Unravelling The Weave: An Analysis Of Architectural Metaphors In Nonlinear Dynamics

R. J. Moore and M. J. Ostwald

INTRODUCTION

The metaphoric and metonymic presence of architecture within diverse disciplines including philosophy, psychology and literature has recently been traced. Such studies represent a strategic conceptual shift; a shift from theory as accessory/architecture to architecture as accessory/theory.

Throughout the last twenty years there been an increased desire in architecture for theoretical positions which are derived from nonlinear mathematical and geometrical models. While such theories have been applied in architecture, through different theoretical mechanisms, there has been a complete lack of recognition of the architectural metaphors which have been used by mathematicians working in nonlinearity to describe their ideas. In this context the position of architecture has been subverted until it becomes accessory/theory. It is this reversal of usage, in the field of nonlinear mathematics, which is the focus of this paper.

NONLINEARITY AND ARCHITECTURE

For more than ten years architectural designers and theorists have appropriated geometric and philosophical ideas from the fledgling discipline of Nonlinear Dynamics. Better known in populist, and less accurate, terminology as Chaos Theory, Nonlinear Dynamics has become a distorted and fragmented theme appearing intermittently in architectural theory. From its early adoption in design (linked with post-structuralist philosophy) as a means of questioning origins, to its more recent (mis)use as a metaphorical licence for fragmentation of the architectonic object, nonlinear dynamics has been opportunistically utilised by a growing number of architectural designers.

While the historic appropriation of philosophy and mathematics by architects has been recorded widely the more recent connections between Nonlinear Dynamics and architecture have been largely un-noted. Although conscious traces of nonlinear theory may be unearthed in architecture as early as 1983, attempts to uncover the exact manner in which nonlinearity has been appropriated are more difficult.[1] The vestiginous traces of nonlinearity may be seen intertwined with various diverse strands of theory in architecture. Derrida, Heraclitus, Freud and Deleuze have all been freely commingled within the fabric of architectural theory with the work of the nonlinear mathematicians Barnsley, Mandelbrot, Prigogine, Peitgen, Richter, Schroeder and the journalist Gleick. In addition, the vast differences between Chaos Theory (Mandelbrot et al) and Catastrophic Theory (Thom et al) have often been ignored entirely by architects freely appropriating from both fields. While connections envisaged between the writings of Deleuze[2] and nonlinearity may be traced through the constructions of Mandelbrot, and have been identified belatedly by Massumi,[3] the more commonly opened links between Derrida and nonlinearity are complex and as yet this path has not been uncovered with any degree of success.[4] Elsewhere in architecture, nonlinearity has been used as a method of freezing the conceptual design sketch;[5] a reference to the unpredictable nature of cities;[6] and as a form of communion between nature, the city and the machine.[7] In several cases the iconography of nonlinear dynamics has been used as an architectonic generator while other unrelated strands of theory have been drawn in to support the aims of the designer.[8] After a decade of complex and opportunistic appropriations from nonlinear dynamics it is difficult to trace its passage into the fabric of architectural theory. Without some knowledge of the first connections between architecture and nonlinearity it may indeed be impossible to separate the strands of theory with any accuracy.

Architecture has not been alone in its appropriations from nonlinearity; yet other disciplines have habitually retained the purity of the original mathematical structures leaving them un-muddied with other areas of theory. Quixotically, in art,[9] design,[10] music,[11] drama[12] and literature[13] largely unadulterated versions of nonlinear dynamics have been used as a means of studying spatial and textual forms. In contrast nonlinearity has been more widely, more rapidly, and less rigorously, subsumed into architecture. The problem then is that while it may be possible to tease the occurrences of nonlinearity from one of these other disciplines (and still be able to understand the use to which it has been put) in architecture the weave is too elaborate. Any attempt to unravel these strands of theory, to tease out the warp from the weft, will result in the breakdown of the structure of the weave. Moreover the manner in which nonlinearity has been used is not constant. This 'elaborate weave' of theory is, in part, constructed from strands of nonlinearity yet at other times nonlinearity is the tool for teasing apart other materials prior to being woven. At such times nonlinearity seems more the loom than the fibre as it becomes a device for troping the weave - an element which allows the breakdown or construction of new fabrics but which is itself not part of the finished material.[14] Mark Wigley resurrected the conceit of weaving as a means of explaining the difficulty in tracing the impact of theory (in his case Derridean theory) on architecture.

Because there is no safe place to begin, one can only enter this ongoing economy and begin to trace its convoluted geometry. This can be done here by locating those points in each discourse at which the others are made thematic, however fleetingly or partially - points where the other comes to the surface. The lines of argument that surface there are threads that can be forcefully pulled to see where gaps appear elsewhere in the discourse, marking covert levels of entangled relationships that bind superficially discrete areas. These hidden layers are not simply below the surface but are within the surface itself, knotted together to form its texture.[15]

As conceit, the image of the weave is both useful and commonplace in architectural theory. In the context of this paper it acts as an allegory or supplement; providing a model in which theory and architecture may be examined. One of the difficulties in analysing the manner in which an aspect of mathematical theory has been appropriated by architecture is that by removing the fragments of mathematics from their body of architectural theory, with which they are intertwined, they loose their new context as well as their original. However a similar problem exists if they are traced *in situ* as it is difficult to determine how exactly the mathematical theory has been used without some degree of translation - an act which is itself both architectural and problematic.

Catherine Ingraham and Mark Wigley have each, in different ways, provided strategies for overcoming these potential problems in dividing the weave. Ingraham's analysis of lines and linearity has relied upon the fine scale consideration of homologous threads as a means of working at multiple scales simultaneously.[16] Wigley, in contrast, turned away from the architectural fabric itself in search of the right tools for the task. In Wigley's *The Architecture of Deconstruction: Derrida's Haunt*, he considered the role of architecture in philosophy as a reciprocal to the role of philosophy in architecture. The tangled skein was thus unravelled prior to the act of weaving allowing the strands of theory to be more clearly differentiated. The distinction here is between theory becoming accessory to architecture (as nonlinearity has become) to architecture becoming accessory to theory. To extend the conceit of weaving; the fabric of nonlinearity contains a series of threads which are recognisably architectural - just as does the fabric/theory of Heideggar and Derrida. It is thus, to paraphrase Wigley's argument, necessary to step back, to retrace those steps undertaken by philosophers and mathematicians in architecture prior to considering architecture's appropriation of these disciplines. Nonlinearity was not merely a belated grab by architecture for a new degree of scientific legitimacy; the relationship is more complex. Architecture was appropriated by nonlinear dynamics more than ten years prior; adopted by mathematicians to fulfil certain roles in the production of theory, the roles that have always been architectural. Wigley maintains that the seminal texts need to be revisited in order to "locate the architecture that is written into them," that same architecture which structures the possibility of such texts existing and which eventually provides the mechanism for architecture's own reciprocal appropriation of the discipline.[17]

The ignorant and creative translations which have been evidenced in architectural appropriations of nonlinearity may be excised, temporarily, from the problem of analysis through the change in focus from theory as accessory/architecture to architecture as accessory/theory. Just as architecture has often been described through the conceit of weaving so too are other disciplines described through the conceit of architecture.[18] The act of unravelling the weave, like the act of constructing the building, presupposes a systematic and grounded sequence of events. Philosophy and mathematics, disciplines loath to consider unstructured or unstable sequences, have thus sought to structure their metaphysics about the presumed authority vested in the architect and the act of construction. Such architectural traces in metaphysics are many and complex.

THEORY IN ARCHITECTURE / ARCHITECTURE IN THEORY

In philosophy, literature and mathematics, architectural metaphors appear regularly as a form of sub-text providing both a grounding for reason and authority for the user. For example, the opening argument in Rousseau's utopian text, *The People Of The Ideal Commonwealth And Their Expression Of Their General Will* commences with;

As the architect, before he begins to raise an edifice, examines into the ground where he is to lay the foundation, that he may be able to judge whether it will bear the weight of the superstructure; so the prudent legislator does not begin by making a digest of salutary laws, but examines first whether the people for whom such laws are designed, are capable of supporting them.[19]

In this example, of a typical appropriation from architecture, the logic of the construction process is shifted metaphorically to the creation of laws to govern an ideal state. Similarly the authority of the architect as creator is paralleled with the power of the legislator to rule; in both cases the emphasis is on prudence. The construction of a utopian society, by a figure possessing tacit power, is thus described through the conceit of architecture. It is this symbiotic relationship between the realm of theory and of architecture which is the structure of the metaphorical weave. Similarly it is the relationship between architecture and theory which must be further considered prior to unravelling the weave or else the very tools of analysis may be found inappropriate to the task.

