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SCIENCE: A MODEL AND A METAPHOR
IN THE WORK OF FOUR BRITISH COMPOSERS

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Chapter One  Introduction

At the beginning of the 21st century composing music is generally considered to be an artistic practice. However, since the middle of the last century, many composers have become increasingly interested in science. This engagement with scientific subject matter is manifest in the scientific lexicon used to refer to musical material and processes, as well as in the words used to name works. Apart from the linguistic and metaphorical application of scientific terminology, scientific models and the mathematical tools used to express these models—such as probability theory, algorithms, game theory, and group theory—are utilised to generate and control the development of musical material. Evidence of an engagement with science, both as a metaphor and a model, is evident in the work of composers of varied nationalities, working in a range of musical styles and mediums.

To date, almost all of the research on the relationship between music and science in the work of the composers of the last century, has focused on the impact of technological developments on artistic practice.¹ It has much to say about artists who engage directly with the results of these technological advancements such as computer, electro-acoustic, sound and multimedia artists, but little in terms of composers who write predominantly instrumental music. This thesis will address this imbalance by exploring the influence of scientific concepts and tools on the practice of instrumental composers.

Due to the large number of instrumental composers who have referred to scientific concepts and/or who use mathematics to develop musical material, the scope of this thesis will be limited to the exploration of this phenomenon as it relates to the work of four composers from the United Kingdom: Richard Barrett, Chris Dench, James Dillon, and Brian Ferneyhough. The reasons determining the choice of composers is threefold: firstly, and not without controversy, these composers have been defined as members of a subgroup of new music known as ‘The New Complexity’.² Their membership of this group has generally been understood as a by-product of their shared use of complex rhythms, the apparent density of

¹ There are numerous journals that are dedicated to the use of computers and other technical apparatus to create music; one notable publication is the Computer Music Journal (Menlo Park, California Peoples Computer Company, 1978). A more recent publication dealing with the uses of technology in music and other cultural practices, such as architecture and art is Leonardo Music Journal: LMJ Journal of the International Society of the Arts, Science and Technology, (Oxford: Pergamon Press, 1991).
musical information, and the demands that this makes on the performer. However, apart from these chiefly surface characteristics, all of the composers have referred to recent scientific developments such as chaos theory, quantum theory, geophysics, astronomy and biology. Moreover, both Richard Barrett, and James Dillon routinely use algorithms and probability theory to generate and develop their musical material. Secondly, all of the composers in question have recognised their debt to Iannis Xenakis and to a lesser extent Edgard Varèse—two composers of the earlier part of the 20th century whose aesthetic positions were based on their belief in and exploration of the inextricable link between music and science. Therefore the approaches of Varèse and Xenakis will be reviewed, providing a broader platform from which to understand the position of these later contemporaries.

Finally, the four British composers share several interests that lie outside the domain of contemporary music and 20th century scientific theories. These include pre-Socratic philosophy, 15th and 16th century natural philosophy and alchemy as well as cultural theory developed out of the French philosophical movements of the late 1960s. Although these areas of inquiry are beyond the scope of this paper, the relationship between the British composers’ engagement with contemporary scientific models of the universe and these more philosophical concerns points to a further framework from which to understand the composers’ compositional enterprises.

Therefore, the objective of limiting the exploration of the use of scientific concepts and tools to the members of the new complexity is not to perpetuate an outdated and essentially misleading label; rather, the purpose is to facilitate an understanding of the composers that goes beyond the issue of complexity, in the hope of fostering a better understanding of their actual differences and similarities.  

This thesis is set out in three chapters. Chapter One discusses the significance of science in the compositional approaches of both Edgard Varèse and Iannis Xenakis. In particular it will explore the impact of the new discoveries in the early part of the 20th century, such as quantum theory and atomic theory in the work of Edgard Varèse. These developments contributed to a shift from deterministic to probabilistic accounts of the physical world.

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3 A comparison of extra-musical influences predominantly in other artistic practices has been carried out by the musicologist Rachel Campbell. Campbell’s exploration of the influence of various art forms in the British composers’ work has gone some way in facilitating an understanding of the composers beyond the debate about the complexity and performer-difficulty of their work. For further reading see Richard Barrett interviewed by Rachel Campbell, Brisbane, Australia, November 2005 via http://au.geocites.com/masthead__2/issue6/barrett.html (accessed April, 2 2005).
Similarly, this shift in paradigm will be explored in the work of Iannis Xenakis, in particular his application of probability theory to generate musical material. The manifestation of these and more recent scientific concepts in the writings and compositions of Barrett, Dench, Dillon and Ferneyhough will be explored in Chapter Two. Each distinct area of scientific research evident in the lexicon and compositional procedures used by the four British composers will be dealt with separately and in the following order: classical physics, geology, biology, quantum theory, and chaos theory. The final chapter presents my conclusions.
Science, Music and Cognition: an overview of the work and writings of Edgard Varèse and Iannis Xenakis

1.1 Varèse and Xenakis

The foundations on which Varèse (1883–1965) and Xenakis (1922–2001) developed their unique compositional approaches were based on several shared premises that were an extension of their belief in the inextricable link between science and music. Generally speaking, these can be summarised into three axioms. Firstly, responding to the then relatively new science of acoustics, Varèse, and later Xenakis, considered music to be sound and therefore a physical entity existing in three-dimensional space. Following from this premise, they felt that the role of music was to reflect the significant developments in the physical sciences—developments which radically transformed our perception of the world and our place in it. Moreover, they both saw a connection—although very differently—between intelligence and music. Finally, as a result of the centrality of intelligence to music, both composers viewed the act of ‘doing’ science and the act of composing music as similar activities motivated by a shared desire to understand our place in the world.

What follows is an exploration of these features of the composers’ thinking, evident in both their writings and works. This exploration considers the differences in their respective positions, and the implication that these differences have in terms of their proposed view of the nature and function of music.

1.2 Varèse

The centrality of science to the Varèsean project is evident in his comment that “science is the poetry of today”.\(^4\) This seems to suggest that for Varèse, science replaced the role that poetry and literature enjoyed during the romantic period, of providing the primary inspiration by which music was composed. It also suggests that the extent of the influence of science, as seen by Varèse, would be limited to the level of metaphor. Although this is certainly reflected in the bulk of the research on Varèse (most of which typically refers to the composer’s use of

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the notion of crystallisation), John Davis Anderson\(^5\) re-addresses this issue, exploring the then current developments in science, and Varèse’s response to these developments through his writings, interviews, and compositional procedures. Much of what follows in the section on Varèse is indebted to the work of Anderson.

To begin with, Varèse was deeply influenced by acoustics: the then fledgling but rapidly developing scientific discipline. Of particular importance to Varèse was the work of Hermann von Helmholtz, John Redfield and the Polish scientist/mathematician Josef Hoene-Wronsky. Varèse not only read the published findings of these scientists, but also often paraphrased their statements when describing his own compositional approach. The discoveries of these acousticians were, for Varèse, so closely linked to his compositional project that, as Anderson shows, he not only paraphrased their findings, but also often claimed their ideas as his own—often failing to acknowledge the source of his ideas.\(^6\) Anderson argues that the fundamental significance of Varèse’s engagement with acoustics is the re-evaluation of music as sound, and therefore as a physical entity that moves and is transformed in three-dimensional space.\(^7\) As Varèse expresses it:

> when I was 20, my own attitude toward music—at least toward what I wanted my music to be, became suddenly crystallized by Hoene-Wronsky’s definition of music. It was probably what first started my thinking of music as spatial … as bodies of intelligent sounds moving freely in space, a concept I gradually developed and made my own.\(^8\)

Also of great significance to Varèse were the writings of John Redfield—one of the first theorists to apply the discoveries and experiments made in the field of acoustics to the realm of music composition. Notably he is one of the first to advocate a re-evaluation of the dynamic between the creation, production, and reception of music:

> not until all three [composers, instrument maker and musician] have been brought into intimate collaboration, and the air between the instrument and the listeners’ ear is disturbed by the actual playing of the instrument, is music produced.\(^9\)

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\(^6\) ibid., 101.

\(^7\) ibid., 40.

\(^8\) ibid., 13.

As will be shown in Chapter Two, a similar re-evaluation of the relationship between the performer, composer and instrument is crucial in the approach of the four British composers—particularly Brian Ferneyhough, Chris Dench and Richard Barrett.

During the end of the 19th century—when Varèse was a student and beginning to think of sound as a physical object—radical new developments in several branches of the physical sciences brought the tenets of classical physics into question: concepts of causality, the movement of small particles, the structure of the atom and the nature of space and time underwent considerable transformations. Varèse himself commented on the significance of these discoveries, and his belief that composers should engage with and communicate these scientific developments:

Music should reflect the stupendous physical discoveries that have so fundamentally altered most of our inherent scientific beliefs. Varèse, like Xenakis, believed that music, above any other art form, is more adept at this because, as Xenakis puts it, music is both more physical and more abstract than other art forms. However, as stated earlier, the manifestation of this belief was not limited to a metaphorical impression of these scientific developments; rather the very act of composition was, for Varèse, not unlike that of scientific investigation and experimentation. Moreover, the role of experimentation was essential to the development of musical composition:

The emotional impulse that moves a composer to write his scores contains the same element of poetry that incites the scientist to his discoveries. There is solidarity between scientific development and the progress of music. Throwing new light on nature, science permits music to progress—or rather to grow and change with changing times—by revealing to our senses harmonies and sensations before unfelt. On the threshold of beauty, science and art collaborate.

Varèse’s belief in the compatibility of the acts of doing music and science, is manifest in his experiments with electronic devices such as sirens and oscillators: experiments which were inspired by the work of Helmholtz. However the transference of scientific knowledge and models was not limited to his engagement with the electronic

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10 Anderson, 102–119.
11 ibid., 121.
medium, but was equally evident in his instrumental works at the level of naming compositions and the conception and development of musical material. For example, works such as *Hyperprism*, *Octandre*, *Intégrales*, and *Ionisation* indicate an interest in science. In addition, sketches reveal that images of physical entities and forms were crucial in imagining the development of material; often drawings of shapes existed in the margins of his works, particularly that of a spiral. It is interesting to note that within the paradigm of the recently developed branch of science known as biomorphology, the spiral is one of the several basic forms on which all physical objects are derived. Significantly, on being questioned by Gunther Schuller as to the relevance of the seemingly random divisi string writing in the early and regrettably lost work *Bourgogne*, Varèse replied:

> I was trying to approximate the kind of inner, microscopic life you find in certain chemical solutions, or through the filtering of light. I used these strings unthematically as a background behind a great deal of percussion.

