PHI

**DESIGNING
WELLINGTON ZOO
IN HARMONY WITH
NATURE**

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ABSTRACT

The harmonious balance of architecture and nature is undermined by their mutual struggle for control. Their corrosive relationship directly leads to the degradation and displacement of natural ecosystems through economic development, of which modern society is fundamentally reliant. To preserve Earth's ecology and biodiversity for future generations, architecture needs to become symbiotic with nature. As Adolf Zeising speculated the ratio Phi (the Golden Section) to be the morphological law of nature, this thesis investigates whether its principles can help generate symbiotic architecture. This thesis investigates the historical perception of how Phi relates to nature, and applies its core principles to the development of Wellington Zoo's 'Welcome Plaza'. The investigation of Phi finds symbolism to be of central importance reflecting the ancient Pythagorean conception of Aether, later conceived as the medium of electromagnetic fields. The design basis of the Welcome Plaza utilises that which the ratio symbolises, being the Aether and its correlated electromagnetic qualities, rather than deriving its architectural form from the Phi ratio itself. The impact of the Welcome Plaza's generated form, upon the ecological value of the site, determines the appropriateness of the principles of Phi as a design mechanism. This thesis determines whether the principles ascribed to Phi can be used as a design methodology to generate Wellington Zoo's Welcome Plaza in a way that is harmonious with nature.

CONTENTS

	ABSTRACT	III
	PLATES	VI
	FIGURES	VII
CHAPTER 01	INTRODUCTION	01
	NATURE AND ECONOMIC DEVELOPMENT	
	WELLINGTON ZOO'S WELCOME PLAZA	
	PHI, ARCHITECTURE AND SYMBIOTIC DESIGN	
CHAPTER 02	BACKGROUND OF PHI	06
	CONTINUOUS PROPORTION	
	PREVALENCE IN NATURE	
	AESTHETIC AND DIVINE QUALITIES	
	LE CORBUSIER	
	CHAPTER SUMMARY	
CHAPTER 03	SYMBOLISM IN ISLAMIC ARCHITECTURE	13
	HOLISTIC INVESTIGATION	
	PHI IN ISLAM	
	NEO-PLATONIC PHILOSOPHIES	
	COSMIC SYMBOLISM	
	PROPORTION AND UNITY	
CHAPTER 04	AETHER AND THE GREEK PARTHENON	19
	THE PARTHENON AND PHI	
	ATHENA	
	COSMOLOGY AND PLATONIC SOLIDS	
	AETHER, PHI AND METAPHYSICS	
	EXPRESSION OVER SYMBOLISM	

CHAPTER 05	BRIEF AND DESIGN METHODOLOGY	26
	VISION	
	PRAGMATIC REQUIREMENTS	
	OVERVIEW	
	AETHER AND ELECTROMAGNETISM	
	ELECTROMAGNETIC DESIGN METHODOLOGY	
CHAPTER 06	DESIGN AND DISCUSSION	39
	MOTION OF THE AETHER	
	WELCOME PLAZA PLAN	
	BOUNDARY CONDITION	
	INTEGRATION WITH NATURE	
	REFLECTION	
CHAPTER 07	CONCLUSION	58
	INSIGHTS, FINDINGS AND FURTHER STUDIES	
	REFERENCES	62

PLATES

1-1	SEPARATION	02
2-1	HARMONIC GROWTH	07
4-1	ONE, PHI AND THE INFINITE	20
5-1	LOCATION PLAN	28
5-2	UPWARD CURRENT	34
5-3	ROTATIONAL INTENSITY	35
5-4	ELECTRIC POTENTIAL	36
5-5	MAGNETIC FIELD	37
5-6	DOWNWARD CURRENT	38
6-1	ROOF PLAN	41
6-2	GROUND PLAN	43
6-3	NORTH AERIAL PERSPECTIVE	44
6-4	SOUTH/EAST AERIAL PERSPECTIVE	45
6-5	NORTH/EAST ENTRANCE	52
6-6	NORTH/WEST ENTRANCE	53
6-7	SITE MOVEMENT	54
6-8	SECTION LINES	55
6-9	EAST/WEST SECTIONS	56
6-9	NORTH/SOUTH SECTIONS	57
7-1	CLASSROOM	60
7-2	STAFF ROOM	61

FIGURES

2-1	CONTINUOUS PROPORTION	08
2-2	MATHEMATICAL FORMULA	08
2-3	GOLDEN ANGLE	09
2-4	MODULOR PROPORTION SYSTEM	11
2-5	LE CORBUSIER'S UNITE D'HABITATION	12
3-1	TAJ-AL-MULK DOME - JAMI MOSQUE	15
3-2	PHI IN PENTAGONAL PLANE GEOMETRY	15
3-3	PLATONIC SOLIDS/FIGURES	16
3-4	PENTAGONAL GIRIH TILES	17
3-5	MOSQUE OF IBN TULUN / PHI RATIO / CUBE AND SPHERE	18
4-1	PARTHENON (WESTERN PEDIMENT)	21
5-1	WELCOME PLAZA'S ZONES	32

CHAPTER I **INTRODUCTION**

PLATE I - I

SEPARATION

NATURE AND ECONOMIC DEVELOPMENT

Capitalistic development and the persistent growth of human populations have caused the structure and functioning of earth's ecosystems to change more rapidly in the second half of the twentieth century, than in any other period of human history (Millennium Ecosystem Assessment Panel, 2005). Current development practices are leading to irreversible ecological damage, which is evident by the decline in wildlife populations which have fallen, on average, by a third since 1970 (World Wide Fund for Nature, 2008). The taxing demands of growing economies not only degrade natural ecosystems, but also deny many people in urban environments access to natural habitats, habitats that have shown to provide both psychological and physiological benefits (Kaplan & Kaplan, 1989). In *City Form and Natural Process*, Michael Hough (1989) states:

...urban society now takes refuge in the countryside in search of fresh air and natural surroundings that are denied at home. Consequently, unsustainable pressures are placed on environmentally sensitive landscapes. The advancing city has often replaced complex natural environments of woods, streams and fields with biologically sterile manmade landscapes that are neither socially useful nor visually enriching. (p. 2)

This is evident in Plate 1-1, which illustrates how intensification and economic development can significantly increase the separation and disparity between architecture and nature. To reduce the environmental and social impact of development, environmentalists have argued that the relationship between the city and countryside has to change fundamentally (Frey, 1999). Sim Van der Ryn and Stuart Cowan (1996) write:

...we must mirror nature's deep interconnections in our own epistemology of design.... It is time to stop designing in the image of the machine and start designing in a way that honours the complexity and diversity of life itself. (p. X)

For architecture to correlate with the complexity of organic life, to become symbiotic with biological ecosystems, a significant shift is required in architectural practice to meet both economic and ecological requirements. Architecture must do more than focus on myopic design aspirations and the pragmatic requirements of narrowly defined human interests. It is apparent, through the environmental problems we now face, that our current design practices are generally incompatible with nature's own. We must design in harmony with nature if we are to minimise the destructive impacts of our actions.

WELLINGTON ZOO'S WELCOME PLAZA

The design focus of this thesis is on the development of Wellington Zoo's 'Welcome Plaza', due to the Zoo's strong belief in the sustainable co-existence between wildlife and people. The Zoo is currently undergoing development, as part of its ten-year Zoo Capital Programme

(ZCP), to bring people, wildlife and the environment closer together. The Zoo hopes to perpetuate curiosity and admiration of nature, as well as raise environmental awareness to protect and support both native and exotic fauna and flora (Wellington Zoo Trust, 2010). The existing zoo entrance fails to present an image aligned with the Zoo's ideology and is unable to cope with the increasing demand of growing visitor numbers. Meeting the demands of greater visitor numbers would typically require a larger building footprint at the expense of the surrounding environment. However, as trees and low-lying plants surround the current entrance, this would degrade the site's ecological health. This spawns the problem of how to develop the Welcome Plaza to not only meet pragmatic, economic and social requirements, but also to improve the site's biological value.

The difficulty in merging the opposed constructs of architectural development and ecological health is the crux of this thesis. Nature and architecture tend to be in a constant state of conflict rather than concord. It is argued that architecture must follow nature's patterns and the way it functions to achieve sustainable development. To align nature and the architecture of Wellington Zoo's Welcome Plaza, this thesis investigates the Phi ratio, otherwise known as the Golden Section, following speculation that it operates as the fundamental mechanism of nature. The principles of the Phi ratio will determine the design mechanism responsible for generating the Welcome Plaza's architectural form. The relationship between the Welcome Plaza and the surrounding natural habitat will set the criterion for evaluating the effectiveness of the principles of Phi as a design methodology.

PHI, ARCHITECTURE AND SYMBIOTIC DESIGN

The ratio Phi has intrigued philosophers, mathematicians and architects for thousands of years. The first explicit definition of Phi, known at the time as the 'Extreme and Mean Ratio', is given by the ancient Greek mathematician Euclid (fl. 300BCE), in his *Elements*. This ratio is evident in the proportions of the earlier Greek Parthenon (Figure 4-1), in Islamic architecture (Figure 3-5), and a number of other historic buildings. However, as there is a lack of literary evidence, its use in historic architecture is largely speculative. Public awareness of the ratio only became relatively popular during the mid-19th century following the influential work of German psychologist, Adolf Zeising (1810-76 CE). Zeising perceived a close connection between Phi and virtually all facets of life and nature. He conceived that Phi acts as a basic morphological law, hypothesizing that it is the "*ground-principle of all formative striving for beauty and completeness*" (1854, p. V). Zeising formulated a new theory of proportion based upon Phi along with the profound and prolific concept that the ratio is in and of itself aesthetically pleasing. Numerous psychological studies carried out during the 20th century nullified this notion, however, the connection between architecture and nature remains ambiguous. Le Corbusier used the ratio in his famous Modulor proportioning system due to the notion that the ratio contains profound knowledge and truths (Benton, 1987). Determining exactly what this means is essential to understanding how Phi relates to nature, and how the

Welcome Plaza should be designed according to its properties.