The role of architecture in theory is as complex as the role of theory in architecture. This interplay of readings led Jeffrey Kipnis, in *Drawing A Conclusion*, to describe a specific distinction between the realms of architecture and theory; a distinction which he outlines as echoing "the Cartesian separation of mind (mental) and body (physical)."[20] Such a separation, Kipnis suggests, should provide a neutral reading of the relationship between two concepts. The idea of a cartesian separation implies a non-partisan form of differentiation between twin concepts. Cartesian coordinate systems with 'X' and 'Y' coordinates or vertical and horizontal dimensions are intended to be non-preferential yet, many such combinations acquire a form of binary, opposing relationship. These implied hierarchies, which form in binary opposites, seem to overtly privilege one twin in the cartesian system over the other. In the binary relationship that is architecture and theory, Kipnis argues that, it has been taken for granted that theory dominates architecture; yet, at the same time, the constructed, authored, hegemonic and thus, architectural, character of theory has been largely neglected. Kipnis uses this privileging as the starting point for his contention that rather than either one or other aspect of the pairing being superior, that both act within a matrix or web or metaphorical readings. He concludes with the idea that the work of theory is as much architecture as architecture is the work of theory; attempts to separate one from the other are complex and ultimately limiting. Architecture in his working definition is linked to theory just as theory is linked to architecture.

By 1989 the interdependency of architecture and theory had been recognised and had become the subject of study in a number of fields. Hollier's seminal research into the writings of Georges Bataille, *Against Architecture*, contains one of the most important early critiques of the relationship between architecture and theory.[21] Notably Hollier is concerned not with architectural theory but with the idea that theoretical constructs are works of architecture. The distinction here is identical to the one raised by Kipnis that, architecture is theory and that theory is architecture. John Rajchman described Hollier's book as "one of the starting points for the contemporary discussion of the metaphor of architecture in other domains."[22] *Against Architecture* focussed on the manner in which architectural metaphors were seen to dominate discourse, primarily, in the disciplines of philosophy and literature. Bernard Tschumi suggests that this interplay of metaphors has been constant throughout history, despite a lack of recognition of the symbiotic relationship;

Philosophy once imported its metaphors (foundations, structure, etc.) from architecture. In turn, architecture imported concepts from philosophy (from positivism to post-structuralism) and also exported polemics (postmodernism).[23]

While architecture has long accepted this condition, it has been belatedly left to Jacques Derrida to admit, as a philosopher, that his discipline is replete with metonymy; with metaphors both architectural and spatial.

As soon as we speak, so to speak, we are caught in what traditionally are called spatial metaphors, architectural metaphors. Philosophy is full of them: foundations, systems, architectonics, which in philosophy means the art of systems, but even in more everyday language the spatial metaphors are irreducible, unavoidable and anything but accidental.[24]

This overdue understanding of the clandestine relationship between architecture and theory has influenced both discourse and practice in architecture as well as in philosophy and literary critique. As Catherine Ingraham records; architecture, geometry, philosophy and mathematics are concerned with questions of structure, space, stability, order, ethics and propriety. Yet architecture is still primarily subservient to theory;

Architecture has argued, for example, that philosophy has been staggeringly indifferent to the tacit architectures of its ideas. Philosophy traditionally has asked these architectures to stabilize and root it.[25]

The dual role of theory in architecture and architecture in theory is thus complicated through the lack of one half of Kipnis' Cartesian system. While architecture is recognisably theoretical, theory has only belatedly been seen as architectural. Sylvia Agacinsk supports this viewpoint in noting that by separating architecture from philosophy, the very strength of philosophy that architecture seeks to borrow is lost. Thus the benefits of the Cartesian duality (architecture and theory) are negated in separation.

Yet if one must extract architecture from metaphysics, it is mainly because the latter has projected on the art of building its own frames of rational control over reality ... ancient philosophers made architecture an example of work produced according to necessary principles. Whether they come from God, nature or reason, such principles ensure the architect's mastery and authority as well as architecture's autonomy.[26]

Agacinsk's reading relies not only upon the implied order within architecture but also with the implicit authority given to the role of the architect/builder throughout western metaphysics. In the works of Aristotle the architect or builder is the leader; "his knowledge of the foundations and principles (*arkai*) enables him to give orders."[27] Agacinsk's understanding of the power relationship latent in the use of architecture in philosophy recalls Ingraham's claim that philosophy's reliance on architecture has been largely unconsidered until recently. Any power relationship suggests that the idealised Cartesian dualism has been broken down and that a form of hierarchy has arisen - a hierarchy of theory as superior to architecture. A subset of such a hierarchy is the idea that the architect is superior to the materials being shaped. Nevertheless, even if it was assumed, in philosophy, that the architect/builder is superior to the materials utilised in the construction process there is a similarly tacit assumption that the philosopher may masquerade as the architect when it suits them and then leave that role behind once the edifice has been erected on solid grounds. Ingraham summarises this contention, that the appropriations made by both disciplines are merely convenient, as follows;

I take it for granted that philosophical work is at work in architecture and that architectural work is at work in philosophy. These two disciplines will continue to use each other opportunistically, as they have throughout their histories.[28]

It is the disposable nature of the architectural metaphor which Ingraham uses to reverse Agacinsk's reading of power, architecture and philosophy. Ingraham infers that some form of exchange must take place between theory and architecture. This exchange takes place at the moment when architecture is "forced to stand still for philosophy (or any other 'discipline' for that matter) - the moment when architecture is disciplined."[29] Whether architecture is linked with philosophy literature or mathematics, there is a point at which transference occurs and it is this moment when one discipline attempts to gain superiority and thereby break Kipnis' idealised Cartesian relationship. However it is here that Ingraham and Agacinsk differ. While Agacinsk maintains that the architect is temporally given ascendancy, and is thus in a position of power, Ingraham follows this with the understanding that the architectural edifice is static only at that moment when it has been forced to remain still for the purposes of philosophy.

Insofar as architecture is disciplined to stand still while we think our thoughts within it, we might now understand that this discipline, like all discipline, secures only a momentary and provisional, only an apparent, stasis.[30]

The overpowering of architecture is a temporary and superficial state. Architectural metaphors provide a propitious resource for the philosopher. A semblance of power is embodied in the role of the architect even if the very act of assuming the architectural mantle suggests that the philosopher has power over the architect, and by inference the materials (of which the edifice is constructed). In addition the act of the philosopher becoming the architect is often described using spatial metaphors which suggest that the philosopher is seated in a superior position and steps down to take on the more menial and quotidian chores of the architect. This spatial hierarchy itself is bridged by architectural metaphors and fraught with metonymy. Mark Wigley has described the combined role of architecture as metaphor with the opportunistic uses to which it is put by philosophy.

Architecture is constructed as a material reality to liberate a supposedly higher domain. As material, it is but metaphor. The most material condition is used to establish the most ideal order, which is then bound to reject the former as merely material. The status of material oscillates. The metaphor of the ground, the bedrock as the fundamental base, inverts to become base in the sense of degraded, material, less than ideal. The vertical hierarchy inverts itself, and in this inversion architecture flips from privileged origin to gratuitous supplement, foundation to ornament ... Philosophy treats its architectural motif as but a metaphor that can and should be discarded as superfluous.[31]

Here Wigley combines in one sequence the ideas of Ingraham and Agacinsk. The status of the architectonic metaphor is uncertain; it fluctuates between states of philosophy, geometry and mathematics. This oscillation is the factor which underlies (and elucidates) the different readings of power in Ingraham and Agacinsk. At various times the hierarchy is inverted to allow the author (philosopher, architect, or mathematician) to maintain superiority. The final act of discarding the accessory (be it architecture, philosophy or mathematics) identifies the superior role of theory. In an interview between Jeffrey Kipnis and Mark Wigley a similar account of the shifting status of architecture and theory is provided; however in this case Wigley identifies the traces left behind by the discarded trope.

Architecture appears there as a metaphor which one would abandon upon completing the great work of philosophy, but these metaphors cannot be erased from philosophy, because they are not simply metaphors. Philosophy is not so much a mode of inquiry as a preservative mechanism which sustains certain assumptions about objects. Its discourse is riddled with symptoms of a neurotic relationship with architecture. Philosophers describe themselves as architects and philosophy as architecture. Philosophers begin from the ground and work their way up, check the ground, check the foundations, and so on; a philosopher gets rid of ornament ... The whole tradition of Western metaphysics as a technical discourse stands on the foundation of this understanding of architecture.[32]

The architectural traces in metaphysics are many and complex. In philosophy, literature, medicine and mathematics, architectural metaphors provide the grounds for reason and the implicit authority of the user. The studies quoted above have tended to focus on the specific use to which architecture has been put in philosophy; these studies also provide a worthy starting point for an analysis of the role of architecture in nonlinear dynamics. In the works of Wigley, Ingraham, Kipnis, Agacinsk, Tschumi and Derrida a number of common categories have been identified for classifying the role of architecture in the theory of another discipline. Such burdens that are borne by architecture also signify those roles in which architecture is privileged, however briefly or abstrusely, over the body of theory in the discipline. In its privileging, architectural metaphors become most lucid and transparent. It is at such points that the complex weave (that is architecture and theory) may be examined without unravelling and destroying the context.