It is significant to note that not only did the behaviour of gaseous molecules and other small particles interest both Varèse and Xenakis, but that they both chose to reflect this in similar musical textures. That is, the description of *Bourgogne* recalls the divisi string writing of Xenakis’s early stochastic works such as *Pithoprakta*. In summary, Anderson identifies four central scientific areas of influence inherent in the work of Varèse: atomic theory, radiation, relativity and quantum theory. Moreover, he identifies the corresponding compositional manifestations of these theories as sound-mass technique, cellular variation, unrelated metrical simultaneity and the projection in space of musical objects and non-linear development.

Although Varèse believed that music and science were similar activities, and that the essential role of music was to reflect the developments of science, he had little to say regarding the music’s impact on science. Hence the relationship is essentially one of science’s impact on music, and therefore could not be regarded as a truly collaborative relationship.

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15 Biomorphology is the study of basic shapes that constitute the physical world. The most typical shapes found in nature are spirals, meanders, branching patterns, and 120-degree points. This area of science will be explored in the following chapter as it features in the British composers’ compositional approach.
18 Anderson, 121.
Before the more radical position of Xenakis is explored, it is interesting to note that although Varèse did not formulate his ideas to the same extent as Xenakis (who published several books on the subject)—Varèse’s notion of music as inherently intelligent could be seen as prophetic of one of the most significant developments in science in the past 15 years: that of complexity, and self-organising systems such as emergent phenomena.

### 1.3 Xenakis

Although Xenakis shared many of the tenets essential to Varèse’s conception of music and its relationship to science, for Xenakis the role of music had a very significant impact on the development of science, so much so that he believed music’s function was to direct the future developments of science. For instance, Xenakis stated that:

> …nothing prevents us from foreseeing a new relationship between the arts and science, especially between the arts and mathematics; where the arts would consciously “set” problems which mathematics would then be obliged to solve through the invention of new theories. These new artists would be artist-conceptor and be knowledgeable and inventive in such varied domains as mathematics, logic, physics, chemistry, biology, genetics, palaeontology (for the evolution of forms), the human sciences and history. \(^{19}\)

Considering that Xenakis was born almost 40 years after Varèse, during which time the scientific models and explanations of the physical world had changed markedly, it is not surprising that Xenakis’s interest in science lead to a more extreme understanding of its relationship to music. An examination of this radical position will now be carried out, with particular attention given to Xenakis’s comparison of science and music: notably music’s capacity to “condense into abstraction” and its relationship to intelligence.

Like Varèse, Xenakis accepted the definition of sound and therefore music as a physical entity existing in three-dimensional space, proposing that:

> All sound is an integration of grains, of elementary sonic particles of sonic quanta. Each of these elementary grains has a threefold nature: duration, frequency, and intensity. \(^{20}\)

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However, compared to Varèse, he was more concerned with the abstract nature of music. That is, Xenakis believed that the “‘condensation-toward-abstraction’ is part of music’s profound nature (more than any other art’s)”\(^{21}\). Also fundamental to Xenakis’s project is his tracing of the parallel development, through history, of science, music and philosophy. This is evident in his published thesis defence *Arts/Sciences: Alloys*\(^{22}\) as well as the Preface to the second edition of *Formalized Music* (1970).\(^{23}\) Commenting on the significance of this project, Xenakis said: “I could sum up twenty years of personal efforts by the progressive filling in of the following Table of Coherence”\(^{24}\), adding that “there exists a historical parallel between European music and the successive attempts to explain the world by reason”\(^{25}\).

As a result of his historiographical mapping of the development of music, Xenakis concludes that there are common, “more invariable ‘aspects in all musics’”, regardless of the style, era and medium of their composition:

> These material[s] which move in space, have been developed, put into use, and have followed the course of ideas, colliding one against the other, influencing and annihilating one another, mutually fecundating.\(^{26}\)

Xenakis defines these ‘materials’ as ‘man’s intelligence, in some way solidified.’\(^{27}\)

Following from this Xenakis claims that “[t]o make music means to express human intelligence by sonic means”.\(^{28}\)

Clearly for Xenakis, the very stuff of music was intelligence, and the act of composition was to express this material. If the understanding of Xenakis’s position were left here, the relationship of music to science would be identical to Varèse’s; that is, that music is the expression of intelligence and its products such as science. However, for Xenakis the relationship between music and science was substantially different because not only did music express intelligence the way it may express a poetic text or an emotion, but he viewed music as the science of intelligence. In other words, Xenakis argued that the objective of music composition is to “materialise movements of thought through sounds then to test them in compositions”.\(^{29}\) Therefore, intelligence is not an influence used to create a musical work;

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\(^{21}\) Xenakis, “Arts/Sciences,” 3.

\(^{22}\) Xenakis, “Arts/Sciences,” 99.

\(^{23}\) Xenakis, “Formalized,” viii. In particular see Xenakis’s Table of Coherences.

\(^{24}\) ibid., viii.

\(^{25}\) ibid., 1.

\(^{26}\) Xenakis, “Arts/Sciences,” 1.

\(^{27}\) ibid.

\(^{28}\) Xenakis, “Formalized,” 178.

\(^{29}\) ibid., ix.
rather, the musical work is written to test the nature of intelligence. In summary, music is conceived as a quasi-scientific tool and an experimental construct—a tool through which to discover the nature of intelligence.

Intelligence, according to Xenakis, is not limited to reason and logic but encapsulates many complex modes of cognition:

This intelligence in its broadest sense, which includes not only the peregrinations of pure logic but also the ‘logic’ of emotions and of intuition.\(^{30}\)

It is important to understand that his inclusive definition of intelligence is not a strategy to unify the notion of the physical body with the spiritual mind, but rather reason, intuition, and emotion (that which Xenakis perceived as intelligence) was imagined within a physical model of cognition:

for intelligence is fundamentally, the expression of the billions of exchanges, reactions and energy transformations of the body and the brain cells.\(^{31}\)

Therefore, Xenakis’s conception of the physicality of music resides in his claim that music is intelligence solidified, and that intelligence can be understood within the framework of neurophysiology. Although Varèse believed that music was inherently intelligent,\(^{32}\) central to his position was his belief that music was a physical object existing in three-dimensional space, and therefore able to represent other physical entities.

Although Xenakis proposed a physical model of cognition comparable with that used in the discipline of neuroscience, he argued that it was art and music—rather than science—which were better equipped to investigate intelligence, saying that “it is art’s ability to deal with this broader definition of intelligence which gives it its value over science”.\(^{33}\)

This radical claim for art’s influence over the future development of science is based on his characterisation of science and art, as well as his appraisal of the then current state of scientific investigation. He felt there was a need for “a new science … a general morphology which deals with common aspects of all sciences such as physics, biology, logic … an abstract approach free of senses and habits”.\(^{34}\)

According to Xenakis, both science and art share an inferential mechanism and an experimental mode. Xenakis characterised this inferential mechanism as that which:

\(^{30}\) Xenakis, “Formalized,” 178.
\(^{31}\) Xenakis, “Arts/Sciences,” 2.
\(^{32}\) Anderson, 24.
\(^{33}\) Xenakis, “Formalized,” 178.
\(^{34}\) Xenakis, “Arts/Sciences,” 3.
constitutes the platforms on which all theories of the mathematical, physical and human science move about. Indeed games of proportion—reducible to number games and metrics in architecture, literature, music, painting, theatre, dance, etc—all occur on the terrain of inference, in the strict logical sense of the world.\textsuperscript{35}

Alternatively, the experimental mode is that which “challenges or confirms theories created by sciences”, and according to Xenakis, is even stronger in art than in science.\textsuperscript{36}

Moreover, art encompasses a third dimension not shared by science, namely ‘revelation’. Revelation entails the immediate appreciation of beauty, and is equally accessible to the educated or the amateur. It is on account of this additional mode that art could function as the “universal guide to other sciences”.\textsuperscript{37} Art then (particularly music because of its ability to ‘condense into abstraction’), is the meta–science, or general morphology that Xenakis argues modern science lacks. Therefore for Xenakis, science (particularly mathematics) is a tool for the expression of intelligence through music.

\textbf{1.4 The application of mathematics and science}

The question remains, however: are there particular types of science and mathematics that are more useful than others in the exploration of this expanded notion of intelligence?

To understand this, we need to review the implications—as seen by Xenakis—of his historiographic analysis of the parallel development of music and science. For Xenakis, the fundamental concern of his work is the dialectical relationship between determinism and indeterminism. Moreover, he argues that the nature of this relationship has determined the nature of scientific and artistic practices since the Ancient Greeks.\textsuperscript{38}

The desire to explore the relationship between indeterminacy and determinacy, and between order and chaos, informed Xenakis’s choice of scientific and mathematical tools. When discussing the application of mathematics to his musical compositions in \textit{Formalized Music}, he concludes that:

The technics set forth here, although often rigorous in their internal structure, leave many openings through which the most complex and mysterious factors of the intelligence may penetrate. These technics carry on steadily between two

\textsuperscript{35} Xenakis, “Arts/Sciences,” 4.
\textsuperscript{36} Xenakis, “Arts/Sciences,” 4.
\textsuperscript{37} ibid.
\textsuperscript{38} Xenakis, “Formalized,” 1–3.
age-old poles, which are unified by modern science and philosophy: determinism and fatality on the one hand, and free will and unconditioned choice on the other.\textsuperscript{39} Xenakis considers the re-evaluation of indeterminacy and its relationship to determinacy as the most exciting aspect of modern science.\textsuperscript{40} It is therefore not surprising that he uses mathematical tools or ‘transfers’ such as probability theory, Markov chains, and game theory.

On the significance and development of probability theory in his music he states:

In 1954 I denounced linear thought (polyphony), and demonstrated the contradictions of serial music. In its place I proposed a world of sound-masses, vast groups of sound-events, clouds, and galaxies governed by new characteristics such as density, degree of order, and rate of change, which required definitions and realizations using probability theory. Thus stochastic music was born. In fact this new, mass-conception with large numbers was more general than linear polyphony, for it could embrace it as a particular instance (by reducing the density of the clouds). General harmony? No, not yet.\textsuperscript{41}

More specifically:

[I use] mathematics in three fundamental aspects: 1. As a philosophical summary of the entity and its evolution, e.g., Poisson’s law; 2. As a qualitative foundation and mechanism of the Logos, e.g., symbolic logic, set theory, theory of chain events, game theory; and 3. As an instrument of mensuration which sharpens investigation, possible realizations, and perception, e.g., entropy calculus, matrix calculus, vector calculus.\textsuperscript{42}

In summary, Xenakis utilised the mathematical tools used in the study of small particles and quantum theory – two theories that inspired Varèse.

