Eco-machinic Others:[1] From Polarities to Gradients

The discipline of architecture constructs itself between the twinned poles of art and science, producing a schizophrenic tendency of acute ambivalence towards the determinacy of the quanta and the ineffability of the sublime. Quantitative methods have traditionally served as an optimal limit function in the engineering and construction of built form; this paper examines how they can instead be used generatively as search algorithms within a stochastic domain, in an effort to reintegrate the function of ecology into the built environment.

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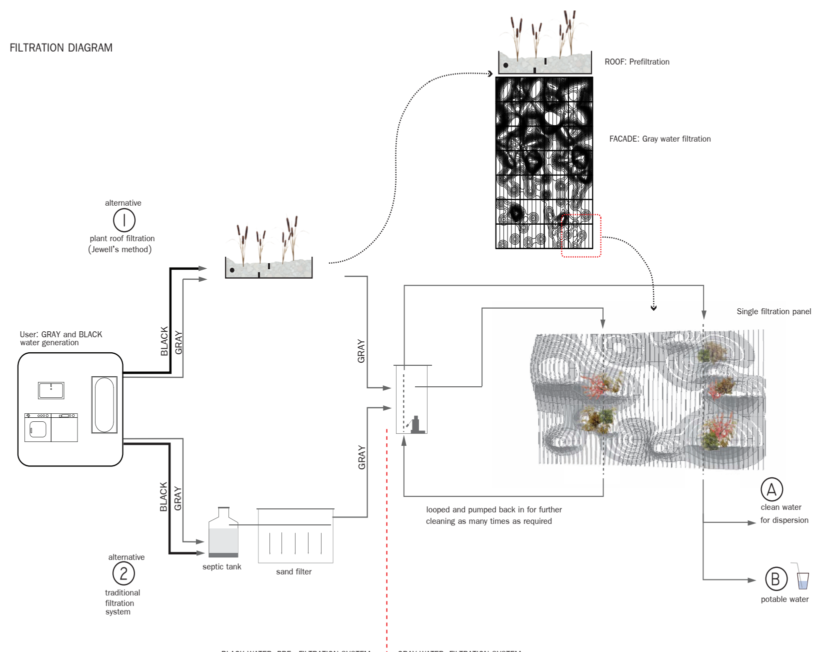
> *"All nature is but art unknown to thee;*
> *All chance, direction which thou canst not see;*
> *All discord, harmony not understood;*
> *All partial evil, universal good;*
> *And, spite of pride, in erring reason's spite,*
> *One truth is clear, "Whatever is, is right."*
> – Alexander Pope, *"An Essay on Man,"* Epistle i, I. 289

All technologies have a foot in both worlds: the world of material operation and the world of social signification. One speaks to the present, one to the future. Since humans are by nature prognostic beings – and perhaps this is what separates us from the beasts – we make judgments based on both worlds: what is and what we hope will be. In the design world of system thinking and computation, the fitness algorithm lives in a netherworld between actuality and becoming. Here, there is no techno-fix, no silver bullet that defies the "monsters"[(2)] of anthropocentric architectural production. Technological processes are explored as passive, malleable, and distributed, propagating technological anarchism, to yield a design framework that engages cultural and social meanings.

> *"Those who guard the gates will soon discover that they have become docents in the museum of fossils."*
> – Christopher Hight, *"Designing Ecologies"*

The contemporary (inter-)disciplinary polarity related to issues of the environment seems rather dated. Are we still perpetuating the dubious nineteenth-century Salon model of highbrow exclusivity? While Christopher Hight, in P*rojective Ecologies*, claims "that ecology is perhaps our most important epistemological and ontic framework for understanding and projecting possible futures,"[(3)] we are still debating the relevance of cultural ecology as an integral parameter for design thinking.[4]

