Biomimetic Architecture: Ecotonic transmutations across the urban membrane

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Keywords: Biomimetics, Process-based Ecotonic Architecture, Biomimetic Sustainability

Biomimetic design maintains a critical role in the development of a sustainable and environmentally responsible society. It relates to the dynamic between climate and living organisms, seeking to work with rather than against the external environment. It raises the prospect of a closer integration of form and function, promising to yield new means by which built environment research and design professionals may respond to and interact with their environment, and the design potential and responsibility of designing within it.

Biomimetic design challenges the notions of `sustainability` and how contemporary ideologies may be translated into living systems with a future, rather than future living systems. Allowing the development of broad areas of research that promote holistic rather than exclusive architectural models for sustainable design, Biomimetic architecture merges an astute selection of observed properties with sophisticated passive and artificial technologies and thus inform their subsequent hybrid development.

The initial architectural encounter occurs at building skin/ecotone level. The ecotone encompasses a zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales. As such it encompasses a myriad of expectation, desire and perception, adhering to the prescription that the skin should at once be symbolic, explanatory or interpretative. Gibson describes how the skin can often explain and indicate of the nature of the relationship, which exists between the animal and its environment: the 'Gibsonian niche' [1] in which we all dwell. The exchange of climatic information and energy functions over time, displaying attributes of growth viewed by D'Arcy Thompson (Thompson, 1992) to always be a 'function of time', so that growth and metamorphosis be considered as events in time and space [2]. This exchange occurs between and within the building skin. Far from an impermeable edifice, the skin is a dynamic network of layers defining the internal environment from the external. It does not simply surround and separate. Mobius like, the distinction between inside and outside remains indefinite but within this continuum a spectrum of micro-niches and their associated microclimates are maintained within levels of order.

The term 'biomimetic' was originally used with reference to chemical reactions. In that domain, biomimetic chemistry refers to reactions that, in nature, involve biological macromolecules (e.g. enzymes or nucleic acids) whose chemistry can be replicated using much smaller molecules. The contention to be argued here is that architecture is chemistry, a complex mediation of interior demands and exterior forces converging on the borderline (Woods, 1998) [3], the ecotone therefore is the place of this chemical reaction. The 21st century has already been deemed the century of biology (Vincent et al., 2005) [4] it is therefore appropriate that this paper should take a biological approach to sustainable

architectural design, advocating a holistic biomimetic approach to the design and interpretation of the building envelope. As Woods concurs: 'If architecture searches for new modes and new typologies from the same experimental potential inherent in difficult borderline conditions themselves, then it can become an instrument for the cultural transformations, struggling today to occur' [5]. Biomimetic and bioclimatic analysis and design deliver a built form that enables oscillations around and between a given set of environmental parameters: maintaining bioclimatic homeostasis. Strategic and tactical approaches regarding successful form and function are informed by a thorough understanding of appropriate site analysis. A climatically derived form simultaneously signs and interprets place whilst maintaining a gradated continuum between interior and exterior.

