

UNDERSTANDING COMPLEXITY THROUGH PATTERN LANGUAGES IN BIOLOGICAL AND MAN-MADE ARCHITECTURES

Comparisons between Biological and Architectonic Patterns

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Abstract

In 1944, the celebrated physicist, Erwin Schrodinger, famously asked, "What is Life?" Neither Schrodinger nor generations of illustrious scientists after him have been able to satisfactorily answer this question. What is generally agreed upon, however, is that being alive is about being complex: forming, transforming, and maintaining a structural organization that consists of multiple constituents arranged in specific orders and patterns. The advances in the theory of complexity have come not just from biologists, but also from architects and urban theorists. In this essay, I discuss how theorists from both life and architectonic sciences have come to a similar conclusion: that patterned and organized form ensures proper function and, ultimately, life. I show how deviation from this principle in biology leads to cancer and death; in architecture, the deviation allows the takeover of mechanical and imagery-based building ideologies leading to dysfunctional and 'lifeless' building and public spaces.

Keywords: pattern formation; polarity; multiscalarity; cancer; architecture.

INTRODUCTION

The science of complexity is predicated on the following questions: why are some things in this world complicated and multi-constituent? Is there a method in this complicatedness? Does the complicatedness correlate directly with function? And lastly, is it even needed in the shorter or longer run? It is a problem that comes up in several disciplines: biology, architecture, material chemistry, and computer theory (Alexander, 2002a; Lineweaver, Davies, and Ruse, 2013). The questions that are framed by their respective practitioners are done so in vocabularies that are inherent to their respective fields. This masks the underlying common thread of logic running through these questions: how does any system or structure acquire or exhibit novel properties over a reasonable span of time? In biology, this problem relates to how an organism exhibits new behavior or begets a new organ, which it was never associated with in its evolutionary history (Newman, Forgacs, and Muller, 2006). In computer theory, one can ask what the minimum amount of steps is required for a system to learn a new function (such as predicting outputs for a certain kind of inputs) (Valiant, 2009). In chemistry, it would involve coming up with the conditions within which homogeneously mixed chemicals would start exhibiting novel spatial and temporal patterns, and waves (Mikhailov, 1990). In architecture, it involves formulating rules and arrangements to make a building habitable, resilient and harmonious with its surroundings (Salingaros & Mehaffy, 2006). The advantage in approaching complexity from a more interdisciplinary generic perspective lies in the ability to see beyond what individual disciplinary methodologies afford. Moreover, common principles and facts accrued in one field can readily be applied and tested in another field to verify if an underlying common logic extends to solutions as well.

In this essay, I will discuss how the problem of complexity is grappled with by practitioners of two disparate fields: biological morphogenesis and architecture (and urban planning). In the first section, I will show an uncanny similarity between some principles establishing pattern and

order in built and biological forms respectively. The second section deals with the consequence of the violation of these rules in biology. The third and final section deals with how these rules are bent or flouted in architecture.

FORM: A GEOMETER'S PROBLEM?

Architecture

If one is to undertake a serious systematic study of the lasting architectural patterns spanning diverse civilizations, it would not be difficult to come up with some structural rules and qualities that are integral to 'successful' buildings and built environments, even separated by swathes of time and space. By successful I mean an immediate, positive, and nourishing visceral appeal to the inhabitants or persons who experience the building first-hand. Research by architectural theorists trained in the physical sciences, such as Christopher Alexander and Nikos Salingaros, has unearthed mathematical principles of design that appear again and again in buildings that have stood the test of time, weather and, taste (Alexander, 2002b; Salingaros and Mehaffy, 2006). The architects building these buildings had neither the access to modern libraries or to the World-Wide Web, or even to crucial contemporary advances in geometry, such as nonlinear dynamics and fractal theory. The overall essence of these principles is to ensure that buildings are not just mechanical entities with a height, area, volume, windows, and doors. Buildings are very complex structures with many spatial scales determining their form and details, and the coherence of the structure has a communicative effect on human perception.