Since the dawn of Modernism, alternative climate-based design investigations have existed parallel to the academic disciplinary mantra. Mid-twentieth century architectural explorations such as Yves Klein's P*roject for a Sheltered City*, Archigram's *Cushicle* or *Walking City*, and Buckminster Fuller's *Weathering Dome over New York City*, among others, projected a willful responsiveness to the environment with a grand and heroic flourish. These projects began to directly engage the constant conundrum and fluctuating nature of our professional identity, described by Reyner Banham in *The Architecture of the Well-tempered Environment* as "the infantile fallacy that architecture is necessarily divisible into function and form, and that the mechanical and cultural parts of the art are in essential opposition."[5] Planting this seed of utopia for future realities – "You can't get anywhere in life if you can't imagine it first."[6] – this work conceptually affected the direction of technical evolution. Today, tempered by pragmatism, it engenders the schism of doubt about its future feasibility[7]; but, at the same time, continues to offer us cues to better understand effective scales and protocols for systems integration.



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ECO-MACHINE

Over the past five years, I have engaged in design experiments and investigations with students of architecture. With a design logic that links algorithmic and stochastic methods of production, we employed environmental metrics and feedback loops in an effort to investigate the eco-machinic constructs within an architectural framework. The eco-machine serves as a conveyance system, a processing model to enable a gradient field that allows for flow distributions of resources, matter, and information between organic and inorganic constructions. The corresponding architectural system is not conceived as an optimized object, but as a flow model for the production and embodiment of operations that can self-sustain and transform over time.

Figure 1: Processing system diagram for distributed grey-water filtration, *EatMe Wall*.

Architecture and Ecology have historically stood in opposition, and failed to understand their relationship as a gradient. This antagonism meant excluding each other's processes within their respective disciplinary frameworks. Just as ecology was conceived as the study of organisms in environments vacant of human existence, architecture and urbanism were constructed through the anthropocentric lens of object-making outside of ecological concerns, serving only the ideological framework of a particular cultural system.[8]

The following projects situate architecture in the framework of natural history. Just as evolution relies on material precedent, historical context offers raw material – the disciplinary norm – in the form of types, organizations, systems, or processes, from which, through code, the new adaptations evolve. In evolution, basic body plans have deterministic effects: an eye cannot become a limb; Here, too, the presence of a fundamental structure determines specificity of invention in the form of hybridization or incremental adjustment. In the context of technological evolution, history constricts the production of crossover effects.[9] These design tactics begin to reposition architecture's relationship to ecology, engaging dynamic processes in adapting formally and organizationally to specific information exchange and energy flows.

COMPONENT ARCOLOGIES

To test the potential socio-political effects of a self-sustaining urban system, we conducted a studio, *Component Arcologies* (2007),[10] with Dubai UAE as our case study. As the geographic site is defined by drinking water scarcity, the distributed water desalination processing system was speculated for use as an ideological subversion tactic against the restriction of collective use of urban space.

This work is predicated upon the belief that decision-making about how and what to build should be rooted in an understanding of particular eco-cultural matrix. To analyze such network of relationships can be studied and its agents distilled into components borrowed from biological categorization: the inorganic component of an ecosystem, or the biotope; the biotic component of an ecosystem, or the biological habitat; and the culture, or constructed human artifice. Such pedagogical simplification allows us to identify particular simulation feedbacks and their systemic relevance to the design problem. Operating within complex feedback loops, these three components are fundamentally dependent upon one another: inorganic matter is the result of physical processes that operate at multiple scales and are causally related to the biological habitats and human cultural constructs; habitats are a result of Darwinian evolutionary processes in which the genotype is modified through the interaction of phenotype, the biotope, and, increasingly, culture; cultural systems arise out the loose interaction of the ecological context, and they evolve in a Lamarckian[11] fashion, meaning that learned or acquired traits can be passed on from one generation to the next, and thus evolve towards greater complexity while deviating from the genetic source.