Several aspects of the approach of both Varèse and Xenakis can be identified in the writings of Barrett, Dench, Dillon and Ferneyhough. Just as the nature of the relationship differed in extent and focus between Varèse and Xenakis, this is also true of the four British composers. Firstly, the appreciation of sound as a physical object in three-dimensional space is evident in writings and works of the composers—particularly in the writings of

\textsuperscript{39} Xenakis, “Formalized,” 178.
\textsuperscript{40} Xenakis, “Formalized,” 1–2.
\textsuperscript{41} ibid., 182.
\textsuperscript{42} ibid.
Ferneyhough, who uses the terms force, weight and mass when discussing the basic elements of his musical material. Moreover, like Varèse, the composers refer to the recent scientific developments informed by the indeterminacy principle, such as quantum theory, chaos theory, complexity, particle physics, geology, astronomy and biomorphology. However, only Barrett and Dillon engage with the mathematical tools associated with these scientific domains as pioneered by Xenakis, making use of: probability theory, Markov chains, and exponential rates of change.

Moreover, the expanded notion of intelligence and the importance of exploring non-rational aspects of cognition (central to both Varèse and Xenakis) are evident in the British composers’ application of scientific metaphors and models.

An exploration of the British composers’ engagement with science as both a metaphor and as a model will be carried out in the following chapter.
Chapter Two

Scientific Tropes and Tools in the writing and the works of Richard Barrett, Chris Dench, James Dillon and Brian Ferneyhough

2.1 Classical Physics

**Force, momentum, weight and energy** are terms often used by Brian Ferneyhough when discussing his approach to the composition of music. Used singularly, the association with science or scientific concerns is not necessarily apparent, as all of these terms are used in the context of everyday language.

For instance, to comment that a person is ‘a force to be reckoned with’ is a comment on an aspect of their personality, rather than an allusion to a quantifiable vector quality explained by, and fundamental to, the mechanical sciences. Similarly, to remark that ‘the momentum for political change has increased’ is not to suggest that the increased political upheaval can be understood in terms of an increase in mass or velocity; rather, the clause is understood to be referring to a web of non-quantifiable changes in the socio–political landscape.

However, taken together force, momentum, mass, and energy constitute the lexical group devised to represent the physical quantities which are the building blocks of physics: the laws of physics situate these concepts in very particular mathematical relationships. According to Newton’s second law of motion formulated in *Philosophiae Naturalis Principia Mathematica* (or *Principia* for short, 1686)\(^{43}\), force = mass X acceleration, where force is the vector sum of all forces acting on the body, weight is the mass multiplied by the gravitational force exerted by the earth on the body, and acceleration is the rate at which the velocity changes over time.

An examination of Ferneyhough’s application of these terms in light of the distinction made between their scientific and everyday use is instructive in regard to both his attitudes concerning the relationship between music and science, and the nature of music itself. For example, when discussing the early stages of his compositional processes, Ferneyhough remarks:

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Normally I come very soon to a sort of ‘mental sculpture’, which has a certain mass and external shape, and which can be turned round in my mind and modified if necessary. The ideas of “energy”, “weight”, “mass” and “momentum” thus have an important role to play in my initial formulations.\(^{44}\)

Several characteristics of this statement allude to a scientific conceptualisation of music. Firstly, several of the terms used to refer to scientific quantities are discussed together. Secondly, Ferneyhough refers to both weight and mass. In common language, these terms are used synonymously to indicate how heavy or large an object is. However, the scientific concepts that these terms denote—although related—are noticeably distinct and are measured by different units. The weight of an object \((w)\) is defined as the gravitational force exerted on it by earth. Therefore, weight is a force with a direction toward the earth’s centre, and is measured in pounds or newtons. The mass of a body \((m)\) is not a force, has a magnitude but no direction, and is therefore a scalar quality. Mass is the measure of the amount of matter in an object. The two magnitudes are related, as is indicated in the following equation: \(w=mg\) (weight = mass * gravity). The mass is therefore intrinsic to the body, whilst the weight is dependent on the locality in relation the earth, because gravity is not consistent on all parts of the earth.\(^{45}\)

Therefore, Ferneyhough’s use of both terms mass and weight, combined with his use of ‘force’, ‘momentum’ and ‘energy’, is an indication of his understanding of the distinction evident within the scientific domain.\(^{46}\) Moreover, it is evident from this statement that Ferneyhough considers it appropriate to transfer these scientific concepts into the realm of music. For Ferneyhough, this is a reasonable extension of his belief that music, like sound, is a physical entity that exists in three-dimensional space. Therefore, as with all physical objects, music is explained by—and is subject to—the laws of physics in which the terms energy, force, momentum, weight and mass have an essential function. Ferneyhough explains that:

> Somehow my mental makeup demands this sort of concrete resistance; music of my ‘inner dialogue’ revolves around concepts derived from the physical world (‘energy’, ‘force’, ‘directionality’, ‘perspective’...). ... Quite recently I evolved the concept of ‘inference form’ to express the importance that the


\(^{46}\) For a discussion of this aspect of Ferneyhough’s project see Richard Toop, “Prima le parole...”(on the sketches for Ferneyhough’s Carceri d’Invenzione I–III),” Perspectives of New Music 32, no.1, Winter (1994): 154–175.
intersection and collision of clearly linear structural tendencies have for my way of thinking and feeling the musical process.\textsuperscript{47}

The conceptualisation of music as a physical object inhabiting three-dimensional space is evident also at the level of imagining more specific parameters of composition, such as gesture, figure, rhythm, and pitch material. For instance, Ferneyhough comments that:

In regards to the gesture … over and beyond its referential, ‘expressive’ function, the gesture usually manifests clear-cut boundaries; it has certain object-like qualities. Once one accepts this analogy, others immediately impose themselves—terms such as force, energy, impetus, momentum, perspective, friction, opacity and so on all of which I associate with my own habits of working.\textsuperscript{48}

Similarly, in reference to the relationship between figure and gesture during transformative processes, Ferneyhough explains that:

At such velocities of figural dissolution and re-formation the gestural object itself threatens to break up, being replaced with a shimmering web of energy exchange.\textsuperscript{49}

An example of the manifestation of this position in the handling of musical material is evident in his treatment of pitch material in \textit{Mnemosyne}, composed for Bass Flute and Tape. \textit{Mnemosyne} involves the gradual reversal of the relative density of pitch material in each part which he describes as a “cross play, an exchange of perceived physical presence, weight, or whatever”.\textsuperscript{50}

Moreover, Ferneyhough imagines the ‘physical objects’ including figure and gesture, as existing in a ‘space’ that corresponds to a measure:

the measure thus tends to function for me, firstly, as a space, secondly (via the bar-line), as the domain of a certain energy-quotient suddenly facing the necessity of leaping to a sometimes quite contrasted state. It is not the emphasis on a down beat which counts, but the feel for what is needed to leap


\textsuperscript{48} Brian Ferneyhough, “ Shattering the Vessels of Received Wisdom: in conversation with James Boros,” (1990) in \textit{Collected Writings}, 386.


\textsuperscript{50} Ferneyhough, “ Shattering the Vessels,” 395.
this experiential hurdle to the immediately subsequent situation.\textsuperscript{51}

Consequently, Ferneyhough conceives of the measure as a space in which the object-like entities of music (such as gesture and figure) reside in a particular state, but have the potential to transform into alternative states.

The particular concepts of ‘force’, ‘energy’, ‘mass’ and ‘weight’ do not feature significantly in the comments of the remaining three British composers. However, when applying ideas derived from geology, biology, and particle physics, they often use more generalised terms associated with the interaction of physical entities, such as ‘collision’, and ‘intersection’. This suggests that, like Ferneyhough, Barrett, Dillon, and Dench are sympathetic to Varèse’s conception of sound, and of music, as a physical entity existing in three-dimensional space.

\textbf{2.2 Geological Metaphors}

The metaphor of \textit{force} is extended beyond the boundaries of classical mechanics by both Dench and Ferneyhough to include the concept of \textit{geophysical force} evident in the frequent use of terms such as ‘geophysical tilt’, ‘strata’, ‘sediment’ and ‘sieve’.

In \textit{Tilt} for solo piano (1985), Dench refers to the concept of geophysical tilt as a central image for its conception.\textsuperscript{52}

Geophysical tilt is used to measure the degree and nature of the activity of volcanoes. By measuring the amount that a layer of earth has lifted or fallen, geologists can ascertain the source, direction and behaviour of subsurface magma, and can generate the force required to effect such changes.

For Ferneyhough, geological analogies centre on the notion of multiple strata that intersect and collide, the final musical product resulting from the interaction of several distinct yet intersecting layers of material. This is particularly relevant in the conception of his work for solo flute titled \textit{Unity Capsule} (1975-76). This work entails taking a single-line monodic instrument, but engaging in a ‘polyphonic treatment’ whereby the ‘initial point of departure for the composition was thus an interweaving of skeins’.\textsuperscript{53}

\textsuperscript{51} Ferneyhough, “Shattering the Vessels,” 378.
Moreover, not only is the concept of material as superimposed layers of sediment fundamental to the act of composition, but as Ferneyhough argues, the essential role of the listener, technical assistant and performer is to respond to the tiered nature of the materials:

Fundamentally, therefore, this composition is polyphonically organized. It is up to each listener to unravel the numerous ‘clues’ offered and, via a process of ‘archaeological speculation’, to reconstruct the work in his or her own image…

Similarly:

the assistants are occupied with transforming, selecting and reorganizing the sedimented residual record of that maximally differentiated confrontation.

Likewise, the role of the performer is an active one. Due to the intercutting and numerous sieving that the strata are subjected to, the performer—like an archaeologist or geologist—has to undo the ravages of time to extract the separate strata, in an attempt to decode the forces that have blended and layered these materials. Ferneyhough explains that due to the gradual accumulation of a residual ‘sediment’… one has to excavate, analyze and re-project.

To facilitate such an approach by the performer, Ferneyhough utilises a notational practice designed to provide the performer with a tool to negotiate the dense material:

Examples of the multilayering of playing techniques mentioned above can be gleaned from the same score page. The upper system in each pair is the stave customarily allotted to pitched sounds, while the lower is more often given over to the representation of all forms of vocal action.

Therefore, geological metaphors in the work of Ferneyhough are not simply private fancies known only to the composer as a way of ‘kick-starting’ a composition; rather, they operate as fundamental generative forces which determine both the musical material and the interaction between score, performer, composer, assistants, and listeners.