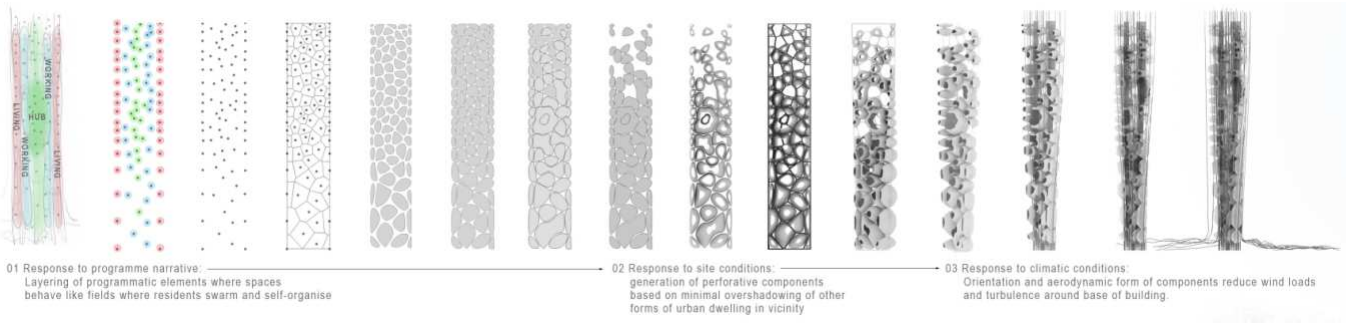

Fig. 1 Biomimetically inspired layering responses to site and climate

This paper proposes a revision of the concept of 'building skin' advocating the proposition and utilisation of the term ecotone with regard to building envelope. It is the contention of this paper that we should no longer regard buildings as truly living or as machines for living in, rather as a process based para-biotic architecture that supports life and living systems whilst exhibiting, but not possessing the attributes of life. This para-biotic stance proposes a revision of the concept of 'building skin' as a descriptor of the building envelope, supplanting it with the concept of the ecotone. The development of which may prove more than a hypothetical metaphor, but a new design paradigm, a model for holistic, sustainable urban design, an ecologically synergistic, generative architecture of an energy positive and progressive tomorrow. It describes how the concept has been tested through research by design, a pedagogical method of architectural research, undertaken in the Biomimetic Research, Architecture and Design Unit at the Manchester School of Architecture, England, through examining a selection of design projects, using Biomimetic design as a generative design process (Fig. 1). The results of which demonstrate the possibilities of Biomimetic architecture as a simultaneous alternative to the limitations of both aesthetic zoomorphism, and stagnant urban development. They offer a process based design model, and an instinctively sustainable synergistic solution to both environmental design challenges, and the education of tomorrow's architects and urban designers.

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1.1 Introduction

Biomimetic design maintains a critical role in the development of a sustainable and environmentally responsible society. It relates to the dynamic between climate and living organisms, seeking to work with rather than against the external environment. It raises the prospect of a closer integration of form and function, promising to yield new means by which built environment research and design professionals may respond to and interact with their environment, and the design potential and responsibility of designing within it.

Initial architectural encounter occurs at building skin/ecotone level. The ecotone encompasses a zone of transition between adjacent ecological system, having a set of characteristics uniquely defined by space and time scales and by interactions between adjacent ecological systems. As such it encompasses a myriad of expectation, desire and perception, adhering to the prescription that the skin should at once be symbolic, explanatory or interpretative. Whichever doctrine one follows, the skin can often explain and indicate of the nature of the relationship, which exists between the animal and its environment.

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The 21st century has already been deemed the century of biology (Vincent et al., 2005) [2] it is therefore appropriate that this research should take a biological approach to sustainable architectural design, advocating a holistic biomimetic approach to the design and interpretation of the building envelope. As Woods elucidates:
'If architecture searches for new modes and new typologies from the same experimental potential inherent in difficult borderline conditions themselves, then it can become an instrument for the cultural transformations, struggling today to occur'[3].

This paper proposes a revision of the concept of 'building skin' advocating the proposition and utilisation of the term ecotone with regard to building envelope. It is the contention of this paper that we should no longer regard buildings as truly living or as machines for living in, rather as a process based para-biotic architecture that supports life and living systems whilst exhibiting, but not possessing the attributes of life. This para-biotic stance proposes a revision of the concept of 'building skin' as a descriptor of the building envelope, supplanting it with the concept of the ecotone. The development of which may prove more than a hypothetical metaphor, but a new design paradigm, a model for holistic, sustainable urban design, an ecologically synergistic, generative architecture of an energy positive and progressive tomorrow. It describes how the concept has been tested through research by design, a pedagogical method of architectural research, undertaken in the Biomimetic Research, Architecture and Design Unit at the Manchester School of Architecture, England, through examining a selection of design projects, using Biomimetic design as a generative design process (Fig. 1). The results of which demonstrate the possibilities of Biomimetic architecture as a simultaneous alternative to the limitations of both aesthetic zoomorphism, and stagnant urban development. They offer a process based design model, and an instinctively sustainable synergistic solution to both environmental design challenges, and the education of tomorrow's architects and urban designers.