The investigation of Phi initially evaluates its unique mathematical properties and its occurrences in nature. The investigation then determines the philosophical ideas and concepts present during the construction of architecture that incorporates the Phi ratio. This holistic investigative direction, covering their metaphysical philosophies, is superior to purely archaeological methodologies due to the difficulty that exists in accurately interpreting architectural ideas and languages. This investigative approach also helps establish the best design methodology for developing the Welcome Plaza as closely as possible to the principles of Phi. The correlation between the design of the Welcome Plaza, and the principles of Phi, allow its architecture to be evaluated to determine how appropriate its principles are for generating architecture in consonance with nature. If a close connection between Phi and nature exists, development based upon its principles should dissolve the discordance between the built form and nature. If Phi and its principles are fundamental to nature, as speculated by Zeising, architecture based on Phi should reduce the negative environmental impacts of traditional development. **This thesis argues that the principles historically ascribed to Phi can help push the architecture of Wellington Zoo's Welcome Plaza, as well as architecture in general, towards a design mechanism that is harmonious with nature.**

CHAPTER 2

BACKGROUND OF PHI

PLATE 2-1

HARMONIC GROWTH

CONTINUOUS
PROPORTION

FIGURE 2-1
CONTINUOUS
PROPORTION

Phi, Φ , is an irrational number, expressed mathematically as $(1+\sqrt{5})/2$, with unique geometric and algebraic qualities that distinguishes it from any other number. Phi is approximately 1.618, however, the number is irrational with an infinite number of never repeating decimals. This is because Phi is a proportional relationship rather than a traditional, rational number or ratio.

A proportion can be considered as a relationship of equivalency between two ratios, whereas a ratio refers to the relationship between two different lengths, sizes or quantities. A ratio can also be expressed mathematically as a:b, whereas a proportion can be expressed as a:b :: c:d. Another way to look at proportion would be to consider the relationship between two elements compared to the relationship between two other elements. If the two relationships were equivalent, they would be considered a discontinuous proportion (Figure 2-1.1). The proportion would be discontinuous because the two relationships are separate from one another. On the other hand, a continuous proportion uses three terms, rather than the four in a discontinuous proportion, whereby one term is to a second as the second is to a third. This can be expressed mathematically as a:b :: b:c (Figure 2-1.2). There is however, one unique proportion that can be formed that uses only two terms. This is evident when the ratio between the first and second term is proportionally equivalent to the ratio between the second term and the subtraction of second from the first term (Figure 2-1.3). This unique proportion is Phi.

FIGURE 2-2
MATHEMATICAL
FORMULA

$$\Phi = \sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + \dots}}}}$$

$$\Phi = 1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \dots}}}$$

The two term continuous proportion is the most significant feature of Phi. The mathematical formulas of Phi expressed in Figure 2-2 emphasizes Phi's unique proportional basis and its close connection with the number one and infinite, iterative functions. As Phi represents the simplest continued fraction and the most irrational number, it is also the 'worst' real number for rational approximation. This property leads itself to being able to produce the most compact radial distribution of equal sized entities, expressed in Plate 2-1.

PREVALENCE IN NATURE

Phi is the basis of this thesis, not because of its unique mathematical properties, but rather due to its prevalence throughout nature. Phi is evident in numerous facets of biological ecosystems. The most easily recognisable occurrence of Phi in nature, is within the organization of branch and leaf structures in plants, which is termed Phyllotaxis. The position of leaves and branches follow spiral arrangements around their stem, with divergent angles based on regular fractions of a full circular rotation (Cummings & Strickland, 1998). It is a particularly well known observation that the numerator and denominator of these fractions are Fibonacci numbers such as 0, 1, 1, 2, 3, 5, 8, 13, 21 (Adler, Barabe, & Jean, 1997). The Fibonacci numbers are formed through the addition of its two preceding terms. This sequence is significant because the division of any of its terms by the preceding number will approximate Phi and converge on the Phi ratio as the size of the two Fibonacci numbers increase.

FIGURE **2-3**
GOLDEN ANGLE

Another important case is if the circumference of a circle is divided by the Phi ratio, the angle equals approximately 137.5°. This is known as the 'Golden Angle', which frequently corresponds to the divergent angle between the growth of successive flowers and seeds. The growth of a sunflower's head is a common example that exhibits growth according to this angle. Plate **2-1** shows the pattern generated by using the Golden Angle, expressing uniform density and the most efficient radial form (Naylor, 2002). A convincing explanation of why phyllotaxis follows Phi and the Golden Angle has yet to be found. It has been argued that nature conforms to these proportions as a result of achieving optimal packing densities, however it remains an on-going topic of research (d'Ovido & Mosekilde, 2000; Jean & Barabé, 1998).

Investigations into the relationship between Phi and nature has progressed by researchers who have found a connection between Phi and the geometry of DNA and the clock cycle of brain waves (Perez, 2010; Weiss & Weiss, 2003). Phi is also found in the Quantum world through the magnetic spin resonance in cobalt niobate crystals (Helmholtz Association, 2010). This broad prevalence of Phi solidifies its connection with nature, yet signifies a lack of understanding as to why it occurs.

AESTHETIC AND DIVINE QUALITIES

Adolf Zeising (1810-1876) was the first to base a theory of proportion on the Phi ratio due to its close connection with natural phenomena. In Zeising's first publication, he claims to have found a basic morphological law [the Phi ratio], which permeates the whole of nature, and uses this to form a new proportional theory of the human body. Furthermore, he used this morphological law to develop a model of aesthetics that has had a significant impact in architectural theory. Zeising (1854) claimed the morphological law, Phi,

contained the fundamental principle of all formative striving for beauty and totality in the realm of nature and in the field of the pictorial arts, and that it from the very first beginning was the highest aim and ideal of all figurations and formal relations, whether cosmic or individualizing, organic or inorganic, acoustic or optical; which had found its most perfect realization however only in the human figure. (p. V)

Marcus Frings (2002), has stated that in the early stages of this aesthetic movement, there was a lack of methodical reflection and historical anchorage. Nevertheless, following the introduction of this morphological aesthetic ideal, numerous psychological studies arose attempting to prove Zeising's hypothesis. Empirical research on the aesthetic qualities of Phi dates back to the work of Gustav Theodor Fechner, however he failed to find preference for the ratio and claimed Zeising thought too highly of Phi's aesthetic value (Fechner, 1865). Numerous studies have further examined this hypothesis during the 20th century with an overwhelming conclusion that there is no measurable preference for the Phi ratio. Research has however determined that symmetry is the principle determinant in aesthetic preference, which suggests that perceptual organisational processes are more significant than the unique mathematical proportions of Phi (Davis & Jahnke, 1991).

Beyond the aesthetic basis of using Phi in architecture is the ratio's religious significance. One of the most significant works that deal with the qualities of Phi is Luca Pacioli's (1445–1517) *De Divina Proportione*. This is a collective title for the works *On the Divine proportion*, *Architectural Treatise* and *Libellus*. It is commonly thought that Pacioli's Architectural Treatise advocated the use of Phi, or the Divine Proportion, in architecture and art. However, Roger Herz-Fischler has traced this notion to a false statement made in the 1799 edition of *Histoire de Mathematiques*. Pacioli's Architectural Treatise, rather advocates simple and harmonic ratios, based on Vitruvian system of proportion (Herz-Fischler, 1987). The work *On the Divine proportion* discusses the various mathematical qualities of Phi which Pacioli considers an “admirable teaching...touching upon a very secret science”. Mario Livio (2002) has translated the fifth chapter of this work that reveals the five reasons why Pacioli coined Phi the ‘divine proportion’.

FIGURE 2-4

MODULOR PROPORTION
SYSTEM

1. **It relates to the unity of God due to its unique mathematical properties.**
2. **It compares to the trinity of the Christian God as Phi is attributed to the proportion of three lengths ($1/\Phi$, 1 , Φ).**
3. **As Phi cannot be expressed as a rational number, it aligns with the incomprehensible quality of God.**
4. **The omnipresence and invariability of God is indicated by the proportional, self-similar qualities of Phi.**
5. **The Phi ratio is inherent within the proportions of the Dodecahedron, through which it is believe God conferred Being to the entire cosmos.**

By naming Phi as the 'Divine Proportion', previously known as the 'Extreme and Mean Ratio', and forming a correlation with religious doctrines, it effectively drew the attention of an increasing number of eclectic, intellectual groups. The name also increased awareness of Phi and made its core principles available to a greater number of artistic disciplines. Nevertheless, although the work of Pacioli, as well as Zeising, has had a large impact in architectural theory, it has had little influence in architectural practise.

