prions, which revealed that prion secondary structures were changing in response to changes in their environment. This led to the discovery of adaptive changes in prion populations; changes which mean that the behaviour of prion systems is axiotextic.

Protein-only strain classification offers further advantages over the classical “symptom” method of strain classification. The experimental process, focus, precision, and potential depth of inquiry available with methods available under the protein-only hypothesis are superior to earlier “symptom” classification methods, and are important to our discussion here. The classical “symptom” method of strain differentiation requires the capacity to observe the symptoms of prion infection. This has the potential to be problematic, as “Although penetration, translocation, and multiplication in the periphery occur rapidly (within days to weeks in the mouse), clinical symptoms are only apparent after months in the mouse and years to decades in man” (Weissmann, 2005, p. 4).⁵¹ This means that to carry out studies using “symptom” classification methodology can take several months or years. Alternatively, a cell panel assay (in-line with the protein-only hypothesis) assesses cell tropism of strains, allowing for the distinction of prion strains “within about 2 weeks” (Li *et al*, 2010). The result is that researchers are able to carry out studies within a much shorter period of time. Consequently, although the Protein-only hypothesis is a new approach, and therefore a much “younger” theory than the “symptom” classification, it does not suffer from a dearth of research in terms of data or findings.

49 The ambiguity of the “symptom” method of prion classification obscured prion adaptation in secondary structure configurations (Li *et al*, 2010)

50 In other words, prions are classified into strains based solely on the secondary structure of the protein. This hypothesis classifies prion strains in terms of their shape, rather than in regards to the symptoms they cause in an infected host. The protein-only hypothesis has the advantage over the “symptom” classification in terms of precision, as it establishes a one-to-one association between strain and prion.

51 The slow-moving and lengthy incubation and multiplication processes in mammalian prion infections mean that using the “symptom” method of strain differentiation can require long periods (months or even years) before the symptoms needed to complete the classification manifest (Li *et al*, 2010).

4. Adaptation in Prion Populations

Prions are capable of adapting to (changes in) their environment. This directly contradicts earlier conceptions of prion formation, where “It was generally thought that once cellular prion protein was converted into the abnormal form, there was no further change” (Weissmann, 2010, p. 2) This general viewpoint was based upon data drawn from research into prion strains⁵². Research utilizing classical “symptom” strain techniques reported that prion “strain specificity is retained when prions are transferred from brain to cultured cells and back to brain” (Li *et al*, 2010). However, as this research was carried out using symptom strain differentiation methods, the resulting data shows that prion strains which cause particular symptoms in brain tissue continue to cause those particular symptoms if they are placed in a cultured cell environment before being re-introduced to brain tissue. As the method utilized to determine prion strains in these cases examined the incubation time and neuropathological effects (the symptoms), they are blind to any effect that placing the prion strains in an environment of cultured cells had on the prions themselves. This is not the case with cell panel assay (CPA).

the properties of prions while in cell culture could not be determined by classical procedures. We therefore examined prion characteristics using the CPA...(we generated cell-derived prions by infecting a cell population using brain-derived prions) The CPA showed that cell-derived prions and brain-derived prions differed. (Li *et al*, 2010, p. 8)

As their environment changed, so did the prions. Populations of prions transferred from brains to cultured cell populations changed their ability to infect cells. This included how effective the prions were at infecting cells, as well as the type of cells they were able to infect (Li *et al*, 2010).

heterogeneity in the case of the prions is likely to be due to differences in the structure (other than the amino acid sequence) of the PrPSc molecules. These differences could reflect variations in the conformation of the PrPSc resulting during conversion; the conformational changes may be subtle, but sufficient to facilitate propagation in a particular environment. (Li *et al*, 2010, p. 10)

As the prions propagated themselves in their new environment, the characteristic secondary structure of the prions in the population changed: variants in secondary structure which were more infectious within the newly encountered cellular environment came to dominate the

⁵² These studies were performed under the “Symptom” classification, which was potentially ambiguous regarding prion structure.

population (Li *et al*, 2010). These changes produce novelty in secondary structure, which - like those discussed in chapter eight (AN-pattern in evolution) - are adaptive. As prion populations change and adapt, they “evolve”:

prions show the hallmarks of Darwinian evolution: They are subject to mutation, as evidenced by heritable changes of their phenotypic properties, and to selective amplification, as documented by the emergence of distinct populations in different environments.” (Li *et al*, 2010, p. 1)

When prion populations change their properties to suit changes in their environment, they display a pattern of adaptive novelty. Hence, prion populations are creative systems. However, the way in which prion populations produce creative behaviour is different to any of my previous examples. Despite producing similar behaviour, the mechanism(s) that produce this pattern in prion populations are different to those mechanisms which are responsible for the pattern in technological change and the evolution of organisms. Adaption in prion structure occurs without intentional agents (as are involved in technological adaptation), or nucleic acid molecules (as are involved in the evolution of organisms):

In viruses, mutation is linked to changes in nucleic acid sequence that leads to resistance. Now, this adaptability has moved one level down- to prions and protein folding - and it's clear that you do not need nucleic acid (DNA or RNA) for the process of evolution. (Weissmann, 2010, p. 1)

This has two important implications for my thesis. (1), it means that another mechanism has been identified that is capable of producing creative behaviour. (2), it establishes that the diachronic definition has the capacity to identify creative behaviour in non-living systems. I will address (1) in due course, for now I would like to briefly discuss (2).

5. Creativity in Non-Living Systems

There are several proposed definitions for life; in other words, there are various ideas about the “minimum requirements” that something must meet before it is to be considered alive. These definitions include criteria like homeostasis and growth maintained by metabolism, response to environmental stimuli, adaptation, and reproduction (McKay, 2004). Despite their capacity for adaptation, prions have no metabolism, nor are they capable of reproduction: according to these definitions of life, prions are not alive.

Despite not being alive, populations of prions display a pattern of adaptive novelty. The manifestation of that pattern indicates that populations of prions are capable of creativity (in terms of form and/or behaviour). Creativity is both novel and axiotextic. Axiotext is worth

or benefit within a given context. As prions are not alive, it may appear contradictory or incoherent to claim that they are capable of creativity. It is difficult to see how a form or behaviour could be axiotextic to something that is not alive. Put another way, the question is “Is life necessary for creativity?” My answer to this question is “no”, however, one could disagree.

