Biotechniques: Form Follows Flow?

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1. Form follows flow?

This paper examines the eco-systems model that underlies the LEED Green Building Rating System, comparing it to a number of other contemporary manifestations of the same model. As attendants at Greenbuild know well, the rating system offers credit for a number of well-recognized strategies that improve resource efficiency and indoor quality. Those strategies are based on an ecological model of the building and its occupants, which views them as agents in a dynamically interconnected system of flows and exchanges. between humans, their technological activities, and the biosphere. Or, in Sim van der Ryn's apt motto of ecological design: "form follows flow." (van der Ryn 2003)

But flows of what? The dynamic systems model is not limited to ecological studies and in recent decades it has been applied to everything from artificial intelligence to weather, the stock market, industrial production, and traffic flow. While most of these studies have focused on dynamic, non-linear effects—amplification, self-organization, symbiosis, co-evolution, etc.—green design remains largely concerned with linear measures of efficiency applied to discrete instances of flow within systems: using less water, energy, or building material, producing less waste, or producing fewer indoor discomforts. Those are worthy goals, but there are some quite different lessons that can be taken from dynamic models, especially threshold effects that occur in the complex interaction between natural, cultural, and technological systems. To that end, I will discuss two other instances of design according to flow—architectural techniques of morphogenesis and the flow of building product information—and then examine two instances of threshold effects: the development of the highly conditioned, internal-load dominated building and sick building syndrome. These two examples reveal the complex nature of comfort, health, and control and indicate the often neglected subject of environmental design: the conditioned body.

2. Biotechniques

Dynamic systems models are familiar to environmental designers through the computer simulations used to evaluate energy use, air flow, and equipment interactions in buildings. While those techniques began as automated versions of manual equilibrium calculations, they rapidly developed through the 1970s into fully dynamic simulation models like DOE 2.1, BLAST, and EnergyPlus (Ayres 1995). The techniques used for those models derive more-or-less directly from the gunfire control systems developed during the Second World War and subsequently developed as cybernetics and operations research in numerous industries and institutions. The models most immediately relevant to green design are the global climate and global resource simulations, of which "World III" used in *The Limits to Growth* of 1972 is perhaps best known.

To describe the many variations and applications of the dynamic systems models I have adopted the provocative term, *biotechniques*, coined by the architect Frederick Kiesler in 1939. Kiesler used the term to indicate the equivalence between biology and technology and to distinguish his concept from the direct imitation of biological forms or processes, what today we are calling biomimicry, and was being called biotechnics by Patrick Geddes, Louis Mumford, and Karel Honzik in Kiesler's time. In my adapted usage, biotechniques are any method by which buildings are examined as participants in dynamic, "living" systems, whether of the biosphere or of financial, technical, or social systems. They may or may not produce results that look biological, and were initially deployed metaphorically to explain or understand how buildings or artifacts changed or adapted through time. Such biological analogies became more substantial with the introduction of devices and systems that literally flowed or operated—plumbing, electricity, heating, ventilation, and lighting. As these elements were fixed in products, codes, standards, and procedures, the building of flows and devices became the legal norm, while new techniques emerged to understand and regulate the dynamic aspects of design.

Such biotechniques became ever more important in the decades after the Second World War, as cybernetics and general systems theory were applied to organisms and artificial systems alike, rapidly collapsing the difference between mechanical and organic analogies, and making both increasingly operative. This is a critical point. At the moment that living organisms (or ecologies) are understood as kinds of systems, then the difference between mechanical and organic systems virtually disappears. And almost from the beginning of systems research, natural and artificial systems were analyzed together. The career of Jay Forrester, who developed the World III model, exemplifies this process. After early work on air defense systems, he focused his efforts on *Industrial Dynamics* (1961), evaluating the dynamic problems inherent in industrial production, sales, and advertising: seasonal cycles, countercyclical policies, stability, sensitivity, and unexpected responses to all manner of events, actions, and decisions. Through a chance meeting with an ex-mayor of Boston he applied the same techniques to *Urban Dynamics* (1969) and then after a conversation with the Club of Rome applied them to *World Dynamics* (1971), exploring the interaction between population, industrialization, and pollution (Edwardes 2000). Of course, this kind of world and climate modeling was central to the developing awareness of global environmental effects, making the construction and authorization of such models extremely important.