Working within this conceptual framework defies the traditional disciplinary dichotomy of nature versus culture. It also enables us to identify productive flows of exchange that can be mediated by eco-machinic constructs and suggest ways to approach further evolution of the system into a design proposition. The *Component Arcologies* design studio followed this framework, recognizing the potential link between the desalination process and local socio-economic space. In opposition to the trend of development in Dubai, a situation that promoted the agglomeration of isolated buildings lacking any connective tissue, this studio sought to create an urban infrastructural water desalination network that allowed for feedback between the local ecology and social structures. Students were encouraged to socially enable the foreign labor market enclaves imported to the country, in response to their spatially- and legally-imposed restrictions to self-organization. With a focus on scalar relationships between urban ecology and performative assemblies, the studio's goal was to refine a holistic methodology of adaptive component systems. This methodology let to the creation of an architecture tightly bound to the specificity of dynamic local ecologies, while still recognizing that contemporary means of production require a degree of repetition and material uniformity within contemporary production.

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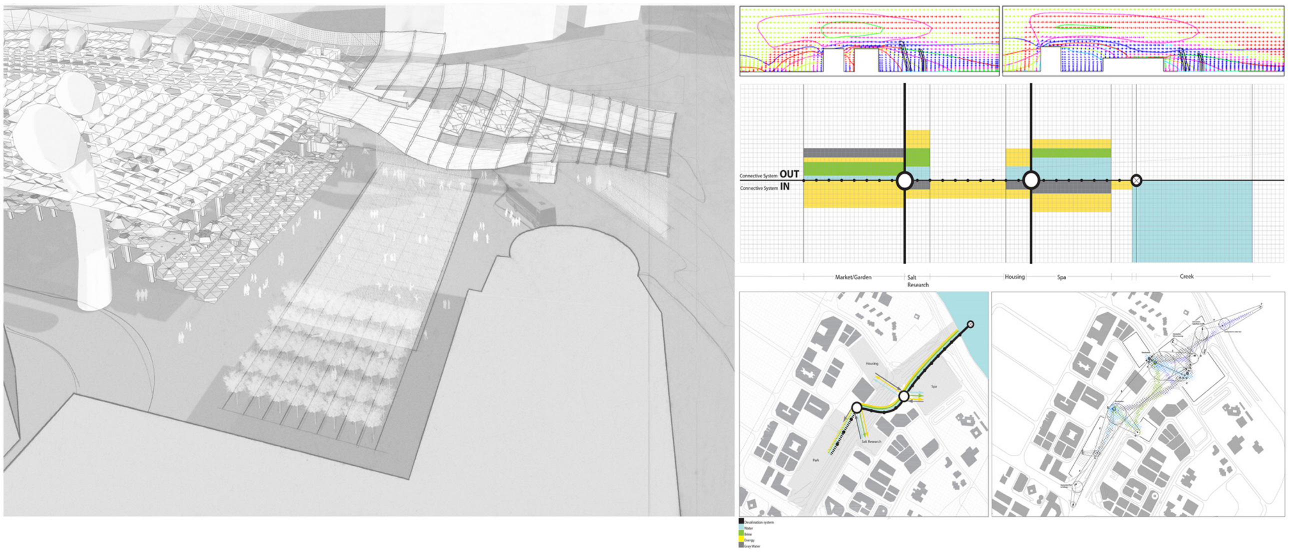

The underlying organizational system of the desalination process serves as a technologically-informed flow-logic, as the transformation to freshwater requires continuous high-energy output and incidentally generates brine waste, greywater, and heat. Taking into account the infrastructural needs for solar exposure, the production and management of a byproducts, as well as the resultant generation of varied microclimatic field conditions, the technical process of desalination and the nuanced consequences thereof informed the definition of new climactically-tempered urban spaces that could mediate the harsh natural temperatures. A programmatic framework also evolved from a close study of the desalination process and its effects: From brine-processing studios, to low-income housing, to steam baths that could post-process the waste heat, the programmatic components tied energy flows of production together with an organization of social systems.