In order to discuss these geometrical qualities, I would like to first introduce the notion of distinct cooperating scales: architectonic and structural elements of a certain size, from the smallest detail going up to the size of the building or urban space itself (Alexander, Ishikawa, & Silverstein, 1977). The smallest scale is essential, and is defined by visual patterns through contrasting structural elements, ornaments, and colors (Figure 1). The largest scale establishes relations between distant elements in a manner that renders their arrangement ordered (rather than random). The relationship between these two scales contributes to the positive perception of a building's architecture (Mehrabian, 1976; Salingaros, 2000). Finally, the overall harmony links all the intermediate scales together through techniques that employ symmetries common in traditional design and architectures. Note, in particular, that there could be relationships even in the magnification ratio between one pair of adjacent scales and another pair (i.e. scaling invariance).

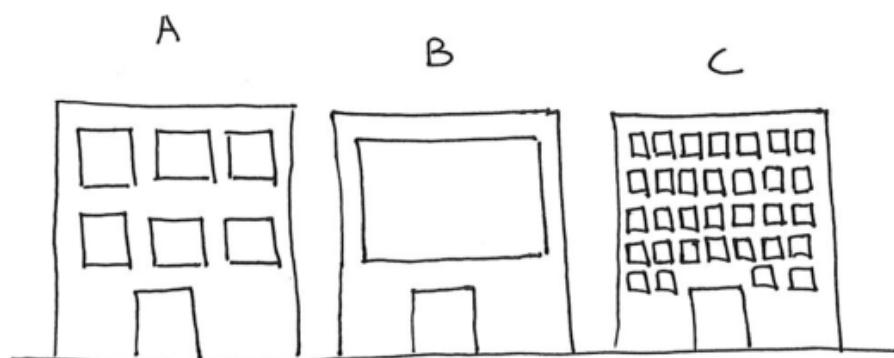


Figure 1: Cartoon showing three buildings with variation in the relationship between scales of pattern (Source: Author).
 A. In building A, the windows are well spaced apart and bear a contrast with the spaces between them. They also bear a fixed ratio in dimensional scale with those of the entire building.
 B. In Building B, the single large window results in loss of contrast.
 C. In Building C, the multiple rows of small windows do retain a contrast with the spaced between them but their dimensional ratio with the dimensions of the building is very large leading to sensory chaos.

To illustrate the notion of scale with a simple example: let us seek to define the proportional relationship between windows and the space between the windows. These two elements set up a contrasting visual pattern to a building's exterior. Seeking coherence qualifies how the windows of a building (and the gaps between them) are oriented and sized with respect to each other. Finally, we need to define the boundaries of the ratio of the average size of the windows to the size of the building (Figure 1).

The underlying core principle is that these adjustments are based on empirical observations, and the analysis of those observations made into a canon of more intuitive than documented, design rules. This suggests that buildings and built environments that have stood the test of time, and appreciation, have common rules of pattern and organization in their substructures. In fact, it is entirely conceivable to envision the 'life' of a built structure as a quantifiable product of the intensity of visual information, due to contrasts set up by adjacent elements, and the harmony of the arrangement of elements across the dimensions of the building (Salingaros, 1997). This is not to imply that buildings are alive in the strictest biological sense, although even biologists have generally been hard pressed to provide a clear-cut definition of life. What this allows us, however, is to have a cogent idea of why and to what extent some built environments and buildings are more breathtaking, more beautiful, and more habitable than some others. It also gives us the freedom to compare, by a set of criteria, two or more buildings of distinct times, divergent cultures, and varied styles. More importantly, it also tells us that structure determines function and utility.

Let us pursue the multiscale issue one step further. The "life" of buildings is not just determined by the structural materials that go into it or how, for that matter, they are arranged. It is essential that the buildings themselves harmonize with the built and natural environment that surrounds them. A positive example of this is the Emoto apartment building in Tokyo. Negative examples would be the skyscrapers housing commercial offices surrounding, and dwarfing the Chinatown district of San Francisco (for further details, see last section). This leads us to the associated subject of urbanism, a detailed elaboration of which I will leave for a subsequent essay. Put briefly, the laws described above hold, in principle for how a building relates to its environment, with other buildings, with the surrounding nature, with roads, plazas, and other elements of organized habitation.