There have been many criticisms of these simple models, mostly that Forrester's results exceeded the precision of any data that was available. In defense, he argued that the "interaction between system components can be more important than the components themselves" and that the "computer model embodies a theory of system structure" (Forrester 1961, 1971). His primary interest was global population and what these early models captured were the dynamic, non-linear effects of multiple feedback conditions, of the effect of pollution, food production, and resource shortages on population and then of population on food, pollution, and resources. But like the contemporary simulations of artificial life, what these simulations lacked were any of the surprising and innovative developments that seem to characterize actual events. They could not simulate the unpredictable effects that occur at certain intensities of population, such as occurred in the political transition from city-state to national political organization or in the technological transition from wood to coal, oil, and gas.

The power of such models lies in their demonstration of effects that are non-intuitive or disproportionate to our actions. For example, many kinds of traffic jams occur once a certain number of people decide to drive, once a certain threshold volume of cars are on the highway. The creeping or stop-and-start traffic that results is not caused by any one person's decision to drive, but occurs like a change of phase as a freely flowing liquid congeals into a solid. One of the greatest challenges for environmentalists is demonstrating the connection between seemingly innocent individual actions (driving to the supermarket, turning on an air conditioner) and these kinds of threshold effects. Ultimately, the question is what flows to model? As Forrester's early work suggested, the critical source of environmental problems are social, cultural, and political, deriving from elusive ideas about health, wealth, and pleasure.

3. Flows: Morphogenesis

Since at least the time of Louis Sullivan's famous dictum, "form follows function," modern architecture has developed novel techniques for generating building form, from formal geometries to diagrams of function to flows charts. These can all legitimately be called morphogenetic if they influenced building form, though the dynamic relation to flows remained largely metaphorical until the easy availability of digital computation. Solar access and orientation were among the first elements to be used in morphogenetic studies (Knowles, 1974), but surprisingly a truly dynamic approach to architectural morphogenesis did not originate with environmental studies. Beginning in the early nineties a variety of architects began to experiment with the animation software developed for the movies. The most intense moment of experimentation was in and around the Columbia school of architecture in the mid-nineties, involving Greg Lynn, Hani Rashid, Jesse Reiser, William Mac Donald, Sulan Kolatan, among others, and the experiments were quickly taken up in settings around the globe by architects such as Ben van Berkel, Lars Spuybroek, and Alejandro Zaero-Polo (FOA). One of the first of these early experiments to be realized, the Yokohama International Port Terminal by FOA, claims to be "not a plastic art, but the engineering of material life (Zaero-Polo 2001)."

The interest in these new techniques is not difficult to assess. In a 1996 article on the premises of animation techniques entitled "Blobs (or Why Tectonics is Square and Topology is Groovy)" Greg Lynn argued that "the mobile, multiple, and mutable body, while not a new concept, presents a paradigm of perpetual novelty that is generative rather than reductive." The novel morphogenetic properties of the new body are made possible by the development and animation of "'isomorphic polysurfaces' or what in the special-effects and animation industry is referred to as 'meta-clay,' 'meta-ball,' or 'blob' models." Lynn explains that "in blob modeling, objects are defined by monad-like primitives with internal forces of attraction and mass. Unlike conventional geometric primitives such as a sphere, which has its own autonomous organization, a meta-ball is defined in relation to other objects. Its center, surface area, mass, and organization are determined by other fields of influence (Lynn 1996).” Those “fields of influence” can include anything from the motion of the sun to the movement of people or of brand identities, anything whose influence can be assigned a value.

In principle, dynamic modeling techniques allow building forms to adapt to highly specific and local conditions, altering the nature of architectural authorship: “sites become not so much forms or contours but environments of gradiated motions and forces,” and the architect’s task shifts to a role more closely resembling cooking or parenting, introducing “flexible prototypes” into “liquid digital environments,” and then guiding their development (Lynn 1997). These techniques emphasized the flexible “reconciliation between building and ground,” allowing the ground to remain continuous and shifting, while the wall or skeleton of the building adapts and is transformed (Robinson 1993). Manuel DeLanda has even proposed that architects should “breed” their buildings using the genetic algorithm and a topological building genotype (DeLanda 2002).

Critics like Michael Speaks have noted the apparent contradiction between the responsive dynamism of these animate models and the inherently static nature of buildings. (Speaks 1998). And though these techniques have remained focused on the production of novel form, they offer powerful lessons for environmental designers seeking to accommodate and direct ecological flows. Speaks uses the critique of novel and autonomous form to ask for a more flexible form of practice, in effect, opening design processes like that described by Lynn to the fluid demands of the market; a proposition that was explicitly formulated by the group that reorganized Sweet Catalog.