Operating simultaneously at the scale of the urban system and the scale of component assembly, feedback loops provided specific energy- and climate-based localized simulation feedback. Within the shared context of industrial ecology the urban scale, the project biased Birkeland's position that "in natural systems there is no such thing as 'waste'" and that "nutrients from one species are derived from death or decay of another."[12] The programmatic components connect to the operative field of desalination through the logic of their energy input and output; infrastructure can be seen as a natural system, feeding itself off the potential waste and allowing for a framework of interconnectedness.

Figure 2: *Component Arcologies* desalination canopy system proposal, airflow simulation and urban diagrams, Cornell University 2007.

In the UAE, the conditions of extreme heat and tightly controlled natural resources are used ideologically to induce certain social systems through spatially-controlled environments: the isolated objects of intensely air-conditioned bubbles – the only officially authorized public spaces – are under constant surveillance, architecturally and strategically preventing the formation of public forums. In response to the region's diurnal climate fluctuation, alternative publics and cultures activate with the setting of the sun, while the streets and sidewalks are cooled naturally with the aid of thermal mass effects that stem from urban object aggregation. In the spirit of Paolo Solleri's legacy,[13] *Component Arcologies* translated a need for continuity across the industrial desalination process into the surplus value of tempered urban public space.

In the design process, we begin by initializing familiar passive principals of existing technologies – solar chimney, thermal mass, evaporative cooling, etc. – with localized climate-based constraints. These are then translated into geometric instances, behavior of which can be easily simulated and visualized. The simulation helps to identify systemic performance variables that form the basis for further parameterization logic. The process of parameterization enables the testing of larger spatial organization and morphology, while maintaining feedback loops as a constraint mechanism.

ON TECHNOLOGICAL GRADIENT

The technological framework, here constrained within geometric behavior, serves as a scientific underpinning to the creative exploration of functional form, rather than an applied logic to the design object. Technology is a critical toolset that enables the production of culture and environment, and its integration this context can be seen as the evolutionary development of the abstract machine. It is a designed mechanism, the validity of which can only be tested through the combination of data and stochastic insight that determine the final design effect. Perhaps we might say that technology is just evolution by other means. Or rather, technology is the development of the machinic other, in the form of operative material algorithm, and in the service of a competitive advantage.[14]

Our means of proceeding with technology depend fundamentally on our approach to the problem: This is an epistemological question, the positing of which predetermines our answer. When we look at technology as apart or disconnected from environmental processes, we create a cognitive landscape with a limited horizon, envisioning the world as a series of problems to be solved sequentially. When we see technology as fundamentally connected to other intrinsic natural processes, our horizon broadens and we see our role not so much as engineers or problem solvers but in more general terms as orchestrators, hydrologists, managers – redirectors of material and energetic flows. One way of achieving this perspective is to analyze the systems we create and deploy in terms of natural systems themselves, thus imagining a unified epistemology where the dialectic between the natural and unnatural dissolves into a gradient. This allows us to see that a) no system is completely of our own making nor completely under our control, and b) process and flow govern the operations of the machinic other.

If we take an evolutionary approach to technology, the questions to determine the design methodology are the following: Temporality: Or when is it alive? Gradient: Or what is the playing field? Genotype: Or what is the information structure? Phenotype: Or what is the material organization? Fitness Algorithm: Or Who Dies? The emergence of architecture comes from the overlap produced between ecological and technological frameworks: the eco-machine. Architecture's role as eco-machine is in production of an active gradient that enables energy flows and transformations across varied domains.

LITTORAL ADAPTATIONS

The following design protocols engage data (metrics) logic at two scales: First at the larger urban/systemic scale, where the understating of context is mapped onto the energy flows based on Odum's systems ecology framework[15]; and then at the localized component scale, where dynamic simulation offers a localized constraint in production of a particular behavioral and formal trend. These design processes force us to shift between forms of representations and operations: from static to dynamic, cultivating intuition towards evolutionary behavior of organizations in the early stages of design.