The most significant impact Phi has had on architecture is through its influence on Le Corbusier, one of the most influential architects during the modernist movement. Le Corbusier (1887-1965) explored the architectural implications of Phi by using the ratio as the basis of his 'Modulor' proportion system. Figure 2-4 indicates the building blocks of this proportioning system, cast into the wall of Le Corbusier's Unite d'Habitation. Le Corbusier believed that, within the patterns embodied by the Golden Section and Fibonacci Series, there is profound knowledge and hidden truths (Benton, 1987). What Le Corbusier implied by this however, is unknown. What is clear through Le Corbusier's Unite d'Habitation is that architecture based entirely on his modular proportion system, and therefore the Phi ratio, does not lead to architecture in consonance with nature. This is evident by its sterile, inhumane concrete roof 'garden'. Le Corbusier's Unite d'Habitation is in fact the cornerstone of the Brutalist architectural movement, essentially the antithesis of ecologically sustainable architecture. Aesthetically, Le Corbusier even criticized his own system stating it has the capacity to produce designs that are "displeasing, badly put together", stating that design should be based on perceptual qualities – "our eyes are your judges" (Corbusier, 2000, p. 130).

At this point, it would seem Le Corbusier's Unite d'Habitation could potentially discredit any motive for investigating Phi in order to design Wellington Zoo's Welcome Plaza in consonance with nature. However, a decided shift exists between his 'Modulor' proportioning system and the architecture that is based upon it. For instance, the continuous proportion of Phi is apparent through a linearly increasing series of arcs in Figure 2-4, yet within the overall form of the Unite d'Habitation (Figure 2-5), there is no perceptible feature indicative of this.

This is significant because as expressed earlier, Phi is not unique as a ratio, but as a proportion. It is unique because it is the simplest continuous fraction, the most irrational number. Utilising Phi as a discrete ratio, limited to arbitrary dimensions and components entirely undermines the significance of Phi. For Phi to be properly expressed in terms of its mathematical significance, every aspect of a building must conform to the same underlying scale. However, because there is no measurable preference for the Phi ratio, as determined during the 20th century, the two term continuous proportion of Phi is no better than any other three term continuous proportion. As Phi has no aesthetic advantage, and because it is incommensurable and therefore highly impractical to use, the rationale for incorporating Phi into architecture must be symbolic. It has to act as a means of communication for it is illogical to arbitrarily infuse the ratio Phi into buildings, especially spiritually significant temples, churches and mosques. This may seem like an overly simplistic deduction, however as Le Corbusier believes that profound knowledge is contained within the ratio, and because Pacioli states that it touches upon a very secret science, it is a logical conclusion to draw.

CHAPTER SUMMARY

This chapter provides a brief background overview of Phi, indicating its mathematical significance and its connection to nature. It has also expressed that there is little evidence to suggest the ratio is aesthetically pleasing as commonly thought, as well as indicating why it was considered divine. This alludes to the question of why Phi was used in historic architecture and exactly what are the hidden truths that the ratio is purported to contain. The following chapter begins to investigate the rationale for incorporating the ratio into architecture and the meaning and significance that underlies it. By determining the significance of Phi, and why it was incorporated into architecture, it endeavours to uncover the best methodology for generating the architecture of the Welcome Plaza in relation to the principles of Phi.

FIGURE 2-5

LE CORBUSIER'S
UNITE D'HABITATION

CHAPTER 3

**SYMBOLISM
IN ISLAMIC
ARCHITECTURE**

HOLISTIC INVESTIGATION

Studies into the use of Phi in historic architecture have generally focused on geometric analyses. This is predominantly due to the lack of surviving plans and documentation that directly supports the use of the ratio. However, this is problematic as analyses that focus solely on architectural forms often generate inaccurate suppositions (Grabar, 1980). More often than not, architectural analyses often translate into a number juggling exercise to support predisposed theories (Markowsky, 1992). This is particularly true in Frederik Lund's *Ad Quadratum* who has suggested that Phi is prominent in the Cathedral of Chartres, the Notre Dame de Paris and the Notre-Dame of Laon. The use of Phi in these chapels has however been refuted by numerous scholars (Padovan, 1999; Livio, 2002). However, the speculative work of Lund and many others emphasizes the difficulty in determining the architect's intent, or to understand what the architecture attempts to communicate, without supporting documentation. This is significant as it shows that research focusing solely on the geometric proportions of historic architecture can easily lead to unsubstantiated conclusions.

In order to overcome the problems associated with interpreting the geometry of archaeological remains, the investigation of Phi focuses on a much broader, holistic perspective. The investigation takes into account the prominent philosophical notions that were apparent during the construction of buildings thought to include the ratio. Islamic architecture is then utilised to support the expression of these historic philosophical ideas. This differs substantially from the typical method of utilising historic architecture to support modern notions of Phi's significance. The principal focus of this chapter is on Islamic philosophies due to the pivotal role Islam played in reintroducing Phi into Europe during the 12th century. Initially an understanding of their basic philosophies is developed, and then assessed, in relation to their architecture. As Phi is evident in particular Islamic buildings, their philosophical ideas will help illuminate the significance of Phi.

PHI IN ISLAM

The Islamic civilisation emerged during the 7th century with an architectural style heavily influenced by Persian, Greek, Byzantine and central Asian empires. This Islamic world prospered during the Islamic Golden Age (c.750CE – c.1258) and became a major intellectual centre for science, philosophy, medicine and education (Falagas, Zarkadoulia, & Samonis, 2006). In Baghdad, in the "House of Wisdom", scholars from around the world sought to translate the world's knowledge into Arabic. This made Islamic mathematicians and philosophers well aware of Phi, as well as the Platonic and Pythagorean doctrines. Euclid's *Elements*, which deals with the 'Extreme and Mean Ratio' (Phi) had been translated into Arabic by the early 9th century, and by the early 10th century, Arab mathematicians knew its algebraic formula (Herz-Fischler, 1987). This is communicated in Abu Kamil's (c. 850 – c. 930) treatise *On the Pentagon and the Decagon* which was later adopted by Leonardo Fibonacci (c. 1170 – c. 1250). Fibonacci is responsible for introducing knowledge of Phi - expressed as $(\sqrt{125-5})/(15-\sqrt{125})$, the Arab numerical system, as well as the Fibonacci sequence that was discussed

FIGURE 3-1

TAJ-AL-MULK DOME
- JAMI MOSQUE

[Brick pattern emphasized]

FIGURE 3-2

PHI IN PENTAGONAL
PLANE GEOMETRY

NEO-PLATONIC PHILOSOPHIES

in Chapter 2, into Europe through his 1202 work *Liber Abaci* (Sigler, 2002). It is apparent that the Islamic civilisation was aware of the Phi ratio, in both geometric and algebraic terms, and signifies that the use of Phi in Islamic architecture is not necessarily a coincidence.

Their broad understanding of diverse philosophical texts, and their firm understanding of Phi, enabled Islam to formulate an architectural language that aligns with their spiritual beliefs. This is significant because every aspect of Muslim life must conform or be regulated by the Quran and its Divine Law. According to Islamic beliefs, creation and reality emanates from a Unity or their One God, encompassing every aspect of our material and intelligible world (Ali, 1987, 57:3). There is no division between the sacred and the profane. Unity exists a priori, everywhere and at all times. Of central importance to Muslims is to extricate, to become aware, of the Unity that is said to exist in them and their surroundings. As every aspect within the Islamic worldview is sacred, Islamic architecture also has an intimate connection to their religious beliefs. Of central importance in architecture, especially within mosques, is to help lead the mind of Muslims back to the notion of Unity or the Oneness of God, known as *tawhid*. As the Phi ratio is found in some Islamic mosques, it implies it has some form of religious significance.

The Phi ratio is apparent in the proportions of a number of mosques as well as within the arabesques and tiles that line their walls. The Great Mosque of Kairouan in Tunisia, founded in 670 AD, is considered the ancestor of mosques in Islam, and expresses the Phi ratio in the overall proportion of the plan, and the position and dimensions of the minaret (Boussora & Mazouz, 2004). The Phi ratio has also been included in a number of other buildings including the Taj-al-Mulk dome of the Jami mosque (Figure 3-1), dated 1088 AD, as well as within the Ali Qapu building dated 1597–1668 AD, both of which are situated in Isfahan (Hejazi, 2004). It is postulated that a number of other Islamic buildings also incorporate this ratio, and I have speculated Phi was used in the Mosque of Ibn Tulun, dated 876AD – 879AD, in Figure 3-5. Furthermore, the arabesques and tile patterns of Mosques also frequently use 5 and 10 fold geometric patterns that inherently contain the Phi ratio, as indicated in figure 3-2. The use of Phi in Islamic architecture substantiates the notion that the ratio could play a role in Islamic theologies, yet without a greater understanding of the theories that concern Phi, its use within architecture is of little significance.

Islamic theology initially faced the pertinent question of how the Qur'anic conception of unity, their One God, could be linked to the multiplicity and diversity of existence. Various theological ideas emerged yet it was the Greek texts, which became available following the rapid growth of Islam in the 8th century, that had a significant influence (Leaman, 1985). This is because Greek philosophers had also contemplated the same question, and although there were a number of differences, many of the Neo-Platonic ideas were adopted (Morewedge, 1995). During the development of Islam, one of the most prominent Arab philosophers was al-

Kindi (c. 801–c. 873). Considered the father of Arab philosophy, al-Kindi considered himself as an interpreter of ancient knowledge and transcribed numerous Greeks texts and dialogues into Arabic (Rosenthal, 1956).