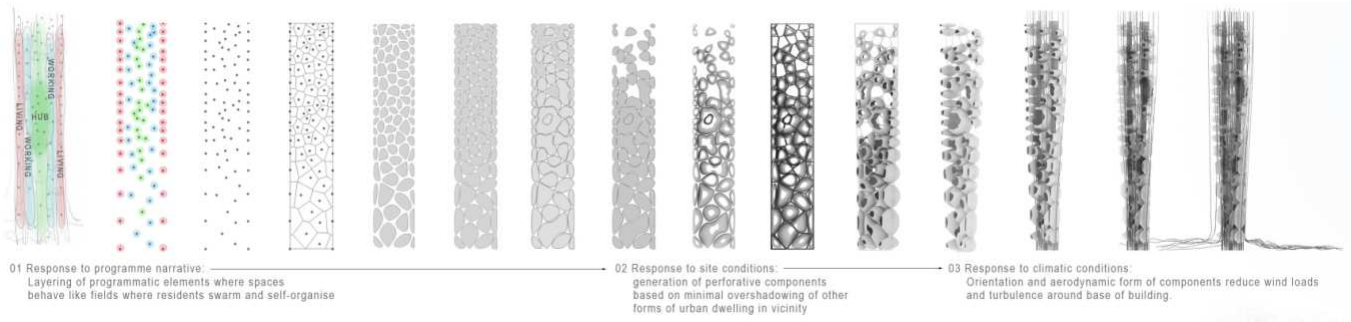


Fig. 1 Biomimetically inspired layering responses to site and climate – R Sim, MSA BArch

1.2 Bioclimatic Architecture: Biomimetic Responses

Bioclimatic architecture concerns itself with climate (or perception of climate) as a major contextual generator, and with benign environments using minimal energy as its target [4]. Drawing first inspiration from Gibson who describes ecology as a fit between niche and occupier [5], we reinterpret place through notions of ecology, evolution and environmental forces. This proposes an advancement from Norberg-Schulz's[6] theories of space, place, space and character, and environmental forces (climatic, social and perceptive) to complete the grammar of architecture. By applying process based natural analogy, mediation is achieved between the architecture of ecological time and times disembodiment, a by-product of the postmodern condition.

Two holistic models of natural systems, organism and community are applied to architecture in order to determine the formation of an environmental ethic. To create an autonomous architecture it is necessary to have a model that is both ecologically and ethically sound; the single idea of an organism is not so. Here individual buildings must be seen as part of an archi-ecosystem, isolatary vacuums both natural and intellectual are biocidic (Fig. 2).

Fig.2 Archi-ecosystem urban masterplan, Manchester – R Sim MSA BArch.

Bioclimatic analysis and design delivers a built form that enables oscillations around and between a given set of environmental parameters: maintaining bioclimatic homeostasis. Strategic and tactical approaches regarding successful form and function are informed by a thorough understanding of appropriate site analysis. A climatically derived form simultaneously signs and interprets place whilst maintaining a gradated continuum between inside and out. Appropriate signing of place clearly acknowledges the already demonstrable effect the climate has upon it. For this purpose, building intelligence is both passive and reactive, mitigating the effects of a dynamic external environment upon internal conditions whilst harnessing their energy so as to maintain optimum internal environment. Through this analysis biomimetic design challenges the notions of `sustainability` and how contemporary ideologies may be translated into living systems with a future, rather than future living systems. Allowing the development of broad areas of research that promote holistic rather than exclusive architectural models for sustainable design, that merge an astute selection of observed properties with sophisticated artificial technologies and thus inform their subsequent hybrid development.