Three overlapping categories have been identified in the works quoted in this section. Each of these looks at a specific form of privileging of architecture which goes on in a domain of theory. These three categories, into which the role of architecture (as adjunct to theory), may be classified, will form the basis for this paper. The first is architecture fulfilling a role as metaphorical bridge between disciplines. This usually occurs through the use of spatial metaphors and architectural terminology. While the infusion of architectural language into a discipline is usually inevitable, in nonlinear dynamics a distinctive form of naming and word-play has developed involving architecture in a power relationship. The second category of classification is based on the role of architecture as a metaphor for precision, prominence or permanence. Architecture, in this sense, acts as an ordering device aligned with a political or power structure. The nature of the power structure in this category differs from the first in that in the first category the action of naming promotes a form of violence and division while in the second architecture becomes a tool for supporting nonlinearity over other disciplines. The final category of classification involves the privileging of architecture as a form of exemplar. This category is linked to the pedagogic tradition in the sciences and mathematics which uses examples of real world objects to teach and or test concepts. This category is less prominent in philosophy and literature where such strategies are often closely linked to architecture's capacity to embody order. In ancient Greek mathematics a tradition arose which used examples from architecture, geography and warfare to explain geometric concepts. This tradition has continued to the present day (although warfare has been largely replaced with sport) and has surfaced in nonlinear dynamics.[33]

CROSSING BORDERS (CATEGORY 1)

Jacques Derrida, while discussing the question of interdisciplinarity suggested that "architecture had provided some possibility of crossing borders."[34] By this he meant that architectural metaphors have been widely appropriated and that the terminology and the form of discourse in many disciplines is derived from architectural tropes. It is through language and metaphor that architecture becomes the bridge between disciplines. Especially it is through readings of space and hierarchy (structure) that architecture becomes a useful metaphor and thereby a bridge between disciplines. This moment is significant, Ingraham claims, because it marks the instance when terminology shifts subtly from one discipline to another. This she sees not so much as the action of bridging but as an 'opportunistic' exchange of prisoners or, at best, a trade between equals. The "moment, for example, that the word structure drifts from architecture into philosophy."[35] This moment of drift occurs when one discipline subsumes language from another for its own purposes.

Just as in philosophy, mathematical polemic has a structure, is grounded and has component parts; all concepts inherently architectural. However in mathematics a different semiotic system has arisen which elides architecture in a way that has not occurred in philosophy. In mathematics the primary linguistic medium of communication is through numerical notation. Mathematical proofs (eg. 2 + 2 = 4), often expressed using meta-mathematical sequences derived from logic, have reduced the reliance of mathematics upon external metaphors. This historical situation though started to change after Gödel proved in 1931 that not all mathematics was solvable.[36] The growing comprehension that mathematical proofs were not inviolate lead to a resurgence in interest in unsolvable mathematics; an event associated with the formation of the discipline, Nonlinear Dynamics. In addition to this act of refocussing, there was a concomitant revival of terminology which sought to found mathematics using the same systems employed in philosophy. In the search for new foundations, Nature, in the form of plants, rivers, mountains and the human body, became the primary metaphor. Using similar allegorical structures to those used historically in architecture, nonlinearity became replete with anthropocentric features and primitive natural forms. Architecture was overtly present only in such discussions in symbolic roles reliant on perceptions of order or control over nature. While the general terminology of architecture has spread into nonlinearity a more notable occurrence has been the way in which nonlinear geometric forms are named after architectonic features. The act of naming is the moment of bridging; the moment when architectural ideas are simplified and translated as static concepts. Habitually also the moment of bridging occurs during the act of naming; when an idea within a discipline is named using terminology from another.

In nonlinear mathematics the most easily traced moments of appropriation are those that involve naming. Fractal geometric forms are named, in the manner of many scientific concepts, in a proprietary act. Iconic forms of fractal geometry are customarily named after their founders although such acts of naming are usually initiated by colleagues, or those who have rediscovered the significance of the concept being named. In nonlinearity there are many examples of this style of naming; the Mandelbrot Set, Barnsley Fern, Peano Curve, Lévy Clusters, Koch Curve and the Sierpinski Gasket are all examples of geometric forms and ideas named after their founders. In each of these cases the act of naming has been undertaken either by a colleague or by someone following in their footsteps many years later.

In contrast to this first model, fractal geometric forms named by the major mathematicians themselves regularly use terms derived from architecture or construction. For example the 'Castle Fractal,'[37] the 'Devil's Staircase,'[38] and the 'Random Pattern Of Streets'[39] are examples of names that are derived from architecture (*figs 1-4*). While the appropriation of architectural terminology for naming is usually linked to the visual form of the geometric construct each of these cases provoke additional readings for the motivation of the act. While Ingraham has suggested that it is the moment when architecture is forced to "stand still" and "be used," that appropriation occurs; in nonlinearity there is a major difference between forms of appropriation in naming. The majority of geometric forms named after mathematicians are distinct and singular, genuinely iconic, stable, forms (wherein the mathematician has been forced to "stand still"). In contrast those fractals named after architecture are commonly families of related forms. Families of fractal forms are those which display geometric variations based on initial input data. Variations in data will produce similar appearing forms but not identical ones. Those forms named after mathematicians are usually distinct and stable, in that a single formula creates a structure of infinite depth and complexity while slight variations in the formula will often loose the form entirely.

Architectural metaphors are seemingly the third most common form of naming; the most prolific source is geography with the names of mathematicians second. This hierarchy of naming is itself intriguing as it implies that nonlinear mathematicians have a different priority to their predecessors. Early mathematicians elevated their own names, or those of colleagues and mentors, above all other forms of naming. The use of terms from architecture or geography is a relatively rare and recent phenomenon connected predominantly with Nonlinear Dynamics. The reason for this change appears to be linked to a shift in motivation. In the politics of the discipline of Nonlinear Dynamics power is not necessarily embodied within the name of the geometric form; rather it is related to the degree to which such a form models (however abstractly) real world phenomenon. Those fractals which most closely resemble the real world are named after the geographic features which they resemble. Fractals named after islands, rivers, trees, ferns and forests are commonplace though each may have a modifier, which may be a name or a numeric modifier; such as either the 'Koch Island' or the 'Island wherein $D < 2$' (*figs 5-9*).

The act of naming fractals is imbued with power and with a degree of symbolic violence. Naming fractals after their founders (eg Poincaré Chains, Cantor Dusts, etc) is usually an act committed by followers or those seeking to capitalise on their work. Mandelbrot named the Lorenz Attractor after Edward Lorenz at a time when he was seeking reassurance that he was not alone in considering nonlinear forms; thus by naming the geometric form after his predecessor his work fitted within a line of thought, even though it was an artificial line. By naming a figure or concept after a scientist a degree of support and continuity was insinuated. This process of naming fractals after mathematicians is a form of architectural structuring in itself; it implies a spatial and temporal hierarchy that has predecessors, supports, founders and foundations.

Naming fractals after geographic features is not simply a visual strategy as nonlinear mathematics, as with any fledgling discipline, is concerned with the appearance of legitimacy. Conventionally a discipline acquires a degree of sanction if it can make two claims; a connection to previous bodies of theory (lineage) and at least a modicum of application (usefulness). Early fractal forms were considered exciting because they seemed to simulate conditions arising in nature. It is this feature, more than any other, which was the catalyst for the widespread interest in nonlinearity. In order to capitalise on this appearance it became politically adept to name the more elaborate geometric constructs after natural features. Following initial interest and further growth, the discipline reinforced its structure, already largely framed by Mandelbrot, through the creation of a more defined structure (predecessors) and firmer grounding (in reality and nature). It was at this stage that the politics of naming shifted as mainstream mathematicians became less sceptical of nonlinearity and as the general public became more interested. Populists started to discuss nonlinearity and the manner in which fractals were 'constructed'[40] or 'designed;'[41] equations became 'built-up,' and computer programs produced three dimensional fractal 'materials.' With the steady rise in interest there was a need to employ the most basic fractal forms as tools for teaching students and non-mathematicians. And, although architecture was already present in nonlinearity, the number of fractals named after spatial forms increased.