6. Objections and Replies

One might agree that prion behaviour is both novel and axiotextic, and yet still dispute that it is creative. Essentially, the claim would be that my definition of creativity over time fails in this case, and misidentifies prions as creative. One could make this claim by producing an argument that life is required for creativity, or one might object on the grounds that including non-living systems as creative is too counterintuitive, and that we “do not use the term 'creativity' in that way”. I will explore the argument that life is required for creativity at the end of chapter ten. For now, let me reply to the claim that to refer to non-living systems is too counterintuitive to fit with our use, or common understanding of, “creativity”.

I agree that to define non-living systems as being creative runs counter to our intuitions. Despite it being counterintuitive, I see the fact that the diachronic definition reveals creative behaviour in a non-living system is an indication of success. I have presented the diachronic definition as a tool to overcome the limits that heretofore restricted the search for creative behaviour. The value of such a tool is that it allows us to explore potentially creative phenomena beyond the boundaries delineated by definition of creativity at a time. Therefore, I would consider it a failing if the diachronic definition of creativity produced no counterintuitive results. The next example is no less counterintuitive, although it differs from every other example of creativity that I have presented thus far. The next example is distinct in that it is the only one of my examples that in no way involves organisms (even prion adaptation occurred in and around organisms). The next example is a hypothetical account and discussion of an early, perhaps the first, instance of creativity: biogenesis, the origin of life.

Chapter Ten

The AN-pattern in Biogenesis

1. Models of Biogenesis

In this chapter, I explore an account of biogenesis which involves a system of chemical reactions that displays the AN-pattern, and is therefore creative. This account of biogenesis can be roughly summed up by the idea that prebiotic chemical reactions formed primitive autonomous agents. By “primitive autonomous agents” I mean “proto-cells”, the precursors to our single-celled ancestors. This example of creativity is important, in that the creative behaviour occurs in a non-living system that precedes life itself.⁵³ This example illustrates the creativity of biogenesis, and does so by appealing to a natural, rather than supernatural, explanation. This salvages a foundational example of creativity. The origin or creation of life is a seminal example of creativity, an important notion upon which the origins of the word “creativity” is based. Since the behaviour of chemical networks and molecular aggregates are beyond our capacity to assess a priori using a theory of mind, it is impossible to subsume a natural account of biogenesis under a “standard model” definition of creativity. By using the diachronic definition, I will demonstrate that a natural (rather than a supernatural) account of biogenesis is creative; thereby allowing us to appreciate the creativity of the genesis of life.

There are competing theories regarding the origins of life on Earth. It is not certain that we will ever come to know the precise molecular details of how life first arose here on Earth. Recent discussions of biogenesis postulate that chemical systems are capable of producing simple molecular autonomous agents that are able to implement heredity and reproduction without requiring genetic polymers, such as DNA or RNA (Kauffman, 2005; Sole', 2009; Fernando & Rowe, 2008). By heredity, I mean persistent variations across “generations” of self-reproducing systems. With the implementation of heredity and reproduction in chemical systems, adaptive changes akin to biological evolution occur through processes analogous to natural selection.

⁵³ Given that we exclude the possibility of exogenesis (an account of terrestrial biogenesis using the hypothesis that life originated elsewhere in the universe, and then came to Earth).

2. Auto-catalytic Reactions and Chemical Equilibrium

For auto-catalytic reactions to be sustained, the chemical network (the “soup” or medium) must be in a state of non-equilibrium. The chemical network cannot be a homogenous “well-stirred” soup; there must be different concentrations of various chemicals in the network as a whole to sustain auto-catalytic reactions. A chemical catalyst accelerates a particular chemical reaction. A medium of highly concentrated catalyst will cause an acceleration of a particular chemical reaction. For clarity, it is helpful to imagine catalysts as “fuel” for a particular reaction. When a reaction is “sped up” by a catalyst, the catalyst itself gets used in the reaction.

In auto-catalytic reactions, the catalyst of a particular reaction is produced by another reaction in the same chemical network. In such systems, a local concentration of a particular catalyst (catalyst 1) will create an accelerated reaction (reaction 1), which will in turn produce the catalyst (catalyst 2) for another reaction (reaction 2). As the catalyst for the first reaction is used up by the reaction, the local concentration of chemicals will change. When the concentration of the second catalyst (catalyst 2) is stronger than that of the first catalyst (catalyst 1), the result will be an acceleration of the second reaction (reaction 2). Assuming that there are only two reactions and catalysts within the chemical network, reaction 1 and reaction 2 will oscillate. Concentrated pockets of catalysts will accelerate a particular reaction, until the balance of concentration tips, and the opposite reaction takes over. As each reaction produces the catalyst for the other, the result is an oscillating interaction between the two reactions in the chemical network. This oscillating interaction is only possible with concentrations of catalysts. If the chemical network was a homogenous soup with no concentrations of chemical catalysts, then the oscillating interaction required for auto-catalytic reactions could not occur.

For multiple accelerated reactions to occur simultaneously within the same chemical network there needs to be spatial differentiation with varied concentrations of chemical catalysts. Simply put, to produce and sustain multiple auto-catalytic reactions in the same medium requires an uneven distribution of chemicals within the medium; ideally with “pockets” of concentrated catalysts.

For instance, if the whole chemical network contained a uniform concentration of catalyst 1, the oscillations between reaction 1 and reaction 2 would still occur. The entire chemical network would alternate between a universal acceleration of reaction 1 induced by

catalyst 1 and producing catalyst 2 until the concentration of catalyst 2 became greater than the concentration of catalyst 1. At which point the greater concentration of catalyst 2 would accelerate reaction 2, consuming catalyst 2 and producing catalyst 1 until the balance of concentration shifts back again. However, the auto-catalytic systems proposed for the origins of life are far more complex than the two-reaction chemical network that I have outlined in my example. The chemical systems proposed as candidates for biogenesis require a complex chemical network or “soup”, where multiple reactions occur and interact with one another as catalyst concentration gradients shift and change. In which case, the chemical network cannot be a homogenous soup in a state of equilibrium. Instead, the chemical network must be able to maintain a state of non-equilibrium (different concentrations of different chemicals).