4. Flows: Sweets

A key insight of many environmental designers is that for most buildings the critical flows are of neither energy nor resources but of money and product information. That situation is exemplified by the ever expanding Sweets Catalog and the whole messy system of selling building materials, products, and processes. Sweets originated in the 1890s as a service of F.W. Dodge Construction (Lichtenstein 1990). The first full catalog appeared in 1906 with an introduction by Thomas Nolan in which he “very gladly consented to commend the idea [of] a really *scientific standard catalogue and index of building materials and construction*.” He explained that he himself had been working for 15 years at “finding some practical solution to the ‘Catalogue Problem’ which no architect has been able to work out himself.” His description of offices overrun with boxes, books, and piles of information and of busy architects with “less and less time” to do “more and more work” still applies today (Nolan 1906). Although the now multi-volume Sweets Catalog has certainly prospered since 1906, becoming an essential tool in virtually every American architectural office, the “catalogue problem” has in no way been solved.

In 1929 a young Danish architect named Knud Lönberg-Holm sent an article to the *Architectural Record* in which he again described the “catalogue problem” as a fundamental crisis for the architecture profession, arguing that the solution lay in a radical rethinking of the distribution of information in architecture:

> … the architect has lost his leadership. From a professional man with a professional ethics he has become a business man subject to the whims of the buyer. The progressive architect acutely realizes that his problem means ultimately the negation of his profession. He has no power to meet his dilemma through his architectural work. As an individual businessman he cannot afford the research work necessary for the proper execution of his ideas; moreover, he is confronted by the gulf which separates him from a client unsympathetic toward an experiment at his expense (Lönberg-Holm 1967).

He argued that "collective problems require collective thinking and collective work" and proposed the invention of an organization that would act as a "clearing house" and "an economically independent research institute," setting standards and organizing information. After a brief stint as a technical editor at *Architectural Record* he moved in 1932 to found the research office of Sweets Catalog Service. In 1939 he was joined in that effort by the Czech designer Ladislav Sutnar and together they reshaped the look and logic of the catalog, developing the bold graphics and characteristic "S" still used today. Of course Sweets is in no way an economically independent institution. It is produced as multi-volume bound collection of short catalog sections provided by product manufacturers, whose fees and advertising tie-ins with the *Architectural Record* and *Dodge Construction Reports* directly support Sweets. As a result, most of Lönberg-Holm and Sutnar's work had to be executed indirectly by persuading and teaching manufacturers. They sought to standardize and discipline their advertising inserts, shaping them into documents readily used by busy architects seeking information. In the late 1940s they formalized their efforts in a pamphlet prepared for product manufacturers and that work was so popular that they brought out an expanded, full color version called *Catalog Design Progress* in 1950. In the introduction they explained that their aim was to produce "dynamic," "living standards" that could keep up with the rapid pace of technological advance:

> Thus with today's industrial development and the concurrent higher standards of industry, corresponding advances must be made in the standards of industrial information itself. The need is not only for more factual information, but for better presentation, with the visual clarity and precision gained through new design techniques. Fundamentally, this means the development of design patterns capable of transmitting a *flow of information*… (Lönberg-Holm and Sutnar 1950)

Their first section charted the "emergence of new flow patterns" in all aspects of contemporary life—transportation, production, communication—then devoted the body of the book to the visual and structural features with which such information flow patterns should be directed in their catalogue. They concluded with a brief theoretical section that offered "flow" as that form of information that emerges naturally from the functional demands of architectural practice. It was a clever formulation that overcame the form-function opposition that continues to worry modern architects. They explained the emergent condition of flow analogically, by comparison with a variety of other entities newly understood according to the generalized concept of *system*: "The flow pattern of any sequence adopts its own form, reflecting function, and its variety of forms may be observed not only in information flow, but in man (the nervous, digestive, and reproductive systems), in industry (production flow), and elsewhere (Lönberg-Holm and Sutnar 1950)."

The management of architectural information by *Sweets Catalog* has continued with the subsequent migration of their catalog information onto compact discs in the 1980s and onto the world wide web in the 1990s, but the original ethic has continued: **"**Comprehensive information correctly formatted and focused on your customer's needs (Sweets 2003)!" In other words, the flow of product information is always, already channeled according to a powerful network of interests: according to brand identities and sales relationships, on the one hand, and to the ever-shifting expression of needs, desires, and identities, on the other. What Lönberg-Holm's original description did not explain was the degree to which they sought to accelerate that flow of information and increase the pace of industrialization:

> For a continuous advance in production standards there must also be a continuous liquidation of obsolete products, enterprises, and beliefs. This is possible only in an economy where property relations impose no restrictions on the continuous development of new productive forces…. This expansion of social wealth implies increasing industrialization (Lönberg-Holm, and Larson, 1936).