The exchange of climatic information and energy functions over time, displaying attributes of growth viewed by D'Arcy Thompson (Thompson, 1992) to always be a 'function of time', so that growth and metamorphosis be considered as events in time and space[7]. This exchange occurs between and within the building skin. Far from an impermeable edifice, the skin is a dynamic network of layers defining the internal environment from the external. It does not simply surround and separate. Mobius like the distinction between inside and outside remains indefinite but within this continuum a spectrum of micro-niches and their associated microclimates are maintained within levels of order.

1.3 Skin

Skin is the greatest of mediators; controlling the critical moment between interiority and exteriority in order to monitor and exploit the differences between the two environments. The boundary is therefore seen as performative, 'designed to catalyse and accommodate change' (Lobsinger 2000)[8]. Clearly, throughout architectural discourse a conceptual distinction has been made between the outer covering or 'skin' of the building and the inner structural and gravity bearing elements, which remain occult. Alberti placed the origin of

Fig. 3 Bio-City - J. Dent & S. Shaw MSA BArch

architecture as constructed naked and later dressed with ornament; therefore surface or skin has been regarded in terms of this oppositional dualism. It is seen as a resultant condition, one in which the 'sur-face'[9] as an upper or outer layer can be scraped back, thereby revealing the true inner architectural surface. Under this conception, surface is generally assumed to have a 'thickness' that covers and masks. However the ephemeral surface, so integral to visual cognition has also been regarded as 'an abstract entity that marks the theoretical distinction between two things, or thing and nothingness'[10] (Fig. 3) (Taylor 2003).

There is much discourse in the architectural forum regarding the perceived aesthetic of the building envelope. Patently, the initial architectural encounter occurs at building skin level. As such the skin encompasses a myriad of expectation, desire and perception, adhering to the prescription that the skin should at once be symbolic, explanatory or interpretative. Whichever doctrine one follows, the skin can often explain and indicate of the nature of the relationship, which exists between the animal and its environment [11]. The skin is also an edge, a boundary between two phases; a linear break in continuity, a lateral reference rather than a coordinate axis. Whilst it may be penetrable it may also form a barrier, prohibiting one region from the activity of another[12]. As Woods notes, the surface is a borderline where dialogical 'others' flourish, 'feeding of its ambiguities and uncertainties' [13].

A skin is an external covering, providing protection; it purveys an interior and an exterior, form and structure, yet is pliable and ever changing, appearing inert, yet capable of gathering knowledge and responding to environmental conditions. A skin is the essence of appearance, a Saussurian semiotic response to the process of naming. Architecture and the body are unashamedly intertwined and yet the skin, the cornerstone of perceptive spatial engagement, could, should, and possibly is something entirely different.

1.4 Bio-City

This hypothesis was tested in the conceptual project Bio-City, a skyscraper which operates as a completely closed metabolic cycle (Fig. 4) in which traffic exhaust emissions are harnessed via CO_2 collectors in order to feed algae grown in photo bio-reactors within the building's facade. Algae and natural by-products produced during algae cultivation are then refined to produce renewable energy sources.

Towering 1.2 km above Spaghetti Junction, Birmingham, the UK's largest and most congested motorway intersection, the scheme portrays a radical concept in high rise, high density urban living. Benefitting from positive solar orientation, in order to maximize solar acceptance toward the dynamic photo bioreactors which are built into the facade, Bio-City acts as a an environmental filter, harnessing harmful traffic exhaust emissions in order to feed and cultivate microscopic algae to produce renewable bio-fuels. These bio-fuels are used to produce renewable electricity to power the vertical city and to cultivate vehicular bio-diesel and liquid hydrogen for use in hydrogen fuel cells.