3. Maintaining Non-Equilibrium

There are a number of options to maintain a non-equilibrium state. First, the medium might be very viscous, like sludge or gel. Imagine pouring some milk into a bowl of gelatin and giving it one quick stir, the milk and gelatin would remain separate for the most part, and there would be pockets of milk stirred in amongst the gelatin. In a sludgy or gelatinous medium the various chemicals would be slow to mix together, and the concentrations of catalysts would be preserved (for a time). The “gel” method of maintaining non-equilibrium is not ideal for our purposes. Although it would take longer, eventually the chemicals in the chemical network would disperse in the gelatinous goo, and the chemical network would come to be in a state of equilibrium. The problem with the “gel” method as a model for maintaining chemical non-equilibrium for biogenesis is that it pits our auto-catalytic reactions in a race against the clock, where they must make the jump from pre-biotic chemical reactions to organic life before the various chemicals dissolve into a state of equilibrium. It may have taken a very long time to make the jump from pre-biotic to living systems, so a different method of maintaining a state of non-equilibrium would be preferable.

Encapsulation maintains a non-equilibrium state with greater longevity than a viscous gel. With encapsulation, the pockets of concentrated chemicals could become effectively sealed off from the rest of the chemical network, which would provide a barrier to prevent the chemicals from dissolving and dispersing as quickly. This maintains the non-equilibrium state of the chemical network for longer, and has two other advantages as well. First, by being encapsulated, the chemical reactions occurring inside the capsule (cell) are potentially

protected from severe fluctuations in the chemical network outside the capsule. This allows reaction interactions that would otherwise disappear in radical fluctuations of the chemical network to “survive”. Encapsulation allows for a more delicate or fine-tuned set of auto-catalytic reactions to exist in a medium than would be possible in a “gel” network. Second, encapsulation provides a natural delineation that is helpful when discussing concepts like “organism” and “environment”. An encapsulated chemical reaction is more easily identified with concepts like “individual” or “proto-cell” than an area of concentrated chemical catalyst within a gelatinous chemical network. The following hypothetical example of biogenesis offers an explanation of how a chemical metabolism capable of heritability and reproduction arose, and how the encapsulation of that chemical metabolism occurred. This example posits that life began in a warm soup, and auto-catalytic reactions were encapsulated in lipid “soap bubbles”.

4. Formation of Proto Cells

The origins of life in this example are chemical reactions enclosed in an oily bubble that forms a kind of “skin”. These oily skins, made up of fatty lipid aggregates contain “chemical reactions that produced holistic autocatalytic molecular replicators” (Fernando & Rowe, 2008). To illustrate how lipid aggregates containing chemical reactions can be considered to be alive, I will first clarify the meaning of “alive” or “living”. To define 'alive', I use Kauffman’s definition of “autonomous agent”. Kauffman’s defines an autonomous agent as “a system capable of self-reproduction and at least capable of performing one thermodynamic work cycle.” (Kauffman, 2003). Kauffman's definition of autonomous agents is a spartan definition of life. The criteria for an autonomous agent does not include any mention of homeostasis, growth, or response to environmental stimuli. Kauffman's definition is minimalist. However, this is not due accident or oversight, as it is tailored to discussions regarding the simplest and most basic life forms. Kauffman uses his definition of autonomous agent in his discussion of the origins of life (Kauffman 1995, 2005). The idea being that the first life forms were very simple (compared to organisms today), and so a definition intended to be used in discussions of the origins of life should be simple as well.

Kauffman’s definition of autonomous agent is well-suited to our current discussion, as it provides a conception of the salient properties required of the chemical systems under discussion. In this example, chemical networks capable of sustaining auto-catalytic reactions

are encapsulated within lipid “skins”, these encapsulated reaction networks become autonomous agents through processes akin to natural selection. The idea is that life began via a process of prebiotic evolution, which acted within or upon a chemical network to produce “increasingly organized chemical supersystems” (Ganti, 2003).

Fernando and Rowe postulate a model of a prebiotic geophysical process for the simplest chemical “machine” capable of natural selection. Natural selection can be understood as “an algorithm that operates in populations of entities capable of multiplication, variation, and heredity” (Maynard-Smith, 1986). Fernando and Rowe state that natural selection can be implemented in a system consisting of geophysical processes, autocatalytic reactions in a chemical network, hydrophobic lipid aggregates, and sunlight. In their paper they provide two models of the simple chemical machine, a laboratory model, and a simplified computer model. The laboratory model begins by creating a chemical network; essentially a “soup” of chemicals speculated to have been present on primordial Earth. Lipids are added to this chemical soup, the mixture is agitated, thinned, and pressurized.

...a solution of lipid aggregates. Initially all grow at some base rate when lipid is added, and divide stochastically when the reactor is vigorously shaken...after this, a reaper removes 50% of the hydrophobic material from the reactor. Conditions are changed to favour rare novel chemical reactions, e.g. high pressure. During this phase a chemical avalanche may occur, which may produce an autocatalyst that may increase the production of food set molecules and so increases the fitness of the lipid aggregate that contains it. (Fernando & Rowe, 2008, p. 4)

The laboratory model proposed by Fernando and Rowe is based upon (and in reaction to) previous experimental results in lipid formation (both laboratory and natural models), including (Miller, 1953; Orgel, 2000; Folsome, 1979; and Segre *et al.*, 2000, 2001).

5. The AN-pattern in Liposome “Populations”

Fernando and Rowe's laboratory model induces prebiotic evolution in the population of lipid aggregates (or as individual units, *liposomes*). Here is how it works. We begin with an initial population (set) of liposomes (oily bubbles). These liposomes vary in their ability to grow larger (absorb and react to external “food” molecules), and to divide (when the reactor is vigorously shaken). The liposomes contain chemicals, and chemical reactions can occur within them. The laboratory model involves a step where the pressure is increased. Pressurizing the chemical network increases the odds of “novel chemical reactions” by pushing the molecules into closer proximity with one another, which increases the chances

that a reaction will occur. These reactions have a chance of creating an auto-catalytic chain of reactions within the liposome. If this occurs, the auto-catalytic chain of reactions can affect the liposome's ability to grow and divide.