In al-Kindi’s treatise: *On the Reason Why the Ancients Attributed the Five Figures [Platonic Solids] to the Elements*, he states it is “one of the profitable works in the trade of one whose market is to establish the oneness of God” (Rescher, 1967, p. 25). As stated earlier, the ‘Oneness of God’, *tawhīd*, is the most fundamental aspect of Islam. Within this treatise, al-Kindi attempts to portray the notion that the causation of reality is based on the ontological principle of Unity. He states -

the cause of everything is a single one without any plurality, which does not depart from its proper nature, and does not resemble any of its effects.(Rescher, 1967, p. 33)

According to al-Kindi, the form that neither expresses plurality nor departs from its proper nature is the ‘Celestial Sphere’ (p.33). The Celestial Sphere is considered the underlying basis of the figures/forms, as he states: “by the existence of the sphere there exists each one of the rest [of the figures]” (p.33). The significance of these attributes is that the Dodecahedron was ascribed to the Celestial Sphere (p.31). The Dodecahedron is constructed with 12 Pentagons, of which the Phi ratio is essential.

FIGURE 3-3
PLATONIC
SOLIDS / FIGURES

CELESTIAL SPHERE		ELEMENTS			
		FIRE	AIR	WATER	EARTH

QUICK		←	MOTION	→	SLOW
Dodecahedron		Tetrahedron	Octahedron	Icosahedron	Cube
Pentagon		Triangle	Triangle	Triangle	Square
5		3	3	3	4
12		4	8	20	6
30		6	12	30	12
Matter		Matter	Matter	Matter	Matter
Form		Form	Form	Form	Form
Circular Motion		Linear Motion	Linear Motion	Linear Motion	Linear Motion
Stable State					Generation
Intelligent Action					

COSMIC SYMBOLISM

FIGURE 3-4
PENTAGONAL
GIRIH TILES

The attributes of the Celestial Sphere and the four elements, stated within his treatise, are outlined in Figure 3-3. Each of the different elements is assigned to particular figure or solid, based entirely upon various geometric and numeric relationships. He further states that the Celestial Sphere touches all figures/forms at the limit of a single boundary and is attributed to eternal, circular motion, which is said to allow movement without generating plurality or change (p.34). This differs from the four elements that are attributed with temporal and rectilinear motion that indicates change. The Celestial Sphere and the Earth are also the extreme opposites within the five elements (p.27). The Celestial Sphere has intellectual qualities whereas the earth has the property of generation. 'Earth' and the Cube is the material principle for everything that is born, for everything that grows (p.31).

In Islamic architecture, an aniconic, geometric language is thought to portray the archetypal ideas of their God. Symbolism is the main premise of Islamic Architecture, which relates the sensible to the intelligible (Burckhardt, 2009). Material objects, tectonic or otherwise, are capable of embodying abstract concepts that lie beyond the confines of their materiality. The implicit goal of Islamic architecture is to enable the mind to channel through to the abstract, cosmic percept of their One God. Their architecture aims to project the order of divine Unity. This is achieved architecturally through geometry and geometric patterns, as it is prohibited to worship through idolatrous art forms. Titus Burckhardt (2009) has stated, in reference to the geometric patterns:

... it is a direct expression of the idea of the Divine Unity underlying the inexhaustible variety of the world ... it is through harmony that it is reflected in the world, harmony being nothing other than "unity in multiplicity" (al-wahdah fi 'l-kathrah) ... (p.73)

The symbolic significance of Islamic architecture is perhaps best understood through the tiles and arabesque patterns that adorn its surfaces. The geometric patterns and arabesques express the concept of 'unity in multiplicity' by the way geometric patterns are interlaced together (Ali, 1999). The continuous nature of the geometric patterns represents the infinite, extending beyond the material world (Canby, 2005). Six, eight and five-folded geometric patterns are the most predominant, each with numeric correlations to the various solids (Lee, 1987). Within the five-sided Girih tiles, indicated in figure 3-4, the Phi ratio is fundamental. The symbolic significance of particular geometries, indicated in the treatise of al-Kindi, enables the potentiality for Islamic architecture to act as a language whereby different aspects of their worldview can be expressed and understood.

PROPORTION AND UNITY

The unity of their one God and the multiplicity of our mundane world is said to simultaneously exist through proportion and geometry. This enables certain geometries and numbers to symbolically portray varying aspects of their One God. Most evident is the Sphere and the Cube. These two basic forms are prolific in Islamic architecture, yet it is due to the proliferation that any direct interpretation is easily refuted. For instance, figure 3-5 could be interpreted in a way whereby the Sphere symbolises unity, the Cube symbolises materiality and polarisation, both unified through the proportion of Phi. Unfortunately, this interpretation can be perceived as a tenuous link. This is because no literary evidence explicitly expresses why Islamic architecture utilises these geometries and patterns. It could be stated that Islamic architecture has nothing to do with neo-platonic ideas and is merely a continuation and progression of older architectural styles. The occurrence of the Phi ratio could also be perceived as a process of number juggling.

Al-Kindi's treatise has indicated that a connection exists between geometric forms, numbers and cosmic ideas. Unfortunately, even though al-Kindi is considered the father of Islamic philosophy, the influence his essentially neo-platonic ideas have had upon Islamic architecture is unknown. Furthermore, although a connection can be found between the Phi ratio and al-Kindi's Celestial Sphere, there is little to indicate the role the Celestial Sphere and the other four elements play within the broader worldview. To accurately determine whether the principles ascribed to Phi can help achieve architecture that is harmonious with nature, a solid theoretical understanding of Phi is essential. This chapter has indicated that a loose connection exists between Phi and greater metaphysical views of nature and reality. These views consist of concepts such as unity, multiplicity and harmony that are potentially symbolised through architecture. To clarify the properties attributed to Phi, the next chapter explores the Parthenon of Ancient Greece and the philosophies that al-Kindi's treatise is based upon.

FIGURE 3-5

MOSQUE OF IBN TULUN -
PHI RATIO / CUBE AND SPHERE

CHAPTER 4

**AETHER
AND THE GREEK
PARTHENON**

$\Phi = 1.618$ PLATE 4-1

THE PARTHENON AND PHI

The Parthenon is an enduring symbol of ancient Greece and is considered one of the world's greatest cultural monuments. The temple was built within the Athenian Acropolis between 447 and 432 B.C and is dedicated to the Goddess Athena Parthenos (Athena the Virgin). The ratio Phi is named after the Sculptor Phidias (c.480-430BCE), who was in charge of the project's construction, under the rule of Pericles (Perrin, 1914). The Parthenon is highly significant because the temple's proportions approximate the Phi ratio. This is evident in Figure 4-1, which shows the western façade of the Parthenon enclosed by a Golden rectangle, with the ratio Phi evident within a number of other significant dimensions.

Many architects and other professionals have claimed the Golden Ratio is embodied into the form of the Parthenon; however this claim is not without its critics. The first to claim the Parthenon was designed according to the Phi ratio was Adolf Zeising, [discussed in Chapter 02] in his 1884 *Der Goldne Schnitt* (The golden section). This is repeated in Lunds, *Ad Quadratum* (1921), Matila Ghyka's (1946) *The Geometry of Art and Life* and Miloutine Borissavlievitch's (1958) *The Golden Number and the Scientific Aesthetics of Architecture*. Many other geometric analyses have been carried out, often accompanied with complex diagrams in attempts to conform the building to various other commensurable and incommensurable proportions (Hambidge, 1924; Lawrence, 1957; Carpenter, 1970). However, George Markowsky (1992)

FIGURE 4-1

PARTHENON

[WESTERN PEDIMENT]

states in his article “*Misconceptions about the Golden Ratio*”, that parts such as the pedestal and roof often fall outside the sketched Golden Rectangle and that analyses often come down to a number-juggling exercise.

To determine if the Phi ratio was used in the Parthenon, I have done my own analysis based upon a photograph, as shown in Figure 4-1. I used a photograph taken from afar to eliminate lens distortion and to overcome the problems of drawn elevations based on inaccurate measurements. On top of the photograph, I have overlaid an early diagram of the pediment, which clearly frames the edges of the building through the Acroteriums positioned at the pediments apex and the outer angles. This is significant as it indicates how to position the golden rectangle upon its façade. Due to the close correspondence between the Parthenon's dimensions and Phi expressed in Figure 4-1, the image tends to suggest that the Parthenon was deliberately proportioned according to Phi, similar to the conclusions drawn by many other architects. Unfortunately, this analysis fails to illuminate the rationale for incorporating the ratio. Without a firm understanding as to why Phi would have been incorporated into the Parthenon, any analysis can be easily refuted. As expressed in Chapter 03, a broad, holistic perspective is required, taking into account their beliefs and philosophies, in order to determine if and why architecture contains the Phi ratio.

ATHENA

In order to determine why the Parthenon would incorporate Phi, it is important to understand the qualities of the Goddess Athena. This is because beyond the guise of the different Gods exist far greater metaphysical doctrines and concepts. Plato's *Cratylus* is perhaps the best indicator that the Gods confer varying qualities and concepts, existing within a broader worldview. It is also supported by the influence the Egyptian ‘Mysteries’ had upon Greek philosophy. For example, the Greek Philosopher Plato (424 BC – 348 BC) has written that the Greek Goddess Athena was equivalent to the Egyptian Goddess Neith (Timaeus, 21e). Athena and Neith are different Gods yet they symbolise the same concept. In Egypt, Neith is considered the cause of both the divine and earthly worlds and is depicted with a ‘was sceptre’, symbolising control over chaos, as well as an ‘ankh’ symbol that represents life (Wilkinson, 2003). There are many correlations between the two, however the significance of their qualities are difficult to interpret without a fuller understanding of the underlying doctrine that the Gods are based upon.