This three stage system of naming is conjectural yet the fractals named after architectural forms are neither prominent early works (usually named after people) or spectacular, irregular and evocative (named after natural features). Fractals named after architectural concepts are more quotidian or, at least if not monotonously regular then, composed of simple Euclidean forms repeated at multiple scales. Naming after architecture, as distinct from the architecture of naming, carries an agenda reminiscent of Ingraham's reading of transference. The moment of bridging is the moment when architecture is forced to stand still. The naming of a nonlinear geometric form after a spatial form carries with it assumptions of the commonplace and the everyday. Architecture here is appropriated as a means of translating mathematics, not to mathematicians but, to the general public. The presence of architecture denotes the moment of interdisciplinary shifting as architectural metaphors are, in nonlinearity, the medium of translation. Acts of naming in nonlinearity, like those of naming in anthropology, geography and philosophy, are violent acts of subjugation.[42] The politics of naming traced within nonlinearity has drawn upon mankind and nature for primary sources but has resorted to architecture when metaphors are required which exemplify the mundane.

ARCHITECTURE AS ESSENCE OF ORDER (CATEGORY 2)

Throughout history philosophy has represented itself as an "arbitrator of order."[43] To evoke this semblance of order philosophy has sourced a variety of tools of which metaphor has been the most common. The most familiar source of metaphors, which prompt illusions of order and stability, has been architecture. In Nonlinear Dynamics architecture has continued in its longstanding role as personification of order. Descriptions from texts on nonlinearity frequently rely upon the mathematician taking on the mantle of the architect and imposing order upon nature. Throughout nonlinear discourse architecture is often paradoxically described as exemplar of precision, permanence or prominence. This use of architecture is paradoxical because nonlinearity is, in part, concerned with the impossibility of prediction, the infinite irregularity of surface and infinitesimal scale. Thus any discipline that uses architecture to exemplify order, even though its proponents should understand the patent inaccuracy of such claims, is consequential to studies of the metaphoricity of architecture.

Mandelbrot has proposed an allegorical device which captures the historical triadic relationships between mankind, nature and God as a starting point for a study of nonlinearity. Mandelbrot chose, as an icon for the symbolic power of the fractal, the frontispiece of the 13th century *Bibles Moralisees* (*figs 10-12*).

The period of Western European history centered at 1200, while stagnant in science and philosophy, was exuberantly active in engineering. In the age that built the Gothic cathedrals, to be a master mason was a very high calling. Thus, the 'Bibles Moralisees illustrees' of that time ('comic strip' Bibles) often represent the Lord holding mason's dividers.[44]

In the frontispiece God is depicted in the role of the master mason or architect defining the geometry of the world expressed in "circles, waves and 'wiggles'." Beneath the image an inscription reads *"Ici Crie Dex Ciel Et Terre Soleil Et Lune Et Toz Elemenz"* (Here creates God sky and earth, sun and moon and all elements). By depicting God in the guise of an architect the divine creator's power over shaping nature was being vested with the architect. Mandelbrot found great consequence in the forms within the frontispiece, especially the "'wiggles'" which he saw as an early, intuitive, understanding of fractal geometry. The *Bibles Moralisees* were produced initially as simple illustrated texts for educating the common classes in liturgy; the use of dividers to symbolise God in the role of master mason, architect and builder was a means of glorifying the role of the cathedral builder and encouraging continued support for the church. For this reason the illustration is simplistic and the role of architecture merely a caricature symbolic of quotidian order and spiritual endeavour. Such a simplistic role is often reserved for architecture. Wigley recorded that the image of architecture is often “a cartoon” because it “is precisely as a cartoon that it plays such an influential role in so many cultural transactions.”[45]

Architecture, when displayed as a caricature or cartoon, becomes sufficiently simple that it is able to be used for multiple purposes, and thus becomes the ideal material for bridging between disciplines. In Mandelbrot’s account of the lack of understanding of fractals, the *Bibles Moralisees* provided a suitable starting point for the linking of philosophy, art and mathematics; a link advanced through the mechanism of architecture. Architecture in that account is a device for spanning between the cognoscenti and the uneducated but it is also symbolic of order. Architecture fulfilled a similar role in the systems of naming nonlinear geometric structures. In each case architectural metaphors of order and precision bridged between the well-informed and the ill-informed.

Barnsley and Schroeder have both used the creation of buildings as emblematic of order. Such examples moreover juxtapose architecture with nature and thus order with chaos. Barnsley stated;

Fractal geometry will make you see everything differently ... You risk the loss of your childhood vision of clouds, forests, galaxies, leaves, feathers, flowers, rocks, mountains, torrents of water, carpets, bricks, and much else besides. Never again will your interpretation of these things be quite the same ... Fractal geometry is an extension of classical geometry. It can be used to make precise models of physical structures from ferns to galaxies. Fractal geometry is a new language. Once you can speak it, you can describe the shape of a cloud as precisely as an architect can describe a house.[46]

Architecture is here seen to embody order and exaction. The architect’s ability to measure and know or understand a structure is a power relationship. The architect is the creator of order within previously stochastic systems. Nonlinear mathematicians, seeking to gain power over nature, use as a device the architect’s metaphorical capacity to structure and build with mythical precision.

A similar theme to Barnsley’s was developed by the artist and mathematician Franke who described computers and their role in nonlinear systems. Franke linked the formation of computer based systems of mathematical projection with the use of computer graphics to understand and depict complex equations. He began by tracing the development of related technological items;

The first rather inadequate means of realizing this transition was the printer, which nevertheless showed the effectiveness of pictorial presentations so convincingly that mechanical drawing instruments, called plotters, were developed almost as a matter of course ... This makes possible the mechanical production of line drawings precise enough for, say, architectural designs, *cartography, and so forth.*[47]

In Franke’s description, like Barnsley’s, architecture has become synonymous with precision, perfection and power. The architect’s ability to work with natural materials and produce a structure which resists nature is the key reading in both Barnsley and Franke. The writers are each instinctively seeking a degree of power over nature through their discipline. Like the constructed edifice, which resists nature and shelters its inhabitants, the nonlinear formula defines nature and in doing so provides a degree of protection for the nonlinear mathematician.

Other than those metaphorical uses of architecture based upon power structures, architecture has also been used allegorically to describe the pursuit of order and knowledge. The nonlinear mathematician Eilenberger used architecture (and notably church architecture) as symbolic of the pursuit and construction of knowledge. He likened the formation of a discipline with the construction of a monumental building, a cathedral.

We scientists are working on the cathedral of the scientific view of the universe. Though this cathedral, like the Cologne cathedral, has its practical uses, our reason for working on it is really, as it was expressed in the middle ages, for the glory of God. Only with this goal in mind does it indeed become a cathedral instead of a factory. And just as the workers in the construction-shack of the medieval cathedral are anonymous today, for it was the edifice itself that mattered not they, the contributions of most scientists will also remain anonymous. The cathedral is a communal work, and the scientists are the journeymen of a huge construction team, or, considering the worldwide extension of their activity, they are brothers in a worldwide order where the individual ought to retreat behind the great common work.[48]

Eilenberger’s analogy is initially between science and architecture, seemingly for the purpose of describing labour for a higher goal and the loss of individuality in pursuit of arcane wisdom. Nevertheless Eilenberger is intent upon raising science and the pursuit of knowledge (especially within nonlinearity) above architecture; as seen in the development of his analogy.

There is, though, an essential difference between scientific endeavors and the construction of a real cathedral: in science there are no blue-prints! The mathematical and physical insights on which [fractal pictures] *are based are, in my estimation, the most exciting development since the discovery of quantum mechanics 60 years ago, insights which will again revolutionize our scientific view of the universe. Our cathedral will be completely transformed; it will lose its gothic coolness and take on baroque features!*[49]

In this instance Eilenberger differentiates between the degree of difficulty in producing architecture and that of studying nonlinearity. Architecture in Eilenberger's analogy is essentially ordered owing to its reliance on a preordained vision or plan. Mathematicians and scientists labouring together within nonlinearity lack such a plan and thus are seen to be striving for a higher goal. Significantly Eilenberger chose to end the analogy with his chimerical aspirations for nonlinearity. He decided to return to architecture, despite already privileging science over it, in order to evoke the imagined richness of his discipline. To do this he contrasted the decorative excesses of the baroque with the structural "coolness" of the gothic; aligning his vision for the future away from the structural towards a more symbolic, more ornamental vision.