A percentage of the auto-catalytic reactions will negatively affect the liposome's ability to grow and to divide, meaning that the liposome will not grow and/or the liposome will be less likely to cleanly divide during vigorous shaking; a percentage of the auto-catalytic reaction chains will also cause the liposome to dissolve. In addition to “negative” reaction chains, there will be a percentage of auto-catalytic reaction chains that positively affect the liposome's ability to grow and divide. Prebiotic evolution is introduced into the system as multiple successive iterations of the laboratory model will select liposomes which maximize “the production of a subset of chemicals that defines its growth set, from a food set supplied as a bolus in each generation” (Fernando & Rowe, 2007).

To test for the evolution of growth reaction sets, a simplified, simulated version of the laboratory model was modeled using a computer program. In their computer simulation,

Only one lipid aggregate was modeled at a time, along with its enclosing water phase compartment containing food molecules. Simulated lipid aggregates were selected on the basis of their supra-basal growth rates resulting from the production of a predefined set of growth molecules. A hill-climbing algorithm was used to assess the efficiency with which natural selection could generate ‘adaptations’ under the above variation and selection constraints. This hill-climbing algorithm worked by testing the fitness of a parent, and generating offspring from that parent until an offspring was produced whose fitness was greater than the fitness of the parent, in which case the offspring replaced the parent, and the algorithm iterated.
(Fernando & Rowe, 2008, p. 6)

Liposome fitness

Fernando and Rowe ran the computer simulation described above until it reached 100,000 iterations and the results demonstrated a fitness increase in the lipid aggregates; “Fitness” being roughly the production of a larger growth set. The simulated lipid aggregates which evolved during the simulation became increasingly complex, e.g. consisting of more “species” of reaction and more reactions overall; this evolution was due to the accumulation of self-sustaining processes resulting from an increase in the complexity of the chemical network structure produced by successive adaptive “avalanches” (Fernando & Rowe, 2008).

Autocatalysts can produce lipid aggregate level fitness by either catalytic reactions or by being consumed in reactions that produce the growth set. Both mechanisms were

observed. Autocatalysts may produce each other, may catalyze each other, or may be independently produced from food molecules. (Fernando & Rowe, 2008, p. 2)

Due to their effect on liposome growth and division capacity, autocatalytic reactions in the chemical network implement a selection algorithm, akin to natural selection. The selection algorithm operating on the chemical network selects for reaction continuation and increased complexity in reaction sets. Through successive cycles of reaping and vigorous shaking, those liposomes whose auto-catalytic reaction sets adversely affected their capacity for growth and division, or dissolved their lipid shell, were winnowed out. Over time, the liposomes with greater capacities for growth and division come to dominate the population. Autocatalytic cycles formed and evolved within the lipid aggregate “shells”. The lipid aggregates were required for the maintenance of the networks of chemical reactions which were beneficial (in terms of growth, division, and surface stability) (Fernando & Rowe, 2007).

(the lipid aggregates) act in their own best interests as a consequence of having been subjected to natural selection and... they contain self-maintaining chemical cycles that utilize external chemical energy sources to produce their constituents. Each turn of an autocatalytic cycle is a molecular thermodynamic work cycle, and each reproduction event at the level of the lipid aggregate that contains a network of such autocatalysts is a higher-order thermodynamic work cycle.

(Fernando & Rowe, 2008, p. 8)

Lipid aggregates in this example, or a similar system of lipids and chemical networks, may have been (or given rise to) the first forms of life. These living lipid aggregates would have been similar in form and function to living cells. The autocatalytic reactions in the chemical networks produce a primitive metabolism, and allow for the implementation of a selection algorithm.

Liposome proto cells cannot self-replicate

The liposomes (lipid aggregates) produced by the geophysical process (bubbling or dripping oil under pressure and vigorous shaking) in Fernando and Rowe's model do not qualify as autonomous agents according to Kauffman's definition. Kauffman's second criterion is met; The self-sustaining auto-catalytic chemical reactions are capable of performing a single work cycle (by virtue of being self-sustaining). However, they fail to fulfill the first criterion, as liposomes do not self-replicate (replication is performed by the geophysical processes and shaking).

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The lipid aggregates form a closed compartment that creates a stable barrier between the delicate internal chemical reaction metabolism and outside perturbations. The chemical metabolism and a lipid container provides the liposomes with two key components required for self-replication. A third component, which is present in cells, is absent in the lipid aggregates. The absent component is the information, or “instructions” for replication. In 1966, John von Neumann famously analyzed the process of self-replication and postulated the minimal requirements for the process to occur.

The self-replicating system (is) composed by a minimal set of four closely related components, namely, the constructor, able to build a physical, new system by using the available raw material in the surroundings. The blueprint or instructions containing information on what has to be performed by the constructor. A duplicator, which takes the instructions and duplicates them accurately. The controller, required to guarantee that the whole process takes place in some well-defined sequence. (Sole, 2009, p. 6)

The parts and process of von Neumann’s analysis of self-replication is diagrammed in the illustration below.

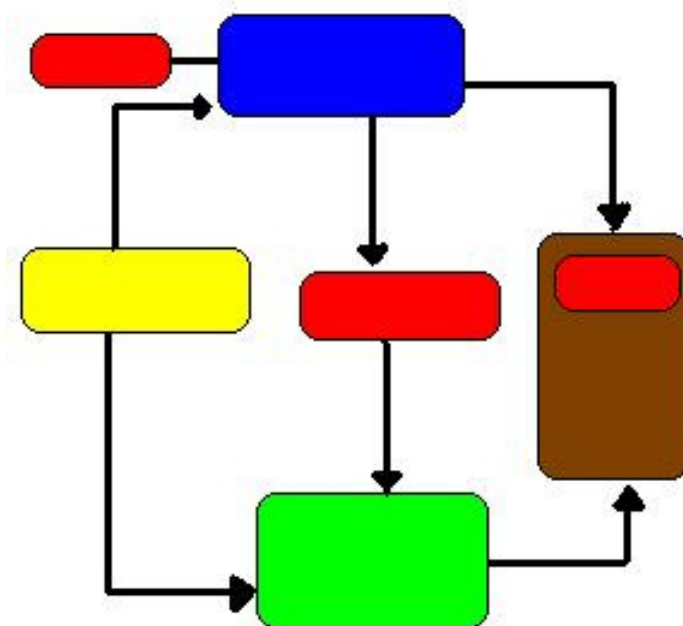


Illustration 33: Von Neumann’s self-replication schematic. Yellow is the controller, Red is the instructions, Blue is the duplicator, Green is the constructor, Brown is a newly produced self-replicating automaton.