In fact, multiscale in building design, and the relationships of different scales to each other, is one of the fifteen structural features identified by the architect-philosopher Christopher Alexander that can sift between which building is "alive" and which is relatively "dead" (Alexander, 2002b). The other fourteen properties are 1. Strong centers (points in space) around which spaces can be organized and divided, contributing to wholeness and components which make up the whole 2. Boundaries that bound, and separate, centers and spaces 3. Alternating repetitions – periodically arranged centers that reinforce each other through their regularity 4. Positive space, which is created by curved structures, such as by spandrels 5. Good shape: a property defined by a coherently arranged set of multiple centers 6. Local symmetries, coherent geometrical patterns at lower scales and not on the highest scale 7. Deep interlock and ambiguity: enmeshing and interconnections between elements 8. Contrast 9. Gradients 10. Roughness: imperfections that are merely signs of human agency 11. Echoes: an attempt to create more than a single scale with the same structural element(s) 12. The Void: creation of an empty space that accentuates the order and solidity of the rest of the structure 13. Simplicity and inner calm: coherence (not symmetry) at the largest scale and finally 14. Not-separatedness, which measures the ability of the building to harmonize with its surroundings.

These fifteen properties can be considered to constitute the grammar of pattern language, an index of patterns for the construction of cities and towns down to individual buildings. The incorporation of these fifteen properties contributes to the function and sustainability of built forms.

Biology

What is more surprising is that these principles find echoes even in case of structures and environments that have not been sculpted by the collaboration of human hands and minds: the morphologies of living things. There is probably no solid organ in the body that does not bear some mark of organization and pattern. Our liver, skin, breast, and brain all consist of cells and non-cellular scaffolding elements in definite spatial arrangements.

For example, every single species of the animal kingdom that has limbs exhibits the very same geometrical pattern of bones within the limbs (Figure 2). Closest to the body is a single bone within the arm or thigh; following this are two bones within the forearm or shin and farthest from the body are a series of bones which form the fingers or toes. Not only is there a gradational increase in number of skeletal elements, there is a gradational decrease in element width. A second example is that of branched organs such as the lungs. Each major airway breaks into progressively smaller and thinner airways. At the smallest scale, for both these examples, one sees contrasting visual patterns (during development, fingers are separated by cells that do not form fingers but later die or form webbing; branches of airways are separated from each other by connective tissue). At the largest scale, one can envision the harmony of the arrangement: the bones of our body are all arranged along the same axis, parallel to each other, and the airways are oriented as to form a radiating centrifugal tree, without any centripetal motifs. The transformation of the largest to the smallest scale is never sudden, but through intermediate scales with progressive gradational shifts.

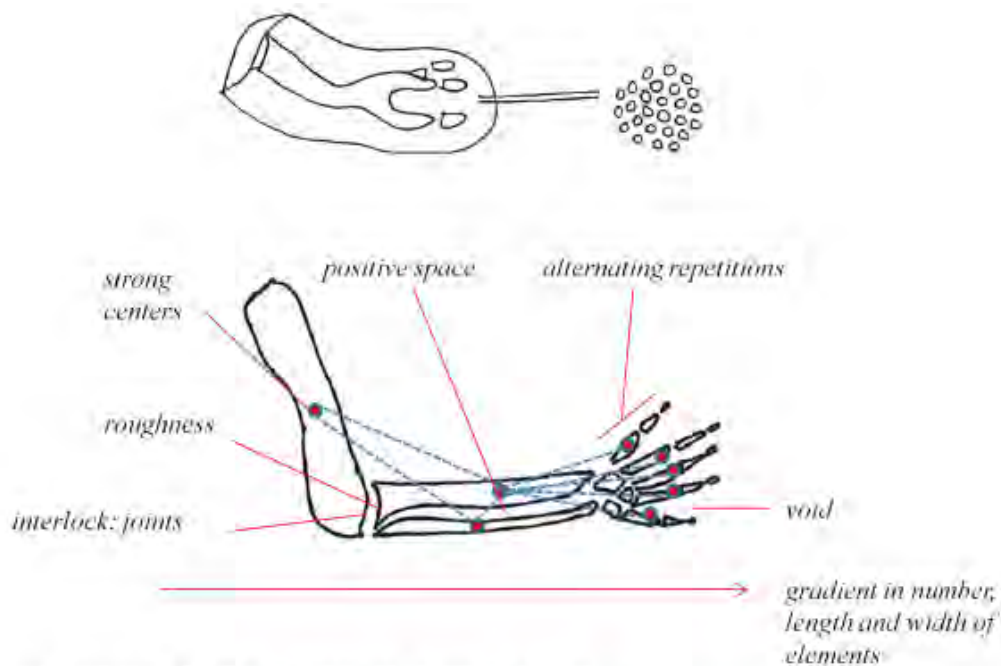


Figure 2: Cartoon depiction of the development of limb skeleton

Upper panel: Developing limb skeleton during chick embryogenesis: cells cultured from limbs at this stage form regularly spaced cartilage nodules suggesting that the ability to form coherent biological patterns is inherent to biological material and is manifested in changed conditions as well.