To determine the significance of Athena it is important to turn to earlier work, for Plato was not alive at the time the Parthenon was constructed. The most significant text concerning Athena is the work of Zeno of Elea (490 BC – ca. 430 BC). Diogenes Laërtius, a 3rd century AD biographer of Greek philosophers, indicates within his *Lives and Opinions of Eminent Philosophers* the views of Zeno stating:

The deity, say they, is a living being, immortal, rational, perfect or intelligent in happiness, admitting nothing evil [into him], taking providential care of the world and all that therein is, but he is not of human shape. He is, however, the artificer of the universe and, as it were, the father of all, both in general and in that particular part of him which is all-pervading, and which is called many names according to its various powers. They give the name Dia (Δία) because all things are due to (δία) him ; Zeus (Ζηνά) in so far as he is the cause of life (ζην) or pervades all life; the name Athena is given, because the ruling part of the divinity extends to the aether; the name Hera marks its extension to the air; he is called Hephaestus since it spreads to the creative fire; Poseidon, since it stretches to the sea; Demeter, since it reaches to the earth. Similarly men have given the deity his other titles, fastening, as best they can, on some one or other of his peculiar attributes. (Laertius, 1925, p. 251)

This passage expresses that the Goddess Athena indicates a particular quality or power of the all-pervading God / Deity. Athena refers to the power over the Aether. The correlation between Athena and the Aether is also expressed by Sallustius, a 4th-century A.D. Latin writer, in his treatise *On the Gods and the Cosmos* (Sallustius, 1996, p. 1x). So far, a connection between Athena and the Aether is apparent although its relevance to Phi and the proportions of the Parthenon is still unknown. To uncover the significance of Phi a better understanding of the Aether and the Pythagorean/Platonic worldview is necessary.

COSMOLOGY AND PLATONIC SOLIDS

Within the Pythagorean and Platonic doctrines, there are two primary principles in the universe, the active and passive. The active principle concerns reason and intellect whereas the passive principle concerns substance and matter. The principle of reason and intellect is located at the top of the hierarchical order within their worldview and is always ascribed to Male God or Deity. The Pythagoreans call this the Monad, whereas Plato calls this, the One, or the 'Good'. This principle is said to be eternal, unchanging and separate from our conception of space and time. It is only through the second passive principle, which is ascribed to a female God or Deity, that time and space is created. The Pythagoreans call this the Undefined Dyad; Plato calls this the Indefinite Dyad. The two Pythagorean principles are recorded by Alexander in his *Successions of Philosophers*, following his reading of the Pythagorean memoirs (Laertius, 1925). Plato expressed the two Platonic principles in a lecture titled *On the Good* (Aristotle, *Metaphysics*, 350 BCE, p. 987b). As the Pythagoreans had an oath to secrecy these principles were not commonly known (Kirk & Raven, 1975). Plato, who was also a Pythagorean, states in reference to what he studies seriously, "*there does not exist, nor will there ever exist, any treatise of mine dealing therewith.*" (Seventh Letter, 341c). His public lecture '*On the Good*', which contains his ontological principles, was only presented to deter criticisms that were mounting against the Academy (Gaiser, 1980). The One or Monad is also ascribed to the form of the

sphere, whereas the whole of the created and changing universe is ascribed to the form of the dodecahedron. (*Timaeus*, pp. 33b,55c)

The form of the dodecahedron is one of the most closely held secrets of both the Pythagorean and Platonic doctrines. In Plato's *Timaeus*, the details that would refer to the dodecahedron are conspicuously absent. It has also been stated that Hippasus perished at sea, at the hand of the Pythagoreans, as a consequence of divulging the method of forming a sphere from twelve pentagons (Iamblichus, 1818, p. 47). Due to the secretive nature of both the Pythagoreans and Plato, the properties ascribed to the dodecahedron have not been explicitly stated, however later philosophers have perceived that its form was ascribed to the Aether (Plutarch, 1874, p. e11). This is supported in Plato's *Epinomis* with Athenian stating :

There being five bodies [regular Solids], then, we declare that they are fire, water, air, earth, and aether, and that each of the many and varied kinds of living things is brought to perfection with one of these playing the chief role. (891c)

As there are only five platonic solids, or regular convex polyhedral, and because the four regular solids [Tetrahedron, Icosahedron, Octahedron, Cube] are ascribed to fire, water, air and earth in Plato's *Timaeus*, the dodecahedron is therefore thought to align with the Aether. This has a very close correlation with Chapter 3 and Figure **3-3**, whereby the Aether correlates with al-Kindi's Celestial Sphere. The most significant aspect of the Aether/Celestial Sphere being attributed to the Dodecahedron is that the ratio Phi is intrinsic to its proportions. As the Parthenon is dedicated to Athena, whom has power over the Aether and because the Aether is expressed through the form of the Dodecahedron, of which the Phi ratio is fundamental, it substantiates why the Parthenon would infuse the ratio into its proportions. Of course, this seems like a very tenuous link. If the Phi ratio was incorporated in the Parthenon to symbolically portray the concept of the Aether, there should be a much greater connection between the two seemingly distinct aspects.

AETHER, PHI AND METAPHYSICS

According to Chrysippus' *On Providence*, the Aether is said to have "*pervaded all that is in the air, all the animals and plants, and also the earth itself, [acting] as a principle of cohesion*" (Laertius, 1925, p. 243). This is repeated in Aristophanes play titled *Thesmophoriazousae* whereby the aether is said to have '*separated the elements and bore the animals*'. (Aristophanes, 1938, p. line 15) Furthermore, Alexander who is the authoritative source of the Pythagorean doctrines states in his *Successions of Philosophers* that "*the sun's ray penetrates through the aether, whether cold or dense—the air they call cold aether, and the sea and moisture dense aether*" (Laertius, 1925, p. 341). The significance of the Aether is indicated in Antipater of Tyre's eighth book *On the Cosmos* who states "*the whole world is a living being, endowed with soul and reason, and having aether for its ruling principle*". (Laertius, 1925, p. 243).

The various references to the Aether above begin to indicate how it operated within their metaphysical doctrine, however to determine its correlation with Phi, it is important to express how the Pythagoreans and Plato perceived the world. According to their worldview, our sensory perception is constituted through difference and relativity. In Plato's *Theaetetus* Socrates writes "*wherever you turn, there is nothing ...which in itself is just one thing; all things 'become' relatively to something*" (157b). This is highly significant for it indicates that nothing is truly separate from something else. As nothing is, in itself, something, everything is interconnected. Our perception of the world is only due to the relative differences existing within the Aether. This is why Chrysippus wrote that the Aether is a principle of cohesion and is why Alexander wrote that Air is cold Aether and Water is dense Aether. It is also why it is considered the ruling principle.

As stated above, our perception of the world is constituted through differences, created and bound by the Aether. All things are relative and therefore connected through a common bond. In terms of its relationship to Phi, Plato states in his *Timaeus* that "*the best bond is one that really and truly makes a unity of itself together with the things bonded by it, and this in the nature of things is best accomplished by proportion*" (31c). What is significant is that although all continuous proportions form unity through equivalency, the Aether is generated by two ontological principles. These are the One/Monad and the Undefined/Indefinite Dyad. The only continuous proportion that consists of two terms is the proportion Phi, expressed in the beginning of Chapter 02. Phi is unique because it is both One, infinite and never repeating, of which I have attempted to illustrate this in Plate **4-I**. A direct correlation is therefore found between Phi and the Aether. It also supports why the Parthenon's proportions conform to Phi, since it is dedicated to Athena who has power over the Aether. As indicated previously in this chapter, it is also supported through the correlation between Phi and the Aether by the Dodecahedron.

EXPRESSION OVER SYMBOLISM

The Pythagorean and Platonic worldview suggests the occurrence of Phi within the proportions of the Parthenon is likely to be symbolic. Phi is considered to reflect the Aether, the principle of cohesion and harmony. Phi and the Aether are responsible for enabling space and unity to exist simultaneously through proportional equivalencies. What is significant in terms of architecture is that, without prior knowledge or teachings, the symbolic nature of Phi is incomprehensible. It is therefore inappropriate for the architecture of the Welcome Plaza to simply infuse the ratio into its proportions. This is enforced by the fact there is little evidence to support the notion that it contains aesthetically superior qualities and that it is impractical to utilise as it is incommensurable, as indicated in Chapter 2. It is therefore preferable for the design of the Welcome Plaza to be based on what the Phi ratio attempts to communicate, to be based upon the principles of the Aether, rather than simply utilising the ratio itself.

CHAPTER 5

**BRIEF AND
DESIGN
METHODOLOGY**

VISION

Wellington Zoo believes in a sustainable co-existence of wildlife and people. Wellington Zoo envisions for its future, *‘a seamless environment of animals, plants and people where learning is effortless, and advocacy for nature is paramount’* (Wellington Zoo Trust, 2004). To achieve its vision, the Zoo is currently undergoing development as part of its 10 year Zoo Capital Programme (ZCP). Wellington City Council has committed \$15.6M towards funding the upgrades and developments, with the Zoo attempting to raise another \$5M through donations. The overall ZCP development plan can be seen in Plate **5-1**. The programme is roughly half-way complete, of which the first two major projects of the ZCP, the ‘Wild Theatre’ and the ‘The Nest’ animal hospital, opened in late 2007. In 2008, the African Savannah project was completed and currently the ‘Meet the Locals’ project, which focuses on New Zealand’s natural landscape and ecosystems, is underway. This is to be followed by the ‘Hub’ dining pavilion, positioned near the centre of the zoo. The focus for this thesis is the ‘Welcome Plaza’ as it is the gateway into the Zoo. The Welcome Plaza is the first image visitors will be greeted with, as they approach the Zoo. It is of central importance that this image correlates with their broader vision and demonstrates how the people, wildlife and nature can harmoniously co-exist.