The components of von Neumann's schematic for self-replication describes the parts necessary for the process of cellular reproduction.

We can identify the components of the automaton with those of living cells as follows: (a) the instruction set is the DNA molecule; (b) the duplicator is provided by the DNA polymerase and other components of the cell's replication machinery; (c) the constructor corresponds to the RNA polymerase and the translation machinery (allowing proteins to be formed) and (d) the controller is nothing but the regulation of transcription and translation. (Sole', 2009, p. 6)

As is illustrated in the diagram above, a cellular automaton capable of self-replication requires a blueprint or some instructions to inform the construction of further duplicate automatons. In the case of cells, these instructions are contained in the DNA molecule. Eukaryotic cells have specialized protein mechanisms which can produce a duplicate cell.⁵⁴ These mechanisms "follow" the information contained in the DNA molecule. This means that both the instructions and mechanism for self-replication are housed within the cell itself. However, in the case of the lipid aggregate, there is no instruction or blueprint for replication within the liposome. The mechanism for the formation and replication of the liposome is not contained within the liposome. The lipid aggregates are self-organized or self-forming,

The essential components of membranes, so-called amphiphiles, spontaneously self organize in space within a water environment to form well-defined structures. Amphiphiles are polar molecules having a well-defined hydrophilic head group (showing attraction for water) and a tail group (usually a long chain) showing hydrophobicity. As a consequence of this conflicting relation towards water molecules (which are themselves polar too) amphiphiles can self-assemble into compact spatial structures showing a 'phase-separation' between water and amphiphiles.
(Sole', 2009, p. 11)

Liposomes replicate via external processes (bubbling or shaking), or division due to molecular instability. The latter was recently modelled, and a robust picture of liposome growth and division emerged (Fellerman *et al.*, 2007). (*See illustration below*)

The model was implemented using a so-called dissipative particle dynamics (DPD) approach. This is a coarse grained simulation technique which has been successfully used to capture the dynamics of membranes, vesicles and micelles. In this computational view, the system is represented by a set of N particles... These particles (or "beads") are not meant to represent individual atoms. Instead, they represent

⁵⁴ A eukaryote is a cell in which the genetic material is DNA, which takes the form of chromosomes and is contained within a distinct nucleus. Eukaryotes are distinct from prokaryotes, the latter having neither specialized organelles nor a distinct nucleus.

groups of atoms within a molecule (like several CH₂ groups within a hydrocarbon chain) or even a group of small molecules such as water. (Sole', 2009, p. 12)

