A. Adaptive complexity cannot be designed

Nature and the built environment are both complex. But they don’t always have the same type of complexity. Nature shares a high degree of organized complexity with certain parts of what we have built ourselves: those portions that have the greatest healing effect on us are found predominantly in traditional and vernacular built environments. Architects would love to know how to use mathematical knowledge to design complex forms, and then build them as actual structures. Nevertheless, “natural” complexity is not “designed” in the sense that one person — the designer — determines all details beforehand.

Architects (and, as a result, much of the educated population) assume that complexity in general is something that has to be designed. That’s a misconception. This way of approaching complexity can hardly ever lead to adapted complexity. It cannot reproduce or imitate the organized complexity found in nature, except in the most superficial, not functional manner. And we certainly want to understand how to build this same type of complexity so as to generate a better, more adaptive environment. Sustainability depends upon creating organized complexity, where all different structural scales link together coherently. The “organized” part is its most important characteristic.

That doesn’t stop some architects from trying to “design” complexity, however. Computer programs generate innovative complex shapes that look impressive on screen. But those designs are relevant only as images, because they fail to grasp the primary quality of evolutionary adaptation. Mathematically, many of those complex contemporary structures are disorganized, hence random. How can that be? The criterion for making this judgment is that any other structure could be randomly put up in their place, and nothing would change as far as improving adaptation to users. The building’s low degree of adaptation would remain the same.

Random design is not meant to adapt to human needs: it is abstract art, design as styling, a pursuit dealing with appearances and not so much the functions of a building and the needs of its users. Using random input for a design might produce a visually-striking and interesting sculpture. If that’s what the client wanted, then everybody concerned is satisfied (except, perhaps, the hapless user in those frequent cases where client and user are distinct persons).
The methods that we seek for generating organized complexity are to be found in adaptive techniques for design. Those organize existing elements that are responding to actual and latent complexity, which makes it imperative to be sensitive to and enable feedback from such responses. Forget about generating complexity: the sequence of steps followed in adaptive design will generate it for you. All you have to do to design adaptively is organize the emerging complexity as it is being generated in each step. By focusing on adaptation and organization, the end result will be organized complexity that is adaptive to human use and physiology.

B. How to build up organized complexity

Standard techniques for organizing complexity include:

(i) Connecting all the parts.
(ii) Aligning multiple flows (but not to a rigid axis or grid).
(iii) Creating local symmetries (but not an imposed global symmetry).
(iv) Implementing spatial correlations using similarities at a distance and scaling symmetries (similarity under magnification).
(v) Repeating things adaptively, so that they will vary in each repetition.
(vi) Building a system up using a sequence of adaptive steps, where the organized complexity arises from a process of evolution.
(vii) Accepting complexity as the result of dynamic processes, and not the equivalent of our static “art”.

These tools create organization. A sequence of adaptive design steps generates the complexity required for any specific brief or function. The designer implements a step-by-step procedure that allows feedback into the design process, at the same time as it is being carried out. Design components arise from adapting every detail to human dimensions and movements, and to the human psychological response to spaces and uses. This has to be done on all scales.

In adaptive design, there exists no regularization as seen with monotonous repetition, for example, because that reduces the information content of a complex system. In music, this is the principle of variation, which illustrates an important point: each variation in a piece of music is not generated by injecting arbitrary randomness. Instead, it comes from following an organizational framework that generates a particular variation from the basic theme. Randomness is out-of-place in tonal music. Exactly as in adaptive design, a variation is an unexpected yet carefully-controlled excursion into musical possibilities, while applying the constraint of organization and coherence.

As human beings, we find ourselves in a complex world that we did not create, but which we manipulate and transform in profound ways. We see complexity embodied in different forms all around us, and we are constantly producing
structures having various degrees of complexity. People tend to forget that there is a
dynamic reason for observed complexity. A working mechanism and its complex
supporting framework generate a complex product that depends on dynamics and
organization.

The complexity of traditional buildings is highly organized, motivated by
analogous forces driving natural and biological complexity. The traditional built
environment was shaped adaptively to contain our movements and vital actions. We
find here neither a deliberate attempt for randomness, nor the opposite attempt to
create simplicity for its own sake. Instead, a determined yet unconscious drive
mimics in human creations the degree of organized complexity found in nature.
Nature provides the template for useful complexity, and human beings are hard-
wired to follow it. In doing this, we are not really copying nature’s forms, but
instinctively try to reproduce one of its essential mathematical qualities.

When we do observe either randomness (as disorganization) or extreme
simplicity (as uniformity) in traditional buildings and urban fabric, it is there
because it is the simplest and easiest energy alternative; or it has been produced by
forces that have built up organized complexity elsewhere. In this second case,
randomness or simplicity are left over after focusing on organizing complexity
nearby, where the functions are more important. There are functional reasons for
what is happening, and where it occurs, and it is not due to some designer’s whim.

C. Conserving versus reducing complexity

Computer scientists conjecture that functional complexity is conserved. When a
specific task is simplified, what actually happens is that the organized complexity
needed to perform it is merely shifted somewhere else. For example, simplifying a
computer-human interface throws the complexity onto the invisible part of the
system (Tesler, 1984). Within software, simplifying on one level usually shifts the
complexity into another level. Another implementation transfers complexity from
hardware to software. Attempts at modularization, driven by the desire to simplify
interchangeability of hardware modules, shift the complexity burden from
hardware onto the software and the interface: again, there is no net reduction in
organized complexity (Coward & Salingaros, 2004).