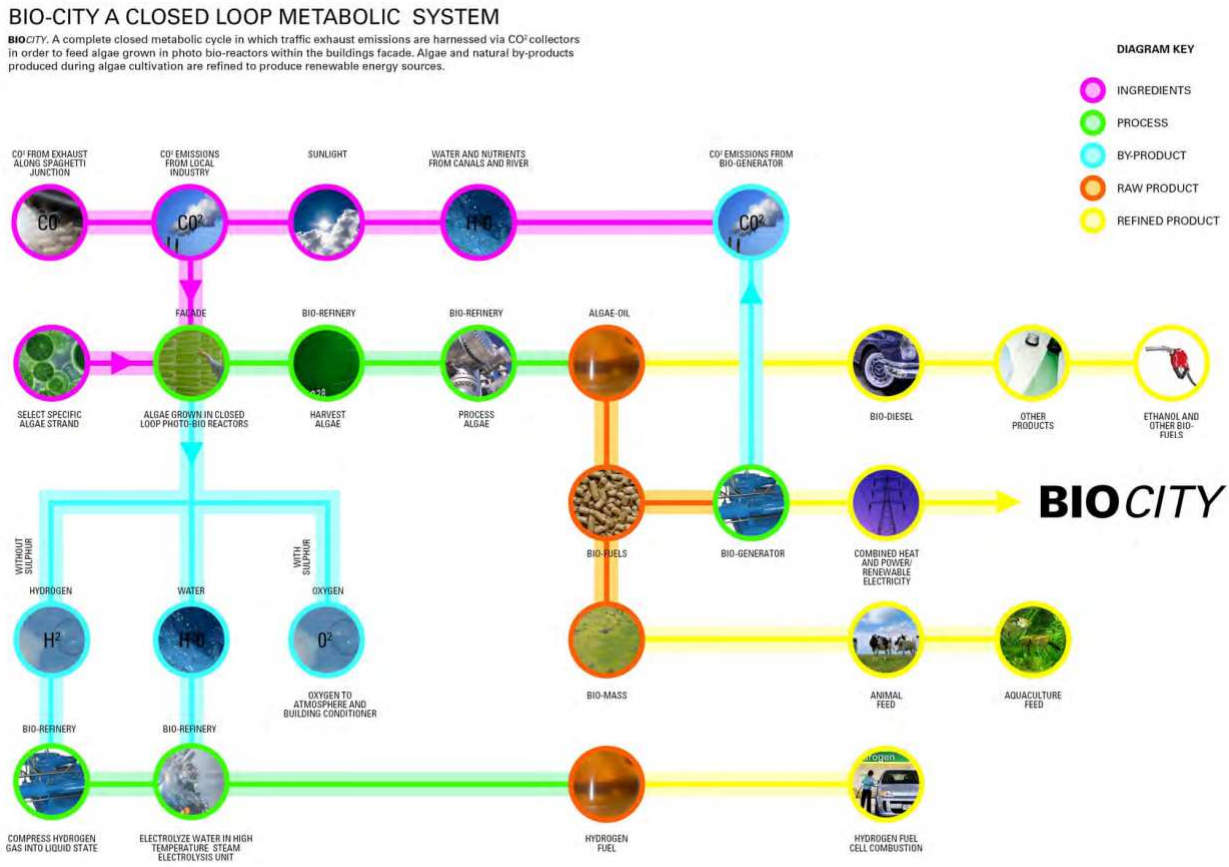


Fig. 4 Bio-City closed loop metabolic cycle - J. Dent & S. Shaw MSA BArch

Since algae need sunlight, carbon-dioxide and water for their growth, they can be cultivated in open ponds. However, the unassisted growth in open ponds is slow, alternatively, for use in the vertical city, algae is grown in closed photo-bioreactors, where the environment is better controlled. Three towers constituting a massive 1,850,000 square meters of facade area, allow for algae bio-cultivation to take place within plastic tube photo bio-reactors integrated within the double skin facade. With the cultivation of 150,000 gallons of refined algae oil per hectare, this adds up to an impressive 1,300,000 barrels of renewable bio diesel produced by Bio-City each year.