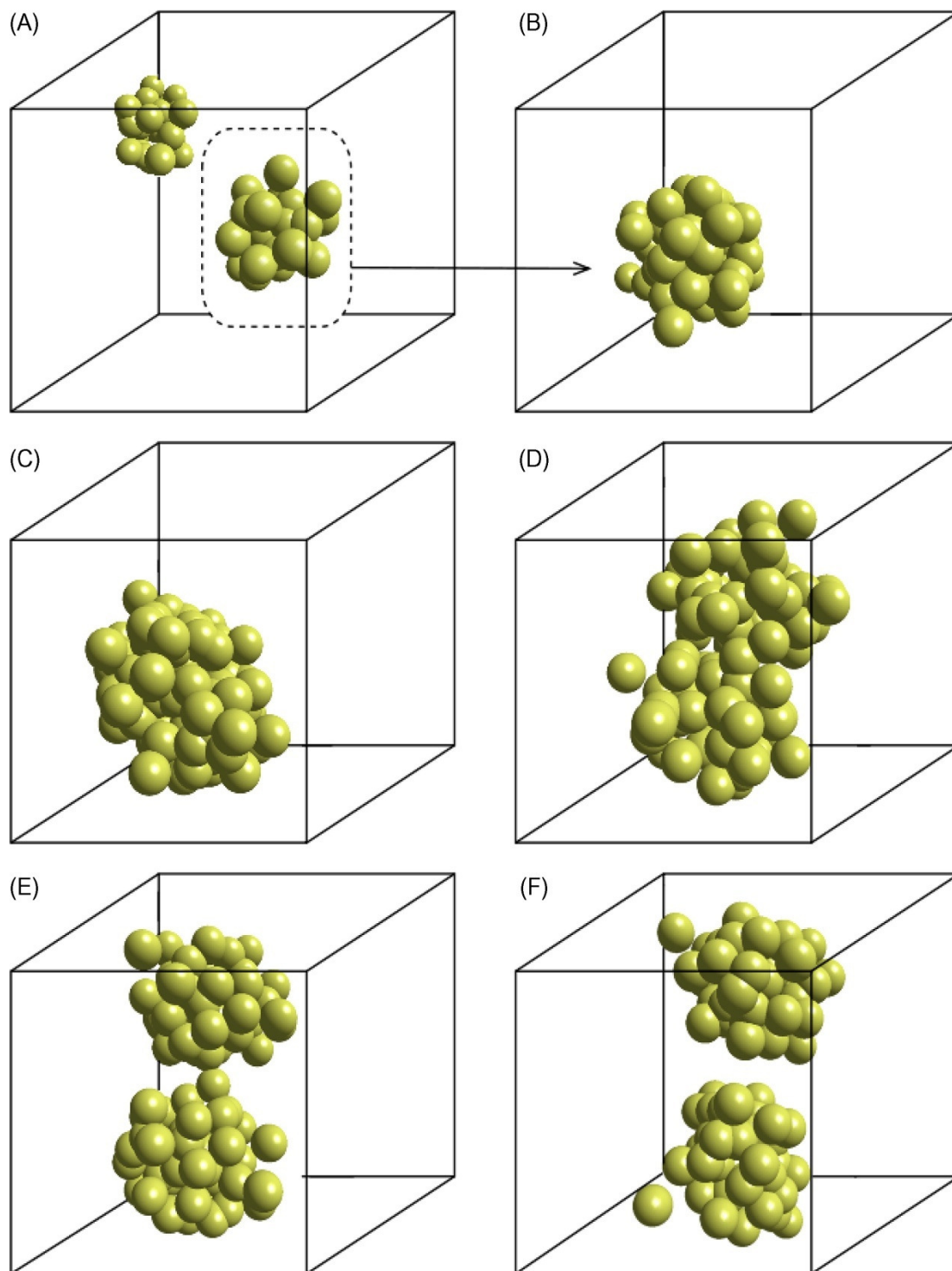


Illustration 34: In (A) an intermediate step is shown with two large $N \approx 30$ amphiphiles each. One of them (surrounded by a dashed square) keeps growing (the other one too, but we don't follow its growth) and in (B) and (C) we can see its larger size. As it grows beyond $N \approx 100$, it destabilizes and starts to deform (D). Eventually, two subsets get formed (E) and split (F). (Sole', 2009)

The bundling, self-organizing properties of lipid aggregates result in the natural assembly of spatial forms capable of encapsulation. These naturally assembled liposomes are able to divide, and therefore are capable of replication. Whether this division is achieved via structural instabilities in amphiphile molecular configurations (Sole', 2009), or as in the model proposed by Fernando and Rowe, division of liposomes is achieved by external physical processes (bubbling, vigorous shaking); the result is the same in either case. As is the case with prions and viruses, liposome replication is achieved by processes that are external to the liposome itself. Consequently, liposomes do not meet the requirements to qualify as autonomous agents (self-replication and capacity to undergo a single work cycle): as such, liposomes are not alive. As this is an account of biogenesis, eventually the lipid aggregates “evolve” into proto-cells and thereby become something that we would define as alive. However, the liposomes in the example are not yet living.

6. Biogenetic Creativity

Anyone who tells you he or she knows how life started on the sere earth some 3.45 billion years ago is a fool or a knave. Nobody knows. -Kauffman, 1995

The origin of life, biogenesis, was creative. This is not a new claim. The creation of life is one of the earliest, perhaps the original, example of creativity. The etymological origins of the word “creativity” affirms this, as the root L. *creatio* from which we get “creation” and “creativity” meant “that which God has brought into being”, referring to the creation of the natural world (including life itself) by God *ex nihilo*.⁵⁵

The proponents of prebiotic evolution as an explanatory mechanism for the origins of life on Earth (biogenesis) argue that a chemical process roughly akin to natural selection (implementing variation and adaptation) was responsible for producing the first proto-cells. These liposome proto-cells eventually grew more complex, gained the capacity for self-reproduction and made the transition from prebiotic molecular compounds to living, autonomous agents. Essentially, that is the story of biogenesis according to proponents of prebiotic evolution. However, biogenesis is still a matter of debate: no one knows for sure, and the proponents of prebiotic evolution may turn out to be wrong (Orgel, 1998, 2000; Kauffman, 1995). Either way, there are claims that can be made regarding creativity and biogenesis.

⁵⁵ For a rich account of the historical transformation of the cultural conception of “creativity”, see (Tatarkiewicz, 1980; Sternberg & Lubart, 1999)

If it is the case that the prebiotic evolution story of biogenesis is true (it accurately describes the chemical origins of life), and there is no immediate and definitive proof that it is not, then the processes responsible for the origin of life display a pattern of adaptive novelty. The system of replicating liposomes is adaptive, in that there is a selective algorithm producing a trend towards greater growth sets (increasingly organized auto-catalytic chemical reactions). Therefore, the trajectory of the liposome/chemical network system through state space is adaptive. The chemical evolution of increasingly organized systems produces “Random rare species” via “novel reactions within the liposome” (Fernando & Rowe, 2007). The production of new liposome “species” through novel reactions is the source of variation which makes the chemical analogue of natural selection possible. Without variation, there is no pool of difference to be selected for or against. Conjointly, the mechanisms responsible for replication, adaptation and variation produce a diachronic pattern of adaptive novelty in the liposome/chemical network system. Hence, the liposome/chemical network system displays the AN pattern; which means that the system is creative. To put it another way, if biogenesis occurred through prebiotic evolution, then biogenesis was creative. Of course, this rests on the assumption that prebiotic evolution explains biogenesis: which may prove to be wrong.

If biogenesis occurred without prebiotic evolution, then my example highlighting the AN-pattern in liposome proto-cell formation will have to be reconfigured or discarded. However, even if the story of biogenesis does not star prebiotic evolution as the hero, that would not necessarily contradict my claim that biogenesis is creative. Other accounts of biogenesis may be creative as well. For instance, suppose it turns out that a divine creator was responsible for biogenesis. If this were the case, then biogenesis would fall within the definition of creativity at a time which I established earlier in the thesis. There are a number of ways one could establish creativity in this case, as the history of creativity is filled with arguments for the creativity of the divine: especially in the case of the creation of the natural world and of life (Sternberg & Lubart, 1999). As it is perhaps *the* original, seminal example of creativity, it would presumably not be difficult to produce an argument that the creation of life was a creative act.

Of course, prebiotic evolution and divine creator are not the only two explanations for biogenesis available. For example, other posited explanations for biogenesis involve the creation of molecules capable of replication in the tiny unfrozen pockets that naturally form

in sea ice (Trinks *et al.*, 2005), and near-critical, self-organizing dynamic systems (Kauffman, 1993, 1995 & 2000; Sole' *et al.*, 1999; Weber, 1998).⁵⁶

For the purposes of my argument, it is not necessary to present and explore these alternative accounts of biogenesis. The question of how biogenesis occurred is still very much open, and this is not the place for a full exposition on each theory. I propose that no matter how it occurred, biogenesis counts as creative. If we understand biogenesis as a fundamental change in the trajectory and state space of the universe, thus that matter is able to behave in new and remarkable ways (many of which are creative), then it is creative. Of course, to view biogenesis as creative has certain implications and consequences in terms of our understanding of creativity, and what can be creative. Some may consider this to be highly counterintuitive, and might object; not just to the idea that biogenesis is creative, but to the claim that non-living systems can be creative.