Understanding Eilenberger's argument at this point is difficult as the extent of his understanding of architecture is unknown. His text implies that some value has been prescribed to these period styles which places the baroque over the gothic but the basis for this act is not described. While such a comparison could be made in terms of historicity, colour, ornament or structure at no point may one form be arbitrarily privileged over the other. As if to confound his own logic Eilenberger continues to use architecture despite degrading it in his earlier analogy. Architecture has, at the endpoint, lost its role as giver of order in favour of being yet another metaphorical pawn sacrificed at will. The caricatures of the gothic and baroque have been stripped of so much of their meaning that ultimately Eilenberger's argument is nonsensical.

In a manner reminiscent of the philosophers who discard architecture, once it is no longer useful to their polemic, mathematicians are equally wont to place themselves above the implied supremacy of the architect. After using architecture as a means of defining order and structuring an argument of power over nature, Barnsley discarded architecture (and all man made structures) implying that they are limiting because they are based on a flawed Euclidean orthodoxy. He claimed that systems of measurement and representation for "man-made objects, such as bricks, wheels, roads, buildings and cogs" are not appropriate for fractal forms.[50] From that point on Barnsley avoided obvious metaphorical uses of architecture in favour of a new set of images. In contrast to Eilenberger, Barnsley discarded architecture prior to considering nonlinearity yet in doing so he sought a different strategy to retain a link between man and nature. While Eilenberger returned to architecture, at the last, Barnsley avoided architecture after he had discarded it as if any revision would weaken his argument.

Fractal dimensions are important because they can be defined in connection with real-world data, and they can be measured approximately by means of experiments … Fractal dimensions can be attached to clouds, trees, coastlines, feathers, networks of neurons in the body, dust in the air at an instant in time, the clothes you are wearing, the distribution of frequencies of light reflected by a flower, the colors emitted by the sun, and the wrinkled surface of the sea during a storm.[51]

Everything, from large scale geographic features to personal items of clothing, is considered by Barnsley to be fractal yet, rarely is architecture included in these later lists. While architecture is demonstrably fractal, in that it is made of natural materials which, when examined at increasingly fine scale, exhibit self-similarity, it has been given a position in the pantheon of nonlinearity closely aligned with order and precision and as such it is habitually not discussed in direct connection with fractal geometry.[52]

Mandelbrot's approach to architecture differs from those of Barnsley and Eilenberger. Mandelbrot maintained that "there is nothing illogical about including articulated engineering systems in" an analysis of nature and geometry.[53] To illustrate his point, that fractal forms have always been intuitively understood, he undertook a comparison between the *Eiffel Tower* and the Sierpinski Gasket (an iconic nonlinear geometrical construct) (*fig 13*). The catalyst for Mandelbrot's foray into engineering and architecture was the 1956 paper by Hahn which suggested that "intuition seems to indicate that it is impossible for a curve to be made up of nothing but … branch points."[54] In order to refute Hahn, Mandelbrot chose a deliberately recognisable and monumental structure which had been produced by an engineer/architect. Mandelbrot began:

My claim is that (well before Koch, Peano, and Sierpinski) the tower that Gustave Eiffel built in Paris deliberately incorporates the idea of a fractal curve full of branch points … the Eiffel Tower is made of four A-shaped structures … All four A's share the same apex and any two neighbors share an ascender. Also, a straight tower stands on top. However, the A's and the tower are not made up of solid beams, but of colossal trusses. A truss is a rigid assemblage of interconnected submembers, which one *cannot deform without deforming at least one sub member. Trusses can be made enormously lighter than cylindrical beams of identical strength. And Eiffel knew that trusses whose 'members' are themselves subtrusses are even lighter. The fact that the key to strength lies in branch points, popularized by Buckminster Fuller, was already known to the sophisticated designers of Gothic cathedrals.*[55]

Architecture here, in the form of the *Eiffel Tower*, is a mechanism for refutation. Mandelbrot's censure used architecture as a means of positioning the ideas of Hahn beneath those of the engineer/architect. In this way Mandelbrot, who has used and discarded architecture with abandon, positioned himself above the architect who was in turn placed above Hahn. Architecture, in this example, is acting as both exemplar and tool of empowerment. However, unlike Barnsley, who discarded architecture whenever serious concepts were explored, Mandelbrot returned to architecture repeatedly, even if only to use it as metaphorical device for chastisement.

Schroeder has recounted Mandelbrot's corollary between the geometry of the *Eiffel Tower* and the Sierpinski Gasket without direct reference to Hahn though making a similar point. Schroeder argued that both nature and architecture have developed structures which are made up almost entirely of branch points.

Sierpinski gaskets in two or more dimensions model many natural phenomena and man-made structures. Think of the Eiffel Tower in Paris, designed by Gustave Eiffel. If, instead of its spidery construction, it had been designed as a solid pyramid, it would have consumed a lot of iron, without much added strength. Rather, Eiffel used trusses, that is, structural frames whose members exploit the rigidity of the triangle … However, the individual members of the largest trusses are themselves trusses, which in turn are made from members that are trusses again. This self-similar construction guarantees high resilience at low weight. The structures of Gothic cathedrals, too, betray great faith in this principle of achieving maximum strength with minimum mass. And Buckminster Fuller (1895-1983) and his skeletal domes popularized the fact that strength lies not in mass but in branch points. *In fact, counter to intuition, the Sierpinski gasket and like constructions consist of nothing* but *branch points.*[56]

Schroeder's text, despite seeming a poorly copied version of Mandelbrot's, commenced by noting the similarity between the *Eiffel Tower* and the Sierpinski Gasket but instead of considering precedence he focused on the question of knowledge and structure. The lessons learnt in architecture were deemed by Schroeder as appropriate models for nonlinear mathematicians. Moreover the account is presented without reference to the obvious power relationship which is implied in Mandelbrot. Unlike Eilenberger, Schroeder refrains from privileging any one form of architecture over another.

In the initial examples from Barnsley and Franke architecture was metaphoric of order; it embodied ideas of precision and permanence. However while Barnsley retained a form of separation between those sections of text which openly utilised architecture and those that did not, Eilenberger presented an account of nonlinearity reliant on the leadership of the architect yet stressing the spiritual and team orientated goals in the process. In carefully using architecture to only imply order and precision Barnsley avoided the complex and often inarticulate allegory which Eilenberger resorted to.

In contradistinction Mandelbrot's use of the frontispiece of the *Bibles Moralisees* contains similar elements to Eilenberger's account of origins, yet Mandelbrot is not inclined to use architecture for serious metaphors, preferring instead geographic sources. By opportunistically using architecture, Mandelbrot reinforces the disposability of the discipline as metaphor and also its flexibility. Architectural metaphors in the writings of Mandelbrot though are aligned to concepts of power more commonly than precision and order; architecture in whatever form is available is used to bolster Mandelbrot's cause.

ARCHITECTURE AS EXEMPLAR (CATEGORY 3)

The illusion of precision and determination attached to architecture is usually manifested in a power structure wherein the mathematician uses the role of the architect (and architecture) to build a logical argument. In contrast the same illusion may provide a metaphor, not for the purposes of constructing a defence or offence, but for purposes of instruction. While distinguishing between these two uses of architectural metaphor is difficult, the manner in which precedence is given provides a possible key. In the examples that follow, architecture, while still being privileged, is not intrinsic to the logic structure being created; rather the aim of the text is to explain not to attack, or define. For example, the argument that - "just as the architect builds from the ground up so too are equations constructed" - uses the presumed authority and pragmatism of the architect to support a viewpoint. In contrast the statement - "by measuring the height of a tall building using a short ruler many errors of dimension will become apparent" - uses architecture as a means of explanation. While there is some degree of commonality, instructional metaphors usually have a clear aim to explain a concept.

The more difficult category which has a degree of coincidence with 'architecture as exemplar' is the category of ‘bridging’; that is architecture facilitating the crossing of disciplinary borders. The role of architecture, when used as an example, is to directly link a concept in a student’s mind with a real world object that they have experienced. In this way it is intended that learning or understanding is promoted. However the process of explanation is itself similar to the process of crossing borders. The difference, however, may be seen in the shift from language to experience. This means that the signified has shifted from the word ‘castle’ to a person’s detailed experience with a real (or imaginary but detailed) ‘castle.’ Thus the hypothetical argument that - “fractals are constructed about founding assumptions and then built up into their final form” - uses architectural concepts to explain the complexity of mathematical processes to the student. The concepts are spatial and involve multiple, but still abstract readings of the concepts of ‘construction’ and ‘building’ and are thus mechanisms for bridging. In contrast the sentence - “the town of Hamburg, when viewed from above, exhibits fractal street form” - draws the students’ attention to a specific example which facilities their understanding process. The line between these two categories is a fine one and despite these distinctions there is a degree of overlap between all three categories.