Wellington Zoo’s entrance faces north towards Newtown, on 200 Daniell Street [Plate 1-1]. The site is located in Wellington’s Inner Town Belt [zoned as “Open Space C”] which has historic, social and cultural significance (Wellington City Council, 2010). The policy surrounding the Inner Town belt has two key points:

To maintain, protect and enhance the open spaces of Wellington City.

To maintain and enhance natural features, including landscapes and ecosystems, that contributes to Wellington’s natural environment.

The council’s policy to protect and enhance the natural environment correlates with the Zoo’s belief and vision for the future, yet the ZCP entails development and intensification. The current entrance includes a café, shop, ticketing booth, classroom, offices and toilets, all of which need to be increased in size to cope with projected visitor numbers. The new Welcome Plaza must also incorporate a new discovery centre. This form of development echoes the problems discussed in the introductory chapter of this thesis, whereby human requirements displace natural habitats. A mode of development needs to be found that not only supports pragmatic development requirements, but also enhances the environment and its ecological value. To explore how this can be achieved, the previous investigation of Phi and its correlation with the Aether will be the principle driving force of the Welcome Plaza’s architecture. The architectural form will determine whether the principles of Phi, and its relation to the Aether, can be used as a design mechanism to generate architecture that is more harmonious with nature.

PRAGMATIC REQUIREMENTS

A number of problems exist within the current entrance that illustrate the need for the new 'Welcome Plaza'. The most pressing issue concerns public circulation through the complex. At present, the gradient of the main path directly past the complex is steeper than what the building code allows. This has significant design implications, as the entire site is sloped. The only flat ground is under the current buildings footprint. This means the path needs to be substantially extended in order to reduce its gradient. Stairs are not suitable due to accessibility issues for those with wheelchairs, and having both stairs and a ramp to the side is not acceptable due to space limitations. The most significant obstruction to movement through the current entrance is due to the close proximity of the ticket desk to the entrance door. The problem is obvious when small groups enter together and it becomes chaotic with large classes of students. The problem is compounded due to the placement of toilets along the entranceway, where parents frequently leave their prams. It is therefore important that the Welcome Plaza enables efficient public circulation.

During the design process there are numerous other factors that need to be considered. As indicated earlier, each zone – the café, shop, ticketing booth, classroom, offices and toilets – all need to be increased in size to cope with projected visitor numbers. The present shop is already cramped and cluttered, which is emphasized by its location next to the ticket-sales. The new shop needs to be roughly 50% larger and a clear distinction is required between the shop counter and the ticket-sales desk. The interior of the current café is sufficiently large inside, however it currently lacks a proper outdoor seating area. Both the café and shop also need to be visually prominent to draw the customers' attention, as they provide a vital stream of revenue for offsetting the Zoo's operating costs. In addition to the current classroom, a new discovery centre needs to be built to provide a suitable learning environment for school and activity groups. The discovery centre must also double as a place to stay during zoo sleepovers. All these requirements need to be met in order for the zoo to function adequately. However, during the design phase these pragmatic requirements must not be prioritised over the environmental responsibility to maintain and enhance the sites natural features and ecosystems.

OVERVIEW

To achieve the Zoo's vision and determine whether the principle of Phi can help generate architecture that is harmonious with nature, a design methodology is to be formulated based upon the investigation of Phi in the preceding chapters. As indicated in the introduction to this thesis, the Phi ratio is found in nature, with speculations suggesting that it is fundamental to nature, that it has divine characteristics and that it is aesthetically pleasing. I had therefore perceived the ratio Phi as a potential means to generate the architectural form of the Welcome Plaza in a way that is both harmonic, and symbiotic, with nature. The second chapter found that, although the Phi ratio was thought to have been used in many architectural buildings, interpretations were often unsubstantiated. There was also little evidence to support the notion that the ratio is aesthetically pleasing, with its divine qualities appearing to be a rather loose

association with religious beliefs.

To understand the significance of Phi, and why it was used in architecture, Chapter 03 investigated Islamic architecture alongside their philosophies. This chapter found evidence to suggest their architecture is symbolic of ‘unity in multiplicity’ and other correlated principles. Through the treatise of al-Kindi, a connection between Phi, the Dodecahedron and ‘Celestial Sphere’ was also apparent, however its role within the greater Islamic worldview was incoherent. As his treatise was essentially Neo-Platonic, the following chapter assessed the Ancient Greek Parthenon alongside Pythagorean and Platonic philosophies. The Goddess Athena, of which the Parthenon is dedicated, was found to represent power over the Aether, with the Aether expressing qualities similar to Al-Kindi’s ‘Celestial Sphere’. The Aether correlates with the ratio Phi as their conception of reality is formed through two ontological principles, the One and the Indefinite Dyad. These two principles require Phi in order to form a continuous proportion that generates difference whilst remaining self-similar or ‘One’. However, as the symbolic nature of Phi cannot be understood in architecture without prior knowledge, the last chapter determined the architecture of the Welcome Plaza should be generated according to what it symbolises. The design methodology of the Welcome Plaza is therefore based on the principles of the Aether, which is expanded upon below.

AETHER AND ELECTROMAGNETISM

In Chapter 04 the principles of the Aether were expressed. The Aether was perceived as a continuous medium generated by two ontological principles - the ‘One’ and the ‘Indefinite Dyad’. Phi was deemed to express the Aether for it is the only proportion capable of creating a continuous proportion through two principles. Aether was considered the principle of cohesion, connecting and unifying the physical world through the proportion. It was perceived as the underlying basis of nature and reality. The elements and various forms of our world were considered as relative differences existing as intricate patterns modularity of within the medium. More significantly however, is the fact the Aether is not confined to ancient Greek beliefs. The Aether has had a profound influence on our modern scientific understanding of nature.

Specifically, the Aether has been critical in explaining the medium in which the waves of electromagnetic energy propagate. This concept dates back to the 17th century theories of Descartes and has continued to play a significant role in modern theories (Whittaker, 1910). For James C. Maxwell both light and electromagnetic radiation were viewed as disturbances within an all-pervasive medium, the aether (Sklar, 1977, p. 195). This electromagnetic aether can be regarded as the only actuality with matter existing as a special manifestation of the aether’s condition (Livens, 1918, p. 549). It is often stated that the 1887, Michelson – Morley experiment ended the notion of electromagnetic waves propagating in Aether, however, this is not the case. In regard to General Relativity, our modern physical understanding of gravitation in an address given at the University of Leiden in 1920, Einstein (1922) states:

According to the general theory of relativity space without aether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. (p. 23)

His conception of the Aether was a medium that determines mechanical and electromagnetic events whilst itself being devoid of any mechanical and kinematical qualities. For Einstein the Aether was “*exclusively the seat of electromagnetic fields*” (Einstein, 1922, p. 10). As electromagnetism is also known to be responsible for practically all phenomena encountered in daily life, the Aether, within both our modern and the ancient Greek conception of it, has a fundamental connection to nature and reality. As such, the laws and principles of the electromagnetic Aether are used as the design mechanism for the Welcome Plaza.

**ELECTROMAGNETIC DESIGN
METHODOLOGY**

The Aether is the pervasive, continuous medium of electromagnetic fields. It is knowable not through itself but through the differences that exist within it. The electromagnetic aether has a twofold nature, composed of both electric and magnetic forces which are intrinsically related. One cannot exist irrespective of the other. To generate the architecture of the Welcome Plaza, I have taken the site indicated by the red rectangle in Plate 5-1, and treated it as a cross-section through an electromagnetic field. As the electromagnetic aether is continuous, the entire site is treated as a whole rather than sub dividing the site into discrete components and zones, forcing a correlation between the human and ecological requirements. The electromagnetic field that has been generated over the Welcome Plaza’s site is a single field that extends infinitely, connecting all elements. To differentiate the field, and force it into correspondence with the natural site and the zoo’s functional requirements, the field is based on ten electric currents. These electric currents travel vertically into and through the site, as indicated in Plate 5-2 and 5-6. I have used 10 currents so that the field is an appropriate scale for the size of the building. The number is based upon the number of main zones I deemed significant to meet the functional requirements of the Welcome Plaza, outlined in Figure 5-1.

FIGURE **5-1**
WELCOME PLAZA
ZONES

- Ticket Centre** Gathering Point
- Shop** Otter Exhibit
- Cafe** Outside Seating
- Offices** Discovery Centre
- Classroom** Outdoor Classroom

The position and voltage of each electric current is based on the resulting rotational intensity map, indicated in Plate 5-3. The predominant focus during the process of positioning the currents was to ensure the movement, inferred through the rotational intensity map, would be sufficient through the building. This is because circulation was deemed to be one of the most significant problems in the current entrance. Plate 5-4 and 5-5 indicate the corresponding electric potential and magnetic fields of the electric currents. Each diagram was calculated using the program, Comsol Multiphysics ensuring that the diagrams are an accurate representation of the effects and laws of electromagnetism. Each diagram is however only an expression of the different properties within the same field. Furthermore, as there is only a single continuous field, it is not possible for there to be discordant elements. Each part of the field is harmoniously interconnected with the rest of the field. Difference is only indicated through periodicity and patterns within it. By using this electromagnetic field to derive the geometric form of the Welcome Plaza's architecture, it will ensure each component is harmoniously interrelated with the rest of the building. This is because the electromagnetic Aether is all pervading and continuous. Nothing is considered separate from it, therefore forcing correspondence and harmony within the Welcome Plaza's constituent parts.