In Ferneyhough’s works where the extra-musical influence cited is literary, the literature referred to often involves a scientific subject matter. For instance, of Terrain (1992) for mixed ensemble, Ferneyhough explains:

it might, I suppose, be considered a distant reflection of some of Smithson’s ‘mental tectonics’ imagery of the ruined inner world, even though the title is in

\[54\] ibid.
\[55\] Brian Ferneyhough, “Time and Motion Study II,” (1977) in Collected Writings, 111.
\[56\] ibid., 108.
\[57\] Ferneyhough, “Unity Capsule;” 106.
fact taken from a poem by A.R. Ammons which also concerns itself with meditations on geological and other natural phenomena as manifested in the living world around us.  

It is evident in this example that the geological metaphors are linked to notions of mental construction and destruction. Specifically, the image of a physical phenomenon (such as geological strata, which involves the superimposition of several intersecting layers which are then worn away) are used to imagine the internal cognitive functioning of a human being, the mechanics of which are largely imperceptible.

The coupling of geological imagery and concepts with notions of psychological deterioration is a significant and enduring feature in the work of Richard Barrett. Moreover, he explores notions of strata in the geological domain, and links them with ideas surrounding cultural transformation and destruction—a central component of archaeological research.

What follows is an analysis of Barrett’s uses of geological metaphors, in particular their conjunction with an ecology of ideas, including notions of loss, and psychological and cultural ruin and deterioration. Due to Barrett’s propensity for writing single works over several years, as well as his habit of writing several works simultaneously, a chronological analysis of the development of metaphorical import in his work is near impossible. However, as the composer makes the distinction between a work’s conception and its completion, works will be dealt with in chronological order in terms of their date of conception.

The first work to show evidence of the application of geological concepts is a series of works called Negatives (1988–1993). Conceived three years after Anatomy (the first work in the Fictions series), the Negatives series employs the images of several specific geological microscopic and macroscopic structures. This is evident in the words used to name the individual works, such as ‘basalt’, ‘colloid’ and ‘archipelago’. The geological significance of these terms is unmistakable, as Barrett supplies short definitions of the words accompanied by a list of adjectives, which suggests how these geological structures influence his compositional approach. For example, at the microscopic level, he composed a work Colloid-E for nine instruments, based on an earlier work Colloid written for solo guitar. In the program notes Barrett defines a colloid as:

n.1, a mixture having particles of one component suspended in a continuous phase of another component. The mixture has properties between those of a

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solution and a suspension.\textsuperscript{59}

Barrett suggests that the idea of a colloid is evident in how the guitar part was conceived, commenting on the 10-string guitar “as an instrument of fluidity/micro and macro turbulence/dissolving and precipitation.”\textsuperscript{60}

At a macroscopic level, he named a work *Archipelago* (1990–92), which he defines in the score as “n.1. a group of islands. 2. a sea studded with islands”, and his interpretation of this geological concept into sound involves ‘sound-objects in a sea of silence/extravagant instrumentations/mandolin-pointillism…’\textsuperscript{61}

Apart from the variation in scale of the different geological phenomena cited in the series, their creation and transformation occurs at distinctly contrasting rates of change. For instance, the fourth work in the series titled *Basalt* (1991) for solo trombone, refers to the igneous rock resulting from molten material or magna which is cooled relatively quickly, once exposed to the atmosphere. This results in the formation of minuscule crystals, creating a rock of very fine dense textures. Moreover, basalt was the original solid rock of the earth’s crust. This rock often manifests as vertical, flat-sided columns called columnar jointing, which are thought to be a result of the lava shrinking during the cooling process.\textsuperscript{62}

Alternatively, the first movement of the *Negatives* series is called *Delta* (1990–1993). A delta is defined by Barrett as an “alluvial area at the mouth of some rivers where the mainstream splits up into several distributaries”.\textsuperscript{63} A delta, therefore, involves the constant movement of water over solid rock and rock particles, such as sand and fine sediments. In terms of rate of change, a delta is constantly changing its shape, and depending on the season, involves constantly changing amounts of water, thereby varying the amount of energy acting on the miniscule sediments.

Finally, *Archipelago*, which was explored earlier, involves essentially stable rocks and islands of large dimensions sitting still within an expanse of water. Any change to this geological phenomenon occurs slowly, over a long period of time.

\textsuperscript{60} ibid.
Hence, geological metaphors have enabled Barrett to articulate his interest in sound as a three-dimensional object in space, as well as his interest (evident in his earlier work *Coïgitum*) in exploring different rates of change, and statistical expressions of the physical world—an approach he indicates was made possible for him due to the work of Xenakis.\(^{64}\)

In addition to the incorporation of different rates of change, the geological phenomenon informing the *Negatives* series involves varied, yet ambiguous, relationships between the central geological objects (such as the rock in *Archipelago* and the sediments in *Colloids*), and the water or agents acting upon these objects. Hence the concept of what is internal or external to the central geological material is in a continuous state of transformation.

Although Barrett’s use of geological imagery is linked to the conception of sound as a three-dimensional object, the geological concepts are often used in conjunction with notions of cognition, in particular loss of memory. For instance, Barrett quotes the work of several writers in the program notes for *Negatives* including Samuel Beckett and Paul Celan. The Samuel Beckett quotation reads: “all that goes before forgot.”\(^{65}\) This tendency to blend the geological with the psychological is also apparent in the program notes of *Ruin* (1985–95), the eleventh work in the *Fiction Series* (1983–96). Barrett describes *Ruin* as involving:

- a set of seemingly independent compositional structures, for a variety of instrumental and spatial configurations, which are broken up interspersed and confused with one another, like archaeological or geological (or psychological strata…).\(^{66}\)

Therefore Barrett couples geological concepts with notions of psychological and cultural ruin, deterioration and confusion.

Moreover, as Ferneyhough uses geological metaphors to explain the role of the composer, Barrett extends his use of the network of images created around geological and archaeological concepts to meet the same end. This is evident in his conversation with Arne Deforce, where he likens the role of the composer to that of an archaeologist unearthing long-buried objects:

One of the reasons why I use the compositional techniques that I do is not just

\(^{64}\) Toop, “Four Facets,” 32.
to realize an idea that I have in mind, but also to give that idea a life of its own—so that I feel I’m being surprised, I’m discovering things as well as inventing. Somehow one could imagine … that the music was lying buried somewhere, and what I did was dig it up.\textsuperscript{67}

This notion of the music existing irrespective of the composer resonates with the Varèsean idea of music as being inherently intelligent and therefore existing externally to, and in spite of, the composer.

Several of the other works in the \textit{Fictions} series engage with this constellation of ideas, notably \textit{Earth} written for trombone and percussion (1988–1997) and \textit{Dark Ages} (1987–90).

\subsection*{2.2 Biological metaphors}

The references associated with the natural sciences made by the British composers include metaphors pertaining to biology. As with the references made to mechanical physics and geology, the significance of the allusions to biological functioning and organisms lies in their ability to represent complex procedural and transformative behaviour between numerous distinct yet interactive entities. The terms ‘organism’, ‘catalyst’, ‘biomorphology’, and ‘environment’ are present in the statements of all of the composers dealt with in this paper.

For instance, composers often employ the term ‘organism’ when discussing distinct types of musical material. The use of this term indicates that the musical material is conceived of as having three properties: 1) it has a family of distinct characteristics; 2) it interacts with other organisms and environments; 3) it undergoes significant change and transformation.

For instance, in referring to the material he created in the \textit{Unity Capsule}, Ferneyhough explains:

the secondary material consists of a series of individual commentaries on six distinct, basic articulation types—organisms distinguished by a significantly looser precomposition…\textsuperscript{68}

Furthermore in reference to his work \textit{La terre est un homme} (1979) inspired by a painting by the Spanish painter Matta, he says:

I conceived of the texture as being composed of individually developing—


\textsuperscript{68} Ferneyhough, “\textit{Time and Motion Study II},” 109.
sometimes dying—life forms in permanent movement and realignment. Each had compositional techniques in common with some but not all other organism’s and usually was distinguished by a particular orchestral timbre group.\textsuperscript{69}

For Ferneyhough, these organisms exist in an environment or ‘life-support system’ that applies several forces on the organisms, transforming and creating interaction between organisms and the environment, thus facilitating the organisms’ survival. Commenting on the treatment of repetitive rhythmic and pitch patterns in the \textit{Sonatas, String Quartet, Epicycle,} and \textit{Missa Brevis}, Ferneyhough states:

\begin{quote}
They thus act very much as an atmospheric envelope or life-support system within which other events can live and breathe. I was definitely concerned with researching the implications of the simple fact that, if you change the speed of an object, it becomes very often a completely different form of life indeed, not just measurably different, but imbued with all sorts of unpredictable quirky qualities.\textsuperscript{70}
\end{quote}

Ferneyhough uses biological metaphors to formulate a relationship between music and human intelligence, and not unlike Xenakis, he views the expression of intelligence as music’s primary function:

\begin{quote}
What is music ‘about’? Possibly, about the relationship pertaining between the realm of the senses and the ordered object of their perception seen as an extended metaphor of possible forms of life. The idea of a work acting out the conditions for possible worlds of order which are not immediately subjected to external cost/efficiency categorization seems a reasonable point of departure, although each individual instance will, by definition, expand and distort this basic position in hitherto unimaginable ways. Experimental music is not necessarily one that juggles half-digested ideas and materials in order to be surprised by what comes out: rather, it is a form of living discourse, which, at every moment, offers many possible paths towards its own futures.\textsuperscript{71}
\end{quote}

\begin{flushright}
\textsuperscript{69} Brian Ferneyhough, “Interview with Philippe Albéra,” in \textit{Collected Writings}, 327.
\textsuperscript{70} ibid., 307.
\textsuperscript{71} Brian Ferneyhough, “Interview with Paul Griffiths,” in \textit{Collected Writings}, 243.
\end{flushright}
In the case of James Dillon the significance of biological concepts has long been recognised as central to his compositional endeavours. In particular, critics make mention of the centrality of biomorphological forms in the work of the composer. In particular, Michael J. Anderson argues that these biomorphological forms including spirals, meanders, branching and turbulence, are fundamental to the rhythmic organisation of Dillon’s percussion work East I\textsuperscript{10} St NT10003.

One of the tenets of biomorphology is that form is a result of several interacting forces. The use of biomorphology as a model for the interaction of musical material illustrates the composer’s intention to incorporate a more complex model than that of classical mechanics, which has difficulty accounting for the interaction of forces between more than two physical bodies.