7. Objections and Replies

One might object to the examples of creativity in non-living systems by claiming that the diachronic definition “lets too much in”, by including things that our intuitions tell us cannot be creative. Roughly put, the objection would go as follows: “The diachronic definition of creativity shows that some non-living systems are creative. However, it seems like it is somehow wrong or incoherent to talk about the creativity of non-living systems.”

This objection is based on the idea that there can be no axiotext in the absence of life. Roughly, the only things that are capable of finding something to be axiotextic or detrimental are living things, and for me to claim otherwise is similar to making the claim that there can be value without valuers. I already addressed this concern in Chapter Six, where I argued that to properly explore creativity required a general method of assessing axiotext. However, that chapter was prior to the chapters in which I demonstrated that non-living systems can be creative. Hence, in light of the application of the proposed method of assessing axiotext to the behaviour of non-living systems, what may have seemed reasonable in Chapter Six, might now seem absurd. One might say “It was fine when I thought that you were going to use the AN-pattern to identify creativity in the behaviour of animals, and maybe even groups of organisms; but the idea of non-living systems like prions or lipid aggregates being creative is

⁵⁶ These alternative explanations of biogenesis differ from the prebiotic lipid “evolution” story that I have presented here, although not necessarily in terms of producing adaptive and novel trajectories. For example Kauffman's explanation of self-organizing, near critical systems describes a pattern of adaptive novelty

too far fetched! How could anything be axiotextic for a folded protein or a complex chemical reaction.” I can appreciate that, at first blush, the idea of a creative protein sounds bizarre, or even wrongheaded. However, here is my reply.

To claim that it is impossible for anything to be axiotextic for a prion or a lipid aggregate is to enter into a discussion roughly akin to the discussion of objective, implicit, and instrumental value. It may well be impossible for us to imagine what could be axiotextic, or that anything could be axiotextic for a non-living system. This is similar to the idea that it is incoherent to claim that value can exist independently of human (or conscious) valuations. Philosophers have argued along these lines for subjective values. For instance, Ross states that value is impossible in non-living systems (without mind): “Contemplate any imaginary universe from which you suppose mind entirely absent, and you will fail to find anything in it you can call good in itself.” (Ross, 1930, p. 140)

We may be unable to imagine axiotext in a universe where mind is absent. However, this does not inform us as to the possibility of axiotext without life or mind. It is a mistake to claim that since we cannot conceive of what could be axiotextic for a prion, that it is therefore impossible for anything to be axiotextic for a prion. Remember, it is this limitation of our ability to assess axiotext that prompted the creation of a general and objective method to assess axiotext. The purpose of producing a definition based on the AN-pattern was to facilitate a further exploration of creative behaviour than our ability to assess axiotext according to our empathy and intuitions would allow. To object to the findings of that exploration because it has defined creative systems that we would otherwise not recognize as being sensitive to axiotext is to miss the point entirely. It is not surprising that the AN-pattern has identified creative systems that we would not otherwise recognize as creative, as this was the point of utilizing the AN-pattern to explore creative behaviour. The fact that some of the systems that the AN-pattern defines as creative are at odds with our intuitions about creativity is a mark of success.

To suggest that the AN-pattern “lets in too much” in the way of creative systems, to the point where the word “creative” is threatened with becoming meaningless is simply not true. For that to be the case, the AN-pattern would have to identify every (or almost every) system as creative. Instead, the AN-pattern allows us to view every system as *potentially* creative. Although the range of potentially creative systems becomes universal, this does not mean that every system is necessarily creative, or even that most systems are creative. As I

have demonstrated, the AN-pattern allows us to explore a far broader array of systems and behaviour than was possible using a definition limited by a theory of mind. This broader range does not come at the cost of a weaker definition. The AN-pattern does not relax the requirements for a system to qualify as creative. The criteria of novelty and axiotext - which were strict enough criteria when examining human and animal behaviour - still apply; they were “translated” into (used to identify) a general systems law. Not every, nor almost every, system produces a pattern of adaptive novelty. Adaptive, novelty producing systems are actually uncommon. The AN-pattern is discerning and selective, but since the range of systems that can be explored is greatly expanded, one can reasonably expect that the number of systems recognized as creative will increase accordingly.

Conclusion

1. Summary of Thesis

This dissertation has been an exploration of new cases of creativity, examining a broad array of behaviour and systems, using distinct, but complimentary definitions: the monochronic and the diachronic. The first definition illuminated the essential characteristics of creativity, novelty and axiotext. This enabled an investigation which transcended the domain of human activity, to examine a collection of examples of animal and group behaviour which were novel and axiotextic. These examples illustrated the effectiveness of the monochronic definition of creativity (my modified version of Boden's definition) as a tool for finding new cases of creative behaviour, and also provided a broad set of examples necessary for the construction and implementation of a new definition.

Using the monochronic definition of creativity to produce a set of examples of creative behaviour was a necessary first step, as it provided the basis for the creation of the new diachronic definition (the AN-pattern), as well as highlighting the need for a new method of exploration. The collection of varied examples was necessary for the creation of the new diachronic definition. Additionally, the exploration of creative behaviour using the monochronic definition of creativity highlighted the limitations of that definition. Our ability to assess creative behaviour depended on our ability to recognize and assess axiotext. By extending the investigation of creative behaviour to animal and collective behaviour, the limits of our ability to assess axiotext were exposed; providing not only the means for the creation of a new definition, but the impetus for its creation as well.

The limitations of the monochronic definition were illustrated by the examples of animal and group creativity; although the examples of creative groups highlighted them most clearly. A limited definition will produce a narrow conception of who or what can be creative. To avoid adopting a wider, yet still incomplete view of creativity, requires a definition that is able to overcome the limits imposed by our ability to assess axiotext. As I have argued, creativity is produced by systems where we are unable to recognize axiotext, and even by systems that we would otherwise assume that it is impossible or incoherent to assign axiotext to. The creativity displayed by prions and the hypothetical biogenetic lipid

system are two examples that, until now, were beyond our ability to assess axiotext.⁵⁷ To identify and address these examples and others, a new approach to creativity was required: the diachronic definition.