Fractal geometric forms possess ‘characteristic self-referentiality.’ That is, when they are viewed at increasingly fine scales similar geometric patterns may be uncovered. To explain this concept Manfred Schroeder used two examples from the real world; the first was Russian dolls. These are nested wooden carved dolls which have been made to open up revealing smaller dolls inside (which when further opened reveal further small dolls). In this way Schroeder attempted to show how an object could have self-similar geometry at a variety of scales. To further develop the concept of self-similarity (as a means of explaining fractal generation) Schroeder moved on to describe a thirteenth century castle as an example of fractal form.

The result of an early attempt at self-similarity in architecture is the monumental Castel del Monte, designed and built by Holy Roman Emperor - also King of Sicily, Germany, and Jerusalem - Frederick II (1194-1250) the great falconer, rare mathematician (among medieval emperors, anyhow), and last but not least, irrepressible castle builder. The basic shape of the castle is a regular octagon, fortified by eight mighty towers, again shaped like regular octagons. (These towers were devised for the easy release and retrieval of hunting falcons.)[57]

Schroeder’s description of the castle and its architect is curiously detailed given that the building possesses self-similarity at two scales only and is thus barely able to support his claim. Not only is the castle barely self-similar but having warned the reader that the architect was a great mathematician they are then informed that the geometry of the castle was not necessarily the reason for its existence, rather it facilitated falconry. As if to increase the irony surrounding his description Schroeder also relates the curious tale of the Frederick II’s birth and proof of a legitimate claim to the throne; a convoluted tale of tents, birth places and lines of sight. The reader of Schroeder is further informed that Frederick II was acquainted with the famous mathematician Fibonacci and was author of a well known illustrated text on hunting. In his example Schroeder balances between supporting the idea that the *Castel del Monte* was “an emperor’s early attempt at self-similarity,”[58] and that it is merely a whimsical building designed by a dilettante. As an exemplar the castle is contradictory. While the Russian dolls are treated seriously (and they are a better example of self-similarity) the castle is treated in an ambiguous manner. Indeed the reader is left with the feeling that there is a vast difference between fortress architecture (which is self-similar at two scales as the *Castel del Monte* is) and fractal architecture (which must be self-similar at more scales) (*figs 14, 15*). The end result is that the example is not taken seriously; architecture is fine as an example but when real instruction is required Russian dolls are better. Once again the role of architecture as accessory is made clear. The opportunistic nature of the appropriation, as Ingraham has maintained, is clear in Schroeder’s use, misuse and then disposal of architecture.

Schroeder’s metaphorical appropriations from architecture frequently fulfil pedagogic requirements. Later in his book, while searching for an example that can explain why self-similarity may be more than geometrical, Schroeder recalls that one reasonable method for “designing concert halls and opera houses” is to “build scale models first and study sound transmission in them, instead of in the finished hall.”[59] Schroeder developed this analogy by drawing the readers attention to the way in which architects have, in the past, completed the building before testing it acoustically. The author’s mocking voice once again using, misusing and then discarding architecture; the failed building is thus “remodelled”[60] Schroeder remarks sarcastically.

Schroeder’s final foray into construction and building differs from his early uses of metaphor. In this example he claims that an understanding of fractals and self-similarity could result in more improved engineering structures.[61]

Self-similarity is not only amenable to measurement*; self-similarity can also be employed profitably in the* design *of fractal structures and materials with increased durability or lower cost (or both). A case in point is the construction of field walls on many New England farms ... There are large stones* *whose gaps are filled by smaller stones, whose interstices, in turn, are filled by still smaller stones. As a result of this roughly self-similar composition, the wall keeps standing upright without the customary edifying intervention of expensive cement to fill and fixate the cracks.*[62]

Schroeder argues that the process of creating dry stone walls embodies an intuitive grasp of fractal form. From this fine scale, primitive work of engineering Schroeder is able to suggest that lessons may be learnt which will not only make structures more stable but will be more cost effective.

In a column in Nature entitled "Abstract Concrete," David Jones argues that by employing ever finer particles, from the coarsest gravel to the finest dust, the volume to be filled by expensive binder can be made arbitrarily small, thereby cutting cost[63]

Given Schroeder's previous history of use and misuse of architecture it is difficult to see where this bucolic vision of construction is leading. It is also difficult to determine why the primitive art of dry stone wall construction should be supported at length as an example for instruction while architecture is never so used. The answer may lie in Wigley's claim that 'building' is frequently privileged over 'architecture' when it is used metaphorically in theory.

This is yet another symptom of philosophy's indecision about architecture. It makes a double claim: revering yet subordinating architecture by means of the split between building and architecture, presentation of the ground and representation detached from it. Inasmuch as it is condemned it is condemned as architecture. Inasmuch as it is promoted, it is as building. Building is privileged as the special scene of structure, of construction, of the construct, of everything that philosophy stands for.[64]

Schroeder's indecision is manifest in his cyclic use and disposal of architecture. The dry stone wall, owing to its conceptual purity, is un-muddied by ornament or the frivolous pastimes of royalty. In its simplicity Schroeder sees beauty, strength and economy. Architecture, with its messy pretensions and egocentric creators, is worthy for instruction only if a frivolous example is required.

Ian Stewart and Martin Golubitsky in *Fearful Symmetry* have analysed the complex geometries associated with nonlinear dynamics focussing on symmetrical curiosities. In contrast to Schroeder, architecture is mentioned by Stewart and Golubitsky only in simple and readily supportable contexts. For example the decorations and ornamentation in Islamic architecture are described only where they are identical to forms of mathematical period tiling. Similarly their only discussion of architecture is a historic one which seems to recognise the symbolic, rather than literal, quality of geometry in architecture. In a short section of their work which discussed the misuse of geometry they identify a series of misuses of geometrical systems.

Indeed ... scientists and mathematicians aren't the main culprits among those who place too heavy reliance upon non-existent patterns. It's a common human failing. A whole breed of financial analysts currently attempts to predict the behaviour of the stockmarket by applying a range of 'patterns,' either geometrical or numerological, whose basis is - to say the least - dubious ... Several schools of architecture - often respectable and respected - are based upon number mysticism. Le Corbusier's 'modulor' emphasizes ratios based on Fibonacci numbers and the golden ratio. It's not that people don't design good buildings by these methods; it's that their design sense plays by far the greatest role, and the mystical framework is so flexible that any reasonable design can be incorporated into it.[65]

Stewart and Golubitsky, alone of all of the scientists and mathematicians studied, seem to appreciate that architecture often misappropriates mathematical forms. Once this position was stated though, Stewart and Golubitsky were not interested in further isolating architecture and attacking the weaknesses of this area of theory, rather they have recorded their well supported views without further embellishment. Unlike in Schroeder, architecture is not subjugated by Stewart and Golubitsky, it is accepted and used to instruct.

Benoit Mandelbrot's professed enthusiasm for architecture, painting and music has lead him to use metaphors from each of these areas to explain his theories. Mandelbrot however is wont to use such instruction for political purposes and therefore his motives are rarely limited to the instructional. For example, while trying to explain the significance of fractal geometry to all disciplines he indulges in both a critique of architectural movements as well as in an attack on a fellow nonlinear dynamicist.

A paradox emerges here: As observed in Dyson's quote ... modern mathematics, music, painting, and architecture may seem to be related to one another. But this is a superficial impression, notably in the context of architecture: A Mies van der Rohe building is a scalebound throwback to Euclid, while a high period Beaux Arts building is rich in fractal aspects.[66]

This quote from Mandelbrot is, itself, complex to dissect. On its most obvious level Mandelbrot is disagreeing with the mathematician Freeman Dyson on the grounds that modern architecture is not fractal. Yet Mandelbrot, like Eilenberger discussed earlier in this paper, also makes a judgement on architectural grounds without any clear reason. While Eilenberger made a confusing distinction between the Gothic and the

Baroque, derived from visual characteristics, Mandelbrot has made a similar unsupported claim concerning Beaux Arts and Modernist architecture. One of the many problems with Mandelbrot's use of architecture is that his judgement is based upon a purely visual system of values. It would be simple to argue that a Miesian building is self-similar at multiple scales and thus should be considered fractal[67] yet Mandelbrot raises the Beaux Arts building above it on aesthetic grounds. While the Beaux Arts building displays a superficial and organic complexity it possesses no more true self-similarity than a Gothic cathedral and probably far less. As was the case with Eilenberger, Mandelbrot's claims are difficult to understand owing to his idiosyncratic understanding of architecture. Is Mandelbrot referring to the artistic and craft-based tradition of the Ecole Des Beaux-Arts; a tradition often linked to the works of Gottfried Semper? Is Mandelbrot referring to the end period of the Gothic revival in the nineteenth century which segued into art nouveau? It is not clear exactly what form of architecture is being given precedence, however it is clear which architectural works are being criticised.