Apart from the use of biological forms and concepts to handle and create musical material and processes, for Dillon the very act of composition is imagined and explained through the use of biological concepts. He explains that at the beginning stages of a composition he imagines himself as:

[a]… mad scientist …[who] … start[s] making calculations … I like to see it in terms of certain kinds of enzymes. The biological function of an enzyme is as a catalyst—it sets off other processes. And this notion of a piece that I’m talking about: I feel it in every part of my body … I have a tactile feeling of it.

Therefore, like Ferneyhough, biological concepts are used to understand the composer’s own mental functioning during the act of composition. This resonates with the positions of Xenakis and Varèse, who associated music with cognition. As will become apparent, the close association between mental functioning and music leads to the conclusion that the

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\textsuperscript{73} Biomorphology is the study of basic shapes that constitute the physical world. It is an area of study developed out of the observation that seemingly different natural phenomena share the same basic forms, and that nature favours several of these. For instance it has been observed that the branching of trees is similar to that of rivers and arteries, and that the grains of crystals resemble both soap bubbles and the plates of a tortoises shell. The most typical shapes found in nature are spirals, meanders, branching patterns, and 120-degree points. Essential to this approach is the re-conceptualisation of space by Einstein that saw space not as a void or nothingness, but as having a structure that determines the forms of all entities in the physical world. Form, therefore, is not seen as a function of genetic coding, but as a response to forces of space on the entity.

\textsuperscript{74} Alexander, “Changing States,” 74.

\textsuperscript{75} For an explanation of biomorphology see Peter S. Stevens, *Patterns in Nature,* (Boston: Atlantic Monthly Press, 1974).

\textsuperscript{76} Toop, “Four Facets,” 40.

\textsuperscript{77} See Chapter 1 of this paper.
composer has a significant role in the discovery of knowledge of the physical and cognitive universe.

For instance, Chris Dench is explicit in expressing his view that the function of music is as a reflection of cognition, as well as of the patterns in the physical and biological world. Moreover, the argument that music should be organised and purposeful is crucial to Dench’s theory of composition explored in his masters’ thesis Towards an Ethics of Composition. 78

As the title of the thesis suggests, for Dench, composition is an ethical rather than an aesthetic endeavour. That is, in order to create an authentic artwork the composer is obliged to create music whereby the material itself, and relations between the material and its environment, are appropriate to the composer’s objective in creating the work. In Dench’s opinion “the artist’s productions are either efficacious or they are not and life continuing depends on the difference”.79

Dench’s comment suggests a comparison with Xenakis’s comment, that: “‘beautiful’ or ‘ugly’ makes no sense for sound, nor for the music that derives from it; the quality of intelligence carried by the sounds must be the true criterion of the validity of a particular music.”80

Therefore the creation of art is likened to maintaining life. To understand these biological allusions, Dench’s definition of music will be considered. In the chapter of his thesis titled ‘Music as an Organism’, Dench begins by stating that he has “long regarded works of music as segments of mind”.81 The justification for this statement is that if the social scientist Gregory Bateson’s criteria for identifying a mental process are considered, the phrase ‘mental process’ can be replaced by ‘piece of music’ and continue to “make sense.”82 It has often been mistakenly suggested that Dench conceives of music as a metaphor for the mind.83 However, Dench draws on Dawkins’ theory of memes84 and the recently developed area of

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80 Xenakis, “Formalized,” ix.
82 ibid., 25.
83 In an interview with Chris Dench, Peter McCallum responds to the composer’s comment that ‘[his] view is that music consists of a kind of tidal funnelling of archetypes...[o]ne cannot help but think along these routes because they are the routes that inhabit human minds’ by stating that ‘[t]his idea of music as a metaphor for human thought explains Dench’s fascination with Bateson.’ quoted from Peter McCallum, “How complex is complexity?” Sydney Morning Herald, February 13, 1992.
84 Dench, “Towards,” 26–29. Dench in particular refers to Richard Dawkins’ The Blind Watchmaker, where he posits that between people ‘germs of cultural propensity’ or memes can be transferred, not unlike the manner in which information can travel between two computers. 26.
scientific research of emergent phenomena\textsuperscript{85} to suggest that although the link between
cultural, biological and physical patterns are not necessarily apparent—that is they are
immaterial—they are nonetheless real.

These theories have significant implications for the function of music and the
relevance and role of the composer. That is, if the stuff of music is the same as the patterns
which constitute mental processes, biological structures and those patterns inherent in the
physical and cultural domains, then composers are involved in the creation of life-sustaining
systems in which ideas and forms can be cultivated, whereby the composer will be seen as
“contributing to the sign-câche of our culture, a living reservoir of pre-formed thought”.\textsuperscript{86}

Therefore, like Xenakis’s radical reformulation of the position of the composer as an
artist-conceptor with the ability to direct future developments in science, Dench’s position is
dependent on the careful re-evaluation of the relationship between music and intelligence. His
conception of “music as segments of mind” resonates closely with Xenakis’s definition of
music as ‘solidified intelligence’.

Moreover, like both Dillon and Ferneyhough, Dench imagines the interplay between
the performer, score and composers in biological terms, and as with his definition of music as
a mental process, draws on the work of Gregory Bateson to support his position:

the concept of treating each performer as a single cell in a ‘meta-musician’ is
quite intently an echo of the models described above which derive from the
Batesonian criteria of Mental Process and see the work as a kind of pseudo-
life.\textsuperscript{87}

Despite Barrett's experience in the biological field of genetics (he studied genetics before
becoming a composer), biology is not a central image in his thought. When asked if his
degree has influenced him, he responds that it has assisted him in his fluency with
mathematical tools, and that his work \textit{Ne sone plus à fuir} “may be considered ‘genetic’ in the

explains that ‘emergent phenomenon’ refers to the notion that complex patterns can develop from much simpler
systems, and that it is often impossible to predict what type of pattern these simple systems will develop into.
The notion that systems become ordered over time is in direct conflict with second law of thermodynamics, and
the concept of entropy; which states that over time, systems move from order to disorder. Scientists who study
emergent phenomena argue that this occurs because emergent phenomena are open systems, and therefore able
to interact with their environment—deriving order from their surrounds.

\textsuperscript{86} Dench, “Towards,” 26.

\textsuperscript{87} Dench, “Towards,” 41–44.
way that each section proceeds through ‘generations’ of phrases, with evolutions and extinctions’.

However like Dench, Ferneyhough, and Xenakis, Barrett argues for a very close connection between music, cognition and intelligence. Discussing his work *Dark Matter*, he stated that the “central motivation for *Dark Matter* was to explore the ‘structure of the imagination…and perhaps to discover something about its nature … inaccessible to scientific method’.” Barrett’s position resonates with Bateson’s definition of evolution and mind. Bateson claims that the human mind is a physical structure that evolved like all other physical structures with the universe. Therefore the “substructure of a work involves a complex web of ideas, associations, evolutions and sound forms”, and because the mind is a physical entity, this musical substructure is a physical thing.

Hence for Ferneyhough, Dillon and Dench, the application of biological concepts is coupled with ideas of cognition and reflects their interest in recent theories of order and chaos, and a desire to understand the process of composition in a larger paradigm than just organising sound. This will present itself as other scientific areas of research are examined, particularly those which involve indeterminism such as chaos theory.

Alternatively, Barrett does not draw on the imagery of biological sciences but like the other composers suggests that music is essential to intelligence. Like Xenakis, Barrett believes that music can explore aspects of cognition not available to the human science.

In Barrett’s case his exploration of music and cognition is most apparent in his engagement with theories of particles and waves, which will now be considered.

### 2.3 Wave and particle physics

The concepts of interference and diffraction are evident in the work of Dillon, Ferneyhough and Barrett, often manifesting as the titles of their compositions. Before instances of the application of concepts associated with theories of light and particles are explored, these concepts will be defined.

The term ‘interference’ refers to the phenomenon in all waves including matter, sound, and light, whereby two or more waves positioned in the same place at the same time interact. The nature of the interaction is such that the net wave disturbance is the sum of all wave

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88 Richard Barrett, “Interview with Deforce.”
89 Richard Barrett, “Interview with Buckley.”
90 ibid.
disturbances at that particular time and place.\(^{91}\) ‘Diffraction’ refers to the ability of waves to bend around an aperture or obstacle. These patterns in light were first made observable in 1801 in the famous two-slit experiment designed by the British physicist Thomas Young. This experiment involves the shining of light through two small adjacent slits, resulting in bands of light and shadow indicating the presence of two interfering and/or diffracting waves.\(^{92}\)

Both the concepts of interference and its relationship to the principle of superposition are evident in Brian Ferneyhough’s comments on his *Second String Quartet* (1980):

The voice part itself was constructed on three distinct levels, each with its own characteristic metric and density patterns. I term this ‘interference form’, since the superposition of several independent layers of activity in one voice or instrument creates tremendous pressure according to the collision or intersection of events. The manner in which one can accommodate more or less incommensurate things concurrently is another part of the restrictional costume one dons when setting out to compose.\(^{93}\)

Thus, for Ferneyhough, the concept of interference—as with the concepts of geological strata, sediment and biological organisms—is instrumental in dealing with the notion of multiple layers of activity which progress in a manner which is both independent and able to interact with its environment.

Similarly, there is evidence to indicate that the concept of interference is relevant to the work of James Dillon. Michael J. Alexander observes that Dillon’s orchestral work *Überschreiten* (1986) opens with a chord that consists of an harmonic spectrum, whereby harmonic and timbral transformation is effected by the gradual introduction of inharmonic partials that operate as “a kind of interference filter”.\(^{94}\) In addition, with *Diffraction* (1984) written for solo piccolo, Dillon’s choice of title is an obvious reference to wave-like properties. Paraphrasing the composer, Alexander explains that “a complex figuration will ‘bend’ or ‘spread’ as it touches a pre-determined frequency margin—in his case a low piccolo.

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\(^{91}\) There are two types of wave interference: constructive and destructive. ‘Constructive’ refers to instances of wave interference when the sum of the amplitudes of the resultant wave is greater than the amplitude of either of the component waves. The second type is ‘destructive interference’ whereby the sum of the component waves is less than either of the original waves, occurring when waves are out of phase. If completely out of phase and the initial waves of are of equal amplitude the resultant amplitude is zero i.e. silence, see Halliday and Resnick, “Fundamentals,” 722–730.

\(^{92}\) ibid., 741–759.

\(^{93}\) Brian Ferneyhough, “String Quartet,” in *Collected Writings*, 160.