Lower Panel: Fully formed limb skeleton showing a significant subset of the fifteen structural rules for architectural life that have been proposed by Christopher Alexander (Source: Author).

In fact, when the cells of limbs in which the skeleton has not yet formed, are taken out and 'cultured' on a plastic plate, they organize themselves spontaneously into a pattern in which subsets of cells form spherical aggregates, known as condensations. Condensations are the

culture equivalents of digits and become nodules of cartilage (precursors of bone). Condensations are separated from each other by surrounding cells that do not become cartilage. Interestingly, the overall organization concurs in principle with the architectural laws: the spots, along with their surrounding non-spot cells, constitute contrasting elements and far away spots are similar to each other in terms of size and spacing (Newman and Bhat, 2007) (Figure 2).

It is also interesting how some of the descriptive terms are common in the respective fields of built environments and biological form. Thus when cells of our body gradually transform from a homogenous mass into an ordered one, the process is referred to as pattern formation. In an adult organ, the cells are not only patterned with respect to each other, but also have specific arrangements with respect to other non-cellular structures, such as the extracellular matrix (ECM), which is defined as the scaffolding of huge, often fibrillar macromolecules that acts as a substratum and façade of the cells. The composite superstructure is referred to as the tissue- or organ architecture (Bhat and Bissell, 2014)!

There is an increasing body of elegant literature that shows that, just as in-built architecture, the structure of the organ determines its functioning (Bissell, Hall, and Parry, 1982). Specifically, the functioning of genes coding for proteins that determine the activity of the cells is under the constant regulation of the cells' microenvironment. The latter decides whether a cell turns the right genes on and functions as part of the organ. For example, cells derived from the breast, if cultured on plastic, grow into a carpet like arrangement, showing absolutely none of the branching or gland-like structure or function that are characteristic to the organ. Give them their native microenvironment (ECM) and they organize into branching hollow tubes and can even start producing milk (Streuli et al., 1995)! Therefore, while we can keep cells alive by giving them their nutrition, organs come 'alive' only when the essential elements of tissue architecture, the microenvironment, is present.

If we were to analyze the structural characteristics of biological organs through the eyes of an architect, we would find that they bear an astounding level of congruence with principles of design that contribute to the beauty and resilience of man-made architectures. For example, the fifteen structural principles that I elaborate in the previous section are an exhaustive set of crucibles against which to test any given example of a biological architecture. Let us take two divergent examples of biological architecture introduced briefly above – the breast tissue and appendicular skeleton, and analyze them further.

The structural and functional units of the functioning adult breast organs are known as the terminal ductal lobular units (TDLU), so called because they lie at the end of the ducts which fuse together to form the channel that connects with the nipple. The TDLUs synthesize and secrete milk which passes through the ducts and comes out through the nipple. A cross-section through the TDLU gives a clear picture of its structure: a concentric ring of cuboidal cells (known as LEPs) surrounding the lumen, bounded on the outside by a ring of smaller rhomboidal cells (known as MEPs) which in turn are bounded by what is known as the basement membrane – a specific topological arrangement of ECM proteins that acts both as a scaffold and the signaling hub (Figure 3).