Trying to explore the possibility of a closed loop system, the mapping of energy processing, using Odum diagrams, was central context analysis and programmatic organization for the *Littoral Adaptation* (2009) studio[16]. The prompt was for a minimal impact coastal research station within the transient and ecologically fragile littoral zone of La Jolla, California; with the projection of global warming and rising sea levels, the focus of the Littoral Adaptation studio was the investigation of minimal attachment to the ground within this ecologically fragile zone. This inquiry married systemic architectural responsiveness with the support of ecological resilience, while enabling the symbiotic coexistence of the fluctuating natural environmental and embedded architectural form.

Combining the needs of a hybrid program – algae processing infrastructure and an oceanic research institute – with a heightened sensitivity to the siting process, the design methodology relied on parametric digital technologies coupled with environmental data sets simulated through both linear and non-linear dynamic data modeling. The simulations and the iterative responses thereto were deployed in search for a new holistic sustainable material form, allowing for the adaptation to deviation in sea level over time. A hierarchy and programmatic subgrouping logic kept the complete system flow in check: variable material component systems addressed and mediated localized ecological conditions within larger organizational energy flow. Fundamentally, this is a biomimetic methodology, in that it seeks to exploit the malleability of flexible component assemblies, a process tuned to obtain a definite set of points in both space and time.

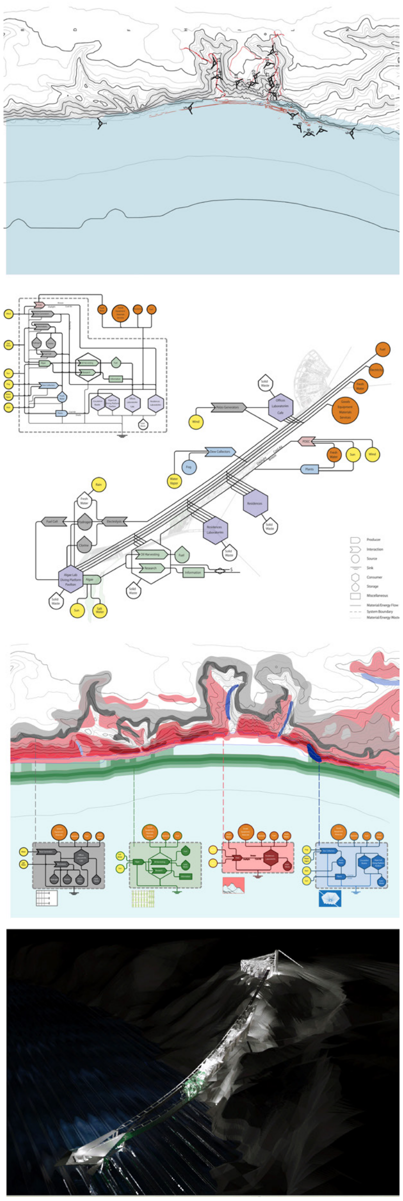

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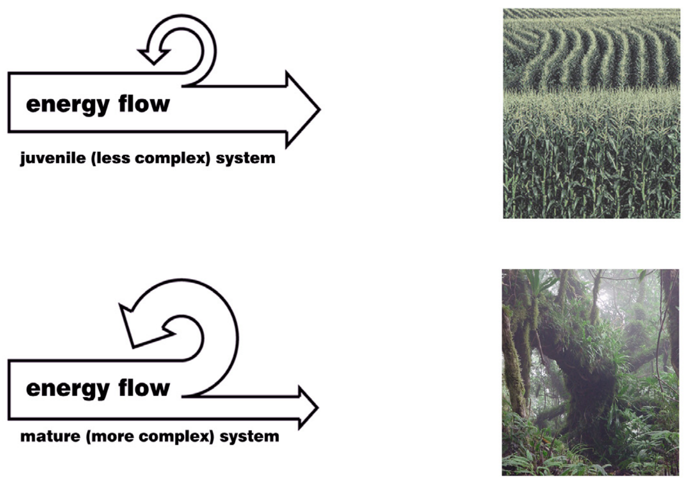
Figure 3: *Littoral Adaptation* tension cable system proposal; topography and energy flow diagrams, Cornell University 2009.