\(^{94}\) Alexander, “Changing States,” 76.
F—with the resultant emanation of an ‘interference spectrum’.” 95

This statement not only illustrates that Dillon is interested in the phenomenon of diffraction, but that he understands that diffraction and interference do not always exist as separate phenomena. That is, when diffraction occurs as a result of passing light through two narrow slits, the resultant pattern is an interference pattern within a diffraction pattern. This phenomenon is called ‘double-slit diffraction’. 96

Similarly, the notion of interference as the principle behind pitch organisation is evident in the work of Richard Barrett. In an interview with Daryl Buckley on his collaborative multimedia work Dark Matter (1990–2001), Barrett explains his treatment of pitch in the central section titled Ars Magna Lucis et Umbrae as consisting of: “scales with gaps in them generated by taking two scales and superimposing them in different ways, then removing (as if by wave-cancellation) those pitches which the two scales have in common”. 97

Likewise, in Interference (a subsection of Ars Magna Lucis et Umbrae) written for solo contrabass clarinet, the concept of interference is evident at the level of sound production. In this section scales sounded by the instrument are repeatedly interrupted by a vocal part, the text of which is based on a section of Lucretius’ De rerum natura. 98 The Roman Lucretius (50–9 BC) was a follower of Epicurean philosophy. His work De rerum natura (‘On the nature of Things’) is celebrated as not only a remarkable literary feat, but also the first account of the atomic structure of the universe. Moreover, the title Ars Magna Lucis et Umbrae refers to a work by the 17th-century Jesuit polymath, Athanasius Kircher, 99 which in English translates to The Great Art of Light and Shadow. This title recalls the visual manifestation of interference and diffraction; that is, alternate bands of dark and light.

The frequency of the concept of interference, coupled with the references to early Greek thought and early 17th-century natural philosophy, suggests that the conceptualisation of the notion of interference by Barrett is extended beyond the purely materialistic definition dealt with by Ferneyhough and Dillon. Moreover, the relevance afforded to the concept of interference by Barrett is not simply one of recognition of the extended conceptual hardware resulting from the analysis of sound developed by acousticians. Rather, it indicates that

95 ibid., 70.
99 Barrett, Interviewed by Buckley.”
Barrett is more concerned with the phenomenon of interference as it relates to light, and the philosophical and scientific implications of such an understanding.

Barrett explicitly acknowledges that the interference patterns observed in light waves were of primary interest when writing *Dark Matter*. Notably, he makes mention of Thomas Youngs’ famous two-slit experiment, which ultimately led to the conclusion that light was not a particle or a wave, but exhibited wave-like and particle-like behaviour, depending on the experiments. This became known as the wave-particle duality.\(^{100}\) This discovery had far-reaching implications, not only for the way we understand light, but also for the development of Quantum theory\(^ {101}\) and the nature of scientific knowledge itself.

Barrett’s comments on the two-slit experiment reveal he was not only aware of the implications of such a discovery, but that these implications were his primary concern:

What fascinates me most about the two-slit experiment is that an apparently simple procedure opens up problems and mysteries which bear on the nature of reality, our ability to perceive it even whether reality consists of one or many universes. It’s a classic demonstration of the dual nature of quantum objects like photons or subatomic particles.\(^ {102}\)

### 2.4 Indeterminism: Probability and Stochastics

In chapter one, Xenakis’s interest in the relationship between indeterminism and determinism was explored. Part of this project involved the application of the mathematical tools which

\(^{100}\) David Halliday and Robert Rensnick, “Fundamentals,” 721–730. The nature of light has been a highly contentious issue. Since the time of Newton, it was thought to consist of a continuous stream of particles. In 1801, Young, investigated the idea that light consists of wavelike properties. He reasoned that if light were a wave, it would display interference patterns analogous to those observed in the wave behaviour of water. To manifest this behaviour, Young designed an experiment that consisted of shining light onto a board with two narrow slits. The result was a pattern of light and dark bands consistent with the phenomenon of wave interference. Subsequent research however revitalised the particle model of light. Notably in 1924, the French scientist Louis de Broglie concluded that light was not a particle or a wave but exhibited wavelike and particle-like behaviour depending on the experiments. This became known as the wave-particle duality.

\(^{101}\) Robert Eisberg and Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, Chap. 3 (New York: John Wiley and Sons, 1974), 77–80. Because classical physics could not account for the wave properties of electrons, quantum mechanics or wave mechanics was developed to meet this need. Quantum physics shows that like Young’s experiments with light, small particles also have a dual nature; behaving like a wave and a particle. Therefore, the uncertainty principle stating that we can only achieve a probabilistic account of light, applies also to our account of small particles. Moreover, according to Neils Bohr’s *Copenhagen interpretation* of quantum theory, the deterministic accounts derived from classical mechanics are redundant because they do not represent the physical world.

\(^{102}\) Barrett, “Interviewed by Buckley.”
dealt with the laws of large numbers such as probability theory and Poisson’s Law of Gases to create his stochastic music.103

Like Xenakis, Barrett, Dillon and Dench are also interested in the concept of indeterminism and its relationship to determinism, and not surprisingly they have used similar tools to create music. What follows is an exploration of the use of probability theory and stochastics by Barrett, Dillon, Dench and Ferneyhough which in broad terms can be understood as a response to the re-evaluation of indeterminacy in the second half of the 20th century.

Dench’s interest in indeterminate behaviour is manifest in his enthusiasm for engaging with models from the natural sciences, specifically with the image of a ‘force-field’:

I have often observed that a piece of music can be considered as the connection of several force-fields, into which the notes are then dropped to make the force-field behaviours audible.104

He clearly makes the connection between the image of a force-field that he uses to write music and that which exists in the realm of scientific research by stating that:

a force-field provides a set of probabilities, continuous at every point in space, as to the likelihood of finding an entity-particle in three of the four forces known to physics (the particle of gravity, the graviton, if real, being as yet undiscovered), and in the musical analogue, a sound. Force-fields are not deterministic: … they provide a way of mapping the subatomic territory without direct evidence of the landscape. In our musical image the pre-compositional constraints are force-field-like, they do not provide enough information … they are examples of phenomena not yet much researched outside of culture, the real but immaterial, also known as the “emergent”.105

It is specifically the indeterminate nature of a force-field that he finds appropriate to his musical language. Moreover, Dench explains that force-fields can interact via superimposition, creating interference patterns, which can be applied to the music at a global

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103 See Rosalie La Grow Sward in “An Examination of the Mathematical Systems Used in Selected Compositions of Milton Babbitt and Iannis Xenakis,” PhD. Thesis, Northwestern University, 1981. For an examination of the principles behind Xenakis’s method of stochastic music. That is in Xenakis’s music, the macro-structure is pre-determined; however the events occurring at the microscopic level are a result of chance or are indeterminate.


105 ibid., 18–21
or local level. These force-fields are related to, and for the most part exist at, the stage of pre-composition and provide the empty space in which a musical work can emerge.\footnote{ibid., 20.}

Dillon’s interest in stochastic procedures is in a large part due to his interest in Iannis Xenakis. Similarly, the organization of musical material is often derived through the use of mathematical procedures such as probability functions.

Dillon wrote of Zone (…de azul) (1983) that it was written in response to his observation of the Milky Way:

I had this idea of a band of sound, with things breaking off it, with splinters: not a clean band with edges—but there was a kind of concentration at the centre of it. And this thing, as it moved away from you in distance, would gradually merge into a more statistical distribution of these contrasts.\footnote{Toop, “Four Facets,” 44.}

The beginning of Barrett’s uses of statistical procedures was in his breakthrough work Coïgitum (1983–85). Barrett comments that the most significant and enduring aspect of the technical component of work was the “dependence at every aspect of the music on highly directional processes articulated by statistical procedures”.\footnote{Richard Barrett, program note for Coïgitum (1990), from http://www.ump.co.uk/barrett (accessed December 20, 2002).}

Similarly, Barrett explains that “I think the psychological function of each event in a work is the most important thing. But material for me always works in terms of processes which are statistically elaborated, using a computer.”\footnote{Barrett, “Interview Arne Deforce.”} Moreover, he has had an enduring interest in exponential functions.

Barrett said of his mathematical ‘toolbox’ that for the most part, it allows degrees of ‘statistical uncertainty’. Its built-in uncertainty means that at every stage “there is freedom to move and, so to speak, to ‘breathe’ compositionally”.\footnote{ibid.}

In the case of Brian Ferneyhough, his use of scientific concepts and lexicon suggests an interest in the phenomenon of indeterminism. For instance in the instrumentation for Bone Alphabet, Ferneyhough allows for a degree of flexibility. Moreover, he comments that he maintained a ‘stripped-down’ sonic world which “encouraged … further investigation of
linear versus non-linear modes of formal organization.”¹¹¹

However, Ferneyhough separates the manner in which he engages with the issue of indeterminism from that of the younger British composers. Ferneyhough argues that the younger composers’ application of stochastic probability (derived from the work of Xenakis) leads them “to manifest a form of negative frenzy”.¹¹² This, he claims, is in direct opposition to his ‘late modernist position’, which involves a “… continual re-evaluation of function and linear process which, however provisional, is light-years away from the essentially stochastic imposition of subjective will on the absurdist void which I admire in certain figures of the younger generation”.¹¹³

Ferneyhough considers the younger British composers’ application of stochastics (chance) as lacking any sense of determinism, or linearity. In his use of the term ‘chaos’ he is interested in how it operates in conjunction with order, he says:

Like much of contemporary research into the dynamics of complex physical states, I am vitally interested in exploring, not stochastic probability, but that small, unstable frontier between a limited number of governing principles of order and the interference phenomena that emerge when such systems impinge, intersect or collide.¹¹⁴

Therefore, the essential difference between Ferneyhough and the other British composers is not the degrees of order or chaos generated by the composers’ uses of their prospective mathematical functions, but that Ferneyhough is interested in how chaos is created from order (i.e. the interaction of two or more ordered systems), whilst the application of stochastic procedures by the younger British composers involves generating degrees of order out of chaos. The examination of Ferneyhough’s interest in complex physical states will be carried out in the following section on chaos theory.