The TDLU shows sequential radial scales with the outermost sphere formed by the BM, followed by the MEPs followed finally by the LEPs. It has a strong center in the lumen which is reinforced by the centers of each other the spheres surrounding it. It has a strong thick boundary in the BM, which is an ECM superstructure as well as the MEPs, which, being the producers of the BM, reinforce the boundaries. Each TDLU is surrounded by several other TDLUs, all of which are connected by ducts that converge finally onto a single large duct that transmits the milk out. Hence, the TDLUs together form a repetitive motif. On the other hand, the entire mammary ductal tree forms by growing into, a positively shaped stromal environment which acts as a reservoir to contain a host of different cells and proteins that signal and reinforce the architecture of the TDLU. The LEPs within the TDLU are deeply interlocked with each other through intercellular bridges. While the whole glandular tree is randomly structured- no tree can match another perfectly, there are inbuilt local symmetries- the density of branch points is roughly the same and

so is the general direction within which the branches grow. The TDLUs and their ducts form strong contrasts with their surrounding stromal space. The BM in growing glands is made in a gradient-like fashion trailing the invading tip of the branches of the gland. The entire glandular structure manages to fill the space within which it grows in a rough undirected manner, but the branches form suitably to maximize its volume within the constricted space. And yet the principle of branching as a means to maximize volume is a simple yet powerful method.

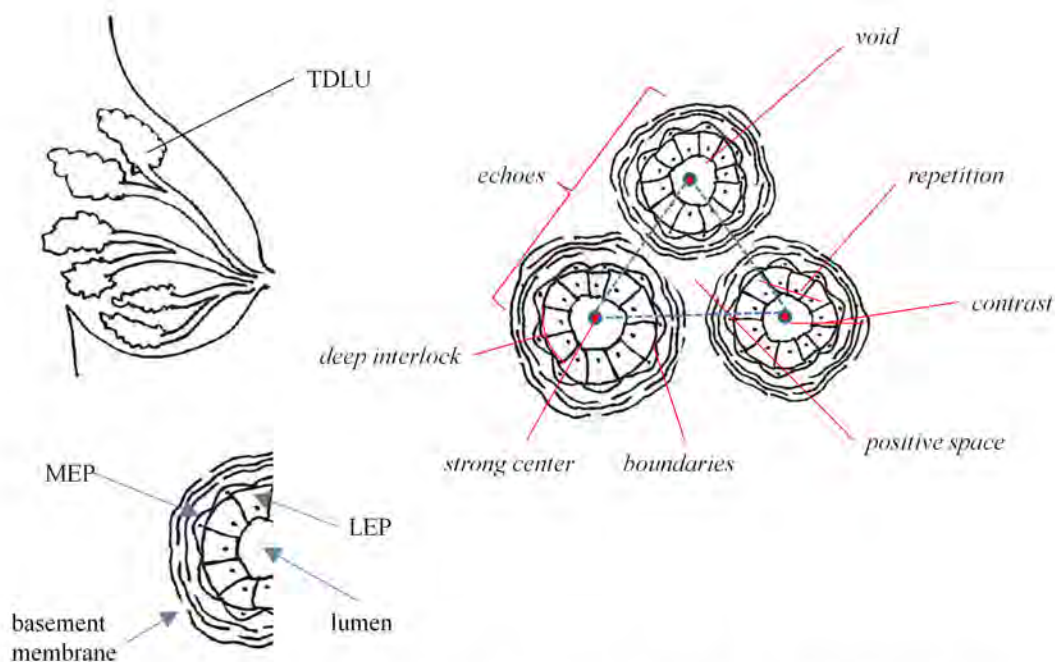


Figure 3: Cartoon depiction of the breast architecture showing TDLUs. The internal anatomy of the TDLUs consists of acini embedded in matrix. the acinar pattern shows a significant subset of the fifteen structural rules for architectural life that have been proposed by Christopher Alexander (Source: Author).

The appendicular skeleton shows sequential changes in spatial scale with the number of bones increasing and the size of the bones sequentially decreasing further away from the body (Figure 2). The effect of having tandem and parallel arrangement of bones creates strong centers that reinforce each other. The tandemness creates repeatedness. The bones are interlocked in joints to create a rigid though immensely mobile structure. The parallel bones also create contrast by creating positive inter-skeletal spaces between them, which allow for the muscles to attach and pull them in different directions. The bones are shaped in ways which make them asymmetric albeit the translational symmetry of the skeleton. The size and number of bones form a uniform gradient. The appendicular skeleton is built to be agile and flexible, while at the same time rigid enough to withstand extensive stress in the form of a Type III lever. The physics that is embedded in its architecture is thus complicated but an emergent property: the latter has a simplicity that deceives.