In other words, the system of information flow and industrialized construction has its own momentum fueled by our individual needs, choices, and actions. As many critiques have argued, merely fitting better products into normative construction will only modulate the effects that industrial development has on the biosphere. To make a difference, it is necessary to understand both the structure and velocities of the flows already in place and to locate the threshold effects that occur in building.

5. Threshold Effects: highly conditioned buildings

In 1957 it was already observed that "whenever 20 percent of the office buildings in any one city include air conditioning, the remaining buildings must air-condition to maintain their first class status (Wampler 1957)." That process had apparently taken about 10 years, and after the late 1950s it was largely assumed that a high-quality office building in an American city would be conditioned to some degree. The technology had been available for many decades, but it took the particular arms race dynamic of post-war real estate development to change it from a desire to a "need." A similar process had occurred among movie houses in the 1930s, which along with luxury hotels had rapidly adopted air conditioning once its competitive advantage had been demonstrated, and they served to introduce the public to the experience of conditioned air, preparing them for the ever increasing amounts of conditioning.

This is one kind of threshold effect that occurs in highly competitive situations, when an arms race develops between competitors. They rapidly adopt new products, strategies, and quite expensive technologies if their customers are free to make other choices. Who would go to a hot movie theater or rent a hot office if a cool one is readily available? And in the process, a new, higher standard emerges and is fixed not only public desires, but in normative construction practices and regulatory codes and standards. At that point, the new standard no longer represents a choice, but a culturally and officially recognized need. It is not easily reversed and can apparently only be altered by a similarly dynamic cultural process. The energy supply crises of the 1970s, for example, temporarily altered thermostat settings, but the logic of energy conservation quickly paled in comparison to the desire for cooling, and the effect was short lived.

I don't mean to argue that air conditioning is inherently bad, far from it. The relief from sweating simply feels good, and that is precisely why it becomes such an effective element in competitive situations, leading to a steady escalation of expectations. The problems are twofold. The first are very familiar to this audience: greater levels of conditioning produce a whole host of secondary environmental effects through the heat island conditions, the use of greater amounts of energy, the release of CFCs and so on. Many of these are amenable to better design or greater efficiency, and form the basis of most green strategies, but the second kind of problem are more troublesome. Not only does the escalating aspect of this process establish ever higher standards, requiring ever greater levels of conditioning, but the techniques of conditioning profoundly alter the size and character of the buildings that can succeed in the marketplace.

In other words, once the process described by Wampler takes place, and conditioning becomes the norm for commercial buildings, then the scale and configuration of the buildings quickly expands so that they have to be conditioned. The environmental aspects of a commercial building without air conditioning are effectively defined by its external skin, meaning that every inhabited workplace has to have ready access to a window for light and air. As a result, even the biggest of the early skyscrapers were made thin by cutbacks, light courts, and reentrants. Once the connection to windows is severed by air conditioning and efficient lighting, the buildings are free to grow (out and up) until they encounter other scale limits: circulation, the size of elevators, and so on. And like escalation of comfort standards, this is simultaneously a technical process of conditioning buildings and a cultural one of conditioning the individuals who inhabit them.

A building's balance-point temperature provides a rough index of when it crosses that threshold, when its spaces are no longer directly connected to the outdoor climate. When a building becomes both sufficiently big and contains a sufficient intensity of internal conditioning and support systems, its balance point temperature will fall below the average outdoor temperature and it will have to provide cooling most of the year. This is involves a fairly simple cascade of effects: first air conditioning and efficient fluorescent lighting make it possible to fill large interior areas with people and the equipment they use at work, but the people, lights, and equipment all produce heat, which requires even more air conditioning. As heat removal becomes ever more important, windows are sealed and designed to exclude as much sunlight as possible, making the interior environment more efficient, but less and less pleasant.

Those two thresholds—higher comfort standards and bigger buildings—were passed for many buildings by 1960, establishing the now familiar norm for commercial construction of highly-conditioned buildings with vast interior spaces. But of course that norm has been subject to many criticisms and it has been criticized and modified, sometimes radically, in recent decades. Beginning almost immediately in the early 1960s there were parallel efforts to introduce green plants and natural light into the cores of the larger buildings. The plants initially arrived as part of the office landscape movement (*büronlandschaft*) and rapidly found a place in the reinvented (and conditioned) atriums of the late 1960s: the Ford Foundation and the Hyatt Regency are important examples. In addition to its humane qualities, the atrium was subsequently recognized as an energy conservation technique in the late 1970s and 1980s, and become a hallmark of the high-quality office buildings of that period.