Patterns of airflow, projected water fluctuation, humidity variation, and solar exposure were used to define a framework for the energy throughput, identifying specific geo-local and microclimatic conditions within the landscape: We were looking for discreet ecological niches across the topographical variation between the cliff and shore. Translating the input and output of algae production and occupant habitation cycles using Odum's environmental math diagrams,[17] we mapped the energy pathways into a holistic system flow that nested particular programmatic elements within their respective environmental niches. The distribution of programmatic and architectural components was linked to energetic coupling of thermodynamic processes to form a closed loop system.

As in *Component Arcologies* studio, the *Littoral Adaptation* workflow governed the organization of information flow and exchange among the students: from a collective workflow to their individual projects. The organizational / infrastructural diagram was negotiated and established collectively, as a single shared urban-scale project, and the localized programmatic components, designed individually or in pairs, were continuously negotiating their input and output with the holistic system. The continuity of closed loop logic became a reality of the studio setting and collective work ethic.

ON SYSTEMIC COMPLEXITY

The critical insight we can borrow from ecology really comes from evolutionary biology: Evolution and adaptation can only take place in an open system. Evolution occurs in a feedback loop between genes, their mutation (code) and expression, and the environment. If we have mutation and consequent variation without external selective pressure, no adaptation can occur. This is particularly relevant in contemporary architectural practice engaged within the current bio-computational paradigm. Most often when we talk about a design "evolving", what we are really doing is creating variation using hermetic or internalized processes. Algorithmic design processes that do not respond to external data linked to both the ecological and cultural context, and that do not respond to the environment in which the design artifact is embedded, are merely interesting in a completely hermetic sense.



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Complexity is a significant parameter in understanding systems evolution. Research into the nature of energy processing in ecosystems suggests that complex "mature" systems are more stable, and are better able to capture and retain energy than "juvenile" systems.[18] An example might be the difference between a rainforest ecosystem and cornfield. Solar energy is processed more effectively in a rainforest than in a cornfield: In a cornfield, the solar energy is transformed into carbohydrates via corn kernels that are easily harvested, yet the system requires significant energy input in the form of fertilizers and other additives to survive. In a social-economic parallel, neoliberal systems organize our built environment, cultures, and ecologies as cornfields – seeking to maximize extractable "rents" towards a particular ideology of spatial ownership and control, rather than encouraging the design of systems with a degree of independency, self-sufficiency, and adaptability over time. The eco-machine strives to mitigate mature complexity embedded in its context and energy processing.

Figure 4: *After K.N.Lee*, by Dana Cupkova and Kevin Pratt

EATME WALL

In an effort to engage issues of mature, evolving, and metrically-informed open systems, I initiated a third project, the *EatMe Wall*,[19] that concentrated on issue of biodiversity. Biodiversity is another desired effect produced by eco-machinic systems that can help to rethink and dissolve the dichotomy between technology and environment. As ecologist and eco-urbanist Michael Wells states in his lecture "Biodiversity by Design," "To the ecologist, the tall buildings are no different than a cliff."[20] This understanding of ecology originates in a Guattarian[21] framework of ecology that includes social phenomena and supports the naturalist approach to the construction of the human environment, equally valuing the biotic and non-biotic. The *EatMe Wall* project is an exploration of how the biotic system construction can be used functionally, not as a green applique, but rather as an inherently embedded infrastructural system that supports and localizes wastewater filtration, and evolves independently overtime.