Anatomists and developmental biologists have also taken the structuralist route to analyzing biological form. One tissue-level property that encompasses a subset of the above-mentioned structural principles is that of polarity – the arrangement of cells and ECM in a linear or radial arrangement. Polarity is one of the fundamental characteristics of adult animal organs (Bissell, Radisky, Rizki, Weaver, & Petersen, 2002). Cells have polarity, which is reflected in the

difference in structure and function, especially of epithelial cells. However, tissues have a polarity that is autonomous of cell polarity. Let me illustrate this point with a specific example: that of mammary epithelial cells and the architecture of the breast. Investigation of structure-function relationship within the TDLU shows that the mere coming together of the components of the TDLU is not sufficient for it to function - they have to be present in the correct centripetal configuration – and it is this configuration that is known as tissue polarity. It is only when the tissue is polar that the TDLU starts functioning and producing milk.

If we were to describe polarity in a formal fashion (i.e., without describing the specific biological examples) in terms of the fifteen properties of living architectures that we have mentioned above, radial polarity is thus a combination of strong center, strong boundaries, positive space, good shape, local symmetry, deep interlock and ambiguity, contrast, roughness, and void. Linear polarity subsumes levels of scale, strong centers, good shape, gradient, deep interlock, and echoes. In specific biological contexts, as we show above, polar organs encapsulate even the rest of the fifteen properties. Polarity also maintains the homeostasis of the organ- in other words; it prevents the organ from dysfunction or breaking apart. It also imparts specificity to the organ – in other words, it is not so much the genes, not even so much the cells, but the configuration or architecture that is so immanent to the organ identity.

Polarity is not the only organizing principle of biological pattern formation. In a series of papers on the evolution and organization of biological matter, a set of agents, known as dynamical pattern modules (DPMs) have been identified, which organize homogeneous fields of cells into patterned tissues (Newman & Bhat, 2008, 2009). These agents are mediators of physical effects, specifically on the material properties of biological tissues and are associated with different proteins in different contexts. For example, one of the simplest DPMs, known as ADH, mediates cell-cell adhesion leading to the transformation of a collection of individual cells into a multicellular mass. Polarity is another DPM, using which a homogeneous cell population can organize itself into a centrifugally or linearly heterogeneous organ.

In summary, DPMs constitute a pattern language that is utilized by biological tissues to encode information, and by extension, complexity, in order to give rise to, and maintain, biological architecture. I have shown that there is a strong convergence between the pattern languages that gives rise to living biological tissues and organs on one hand and living buildings and built environments on the other. What are the consequences of violating these pattern languages?

THE LOSS OF BIOLOGICAL ORGANIZATION LEADS TO CANCER

We are thus naturally motivated to ask what happens when the organ architecture is disturbed due to some reason. The answer - cancer - would likely even surprise many biologists. Cancer is a deadly disease that afflicts and kills millions of people all over the world. The cause of cancer is often opined to be mutations of specific genes, elements that code for the proteins, the building blocks of biological form. This is biological reductionism at its most extreme. Abnormalities of the organ's microenvironment result in incorrect signals to the genes, including those that are responsible for tissue structure, ECM production, and even cellular health (Lochter and Bissell, 1995; Sonnenschein and Soto, 2008). The convergence of all these pathological signals is cancer. It is important to note that the gene mutations purported to bring about cancer are present in every single cell of the body and yet the individual is afflicted with only cancer of a particular organ. Cancer is therefore a disease of the organ architecture and not the genes.

Despite the fact that every organ is different and its cancerous state is also therefore unique, there are some properties common to the various types of cancers. The first is, of course, a breakdown in organization of the organ: boundaries between erstwhile well-separated cells are no longer honored. A characteristic 'superstructure-scaffold' that acts as the microenvironment for a large subset of cells (known as epithelia) is the basement membrane. Cancer results in breakdown of this superstructure and results in contact between cells that were not supposed to communicate with each other. The result is abnormal communications and signaling leading to loss of organ function (Bhat & Bissell, 2014).

On a larger scale, the symmetry of the organ undergoes drastic alterations. Hollow tubular organs become solid, soft tissue becomes hard, well-conserved shapes and geometries of the organs get distorted and subverted. In other words, organ and tissue polarity, which I have shown above to be integral to their formation, is completely lost. In the language of architecture, the strong center is lost, contrasts and gradients are obliterated, interlocks are broken down, local symmetries get wiped out, and boundaries are no longer respected (Figure 4).