UPWARD CURRENT

ROTATIONAL INTENSITY

PLATE 5-4

ELECTRIC POTENTIAL

PLATE **5-5**

MAGNETIC FIELD

DOWNWARD CURRENT

CHAPTER 6

DESIGN

AND DISCUSSION

Trees/Bushes
Trees/Bushes
Road to Carparking

Green Roof over
Meeting Room

Outdoor Classroom
Green Roof over
Meeting Room
Skylight

Corten Framing FRAMING
Green Roof over
Discovery Centre
Main Entrance

Corten Edging
Green Roof over
Learning Centre

Concrete Path

Green Roof over Shop
Otter Exhibit
Otter Exhibit
Tunnel

Underground Passage
Shop Skylight

Wind Generator
Tunnel
Waterfall

Shop Stairs
Concrete Path

Green Roof over Toilets
Manchester Street

Trees/Bushes
Trees/Bushes

Café Skylight

Existing Pond

Café Seating

Green Roof over Café
Gibbon Enclosure

Perforated Barrier

Secondary Entrance
Corten Pergola

Trees/Bushes

PLATE 6-1

ROOF PLAN

1:300

**Toilet/Shower
Meeting Room**

**Outdoor Classroom
Office
Garden**

**Discovery Centre
Main Entrance**

**Kitchen
Indoor Otter Exhibit
Staff Room**

**Learning Centre
Discovery Entry
Underground Passage
Counter**

**Shop Entry 01
Shop
Ticket Booth**

**Shop Entry 02
Wind Generator
Gate**

Female Toilets

Male Toilets

Disabled Toilets

Caf é Entry

Counter

**Outdoor Seating
Kitchen
Cafe
Gibbon Enclosure**

**Secondary Entrance
Storage**

NORTH AERIAL PERSPECTIVE

SOUTH/EAST AERIAL PERSPECTIVE

HOMOGENEOUS ENVIRONMENT, DIFFERENTIATED ARCHITECTURE

To explore how Wellington Zoo's Welcome Plaza can be designed in harmony with its surrounding natural environment, its architecture is based upon the Aether, and its correlated electromagnetic field. Its architectural form does not conform to the proportion Phi. Phi is allegorical of the Aether, due to its mathematical significance. It is a means of communication, whereby the message is the key factor. Phi communicates the qualities of the Aether, which is believed to be fundamental to nature in both ancient and modern scientific theories. Due to its connection with nature, the Aether, which Phi symbolises, offers a means to push the Welcome Plaza's architecture towards a form that is harmonious with nature. The electromagnetic Aether can account for virtually every phenomena of daily life, however its laws and principles are permanent. To determine whether the Aether can help resolve the conflict of architectural development and ecological health, to help generate architecture that is harmonious with nature, the design must adhere to its laws and principles.

For development to be ecologically sustainable, architecture needs to be harmonious and symbiotic with nature. The term harmonious means to exhibit equivalence or correspondence among the constituents of an entity, or between different entities. Similarly, the term symbiotic refers to a mutually beneficial relationship between two dissimilar organisms, which live alongside one another. As the Aether was considered the principle of cohesion in Ancient Greece, linking distinct parts and components through proportional equivalencies, it has a close association to these terms. In modern theories, it is conceived as a single, continuous medium of electromagnetic energy. Everything is intricately linked and unified. As expressed in the Plates of Chapter 05, the design of the Welcome Plaza is based on the electromagnetic Aether. Each diagram indicates various interconnected aspects of the same field. Within these diagrams, predominantly Plate **5-4** & **5-5** the contour lines are imposed upon the sites plan. This is because the Aether is said to be all pervading, with nothing existing in separation from it. The Aether is the medium in which the other forms and elements are derived. As such, the existing site and surrounding environment is considered to exist within the field. I have perceived the existing site and surrounding environment, before development, to be in a state of equilibrium, to exist within a homogenous electromagnetic field.

By perceiving the existing site as a homogenous electromagnetic field, the existing environment becomes the medium for the Welcome Plaza to emerge. Is not possible to impose a separate form upon the site, for nothing exists outside the Aether. Only through the differentiation of what already exists can the Welcome Plaza be generated. As a design methodology, the electromagnetic Aether, when used in a way that reflects its all-encompassing qualities, forces the architectural form into harmony with its surrounding environment through integration. As the surrounding environment of the Welcome Plaza is both natural and fabricated, so too is the architectural form of the Welcome Plaza. It would not have been harmonious if its architecture were entirely organic, or entirely artificial, for it would indicate something different to the medium that already exists.

ARCHITECTURAL IMPLICATIONS OF THE BOUNDARY CONDITION

The Welcome Plaza's architectural form is derived through the homogenous field and natural environment. This field is warped by the position and intensities of the imposed vertical currents, creating points of contraction and zones of expansion. The electric currents differentiate and polarise the field, forming zones delineated by gradients and feathering intensities. It can be interpreted as a fluctuation between mass and void, a transitional state of fluid boundaries. This has influenced the Welcome Plaza's architecture by pushing it into an undulating geometric form. This is most evident through its large green-roof that flows into the surrounding environment. Every element gradually emerges from, and decays into, its surroundings, for the electromagnetic field is continuous. As such, there is no immediate distinction between the environment and the buildings form, although the densities of the natural and constructed components waver based upon their locality within the field. The natural ecosystem is densest at the buildings perimeter and the outskirts of the site, away from human movement and interaction. Closer to the more active areas, the ecosystems density tapers down to low-lying plants and paths. Because this transition is gradual, continuity is formed between the two extremes, making the natural and public environments harmonious.

The design of the Welcome Plaza is not a direct representation of the electromagnetic Aether, but is indicated through the building's geometry. The building's elements reflect the influence of the electromagnetic Aether and the way motion would occur within the field. To use the Ancient Greek worldview as an analogy, the motion of the planets is due to the Aether, however the Aether itself is only knowable by the way the planet's move. In the same regard, the Welcome Plaza's architecture does not reflect the electromagnetic Aether, but it determines the behaviour of elements situated within it. The natural motion within the electromagnetic Aether is expressed by the diametrically opposed electric and magnetic qualities of the field. This form of natural motion is indicated through the Welcome Plaza's materiality. In-situ concrete and corten steel are the two principle materials, chosen for their complementary attributes of compressive and tensile strength. The concrete components align with the magnetic contour lines, whereas the corten steel expresses the curvature of the electric contour lines. The overlays of Plate **6-1** and **6-2** express how the geometry of Welcome Plaza conforms to these strict topographies. Every wall, window and component within the complex corresponds to the same underlying field creating harmony between the individual, constituent components. Every aspect of the building is unique, yet harmoniously linked to every other component within the project. Continuity is present, not within the individual components, but through the underlying field that they are based upon.

WELCOME PLAZA PLAN

The planning of the Welcome Plaza is based predominantly around public circulation due the site's topography. As indicated in Chapter 05, one of the most critical design requirements of the Welcome Plaza was to alleviate the circulatory problems of the present entrance. The steepness of the main path leading into the Zoo was the principle problem, alongside proximity

and spatial issues within the complex. To ensure the Welcome Plaza was not subject to the same problems, the underlying electromagnetic field, upon which the plan of the Welcome Plaza is based, was determined through the rotational intensity diagram, indicated previously in Plate **5-3**. The rotational intensity diagram is indicative of rotational motion and was adjusted by the position of the 10 electric currents. This resulted in a field that naturally led to the development of two arterial routes, beginning at the western and eastern sides of the complex's northern frontage (Plate **6-7**). The western route is located next to the pedestrian crossing, and is close to the bus stop as well as the car park located to the west of the zoo. To overcome the existing gradient issues of the main path, the western arterial route that leads into the Zoo is a uniform slope, beginning and ending at the opposite ends of the site. The eastern route caters for those walking from the direction of Melrose. These two arterial routes connect and lead through the main gateway into the Zoo. The entrance to the shop, café, toilets, staffroom and ticket sales desk are located where these two arterial routes meet, with the entrance to the discovery and learning centre located behind the gateway.

The shop and the café are most prominent when viewed along the two arterial routes. Visibility of the shop is enhanced through a second entrance located at ground level under a large green roof, visible in Plate **6-5**. This second entrance is aimed to entice visitors into the shop and ease circulation through it. The visibility of the café is enhanced by the outdoor seating area, partially visible behind the 'green' wall, shown in Plate **6-6**. The two components within the Welcome Plaza are visually prominent to generate a greater revenue stream to offset the Zoo's operating costs. Within the design, the ticket sales desk has been separated from the shop, located to the right of the main gateway. To further ease circulation through the building, an electronic turnstile has been implemented enabling visitors with pre-purchased tickets or permanent passes to walk unimpeded into the Zoo, avoiding those having to queue for tickets. Within the complex, an array of stairs and ramps enables the Welcome Plaza to conform to the site's existing topology and creates efficient circulation routes through the complex. The most significant of these is the ramp that leads down in-between the shop and learning centre, to the staff room. The staff room essentially acts as a central meeting room, a hub, connecting to the computer room, offices, conference room, staff kitchen and seating area. This hub has access to the shop in the north-west direction as well as the learning and discovery centres to the south. The discovery and learning centres are divided by an otter enclosure located within the complex's interior, which is also linked into a greater outdoor enclosure.