### 2.5 Chaos Theory

The term ‘chaos’ denotes several different concepts. Outside the scientific domain it has come to be understood to signify a lack of order and is generally considered to be synonymous with randomness. However, since the 1960s, in scientific circles at least, the phenomenon as it appeared in natural phenomenon such as weather patterns and turbulence, came to be

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¹¹¹ Brian Ferneyhough, “Interview with James Boros,” in *Collected Writings*, 435.
¹¹³ ibid., 426.
¹¹⁴ ibid., 425.
understood as a significant area of scientific research, evolving into chaos theory. Chaos—like recent research carried out in the domain of particle physics—responds to the realisation that the world does not behave according to a few simple deterministic laws. Since 1970, there are two distinct but dominant approaches to the study of chaos. In the 1960s, through studying weather patterns, the scientist Edward N. Lorenz came to the conclusion that natural phenomena that we had previously understood as being completely random and indeterminate in fact behaved in accordance with precise laws.\textsuperscript{115}

Alternatively, whilst studying irreversible thermodynamics, Ilya Prigogine and his colleague Isabelle Stengers, developed the second theory of chaos. They theorised that order emerges from chaos, and that rather than hindering a transformation to order, entropic states support such a change.\textsuperscript{116} Although these two theories of chaos use different mathematical tools to effect analysis of chaos, they have several shared interests such as non-linearity,\textsuperscript{117} complexity, and fractality.\textsuperscript{118} These terms including chaos theory are apparent in the work and writings of the four British composers.

Like the chaos theorists, Barrett is interested in the patterns of behaviour of natural phenomena that occur on a human scale. For instance of \textit{Blattwerk} (2002), for cello and electronics, he comments:

\begin{quote}
[t]he poetic origins of \textit{Blattwerk} (2002) are almost childishly simple: I imagined the path taken by a leaf as it falls from a tree and is then moved in impenetrable complex trajectories by the action of the wind, or just as suddenly laid temporarily to rest by a moment of calm … and I imagined this path as taking place not outside the window but in the multidimensional
\end{quote}


\textsuperscript{117} For a comparison of the two types of chaos theory, see Katherine N. Hayle, \textit{Chaos Bound: Orderly Disorder in Contemporary Literature and Science} (London: Cornell University Press, 1990), 1–29. In particular, Hayle explains that non-linearity refers to the discovery that small changes in a system can lead to disproportionate transformations within the system, unlike linear systems of classical physics, whereby the magnitude of the change in a system is proportionate to the changes they engender. Moreover, the changes in a linear system can be predicted, unlike those of a non-linear system.

\textsuperscript{118} See Lorenz \textit{Chaos}, 167–175. Complex systems are described as being like chaotic systems, in that they are sensitive to initial conditions. However, they differ from chaotic systems because chaos involves regularity over time, whilst complexity involves irregularity over space. Lorenz, drawing on the work of Beno\-it Mandelbrot, explains that the term \textit{fractal} refers to systems with fractional dimensionality. Moreover, self-similarity is a property of fractals whereby a fragment of a shape when magnified, resembles the same basic shape of the whole. The system of tree trunks, and their similar systems of branches and leaves, is often cited as an example of fractality. See also Beno\-it Mandelbrot, \textit{The Fractal Geometry of Nature} (San Francisco: W.H. Freeman, 1982).
“configuration space” of the cello set in motion not by the wind but by conflicting energies of composition and improvisation.\textsuperscript{119}

Evidence of sympathy with chaos theory is also evident in his discussion about his predilection for symmetrical structures and fractals, or as he puts it: “[t]he use of symmetrical (in the wider mathematical sense) forms such as canons and palindromes and recursively self-similar structures”.\textsuperscript{120}

Apart from the two instances cited above, Barrett seems more inclined to make references to more general notions of chaos rather than to chaos theory proper. That is, he often uses the term chaos in the manner in which it is generally used, meaning a complete lack of order. For instance in an interview with Daryl Buckley on his work \textit{Dark Matter} (1990–2001), Barrett describes the final section as consisting of “six guitar parts which create a chaotic and meaningless tangle of notes”.\textsuperscript{121}

Similarly in the program notes of \textit{Ruin} Barrett describes the development of the work as “an attempt to propose a hypothetical wholeness or coherence – based on a collection of clues, connecting theories and fragments, whose chaotic, eroded condition may have resulted from the (mal) functioning of the memory … or the forces of nature”.\textsuperscript{122}

Generally he is interested in exploring the nature of the relationship between order and chaos, which is evident in his numerous references to the concept of entropy, the movement from a state of order to disorder.\textsuperscript{123} For instance in the program notes for \textit{String Quartet} (1983–88) he writes:

> History [is] unimportant except in having evolved potential for extremes of: unanimity/diversification, order/chaos, euphony/harshness.\textsuperscript{124}

Dillon, on the other hand, makes few direct references to notions of chaos, fractals and the like, but as Michael J. Alexander points out in the eighth part of the \textit{Nine Rivers} Cycle (1988–93) the composer utilises “transformational and spatialisation procedures derived directly from Chaos theory”.\textsuperscript{125}

\textsuperscript{120} ibid.
\textsuperscript{121} Barrett, “Interviewed by Buckley.”
\textsuperscript{123} Halliday and Resnick, “Fundamentals,” 409.
\textsuperscript{125} Alexander, “Changing States,” 74.
Like Barrett, however, Dillon expresses sympathy with more complex accounts of natural phenomena common to chaos theory. For instance in *helle Nacht* Dillon explains that his concern is with:

something that potentially is spreading (omni-directionally) and not only through the operation as ‘continuity’ and ‘regularity’ but also by the deployment of certain discontinuities: not the simple (or complex) application of causality, but a polymorphous correlation of change.\(^{126}\)

Similarly, in *Überschreiten* (1986) for orchestra Alexander portrays Dillon as being interested in exploring the “psychological notion of relations between order and chaos”, and making use of “Heraclitean theories of continuous flux”.\(^{127}\) The coupling of chaos with the work of the pre-Socratics is not unlike aspects of Xenakis's project in *Formalized Music*.\(^{128}\) Although the philosophical references of the composers are not within the scope of this paper, I will take a short detour into this aspect of Dillon’s conceptual framework, because they operate in a way not dissimilar from Bateson’s theory of mind in Chris Dench’s project, and the mysteries of particle physics in Richard Barrett’s work. That is, Dillon’s engagement with pre-Socratic philosophy indicates what he perceived to be the role and the function of music. Moreover, Dillon’s references to pre-Socratic philosophy accompany his use of stochastic processes.

Dillon’s interest in pre-Socratic philosophy, particularly in the Heraclitean theory of flux and the notion that fire is the source of all things, is reflected in his repeated references to the notion of fire. For instance, in his orchestral work *helle Nacht*, (1986–87) Dillon explains that he imagines a work that “becomes so seemingly dark and buried in its own processes—massive surges of material just burying themselves … it’s so incredibly dense that it’s glowing … like a dark, black ember”.\(^{129}\)

Alexander suggests that Dillon’s interest in Heraclitean thought supports his use of stochastics and mathematics involving rates of change and transformation. Indeed, it could be argued that the notion of rates of change is inherent in all of Dillon’s non-musical interests.\(^{130}\) According to some commentators on Dillon’s work, the significance of pre-Socratic thought cannot be underestimated as Richard Toop suggests:


\(^{127}\) Alexander, “Changing States,” 76.


\(^{130}\) Alexander, “Changing States,” 74.
it is the pre-Socratic philosophers that have provided Dillon with the strongest revelations concerning the possible scope of art.\textsuperscript{131}

The scope of art, according to Dillon, is evident in a quote that he incorrectly attributes to the pre-Socratic philosopher Aristoxenes. That is the idea that music should always be “sexual and cosmic”. Moreover, Dillon is attracted to the work of these early thinkers because he perceives in them the “recognition … of the strong link between, say sexual activity between humans and animals, and some kind of cosmological activity”.\textsuperscript{132} However, as Toop points out, not only is the comment in fact made by Philo of Alexandria, not Aristoxenes, but Philo stated that music should be both “ethical and cosmic”.\textsuperscript{133}

This error may perhaps point to what Dillon perceives as the scope of music composition. That is, composers are obliged to explore these aspects of the human condition, the generative forces of animals and the cosmos. This explanation is also supported by his discussion regarding the composer Iannis Xenakis, a composer whose early stochastic works of the 1950s and 60s, \textit{Pithoprakta} and \textit{Eonta},\textsuperscript{134} inspired Dillon to use stochastic procedures to transform musical material. Responding to Richard Toop’s comment that one of the startling aspects of Xenakis’s \textit{Musiques formelles} is the abrupt juxtaposition of “purple prose” with mathematical formulae, Dillon expresses sympathy for this aspect of Xenakis’s project, suggesting that it is a position to be admired or worked toward. He suggests that in early western thought (the pre-Socratics to the Scholastics) there was not the “dichotomy between the mathematical nature of the cosmos, and discussing it”. After the Renaissance these two ways of interpreting the universe were separated, the result being that “we no longer have the language to deal with it”.\textsuperscript{135} Dillon goes on to say that “it’s a very difficult problem, because either you’re accused of mysticism, or else you’re accused of some esoteric rationalist approach … hence with Xenakis, this abruption or disruption that occurs between the dreamer and the mad number-cruncher.”\textsuperscript{136}

Therefore, echoing Xenakis, Ferneyhough, Dillon and Barrett argue that the role of music is to examine an extended notion of intelligence that includes intuition. Similarly, through his exploration of the earliest physicists, Dench argues that music can contribute to an understanding of aspects of the human condition, notably sexuality, that have been lost due to

\textsuperscript{131} Richard Toop, notes for sound recording \textit{James Dillon I} (France: Montaigne Auvidis, M0782038, 1995), 10.
\textsuperscript{132} Toop, “Four Facets,” 40.
\textsuperscript{133} Toop, “James Dillon I.”
\textsuperscript{134} Alexander, 66
\textsuperscript{135} Toop, “Four Facets,” 39–40.
\textsuperscript{136} ibid.
the increasing division between science and art since Plato. Although not within the scope of this paper, this position is evident in the philosophical concerns of all of the British composers and is an area for future research.