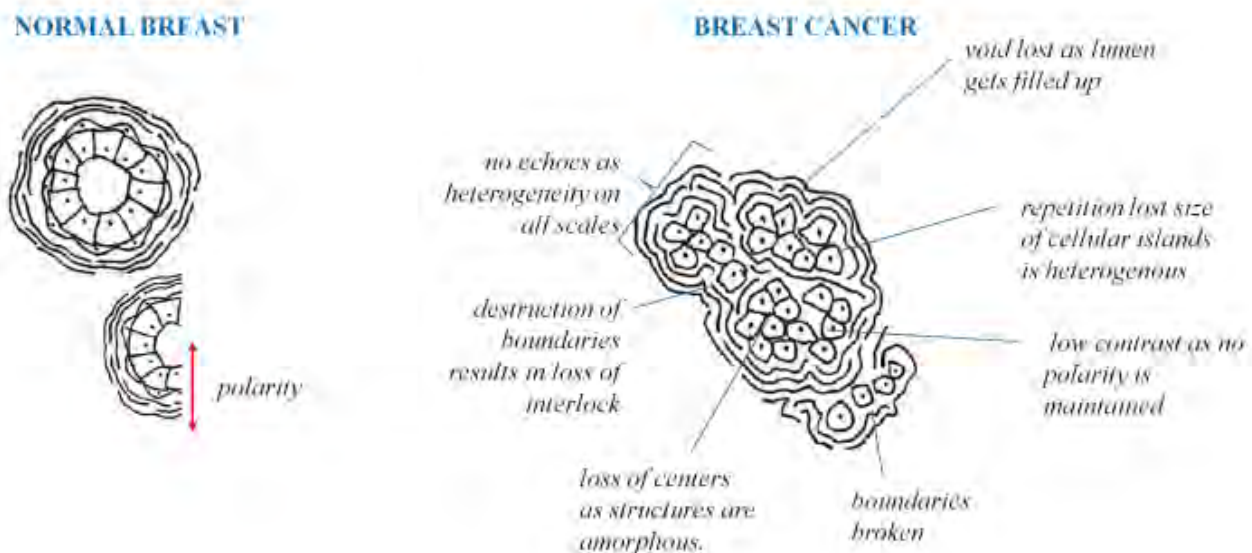


Figure 4: Cartoon depiction of normal breast architecture showing
 Left Panel: polarity is composed of a subset of the structural rules of Christopher Alexander.
 Right Panel: the tissue architecture of breast cancer where most of the structural rules maintaining organization and polarity are found to be violated (Source: Author).

Cancer is characterized by a loss of control over growth: there is an unbridled proliferation of cells of the organ and a loss of cell-cell contact. Therefore, positive spaces and voids get filled up and roughness gets smoothed. In an advanced state, cells invade and metastasize, i.e., they depart from their original locus travel to distant locales and start parasitizing, and proliferating within new tissues. In conclusion, we observe, in cancer, a breakdown in those the very design principles that we found overarching between man-made architectures and biological architectures.

CONSEQUENCES OF SUBVERSION OF ARCHITECTURAL PATTERN LANGUAGE

What of disordered structures in built environments? There are abundant examples of buildings built around us that violate the principles that have been alluded to in the first section. The subversion began at the turn of the century with the modernist school of architectural thought, but has been taken to an altogether new level by 'postmodernist fashionistas' (Krier, 1981; Salinger and Alexander, 2004).

In fact, such urban morphologies not only deviate from the morphogenetic rules presented above, but also start exhibiting the properties shown by cancerous biological tissues. This is not just a matter of the overall shape, size, and topologies of the finished structure (or the lack of it). The first and foremost feature is the loss in identity and vernacularism (by the latter I mean a sensitivity to incorporate materials, themes, and geographical and historical influences from the locality). These properties are ubiquitous to traditional architectural styles and establish the harmony of the building with its surroundings. This characteristic is completely overridden in modernist monuments where choice of materials, more often than not, boils down to being

influenced by globalization, corporatist symbolism, and contemporaneous fashion trends. The almost universal glass-and-granite look of office buildings is a case in point. Buildings such as 30 St Mary Axe (London), the Neutrality Monument (Turkmenistan) and, Antilia (India) were built with an abject disregard to their surroundings generating considerable disharmony.