Conservation of functional complexity in the built environment provides a key
insight into socio-geometric processes. A given set of human actions and movement,
together with the structures that adaptively contain them, define a working
threshold of organized complexity. Often, stylistically-driven simplification reduces
the organized complexity of the built environment, with very serious effects. To
maintain the original actions, the human actors have to handle far more complexity
than before. If the people are unable or unwilling to assume the burden of additional
complexity, the original action stops. Thus, net reduction of complexity can
eliminate useful life functions.

The analogy with computers no longer holds true, since computers are designed
to execute specific functions: the objective of simplification is easier use, not
reduced capability. Users of information and communication technology demand more features implemented in a way that is easier to use. By contrast to the user-driven situation with computers, however, our built environment is replete with instances where geometrical simplification has killed off formerly lively and vibrant community life. In many places, simplistic design severely reduced the variety corresponding to healthy components of individual and social life.

Adaptation requires a high level of the right type of organized complexity, which is not something that can be “designed” in the usual sense that architects understand this term. Design that imposes simplistic forms for reasons of style, aesthetics, or political ideology forgets the need to adapt to the complexity inherent in human life and society. Such image-driven design will not be useful, and is often detrimental to life. Indeed, governments consciously use architectural and urban simplification as a tool in social engineering. Minimalist forms, spaces, and environments have unexpected problems in use that their designers, concerned only with the aesthetic dimension, never considered.

**D. Matching organized complexity**

We might intuitively suspect that the breakdown of life in minimalist environments might be due to unbalanced complexity. That is correct. Nevertheless, whenever we try to compensate for deadening uniformity by adding just any sort of complexity to the built environment, things could become destabilized. Since complexity can be of different types, it is common nowadays to build complexity that is non-adaptive to human actions, which is therefore not helpful in promoting life. Disorganized (random) complexity cannot support the organized complexity that encourages human actions and interactions: the two types of complexity do not add, but instead cancel each other.

It follows from this discussion that built randomness actually degrades human life. Wherever recent iconic buildings and urban schemes embody random forms on the large (and sometimes also on the intermediate) scales, they are not responding to any adaptation. So unless there is an unlikely and fortunate coincidence, the complexity of those spaces and structures does not fit the complexity of people’s emotional and functional needs. There is a mismatch in the *kind* of complexity. Again, it helps to apply the substitution test: randomly-complex designs could be replaced by minimalist ones without making any difference, because their non-adaptivity to life is exactly the same.

The situation was very different in the past. Organized complexity as found in vernacular buildings results from satisfying human needs, functions, psychological dimensions, etc. During most of human history, other than expressions of monumentality, something was built the way it was to facilitate connectivity, necessary flows, life functions, and the dynamic utilization of space as defined by human perception on the ground. Typically, nothing was designed abstractly on the drawing board. Buildings and associated structures evolved from accommodating...
human uses. Over time, those structures evolved into the complex forms of traditional architecture.

Today, we are used to exerting direct control over each and every aspect of our environment, and that includes our constructions. The design process has become terribly deliberate. But this leaves no possibility for adaptively evolving a design into states of organized complexity. Even our randomly-shaped iconic buildings are very deliberately designed using sophisticated software, which generates the construction drawings, and even the building components directly. A developing contemporary taste for design as sculpture supported by our tremendous technological potential leads us to misunderstand the adaptive results from our past.

E. Complexity found in nature

The organized structure of matter is the prime example of complexity in nature. Components on different scales, from the subatomic, to the microscopic, to the macroscopic scales bind coherently to define larger and more complex structures. What is observed is the result of stability among all the components, which is a consequence of system organization. When natural structures decay, scaling hierarchies and local symmetries dissolve, and randomness is generated as organization decreases, accompanied by the production of unrelated components.

There exist two distinct opposites to organized complexity: disorganized complexity (randomness), and extreme simplicity (uniformity). The first — disorganized complexity — occurs when there are many pieces, each one of them possibly (but not necessarily) complex, but without connections among them. Randomness lacks organization. We are not seeing a working system, because the individual pieces do not work together. If they work at something, there is no coordination. Any organization that might be present within individual pieces is unexpected. A random state is heterogeneous without any correlations, consisting of many different non-interacting pieces.

The second and distinct opposite state to organized complexity — extreme simplicity — represents the case without variety. Extreme simplicity occurs when a set is homogeneous: its various components are essentially copies of the same component. Here, every piece is expected, and the group carries no additional information because there is no internal structure. Things no longer have any distinguishing characteristics. Every piece decomposes into its simplest components (which are the same), and the end result of reductionistic simplicity is uniformity. Even with possible correlations among its component pieces, there is insufficient variety to define a system.

Organic forms arose for the purpose of converting energy into information. Energy input from the Sun, but also from some geothermal sources, drives organisms to structure their bodies to utilize this energy. The energy goes into building and upkeep of the organism's complex structure. Life forms show the same features of organization relevant to design: alignment, local symmetries, spatial...
correlations, and scaling symmetries aiding life processes. The death of an organism means the onset of decay, where more complex structures become less complex, less organized, and the organism’s constituents break down into chemical states of either more randomness or uniformity.

These transformations of organized complexity also take place during metabolism. Animals eating food digest complex organic matter that dissolves into its simpler components, which are then re-assembled into the complex body of the animal. Chemical energy stored in the food is released and used to power the metabolism of the organism doing the eating. Organisms profit from various energy cycles they have invented (which transform complexity). Life therefore defines a definite direction for the transformation or build-up of organized complexity: from simple or random towards being concentrated in complex and highly organized systems. The same holds true for adaptive environments.