For Mandelbrot architecture is a useful device for supporting his arguments even while ostensibly helping the reader to understand scientific concepts.[68] While making a claim that certain forms of art are accepted by the general populace, because they posses geometry similar to that present in nature, Mandelbrot once again returns to the Beaux Arts tradition.

The fractal "new geometric art" shows surprising kinship to Grand Masters paintings or Beaux Arts architecture. An obvious reason is that classical visual arts, like fractals, involve very many scales of length and favor self-similarity. For all these reasons, and also because it came in through an effort to imitate Nature in order to guess its laws, it may well be that fractal art is readily accepted because it is not truly unfamiliar. Abstract paintings vary on this account: those I like also tend to be close to fractal geometric art, but many are closer to standard geometric art - too close for my own comfort and enjoyment.[69]

In this case Mandelbrot's reason for viewing Beaux Arts architecture as superior to Modernist architecture is slightly more clear although still not entirely convincing. In that certain artistic (and also architectural) traditions attempted to uncover the geometric basis for natural forms those forms of art, or architecture might exhibit, superficially, the characteristic complexity of fractal form. Nevertheless Mandelbrot once again uses his explanation of beauty in art as a chance to criticise abstract painting, perhaps for the same reason he objects to modern architecture.

These last examples from Mandelbrot fall within multiple categories of metaphoricity. Similarly Barnsley's use of townscape and building form to not only explain a concept but also to describe a way of viewing the world at increasingly fine scales exists in multiple categories simultaneously. Barnsley states;

a map finely colored according to elevation reveals the shapes of the bases of the mountains, the paths of rivers, and - if we look closely enough - the outlines of buildings.[70]

All three categories of metaphorical appropriation are contained within this example to some degree. At its most obvious level Barnsley is using architecture (buildings) as an example of a real world feature which would be seen if a map or aerial photo were truly accurate. Architecture fulfils the role of exemplar just as well as natural features (rivers, mountains, etc) do. Another way of looking at such an example would see architecture being used to bridge between geographic features and anthropomorphic features; between nature and man stands architecture in this episode of scaling. Not only is architecture a means of bridging between the understanding of a teacher and a student, it is also the literal bridge in scale between large geographic features and small organic features. In a final reading of the quote, Barnsley clearly intends that the last stage of his process of fine reading evokes a quality of precision. Architecture carries the imprint of exactitude - any map which can depict such a fine scale must embody (or so it would seem) a capacity to order the real world. All three of these readings of the use of architecture in nonlinearity are possible given Barnsley's use.

Barnsley has two additional uses for architectural metaphor. In the first, which results from his fine viewing of the globe through cartography, he not only displays that maps are inherently inaccurate he further illustrates his point with an iconic sketch of the town of Maidstone. His image of the city and its buildings is fittingly cartoon-like (*fig 16*). His explanation of scaling and the limits of accuracy contains neither Mandelbrot's arguments on the power of architecture nor Schroeder's appropriation and then rejection of architecture. For Barnsley architecture is a tool for explication. In a final visual example of this use of architectural metaphor; Barnsley's own iconic fractal, the Barnsley fern, has been placed in front of a simple (cartoon) house in such a manner that it can be read as a tree (*fig 17*). In this simple display of scaling architecture fulfils the role of a scale element. The architecture is undoubtedly cartoon-like, yet as Wigley and Ingraham have argued, this is because it is precisely as a cartoon that architecture is most easily able to be appropriated.

CONCLUSION

The difficulty with defining architecture as accessory to the body of theory in nonlinearity is that, at a certain level, almost every discourse relies upon spatial metaphors and polysemy. While mathematics has been largely free of overt metaphorical licence nonlinearity is a hybrid discipline, combining aspects of science and mathematics. For this reason nonlinearity displays many of the architectural symptoms identified as present in philosophy. Despite this the question of whether architecture is accessory to nonlinear theory is more contentious. Is architecture, then accessory/theory, or essential/theory in nonlinearity? Is the ease with which a discipline is able to be discarded a measure of the importance of the metaphor? Is the comic depiction of architecture within other disciplines a sign of necessity or accessory?

While it could be argued that to some extent all mathematical constructions rely upon an ordered structure reminiscent of architectural form, this claim is difficult to support unilaterally. The question of whether architecture is accessory to, or essential to, theory may only be clearly answered if an explicit degree of metaphorical licence is defined. Obvious examples of architectural structuring such as those of Heideggar are uncommon in Nonlinear Dynamics yet allegorical use of architecture to embody order may be seen clearly in Mandelbrot, Eilenberger, Barnsley and Schroeder. As many of the accounts of architecture in nonlinearity are caricatures it may be said that an extreme form of simplification goes on in appropriation. For this reason it is difficult to ignore even the most minor metaphorical traces of architecture within a discipline. If architecture is to be a comic depiction then such a reading of structure, form and materials is equally valid and consequential. Thus Nonlinear Dynamics' myriad of 'constructions,' 'designs,' 'materials,' 'joints,' and 'foundations' may not be ignored, nor can the systems of naming. While architecture is a frequently disposable source of metaphor and metonymy, nonlinearity returns to architecture when new devices of empowerment are desired. This ease of disposal is an indicator of the essential role of a metaphor in a theory; if a metaphor is non-disposable then it has ceased to be of importance because it can never be separated from the intent of the discipline.

Architecture in nonlinearity acts as the medium of translation, the contextual device which allows multiple and simultaneous interpretation of ideas. Derrida's reading of architecture providing the "possibility of crossing borders" implies a metaphorical system of transference as well as a linguistic system. In nonlinearity architecture may be seen to fulfil such roles; both the metaphorical reading of spatial systems and the general contagion of architectural terminology argue for architecture's presence as accessory/theory.

NOTES

1 R. J. Moore and M. J. Ostwald, "Charting The Occurrence Of Nonlinear Dynamical Systems In Architecture," *Architectural Science: Past Present and Future* ed. S. Hayman, (Sydney: University of Sydney, 1993), pp. 223-235.

2 G. Deleuze and F. Guattari, *A Thousand Plateaus. Capitalism And Schizophrenia* trans. B. Massumi, (Minneapolis: University of Minnesota Press, 1987).

3 B. Massumi, *A User's Guide To Capitalism And Schizophrenia: Deviations From Deleuze And Guattari* (Cambridge, Massachusetts: M.I.T. Press, 1992).

4 For example Bloomer skirts around the question of relationships between nonlinearity and the works of Derrida on a number of occasions in *Architecture and the Text: The(S)crypts of Joyce and Piranesi*; especially links arising from the work of Hofstadter, Hayles, Deleuze and Guattari which allude to possible connections between Derrida and nonlinearity. See J. Bloomer, *Architecture And The Text: The (S)crypts Of Joyce And Piranesi* (New Haven: Yale University Press, 1993); N. K. Hayles, *Chaos Bound: Orderly Disorder In Contemporary Literature And Science* (Ithaca: Cornell University Press, 1990); *Chaos And Order: Complex Dynamics In Literature And Science* ed. N. K. Hayles, (Chicago: University of Chicago Press, 1991).

5 See Sorkin on Coop Himmelblau: M. Sorkin, *Exquisite Corpse: Writings On Buildings* (New York: Verso, 1991), pp. 346-347.

6 T. Mayne, *Morphosis: Connected Isolation* (London: Academy Additions, 1992), Architectural Monographs, n. 23, pp. 12-13.

7 K. Shinohara, "Chaos And Machine," *Japan Architect* (1988), v. 63, n. 5 (373), pp. 25-32.

8 R. J. Moore and M. J. Ostwald, "Icons Of Nonlinearity In Architecture: Correa - Eisenman - Van Eyck," *Theatres of Decolonization* (Arizona: University of Arizona Press, 1995), forthcoming.

9 R. R. Shearer, "Chaos Theory And Fractal Geometry: Their Potential Impact On The Future Of Art," *Leonardo* (1992), v. 25, n. 2, p. 143.

10 H. J. McWhinnie, "Chaos Theory: Some Questions Of Symmetry And Randomness In Art And Design IV," *Design Methods: Theories, Research, Education* (1993), v. 27, n. 2.

11 B. Hendersonsellers and D. Cooper, "Has Classical Music

A Fractal Nature - A Reanalysis," *Computers And The Humanities* (1993), v. 27, n. 4, pp. 277-284.

12 M. V. Heuvel, "The Politics Of The Paradigm, A Case Study In Chaos Theory," *New Theatre Quarterly* (1993), v. 9, n. 35, pp. 255-266.