Alternatively, Dench makes only a few but very specific references to chaos theory. For instance, Dench explains that it was one of the central ideas, which informed his work *Tilt* (1985), for solo piano:

The notion of *Tilt* came to me when I was reading a book called *The Cosmic Connection*; it is basically a book about quantum physics and sub-atomic particles and the cosmos. In the middle of this book there’s a chapter on randomness, in which he described how at the very centre of the known world, in the centre of Jerusalem, there’s this very ancient building in which, presumably, the Christian Church first started up, and it is now a pinball alley. So here we are in the heart of the world—in the heart of the universe, if you like—and in the middle of it there is a pinball machine. And the author comments that the art of the future will be an art of randomness.\(^\text{137}\)

More specifically, Dench draws on the idea of fractals to articulate the relationship between macroscopic and microscopic levels of the composition:

One can construe the local/global by reference to the neighbouring levels of nesting as ‘local’ and more distant levels as ‘global’. This is a startlingly fractal way of thinking about composition, I suddenly notice, in that it is privileging scale-independence. That this results in a kind of inverted logic where a massive structure may be local with reference to its fellows, but global relative to some macro-event … the material is the same whichever end of the telescope you look through. Only the degree of resolution, the granularity, is altered.\(^\text{138}\)

Thus Dench’s application of the notion of fractals reveals his desire for a unifying concept that determines all levels of activity in his work. Moreover, Dench is most concerned with

\(^{137}\) Toop, “Four Facets,” 77. In the early explication of chaos theory by Lorenz, the pinball machine was used to exhibit that small changes in a dynamic system lead to significantly different outcomes. This phenomenon is known as sensitivity to initial conditions. See Edward N. Lorenz *The Essence of Chaos* (Seattle: University of Washington Press, 1993), 6–13.

emergent phenomena and the account of nature derived from Ilya Prigogine’s chaos theory that suggests order emerges from chaotic states.

Like both Barrett and Dench, the notion of fractals and self-similar sets also appears in the writings of Brian Ferneyhough. In particular, this notion is used to articulate Ferneyhough’s belief in the significance of the same ratios operating at different levels of a composition. Specifically he uses it in relationship to his treatment of rhythm. In Duration as Compositional Resources,\textsuperscript{139} Ferneyhough outlines some aspects of his fundamental approach to rhythm, namely the notion that a rhythmic idea is an audible, meaningful sonic event which can be augmented or diminished in time and still function as a unifying feature of the musical fabric. It can therefore be used to convey a change or transformation. He argues that “rhythmic patterning (for instance self-similar sets—fractal—patterns) are at least as capable as various currently propagated categories of microtonal usage of being reproduced and recognized”\textsuperscript{140}

However, unlike Barrett, Ferneyhough is very particular about the way in which his use of the term ‘chaos’ is understood. It is clear that when referring to chaos, Ferneyhough is not using the term to indicate a complete lack of order, but like those who developed chaos theory, he sees it as existing on a continuum between determinism and indeterminism. For instance, when discussing Epicycle he draws on Lorenz’s theory of chaos stating that “chaos is an indispensable precondition for (relative) order. It is a straightforward matter to create rules, which, if adhered to precisely, bring about their own effective dissolution”,\textsuperscript{141} which resonates with Lorenz’s theory of chaos. Moreover, in questioning the accuracy of Richard Toop’s description of his works as being “an arbitrary by-product”, Ferneyhough is at pains to distinguish between situations which are completely random—whereby later states occur entirely independent of earlier states\textsuperscript{142} (Lorenz refers to these as a completely random set)—and those whereby the initial conditions result in several possible outcomes. This approach seems to have been generated from a knowledge of “recent theories of complex states”. Thus, rather than being random in the sense used by chaos theory, Ferneyhough’s music is non-deterministic in that his compositional procedures allow for a number of possibilities

\textsuperscript{141} Brian Ferneyhough, “Epicycle, Missa Brevis, Time and Motion Study III,” (1976) in Collected Writings, 90.
\textsuperscript{142} Brian Ferneyhough, “Interview with James Boros,” (1992) in Collected Writings, 437.
rather than a single possibility.\footnote{143} Hence, apart from the concept of fractals, there are several key ways in which Ferneyhough applies concepts derived from chaos theory. To begin with, Ferneyhough uses concepts derived from chaos theory as a tool to conceive of the transformation of musical material over time.

For instance, Ferneyhough describes one such tool as a ‘turn’ (\textit{umschlag}). Ferneyhough explains that it is a method that he used in \textit{Epicycle} and he describes it as “something that suddenly moves in a direction not necessarily predictable on the basis of what has already happened, or without advance knowledge”.\footnote{144}

Ferneyhough’s interest in chaos is also evident in the other artists whom he cites as providing inspiration for his work. In an interview with James Boros, Ferneyhough explains that the writer Robert Smithson inspired him in his writing of \textit{Terrain}. Ferneyhough describes Smithson as being an artist who “was deeply aware of how close even the most ordered fields of perception are to collapsing into chaos, and was, in consequence, concerned to \textit{name} this propensity as a condition of its creative harnessing”.\footnote{145} Ferneyhough seems to draw connections between chaos theory and complexity theory and suggests that the findings of these theories have implications for Cartesian logic and notions of order.

Moreover, the notion of chaos is linked to geological metaphors, which is in turn connected to the chaotic, disordered state of human cognition. Ferneyhough quotes the French philosophers Gilles Deleuze and Félix Guattari as a preface to his article \textit{Parallel Universes} (1993): “Chaos is not without its own ecstasies.”\footnote{146}

Ferneyhough seems to extend his scientific tropes into a broader cultural discourse, drawing on both literary and philosophical perspectives. This is given further credence when seen in conjunction with his statement regarding the emergence of ‘complexity’ in music:\footnote{147}

In a time when the ruins of Modernism’s optimism and alienation are busily being paved over with more civil images of our selves and situations, I emphatically feel that the full story is no longer being told and that there is a place for the continued critical investigation of issues pertaining to the

\footnotesize{\textsuperscript{144} Brian Ferneyhough, “Epicycle, Missa Brevis,” 94.}
\footnotesize{\textsuperscript{145} Brian Ferneyhough, “Interview with James Boros,” 436.}
\footnotesize{\textsuperscript{147}Brian Ferneyhough, “Responses to a Questionnaire on ‘Complexity’,” (1990) in \textit{Collected Writings}, 67.}
boundaries where perception, self-awareness, order and chaos collide and *fragmentation*, as terminus technicus, still has concrete (as well as evocative) meaning. The issue of complexity as such is, ironically, coming rapidly to the fore as an interpretive machine likely to change our way of seeing and thinking in the future.\textsuperscript{148}

Again, the use of geological metaphors is also often coupled with these concepts, as well as with the nature and idea of chaotic internal mental states.

\textsuperscript{148} Ferneyhough, “Interview with Barrière,” 409.
Chapter Three

Conclusion

The four British composers discussed in this thesis draw on a myriad of terms, models and theories associated with scientific disciplines encompassing physics, particle physics, biology, geology and chaos theory. The examination of these various scientific references suggests that the composers’ engagement with science transcends a mere interest in the scientific accounts of the universe. Rather, resonating with the positions of both Edgard Varèse and Iannis Xenakis, the composers’ uses of scientific concepts indicates that music, like science, can contribute to our understanding of the human condition.

In Chapter One, the exploration of the projects of both Varèse and Xenakis highlighted three elements that provide support for this position. Firstly, music is a physical entity that exists in three-dimensional space. Secondly, the world is inherently indeterminate. And thirdly, music is equivalent to mind. The examination of the scientific references made by the British composers in Chapter Two shows that these three principles are significant to their respective projects. For instance, Ferneyhough draws on Newtonian mechanics, conceptualising music in terms of force and mass. Moreover, these ideas are used in conjunction with geological terms to imagine the interaction between different musical materials and parameters. Similarly, Barrett draws on geological metaphors coupled with theories of matter and light to imagine the interaction and the development of musical material. Dillon also draws on phenomena associated with the behaviour of light (interference and diffraction). However, rather than geology, Dillon couples these ideas with concepts from biomorphology, in order to imagine sound moving in space. Finally, Dench uses geophysical images, and the notion of force-fields—in conjunction with recent non-mechanistic accounts of biology such as emergent phenomena and Bateson’s theory of mind—to imagine the interaction of various musical materials.

In addition, these British composers often refer to areas of science that present the universe as inherently indeterminate. In particular, this is manifest in their direct references to aspects of chaos theory, notably non-linearity, fractals and complex behaviour. It is also apparent in their use of stochastic processes and probability theory to generate and transform musical material and parameters.

The material presented in this paper so far raises the obvious question of how we are
to understand the British composers’ uses of these various scientific ideas. The most significant indication of the meaning of their engagement with these scientific domains lies in the four composers’ repeated coupling of the scientific metaphors outlined above with notions of the mind. Resonating with Xenakis's argument outlined in Chapter One of this paper, all four British composers argue that music and mind are linked. In the case of Chris Dench, music and mind are equivalent. Drawing on Dawkins’ theory of mind and the theory of emergent phenomena, Dench argues that music, like science, can play a significant role in understanding the meaning and structure of our physical and mental universes.

In a related methodology, both Ferneyhough and Barrett couple geological concepts with notions of unstable and indeterminate cognitive functions such as memory and intuition. This leads Barrett to suggest that music can provide a tool for understanding the inherent indeterminism evident in both the universe and in cognitive functions. Alternatively, James Dillon, whilst drawing on the mathematical tools associated with theories that account for the indeterminism inherent in the physical world, couples ideas of intuition and sexual desires with a general notion of flux inspired by his reading of the pre-Socratic philosophers. Dillon’s conceptualisation of the meaning and function of music is that it is able to re-address what he sees as the division between the scientific accounts of the universe and our understanding and ability to discuss these additional aspects of human nature.

In summary, for the four British composers discussed in this paper, science is a crucial tool in formulating what they perceive as the significance of their own compositional endeavours. This is not indicative of a desire on their part to equate music with science, but rather expresses their arguments that music can provide new questions and explanations for aspects of the universe, particularly those cognitive functions that science cannot fully explain.
Appendix

CD Track Listing and Performance Details

Track 1  The Voice of the Shuttle  18’10”

*The Voice of the Shuttle* was performed by members of Ensemble Offspring, and Halcyon at the Sydney Conservatorium of Music on 1 July 2005. The concert was recorded live by ABC Classic FM, with Stephen Adams (producer) and Thomas Rainer (sound engineer).

Roland Peelman: Conductor
Jenny Duck-Chong: Mezzo soprano
Michael Sitsky: Flute
Jill Taylor: Oboe
Diana Springford: Clarinet
Matthew Ockenden: Bassoon
Saul Lewis: Horn
Claire Edwards: Percussion
Zubin Kanga: Piano
Veronique Serrett: Violin
Thomas Talmacs: Violin
Nicole Forthsyth: Viola
Geoffrey Gartner: Cello
Andrew Meisel: Double Bass

Track 2  Ek-Stasis  7’29”

*Ek-Stasis* was performed by members of Ensemble Offspring at the Paddington Uniting Church, Sydney, 16 May 2002. The concert was recorded live by Damien Ricketson.

Mark Knoop: Conductor
Carl Rosman: Clarinet
Geoffrey Gartner: Cello
Jeremy Barnett: Percussion
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