The purpose of this thumbnail history of conditioned buildings is to illustrate the degree to which the dynamic thresholds important to green design involve social and cultural factors and to explore why they are so resistant to change. A second kind of threshold, one of intensities, is even more critical and difficult to examine because it involves the experience of the bodies being conditioned.

5. Threshold effects: Sick building syndrome

The Environmental Protection Agency (EPA) distinguishes "building related illness," which can be attributed to an identifiable cause, from sick building syndrome (SBS) in which "occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified (EPA 1991)." The inability to diagnose SBS continues, though recent epidemiological studies confirm the correlation between mechanical ventilation rates and reports of SBS symptoms such as "upper respiratory and mucous membrane symptoms (i.e., irritated eyes, throat, nose, or sinus), and lower respiratory irritation (i.e., difficulty breathing, tight chest, cough, or wheeze) (Erdmann, Steiner, and Apte 2002)." In this regard, SBS belongs to a broad class of environmental illnesses (EI), such as multiple chemical sensitivity and Gulf War syndrome, that clearly exist, but that do not fit any biomedical explanation. From one side of the dispute, it is claimed that such syndromes are wholly somatic, learned group expressions of other psychological issues, while on the other side, serious research continues to seek the biomedical causes and etiologies of the distress (Staudenmayer 1999).

What seems evident in both bodies of research is that the perception of indoor air quality, of freshness, temperature, or humidity, is itself quite important. As the early researchers discovered when they first began to investigate ventilation levels, freshness involves both an assessment of the intensity of a odors and a judgment about their quality. Like noise, an odor can be pleasant in one situation and offensive or bothersome in another. What this suggests to psychologically oriented researchers is that sensations such as odors can trigger "social psychological processes of contagion, where complaints and symptoms spread from person to person, and convergence, where groups of people develop similar symptoms at about the same time (Hedge 1996)." From the other perspective, the remarkable sensitivity of the nose suggests the possibility of very subtle toxicogenic processes that have not yet been identified. The statistical correlation between SBS and mechanical ventilation systems, for example, appears to offer evidence of the underlying physical causes related to the rates and processes of ventilation and has quickly been acted on by design professionals. (Seppanen and Fish, 2002).

I can contribute no new evidence or research that might resolve the medical question, but I would argue that as with the previous examples, SBS represents the passing of a critical threshold in the conditioning of buildings, a threshold that is both physical and social. The earlier examples appeared beyond a certain threshold of scale, after a certain number of buildings were conditioned or after a certain size of building was produced, but SBS and other EIs seem to develop at certain thresholds of intensity. Thermal comfort is defined in these terms, as the intensity of air conditions (temperature, enthalpy, wind) at which neither our attention nor our coping mechanisms are required. EI suffers often explain their symptoms in terms of cumulative thresholds of toxins or irritants and use system theories to explain the disproportionate effects that trace amounts of different substances can cause: total body load, limbic bundling, and hypersensitivity (Staudenmayer 1999). For designers, it ultimately makes little difference whether these are medical or somatic explanations, they are the point at which systems designed to provide comfort paradoxically began to threaten health with the very intensity of their conditioning. As a recent sociological study observed, the accounts of EI suffers portray "a body that reacts severely to ordinary commercial furniture designed to offer it at least a modicum of rest; a body that responds violently to air passed through conventional heating and cooling systems designed to make it more comfortable… it is as if this body is in protest against the products of modernity and, in its distress, is calling for a radical change in the conventional boundaries between safe and dangerous (Kroll-Smith, Stephen, and Floyd 1997)." Conditions like sick building syndrome should remind us that the real object of environmental design is not the techniques or measurements of conditioning, but state of the bodies that occupy them, whose concerns continue to exceed any technical assessment of health or comfort.

6. Conclusion: Biotechnical Bodies

I have offered this brief account of the ecological systems model to make two very simple points about the conditioning of contemporary buildings. One, that the most elusive and critical aspect of environmental design is the powerful cultural notion of health, a notion that exceeds any biotechnique. And, two, there are critical thresholds in the scale and intensity of that conditioning, which we must understand more clearly if we are to achieve the goals of green building. The best term I can offer as a guideline to those thresholds is the "living standard" sought by Lönberg-Holm, a standard that adapts to changing arrangements, but that provides allows overly conditioned bodies to heal themselves.

7. References

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