13 M. Berube and "Chaos And Order - Complex Dynamics In Literature And Science," *American Literature* (1993), v. 65, n. 3, pp. 596-598.

14 I. K. McEwan, "Instrumentality And The Organic Assistance Of Looms," *Chora 1: Intervals In The Philosophy Of Architecture* eds. A. Perez-Gomez and S. Parcell, (Montreal: McGill and Queens University Press, 1994), pp. 123-142.

15 M. Wigley, *The Architecture of Deconstruction: Derrida's Haunt* (Cambridge, Massachusetts: M.I.T. Press, 1993), p. 2-3.

16 C. T. Ingraham, "The Burdens Of Linearity," *Strategies Of Architectural Thinking* eds. J. Whiteman, J. Kipnis and R. Burdett, (Cambridge, Massachusetts: M.I.T. Press, 1992).

17 Wigley, *The Architecture of Deconstruction* p. xiii.

18 I. K. McEwan, *Socrates' Ancestor: An Essay On Architectural Beginnings* (Cambridge, Massachusetts: M.I.T. Press, 1993)

19 J. J. Rousseau, *The People Of The Ideal Commonwealth And Their Expression Of Their General Will* reprinted from *A Treatise On The Social Compact: Or The Principles Of Politic Law* (London: Becket, 1764), p. 69 in *French Utopias: An Anthology Of Ideal Societies* eds. F. E. Manuel and F. P. Manuel, (London: Collier-Macmillan Limited, 1966), p. 119.

20 J. Kipnis, "Drawing A Conclusion," *Perspecta* (1986), n. 22, p. 98.

21 D. Hollier, *Against Architecture: The Writings Of Georges Bataille* trans. B. Wing, (Cambridge, Massachusetts: M.I.T. Press, 1989).

22 J. Rajchman, "Weakness, Technologies, Events (An Introduction)," *Columbia Documents Of Architecture And Theory: D* (1992), v. 1, p. 161.

23 B. Tschumi, in C. T. Ingraham, J. Rajchman, and B. Tschumi, "Afterwords: Architecture And Theory Conference," *Columbia Documents Of Architecture And Theory: D*. (1992), v. 1, p. 169.

24 J. Derrida and M. Wigley, "Jacques Derrida: Invitation To A Discussion," *Columbia Documents Of Architecture And Theory: D* (1992), v. 1, p. 13.

25 C. T. Ingraham, in C. T. Ingraham, J. Rajchman, and B. Tschumi, "Afterwords," p. 169.

26 S. Agacinsk, "Shares Of Invention," *Columbia Documents Of Architecture And Theory: D* (1992), v. 1, p. 55.

27 Agacinsk, "Shares Of Invention," p. 56.

28 C. T. Ingraham, "Moving Target," *Columbia Documents Of Architecture And Theory: D* (1993), v. 2, p. 113. It is curiously fitting for this paper that Ingraham chooses the illustration, *Sensitive Chaos* (from Theodor Schwenk, *Sensitive Chaos: The Creation of Flowing Forms in Water & Air*, trans. Olive Whicher and Johanna Wrigley (New York: Schocken Books, 1976), to illustrate her paper.

29 Ingraham, "Moving Target," p. 114.

30 Ingraham, "Moving Target," p. 120.

31 Wigley, *The Architecture of Deconstruction* p. 16.

32 M. Wigley and J. Kipnis, "The Architectural Displacement of Philosophy," *Pratt Journal Of Architecture* ed. S. Perrella, (Spring 1988),v. 2, p. 8.

33 M. J. Ostwald and R. J. Moore, *Exploring The Pedagogical Dimension Of Dwelling: Architecture As The Mathematical Unknown*. (Working Paper: Newcastle University, 1996).

34 Derrida and Wigley, "Jacques Derrida: Invitation To A Discussion," p. 16.

35 Ingraham, "Moving Target," p. 113.

36 Prior to Gödel's theorem all mathematics was assumed to be solvable - those few areas of continuing uncertainty were described as mathematical 'monsters' and attempts were made to classify them outside of mathematics. The mathematician Hilbert's final attempt to do this in the early twentieth century resulted in the creation of a first order language of mathematics in an effort to avoid the instability of self referentiality. It is this very instability which eventually lead to Gödel's theorem. K. Gödel, "Uber Formal Unentscheidbare Satze Der Principia Mathematica Und Verwandter Systeme 1," *Monatschefte fur Mathematik und Physik* (1931), n. 38. p. 173-198; D. Hofstadter, *Gödel, Escher Bach. An Eternal Golden Braid*. (New York: Basic Books, 1979).

37 M. Barnsley, *Fractals Everywhere* (New York: Academic Press and Harcourt Brace Jovanovich, 1988), p. 187.

38 B. Mandelbrot, *The Fractal Geometry Of Nature* (New York: W. H. Freeman, 1983), p. 82.

39 Mandelbrot, *The Fractal Geometry Of Nature* p. 285.

40 Barnsley, *Fractals Everywhere* p. 109.

41 Barnsley, *Fractals Everywhere* p. 107.

42 See Derrida's analysis of naming of C. Lévi-Strauss' *Tristes Tropiques* trans. J. Weightman and D. Weightman,

(London: Jonathon Cape, 1973); J. Derrida *Of Grammatology* trans. G. C.Spivak, (Baltimore: The Johns Hopkins University Press, 1976).

43 Wigley, *The Architecture of Deconstruction* p. 8.

44 Mandelbrot, *The Fractal Geometry Of Nature* p. C2.

45 Wigley, *The Architecture of Deconstruction* p. 12-13.

46 Barnsley, *Fractals Everywhere* p. 1, emphasis added.

47 H. W. Franke, “Refractions of Science into Art,” *The Beauty Of Fractals* eds. H. O. Peitgen and P. Richter, (New York: Springer-Verlag, 1986), p. 181, emphasis added.

48 G. Eilenberger, “Freedom, Science, and Aesthetics,” *The Beauty Of Fractals* eds. H. O. Peitgen and P. Richter, (New York: Springer-Verlag, 1986), p. 175.

49 Eilenberger, “Freedom, Science, and Aesthetics,” p. 175.

50 Barnsley, *Fractals Everywhere* p. 208.

51 Barnsley, *Fractals Everywhere* p. 172-173.

52 Mandelbrot and Schroeder; exceptions to this general observation are discussed later in this paper.

53 Mandelbrot, *The Fractal Geometry Of Nature* p. 131-132.

54 H. Hahn, “The Crisis in Intuition,” *The World Of Mathematics* ed. J. Newman, (New York: R.Simon and Schuster, 1956) v. 3.

55 Mandelbrot, *The Fractal Geometry Of Nature* p. 131-132.

56 M. Schroeder, *Fractals, Chaos, Power Laws. Minutes From An Infinite Paradise* (New York: W. H. Freeman, 1991) p. 19-20.

57 Schroeder, *Fractals, Chaos, Power Laws* p. 84.

58 Schroeder, *Fractals, Chaos, Power Laws* p. 84.

59 Schroeder, *Fractals, Chaos, Power Laws* p. 69.

60 Schroeder, *Fractals, Chaos, Power Laws* p. 69.

61 A view supported without resorting to architectural metaphors by; A. McRobie and M. Thompson, “Chaos, Catastropies And Engineering,” *The New Scientist Guide To Chaos* ed. N. Hall, (London: Penguin Books, 1992), p. 149-161.

62 Schroeder, *Fractals, Chaos, Power Laws* p. 224.

63 Schroeder, *Fractals, Chaos, Power Laws* p. 225.

64 Wigley and Kipnis, “The Architectural Displacement of Philosophy,” p. 98.

65 I. Stewart and M. Golubitsky, *Fearful Symmetry: Is God A Geometer?* (London: Penguin Books, 1992), p. 249.

66 Mandelbrot, *The Fractal Geometry Of Nature* p. 23-24.

67 Consider that the Miesian building is essentially rectilinear in plan. Rectilinear windows, doors and internal spaces divide the overall mass of the building into smaller rectangular zones. Upon further close examination the Miesian building is also composed or right-angled details, and rectangular structural members and cladding forms. The Miesian building, and its modernist progeny, are self similar at up to ten obvious levels of scaling - far more than the Castel del Monte!

68 It should be noted that in teaching scientific concepts two qualities are held in high regard. Firstly all scientific teaching is expected to be derived from logical assumptions, from experimentation and from careful observation. Secondly scientific writing, more so than in any other discipline, is expected to be without personal bias. Mandelbrot fails in both regards.

69 Mandelbrot, *The Fractal Geometry Of Nature* p. 23.

70 Barnsley, *Fractals Everywhere* p. 299.