The diachronic definition (and the AN-pattern upon which it is based) was identified by examining creative behaviour. Creative behaviour displays both novelty and an adaptive trend over time, and was highlighted first in examples of human creativity. The technological “evolution” of the automobile headlight and the tank both displayed the AN-pattern, as over time, both the headlight and the tank incorporated new creative designs. These new designs produced an adaptive, diachronic trend. The AN-pattern is not restricted to human creativity. The evolution of biological organisms, prion populations, and hypothetical biogenetic systems also display the AN-pattern. The AN-pattern allows us to recognize creativity, regardless of our ability to assess axiotext, and therefore an exploration of creative behaviour undertaken using the AN-pattern has a much broader range.

2. Implications

There are several implications that the diachronic definition of creativity has for our appreciation of creativity in general. First and foremost, it significantly increases the set of things that can be creative, as the diachronic definition can be applied generally across systems. This is a radical departure from the standard subject of creativity research: humans and human behaviour. The diachronic definition allows systems to be included in studies of creative behaviour, despite not possessing a brain (slime moulds), or even being considered to be alive (prions & lipid aggregates). The existence of creative systems at different organizational scales with different underlying mechanisms has implications for our study of human creativity, and our study of creativity in general.

Implications for human creativity

That different systems with disparate mechanisms can produce creative behaviour is important, and has implications for how we study creativity. The scope of research must be broadened to address these varied and diverse systems. Essentially, the study of creativity can no longer focus solely on human activity. This is not to suggest that the domain of human activity is a poor subject for creativity research. However, it does show that it is a mistake to focus on human creativity to the exclusion of all else. Research into non-human

⁵⁷ These examples are beyond our ability to assess axiotext using mindreading or a theory of mind.

creative systems has the potential to advance our understanding of elements of human creativity, particularly in regards to the study of the mechanisms that produce human creativity.

Human creativity appears to be a product of the human brain. The structure and operations of the brain are complex; and the fact that it is central to vital “life support” processes in the body and encased within the skull make it difficult to study. If we view the human brain as the only thing in the universe that is capable of being creative, then any investigation of creative mechanisms must focus on the human brain.⁵⁸ However, if we accept that other systems are capable of producing creative behaviour, then we can examine creative systems whose structure and operations are less complex and are easier to observe and study.

My research demonstrates that creativity is not limited to human behavior. Many of the creative systems that I have given as examples, such as the slime mould or ant colony, are less complex and easier to study than the operations of the human brain. I am not suggesting that there should be no study of the mechanisms that produce human creativity, or that current studies are somehow misguided or wrongheaded. Instead, I am suggesting that we should not confine creativity research to the domain of human activity, and the study of the mechanisms that produce creative behaviour should be expanded to investigate systems. This represents a plethora of new research opportunities, with potentially creative systems ranging along the organizational scale from the sub-atomic or quantum to the cosmic. The operations of these systems and the manner in which they produce creativity have the potential to shed light on the workings of human creativity.

The AN-pattern identifies creative behaviour in systems over time, including the “evolution” of technological artifacts. The AN-pattern in the changes in tank design took place over decades, and involved the work of thousands of individuals. These individuals were all responsible for adding something to the “evolution” of the tank, such as the innovation of the top-mounted rotating turret.

One can view the tanks, the factories, the designers, and their designs as a single system of interacting parts. The tank system is not spatially or temporally limited to a single country, or a single time. We can include every individual that ever worked on a tank in this system, from the prototypical designs of “Little Willy” to the tanks of today. As this system

58 With a possible exception being formally equivalent mechanisms in A.I

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contains at least several hundred thousand interacting parts and spans the globe, the creativity of the tank system is complex, continuous, and interdependent. This differs from the more conventional view, where creativity is seen strictly in terms of the particular instances or actions that qualify as creative (those things or ideas that fit the definition of creativity at a time). In other words, the systems theory approach allows us to view creativity as something much broader than certain individuals or particular masterpieces. It is not necessary to view creativity in solely terms of distinct acts, ideas or artifacts; as it can also be understood as an interactive and collective process that people are a part of, or take part in.

Creative innovators (like those who came up with creative tank designs) do not produce their work in a vacuum, devoid of social and historical influences (Glăveanu, 2010). Instead, each generation of innovators in the tank system were influenced by previous designs and ideas, provided with novel design possibilities by advances in materials science, and played their part in producing the AN-pattern in the diachronic “evolution” of the tank system. From this vantage point, creativity is understood as a continuing process of change that displays a pattern of adaptive novelty, produced over time by a procession of interconnected individuals; rather than as pockets of distinct and disconnected instances of inspiration occurring in particular individuals.

Implications for Creativity in General

The broad range of creative systems calls for a strongly interdisciplinary approach to creativity research. In 1979, Magyari-Beck proposed the formation of a new, cross-disciplinary approach to creativity research called *Creatology*. This was intended to bring together various disciplines into a unified field of inquiry, including research in the arts, education, psychology, sociology, economics, business management, history, and philosophy (Magyari-Beck, 1990, 1993, 1999). The diachronic definition of creativity expands the field further, calling for the inclusion of the so-called hard sciences - I have already identified chemical and micro-biological creative systems – as well as systems theory, including complexity studies and self-organizing systems. The study of creativity made possible by the diachronic definition, and the broad range of systems theory, compliments the formation of a new discipline dedicated to the study of creative systems. Currently, none of the various

disciplines involved in creativity research are well suited to study creative systems (particularly non-psychological and non-sociological creative systems).⁵⁹

Creative systems offer a rich new domain to study, with the potential to shed light on other areas of creativity research. We cannot afford to ignore or overlook these opportunities. Systems theory, and the diachronic definition provide the tools necessary to undertake a study of creative systems. The only obstacle that stands in the way of establishing this new discipline is the narrow view of creativity, and I am confident that this will be overcome. The history of the study of creativity displays a trend towards greater inclusion rather than exclusion, and the concept of creativity has grown more comprehensive over time (Glăveanu, 2010). Seen in this light, to include creative animals, groups, and systems is the next step in the progression of the concept of creativity. For our understanding of creativity, it is a change that is both novel and axiotextic.

⁵⁹ The establishment of a dedicated non-psychological and non-sociological study of creative systems was recently proposed by Takashi Iba (Iba, 2010).

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