1.5 Ecotonic Autopoesis: Boundary maintenance

It is an autopoetic assumption that the boundaries of an organism are not defined according to physical boundaries such as skins but are extended along its sensory and functional inputs and outputs [14]. Architecturally inclusive and yet clearly linked to resource flows across the site and through the building. Systems constantly seek to actively distinguish themselves from their environment in an attempt to preserve their distinctness and maintain their identity. It is a complex landscape in which fragments may retain their identity and yet meld, through negotiation and chance, into a new form of continuity'[15] (Woods 1998). Boundary maintenance is a crucial part of the self-preservation of all systems, which can be understood as self-reverentially enclosed life-worlds populated respectively by friends and enemies. Such systems are latent with relevant potentials, both for threats to members of such systems, as well as for possible sources of 'energy' and 'nourishment' able to sustain and evolve new arrangements [16].

Symmetrical schismogenesis occurs when two or more conditions reinforce each other within given situation and encourage exponential growth in one direction [17], generating an architectural ecotone, tectonic intervention. Complementary schismogenesis occurs when 'mutually promoting' actions are essentially dissimilar but mutually appropriate [18]; a concept tested in Alpine_Cliff Climber (Fig. 5), which aims to provide a direct link between two Alpine resorts in one smooth flow creating a parasitic symbiosis. The tower is primarily a cliff scraper with the majority of the building mass climbing the great cliff heights of the fragmenting urban barrier.

Fig. 5 Alpine_Cliff Climber – T. Bedford MSA BArch

Investigation into the growth patterns of climbing plants opened a basis for mimicry in regards to their helical formation and tendril growths used to scale vertical faces. The organic building shape evolved through light studies, creating the optimal shape to collect the maximum available solar gain for energy generation at the site. To take advantage of the location's wind conditions a single large helical turbine is integrated into the top of the tower to generate energy.

The bio construction combined with growth formation of climbing plants is what allows the climbing plant to minimise material usage and to maximise strength and growth height. The tower's internal and external structures mimic the natural helical formation creating maximum strength and stability within an organic shaped cliff scraper. Rock face ties mimicing natures tendrils, reach out from the tower's primary structural cores connecting them to existing natural cracks and faults within the cliff face using adapted rock climbing techniques. This combination allows the tower to freely twist and bend without compromising structural stability.

Ecotones have been described by Holland et al (1991) as 'zones of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of interactions between adjacent ecological systems'[19], as such they are dynamic entities with both a spatial and temporal property (Hufkens et al. 2008)[20]. As such Alpine_Cliff Climber creates the desired direct link to provide efficient movement between the two alpine resorts, whilst also providing an effective transition zone or ecotone, a dynamic intervention to an otherwise fragmenting urban barrier.

1.6 ParaSITE / Ecotone

The study of process in intrinsically context based, one cannot be studied without each other. Process based biomimetics seeks to produce ecologists of built form; Archi-ecologists who through research demonstrate an understanding of the processes involved in nature, seeking to emulate how they work rather than simply how they look, challenging notions of environmental complexity, structural formation and habitation (Fig. 6). Through understanding ecological processes we can extrapolate these into architectural situations.