The curvilinear geometry of the Welcome Plaza's generated architectural form reflects the plan of the electromagnetic section, however within the vertical sections straight lines and right angles assert their presence (see Plate **6-9**, **6-10**). This is principally due to the pragmatic constraints of construction, and to limit the various other difficulties associated with surfaces that are curved in multiple planes. It is evident that the correlation between the Welcome Plaza and the electromagnetic field can be pushed further, however this was not deemed necessary to determine whether the electromagnetic Aether can help generate architecture that is

harmonious with nature. Using an electromagnetic field as the basis of the Welcome Plaza's architectural design also presented a number of challenges. By utilising a single underlying field, any minor change would affect the entire composition. Because each space is interrelated with the next, any change within the complex has a direct impact upon the adjacent space. This difficulty is compounded by the need for each component to conform to the natural motion that the electromagnetic field indicates. Simple changes became arduous tasks. It forced the design of single elements and components to be considered in relation to the complex as a whole.

INTEGRATION WITH NATURE

The Welcome Plaza's form is tempered by the continuous nature of the electromagnetic Aether. As corners and angles conflict with the field's natural motion, its form emerged as an undulating geometric weave, intertwining nature and architecture. With the physical world perceived as a single continuous spectrum of interconnected patterns and geometric proportions, it is the change and difference within the field that is significant. Sim van der Ryn's states that, we are not adapted to live in conditions uniform and constant, writing "*we are most alive when we experience the subtle cycles of difference within our surroundings*" (Ryn & Cowan, 2005, p. 66). This concept has been expressed within the Welcome Plaza, whereby the motion of light, the cycle of growth, and climate variations have all been emphasised. The holes in the structural walls emphasize the motion of light and shadow projected within the building. The cycles of nature is celebrated by the seasonal changes within the plants, which weave throughout the Welcome Plaza's structure. The large wind turbine emphasises the shifting wind conditions, whilst generating electricity. To further express motion within the natural environment, water is channelled from the nearby pond into the Otters enclosure. To mediate the transition between the inside and outside, the holes in the structural walls expand to form a structure similar to porticos. This is most prominent within the Café's outdoor seating area and surrounding the outdoor classroom, whereby secondary glass/polycarbonate sliding walls fully retract to create dynamic spaces, open to sunlight and fresh air.

Many people now live in cities where both ecological and technological processes are hidden from their everyday awareness. Streams are diverted through buried culverts, wetlands drained for firm foundations and forests felled for wood and housing developments. Through the daily experience of the built environment, it is possible to become accustomed to detachment from the natural world. Nature is increasingly rendered invisible. Through the electromagnetic design methodology, the Welcome Plaza is forced to be integrated with its surrounding environment. Its form obscured through its amalgamation with its surroundings, the natural environment becomes the most prominent aspect of its architecture. The site's ecology and the complex's form are balanced, neither prioritized nor emphasized. Its integration with the natural environment accentuates our perception of the lifecycles, patterns and the shifting motions of life.

The Welcome Plaza corresponds with the Zoo's vision, outlined in Chapter 05, of a *'seamless environment of animals, plants and people where learning is effortless, and advocacy for nature is paramount'* (Wellington Zoo Trust, 2004). Nature and our biological environments are the most powerful teachers we have. For learning to become effortless, an outdoor classroom is located adjacent to the discovery centre. This is driven by the idea that direct experiences of the natural environment surpass artificially enclosed learning spaces. This concept is boosted by having the outdoor Otter exhibit linked via a lower waterway to a smaller habitation within the building's interior. As the Otters exhibit is not confined to a single zone, it has become more interactive and integrated with the public environment. The Otters are able to freely swim through the complex creating playful and closer encounters with the people. By giving the Otters an option of living indoors or outdoors their environment is diversified with the additional advantage of enhancing the visitors' learning experience. This exemplifies how both wildlife and people can benefit and helps enforce Wellington Zoo's vision of an integrated environment of people, wildlife and nature. The Welcome Plaza infuses its architecture with the natural environment so they can become united and balanced.

REFLECTION

The introductory chapter expressed that many urban societies are denied access to natural environments, driven by capitalistic motives into environments that are increasingly divorced from their natural counterparts. With modern societies fundamental reliance upon economic growth, I asserted that development needed to become harmonious and symbiotic with nature for it to become ecologically sustainable. Fundamental change was considered imperative to reduce the irreversible ecological damage we, as a civilisation, are causing. The investigation of Phi set out to determine its relationship to nature and determine whether its principles could help generate architecture, specifically the development of Wellington Zoo's Welcome Plaza, is a way that is harmonious and symbiotic with nature. Through symbolism and mathematical correlations, Phi was considered indicative of the Aether, a historic and modern conception of an underlying medium of both nature and reality. The medium was perceived as the field of electromagnetic energy, of which its laws and principles formed the design methodology to generate the Welcome Plaza's architectural form.

The existing site was considered as a homogenous electromagnetic field, whereby the architecture of the Welcome Plaza reflected the disturbances and differentiations within it. The surrounding environment was not perceived as a medium to be created upon, but the medium to be created through. The architecture and the environment emerge and decay within one another through feathering gradients. It indicates that electromagnetism, as a design methodology, is well suited to environments, regardless of their locality. With the curvature and geometry of the Welcome Plaza form based upon the natural motion and topography of the same underlying field, every component is interrelated. It dissolves the disparity between

the environment and the Welcome Plaza as well as wildlife and people. By relating the design process to electromagnetism, neither the artificial nor the natural environment was prioritised. Forced alongside one another, they had to co-exist symbiotically. This relationship can be seen through the Welcome Plaza external paths, for there are no paths that directly lead from place to place. Strips of plants and concrete exist throughout the site, however the paths are formed by how the space is utilised. If the paths are not walked upon, they will become overgrown. Alternatively, the plants, bushes and organic growth will become worn away where there is significant foot traffic. The architecture adapts to its usage, in harmony with the environment.

The Welcome Plaza weaves together human and ecological requirements. It manages to meet the pragmatic requirements set out in Chapter 05 and presents an image aligned with the Zoo's vision of a sustainable co-existence between wildlife and people. It also meets the environmental requirements set forth in *WCC Urban Plan* to, maintain and enhance natural features, landscapes and ecosystems. It does so by creating an environment that brings people and nature closer together in a non-destructive manner. The development has increased the sites ecological health, and eased the discordance between nature and its architecture. As this was the criterion for evaluating the effectiveness of Phi, and therefore the Aether as a design methodology, it can be concluded that it can be utilised to help generate ecologically sustainable architecture. The principles of Phi - the Aether, can generate architecture that is more natural and fluid. As Phi, and the Aether and considered the foundational basis of nature, it can generate architecture that 'honors the complexity and diversity of life itself'.

NORTH/EAST ENTRANCE

NORTH/WEST ENTRANCE

PLATE **6-7**

SITE MOVEMENT

Discovery Centre Otter Enclosure Learning Centre Staff Pathway Counter Shop Shop Entry Underground Path Footpath

SECTION **A-A**

1:200

Outdoor Classroom Indoor Garden Meeting Point Office Staff Kitchen Shop Main Entrance Footpath Road

SECTION **B-B**

1:200

Secondary Entrance Outdoor Cafe Seating Indoor Cafe Seating Skylight Counter Food Display

SECTION **C-C**

NORTH/SOUTH SECTIONS

1:100

CHAPTER 7

CONCLUSION

INSIGHTS, FINDINGS AND FURTHER STUDIES

The aim of this thesis was to determine whether the principles ascribed to Phi, could help generate Wellington Zoo's Welcome Plaza in harmony with nature. Through the initial background investigation, a correlation between Phi and organic growth was apparent, although it is unknown exactly why. Phi's aesthetically superior qualities were considered unfounded, with its divine qualities reducible to mathematical correlations. Within Islamic architecture, I uncovered a connection between the mosque of Ibn Tulun and Phi, which could be interpreted through the philosophical constructs present at the time. This interpretation set the basis for the analysis of the Greek Parthenon (Temple of Athena the Virgin). My analysis indicated that its proportions do conform to Phi, whilst uncovering the need to include the now dislodged Acroteriums to 'frame' the building. Through the texts of Diogenes Laërtius and Sallustius, Athena was found to refer to the power of their supreme Deity over the Aether. It is a connection not widely known, neither today or at the time, due the secretive nature of their religious doctrines. The Aether is attributed to the dodecahedron, of which the proportion Phi is innate. As the Aether is the principle of cohesion produced by two ontological principles, Phi was also found to relate directly to the Aether. This is because Phi is the only continuous proportion able to be formed through two principles, substantiating why the Parthenon could have been proportioned according to Phi. The investigation determined why Phi was considered significant, and its relation to nature.

To express the significance of Phi, the Welcome Plaza's architectural form was generated by the Aether. This meant the Welcome Plaza could not be 'read' in the traditional sense, however it enabled its architectural form to express how it connects to nature. This is because the Aether was considered the basis of nature in both ancient and modern theories. The Aether was thought of as the medium, or rather the field, in which electromagnetic energy resides. As the Aether is 'all-encompassing' the surrounding site, and environment, could not be considered independent of it. This forced the Welcome Plaza to emerge from the site, by polarising and differentiating its field, rather than being placed upon the site. Formed through the existing fabric of the surrounding environment, the natural and artificial elements emerge and decay from one another. This effectively reduces the disparity between architecture and nature. This also reduced its architectural prominence, expressing a form indicative of a transitional state rather than a well-defined geometric form. Due to the cohesive quality of the Aether, the various components of the Welcome Plaza are harmonious and unified due to the singular underlying field.

As a design mechanism, the significance of Phi, the Aether, forces development to be considered holistically, to emerge from its surroundings, and to be constrained by what the environment allows, in order to stay balanced and harmonious. It has helped push the development of Wellington Zoo's Welcome Plaza towards an architectural form that is harmonious with its surroundings. It represents a form of engagement and partnership with nature. With the rate in which our natural environments are deteriorating, investigating ways architecture and nature can co-exist is imperative.

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