EatMe Wall is a collaborative design proposal produced within the framework of the research seminar *Adaptive Component System: From Prefabrication to Operative Ecologies*. The goal was to define a synthetic form that coupled the capacities of a greywater filtration system with the ability to fabricate using flat sheet material. The *EatMe Wall* is a customizable panelized modular facade designed for use both as a retrofit for existing glass curtain walls and in the construction of new buildings. As a secondary facade system, it creates usable exterior spaces along the vertical surfaces. The aggregate formal effect is defined within a repetitive workflow, that constraints the panel perimeter to the repetition of the same and targeted filtration capacity to production of formal difference. This produces a series of unique instances dictated by feedback loops and individual desires. Exterior spaces function as a distributed network of controlled microclimatic pockets for the purposes of climate control, plant growth, leisure use, and maintenance. The surplus benefits for interior spaces might be a control of direct gains and sol-air temperatures throughout the year.

The water filtration logic is based on the Nutrient Film Technique (NFT) for hydroponic plant growth and calculated with William Jewell's method for water purification[22], using a two-stage gravity-based system with the pretreatment roof area and greywater facade filtration system. The projected filtration capacity increases over time with per plant bed surface area growth. The NFT is based on the fact that wastewater carries nutrients necessary for plant growth, such as nitrogen and phosphorus, and the looping process embedded within the panel geometry would enable the water filtration and distribution process. The geometric response to meet the required filtration capacity is embedded in plant-pocket distributions that define both the filtration capacity and the formal logic. Distributed across the surface, these effects and intensities are tested through feedback loop routines that engage other effects, such as plant speciation related to solar incident radiation, shading effects, and fabrication constraint. Here, the particular metric acts upon the structural logic embedded within the surface generation. The negotiation of biodiversity occurs within the context of Jane Bennett's position of speciesism,[23] a type of more sensitive anthropocentrism that focuses on inclusive adaptability by accommodating the prerequisites of other species and larger ecology, yet promotes the central importance of human needs.

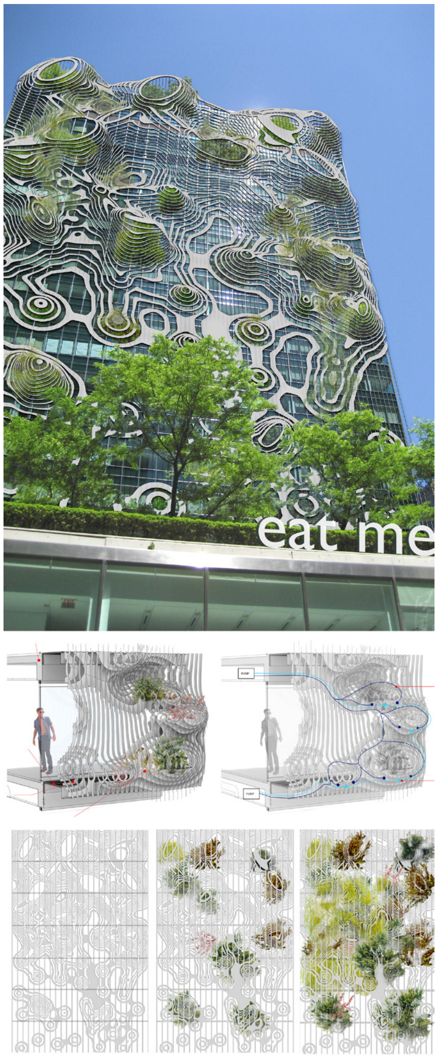

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Figure 5: *EatMe Wall,* panelized greywater filtration system proposal, Cornell University 2009.

ENDNOTES

1. The Other and "Otherness" refer to that which is alien and divergent from that which is given. (Wikipedia)
2. In folklore, the bullet cast from silver refers to a method to kill the "other", the unknown – mythical creatures such as monsters and werewolves.