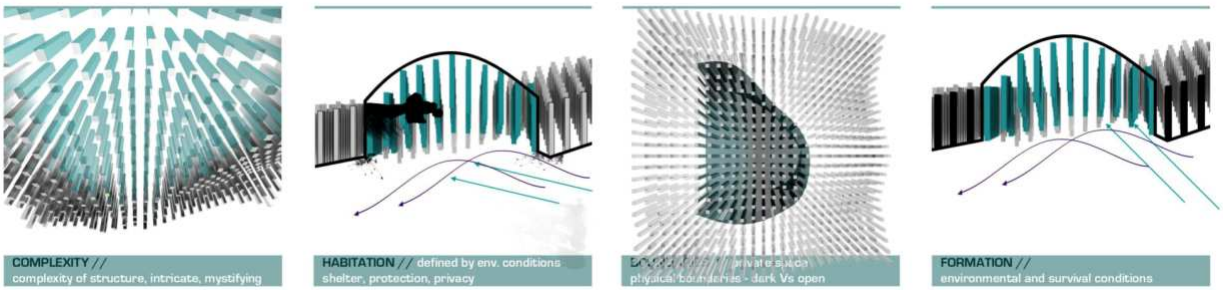
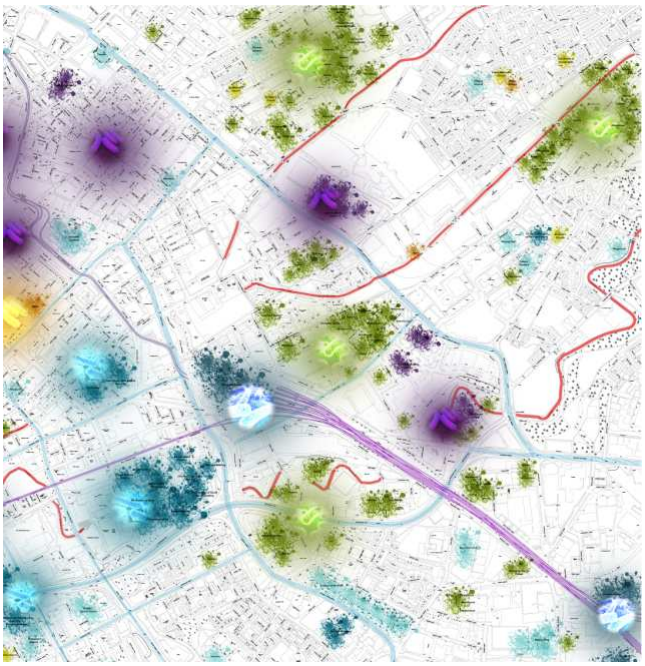


Fig. 6 Urban Cave / Speleogenic Skin – C. Loucaides MSA BArch

Ecotones are edges[21] (Orlóci and Orlóci, 1990), transitional areas [22](Peters et al., 2006) or boundaries[23, 24, 25] (Kent et al., 1997, Fortin et al., 2000, Fagan et al., 2003) and are typically characterised in ecological research as areas displaying a high rate of change compared to that of adjacent areas[26] (Risser, 1995). This high rate of change is reflected in the ecotone dynamics and the fluxes between neighbouring ecological systems, affecting the structure at macro, meso and micro scales within these systems [27, 28, 29](Naiman and Décamps, 1990; Cadenasso et al., 2003; Saunders et al., 1999). As such they occupy zones of transition, transformative spaces that are capable of adaptation and change. This concept has been extrapolated at Manchester School of Architecture through a 'parasitic' site analysis conducted on areas undergoing urban regeneration in Manchester (Fig. 7).



ParaSITE extrapolates a viral analogy identifying areas in need of parasitic regeneration. The biomimetic approach to this project identified Manchester as a healthy organism with a well developed *"circulatory"* network system. Some parts of this organism are thriving and some are disintegrating or undergoing change. The suggestion is to introduce a beneficial parasitic urban remediation process that would catalyse this process of change according to the needs of these areas. Considering the social and cultural needs of this site, one of the parasites introduced was responsible for developing a three-dimensional mesh of networks, thus increasing circulation and furthering the growth of other parasites.

Fig. 7 ParaSITE, Mayfield, Manchester – C. Loucaides MSA BArch

This project formed a complete amalgamation of both site research and environmental factors (Fig. 8), forming a site-specific masterplan. The three-dimensional mesh of networks generated through ParaSITE analysis defined where the spaces, paths, bridges, and access points would be located in the final development. The network is defined by extending the surrounding roads/paths on the site plan, the wind patterns, sun altitude and longitude at different times of day and season and water movement.