Like biological organs, every building is also specific: it has a function and the environment around it, its paths and its connections are structured uniquely to it. A house and its surroundings cannot be planned in the same way as say a downtown plaza or a school. Despite this, most modern buildings, whether they are residential or commercial, get built in the same way. A ride on the Amtrak into New York City shows gigantic cooperative residential towers in the Bronx followed by gigantic corporate mega towers in Manhattan. Postmodernist creations on the other hand, seem to wage a war against their interior and their utility. It is not possible, for example, to envision what the buildings stand for, or what happens inside it by surveying its exterior.

The second feature is one of loss in polarity, proposed above to be integral to the difference between normal and cancerous biological systems. Polarity in architecture defines the distinction between the inside and the outside. Modernist buildings with glass curtain walls have nullified this distinction. Instead of having windows that allow inhabitants to experience diurnal changes in light and fluctuations of the weather, and allowing a harmonious interaction between the interior and exterior, such buildings accentuate a sense of being exposed to the outside, without actually interacting with it. On the other hand, examples of brutalist school of architecture at many times often do away with the concept of windows in order to create an impression of magnificent size and imposition. In his seminal critique on the postmodern ideology, Fredric Jameson levels a similar accusation on examples of affiliated architectural examples: dysmorphic houses constructed by building over partly preserved shells of older houses, and gigantic metropolitan hotels fragment polarity by creating negative spaces and yearn to confuse, in accordance with their ideology, rather than to calm (Jameson, 1991). While adopting a vocabulary that jargonizes advancements in mathematics and complexity theory, the postmodernists ignore the concept that complexity is firstly a systems- and secondly a historical-property. The first means that it has to maintain links and associations of scales with its components and the second means it has to evolve out of a historical and historicist way of thinking. The first criterion is abandoned by postmodernists through their praxis; the second by definition never existed in their ideology. This renders the postmodern monuments and, especially, their subsequent deconstructivist successors, incoherent and amorphous, attenuating their complexity, their utility and, ultimately, their life of the buildings. To complete the epistemic loop, cancerous tissues are in the end, incoherent and disorganized masses of tissue with severed connectivities and lost function.

Lastly, like the most debilitating characteristic of cancer, i.e., metastasis, ill-designed buildings and built environments cannibalize their surrounding urban landscapes by growing, dwarfing, and pushing out smaller and traditionally built structures at the interfaces. A measure over time of the shrinkage of Chinatowns in the major metropolitan cities all over the world is an apt example of this urban pathology (Figure 5).

Built within the city limits, encroachment by commercial enterprises, and an exodus by its inhabitants for zoned ethno-suburbs have led to an implosion of these immensely alive urban neighborhoods vibrant with motifs, design traditions, and colors. A combination of globalization, postcolonial mimicry, and aspirational urges have left burgeoning cities in India, Pakistan, Bangladesh, China, and Brazil dotted with mega towers and zonings which parasitize on their surroundings through labor and energy demands creating even widening peripheries depleted of culture, diversity, and beauty.



Figure 5: Photographs of San Francisco Chinatown.

Upper photo panel: Grant Avenue the commercial nerve center of the ethnic enclave with its unique “Chinoiserie” architecture since when the Chinatown was rebuilt after the 1906 earthquake.

Lower photo panels: Commercial multi-storeyed buildings preside over the horizon of the Chinatown and are harbingers of its shrinkage and eventual disappearance. (Courtesy: Kusumita Rakshit)

CONCLUSION

In this essay, I have put across sets of principles that were not considered ‘mainstream’ in biology and architecture, but are increasingly gaining ground in the respective disciplines. I show that these principles may have different names, but bear a great deal of geometric similarity to each other. Examined closely, these sets of principles are crucial in their ability to give rise to spatial complexity in both biological and man-made architectures. Additionally, they are required for homeostasis (biology) and sustainability (architecture). Their loss leads to cancer in organs. An absence of these principles in architectonic methodologies, especially of the current era, underlies the reasons why some buildings, neighborhoods, and even cities start decaying and dying.

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