ON DISCIPLINARY GRADIENT

Gregory Bateson recognized models of adaptation as proposed relationships between the genetic and somatic changes in response to environmental conditions. He argues "the somatic change may in fact precede the genetic."[(24)] That is to say, the genetic adaptation may be a consequence of the morphological change. Our work probes at the causality between morphology and environment as a primarily scalar and hierarchical relationship. Considering continual and long-term climatic change, contemporary design trends, creating hyper-specific and optimized formal solutions, will ultimately fall short of enabling adaptation. The adaptability built into the systems needs to emerge from the overlap of indeterminate analysis: the process of making a "best guess" while overlapping sets of analytical and observational data sets, and thus conditioning the system to a particular performative desire while accepting the fact that it will eventually grow beyond our control.

The issue of disciplinarity must constantly face the malleability of disciplinary boundaries and their gradients. This concern is inexplicably linked to the methods and processes of investigation, production, and representation. An open system would suggest a very non-deterministic boundary, with the potential to adapt to new set off information; this propagating the need for specific alien – or the other - expertise outside of the original territory. Adaptation equals survivability and relevance. It conditions disciplinary evolution. The boundary condition might be in a constant flux, but perhaps perpetuating the disciplinary schism is what will keep us relevant.

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3. Christopher Hight, "Designing Ecologies," in *Projective Ecologies*, ed. Chris Reed and Nina-Marie Lister, (2014).
4. It is not "if" it is relevant, but "how".
5. Rayner Banham, *The Architecture of Well-tempered Environment* (1984).
6. Kevin Pratt, in his lecture at the *Design for Biodiversity: Architectural Responses to Urban Ecology* symposium, Cornell University (2013).
7. The argument that the recent disciplinary efforts have failed to solve the environmental question is not a reason to stop trying.
8. Charles Waldheim, "Ecologies, Plural and Projective," in *Projective Ecologies*, ed. Chris Reed and Nina-Marie Lister (2014).
9. Not dissimilar from the concept of chaos theory – the butterfly effect: small perturbations may lead to significant change.
10. Design-research studio taught in collboration with Kevin Pratt, conducted in the fall of 2007 at Cornell University.
11. After Jean-Baptiste Lamarck, the French naturalist (1744 –1829).
12. Janis Birkeland, *Design for Sustainability: A Sourcebook of Integrated Eco-logical Solutions* (2002).
13. The term *arcology* was coined by Paolo Soleri to address design principles for high density habitats that incorporated architecture and ecology. Soleri, *The Bridge between Matter & Spirit Is Matter Becoming Spirit: The Arcology of Paolo Soleri* (1973).
14. Based on "Maximum power principle," first defined by A.J.Lodka (1922): The goal of any self-organization is to maximize the power intake. This is a basis to T.H Odum's *Systems Ecology* argument.
15. Howard T. Odum introduced the concept of Emergy: a measure of quality differences between different forms of energy, diagram mappings of which are based on A.J. Lodka's predator-prey diagrams.
16. Design-research studio taught in collaboration with Kevin Pratt, conducted in the fall of 2009 at Cornell University
17. The Energy System Language was developed by H.T. Odum in 1950 to map energy flows into diagrams that helped defined system ecology.
18. Kai N. Lee, "Appraising Adaptive Management," *Conservation Ecology* (1999).
19. *EatMe Wall* project was conceived in consultation with Prof. William Jewell, Department of Biological and Environmental Engineering, Cornell University.
20. Michael Wells, in his lecture "Biodiversity by Design," at the *Design for Biodiversity: Architectural Responses to Urban Ecology symposium*, Cornell University (2013).
21. Felix Guattari, *The Three Ecologies* (1989)
22. William Jewell (1992).
23. Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (2010): Bennett retains the central importance on human vital needs because "I identify with members of my species, insofar as they are bodies most similar to mine. […] So the self-interest of vital materialism still retains a degree of the speciesism prevalent within the traditional moral and political theories."
24. Gregory Bateson, *Mind and Nature: A Necessary Unity* (1979).