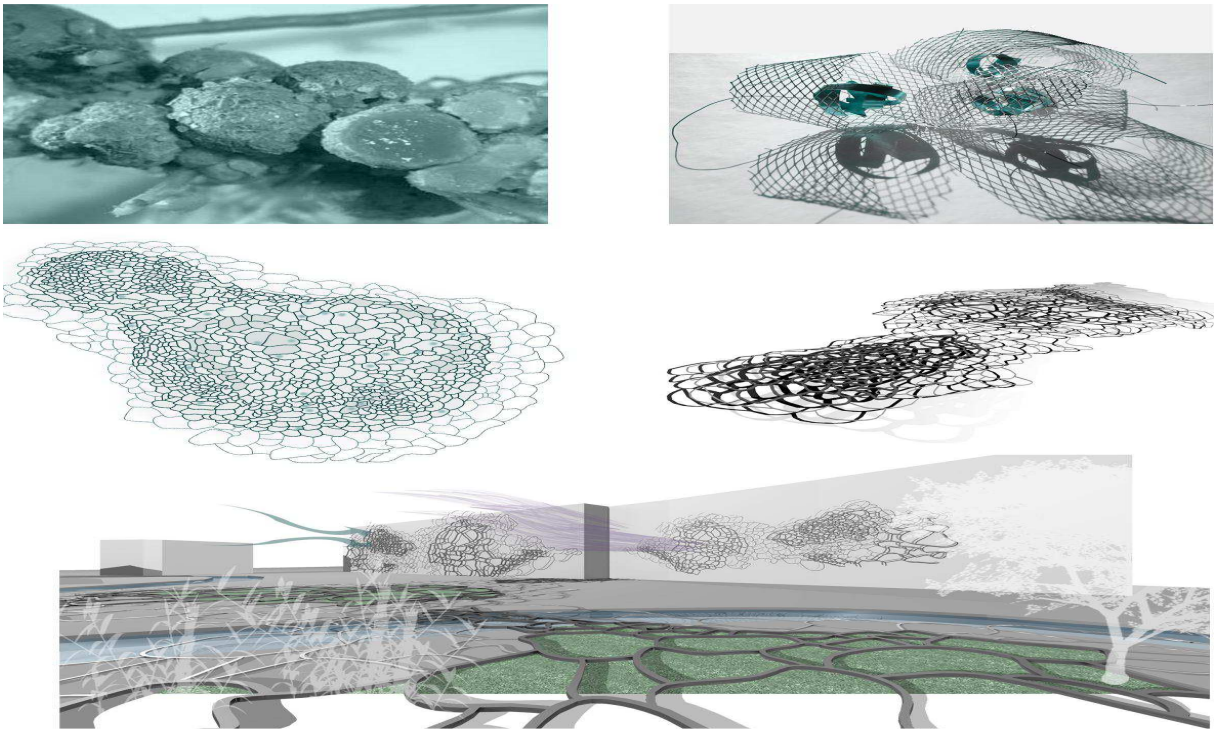


Fig. 8 Development pattern of parasite characteristics; the parasite, conceptual form, growth/life pattern, architectural translation and architectural use. ParaSITE, Mayfield, Manchester – C. Loucaides MSA BArch

Problems identified through the theoretical site research defined which life characteristics were required in order to overcome and solve them. Four parasitic organisms (living on or with a host for mutual benefit) were chosen. One of the parasites was responsible for de-composing/recycling, the other for fixing or controlling, the other for zoning and defining location of spaces, and finally the fourth for generating a "root" network system used for movement. Form and function of the spaces was a mixture of all the above characteristics; a traditionally biomimetic response, the way that nature would solve the problem. Whilst this remains a theoretical investigation, it has evolved to become a scalar ecotone; a zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of the interactions between adjacent ecological systems.

1.7 Conclusion

The research by design case studies discussed in this paper demonstrate the possibilities of understanding natural processes and examining architecture through biological analogy. Para-biotic investigations conducted at Manchester School of Architecture propose that we should no longer regard buildings as truly living or as machines for living in, rather as a process based biotic architecture that supports life and living systems whilst exhibiting, but not possessing the attributes of life. The development and design of ecotonal and parasitic research may prove to be more than a hypothetical metaphor; instead they encompass the possibility of a new design paradigm, a model for holistic, sustainable urban design, an ecologically synergistic, generative architecture of an energy positive and progressive tomorrow.

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