Formal Mutations

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"Novelty in human clocks requires independent acts of creation. Novelty in biological clocks seems more suited to iterative modification from a common origin."
M. Kirschner and J. Gerhart

We all are familiar with writers' or artists' blocks when faced with a clean sheet of paper, white canvas or blank computer screen. As designers, we all are full of expectations and desires to create…, but how to begin, is the real question. Many painters would break through this initial moment by smearing a canvas with abstract and meaningless scribbles. This breaking moment often helps us to forget the difficulty involved in starting a new project. This quickly and randomly chosen context for beginning the act of creation puts us on a specific path where we start thinking in terms of transformations, changes and adaptation, and not in terms of defining something from nothing. The idea of change, adaptation or inhabiting the pre-existing context, seems to be a nature-like process that is intrinsically gradual and as such less threatening for the artist or creator.

Starting with an already predefined canvas may put the creative process into a particular trajectory, resulting in a certain class of solutions. However, this possible pre-determination does not limit the chosen method's creative capacity. Some might argue, it actually increases the creative challenge resulting in more interesting solutions. In Igor Stravinsky *Poetics of Music*, he talks about the necessity of restraints and limitations in achieving creative outcomes. Working against the hard edge of design limitations and imposed boundaries is what makes solutions innovative and unique.

This attitude towards the creative process is present in our material culture as well as in nature. It is also a process that is well adapted for the digital environments. This comparative process that exists in design or in the study of organisms, either within digital environments or genetic coding in nature, allows for explorations in many of the same phenomena through an analogous intellectual approach. It also brings polar forms of reality: virtual (computer based) and actual (nature and physics based), into the same equation.

My interest in studying tectonic evolutions and simulating form mutations in design comes from the observation that these operations are natural ways to manipulate data and models within digital environments. It builds upon the observation that editing already existing data is more native to digital environments than inputting new data. Architecturally this could mean that transforming already existing forms is a potent and effective way to derive new forms, ideas, and designs. Finally, creating new ideas from scratch is almost always more difficult than arriving to new ideas by gradual transformations of the old.

The idea of transforming an already existing reality, as the shortest and most direct way to creating a new reality is being supported by observations from a variety of scientific disciplines. For example as a result of the studies done on DNA as part of the Human Genome project, scientists realized the surprising similarities in genetic information across very diverse species. The daffodil flower happens to share 33 percent of its DNA with humans; and a fruit fly shares 50 percent of the DNA with us as well. We see that there is a significant initial investment in creating life itself. The final outcome of physical differences account for less that one might expect, judging by the evolutional history or taxonomy.

Towards augmented design process

Traditionally, we assume that the design process is a linear, gradual and creative development of products arriving at the finality of a completed design project. This means that if we were to continuously choose the best scenario, we would end up with the most successful design. However this static, somehow optimistic, approach to the design process is often missing many opportunities, while part of some possible scenarios, may be obscured by local inconsistencies. It may miss possibilities that behave like many natural processes, where sometimes a series of uninteresting or inferior solutions will precede a highly innovative form. If we consider the case of the caterpillar and the butterfly, we see that a caterpillar does not visually imply a butterfly, or in other words, a butterfly is not an obvious or 'rational' consequence of an evolution of a caterpillar. We assume that if we always do the right thing we end-up in the best possible scenario. However everyday life, as well as advanced design simulations, do not support this conviction. While experience leads us to this conclusion in real life, we are just starting to realize alternate possibilities in design with digital technology and mathematically based 3D simulations.

Nothing stops the traditional process from exploring a multiplicity of possibilities. The significant difference lies in the digital technology easiness of studying multiple alternatives and pursuing parallel scenarios.

The design process begins with often-arbitrary assumptions, but it results with logical and unique solutions. It is judged by its logic and consistency in the context of its starting assumptions. This consistency and design integrity means that with each step in the design process the number of the possible solutions is being reduced, slowly converging on a final design. We could illustrate it as a design decision tree; with each step forward, towards the resolution, we advance to the higher branch; thus, are left with fewer choices that are consistent with our past decisions. Unlike when climbing a tree, we always can see other branches and understand our past climbing choices, in design the further we progress the more difficult it is to see other possibilities that are not a part of our present design trajectory, also called as design horizon. This continuously narrowing focus brings many benefits in decision-making, but also makes us miss design possibilities that may be more suitable for our intensions.

"Seeing other branches" is especially critical in situations when we are faced with the decision of choosing the less-than-perfect scenario. At that point, the simple method of elimination of less desired solutions does not lead to the best results. A weighted average of the possible scenarios and understanding their final potentials is the best approach to designing.

Types of transformations

Since change and transformation become the norm and basic element in the creative process. The new set of instructions is necessary to direct these design agents. These instructions may involve simple form transformations as well as topological changes including object discontinuities.

The design is executed by applying simple rules and behaviors to the original form. Each of these rules represents limited vocabulary and produces very recognizable effects, like the 'bend' transformation. However, by compounding even a small number of simple transformations, the forms' complexity and design possibilities are growing exponentially and escape predictable visual patterns (fig. 1–4).

In most cases, the order of applied transformations is critical. Different orders will produce different results. In the same way as compounding of mathematical functions F(G(x)) will usually produce different characteristics than G(F(x)); (fig. 5).

The following are three transformation categories:

Continuous transformations that preserve an object's topological identity and continuity while deforming it. Examples are functions such as bend, twist, or smooth with NURBS. These transformations, on occasions, may interfere with sub-object topological levels but will not affect the cohesiveness of an object as a whole (fig. 6).

Destructive or populating transformations that break an object's physical identity resulting in multiple new objects. This is achieved through object fragmentation not copying. Common examples are computer functions such as subdivide, explode, and shatter with each of them having slightly different properties or addressing different topological levels. The rate of population can be controlled by transformation parameters, but also by the object's sur-

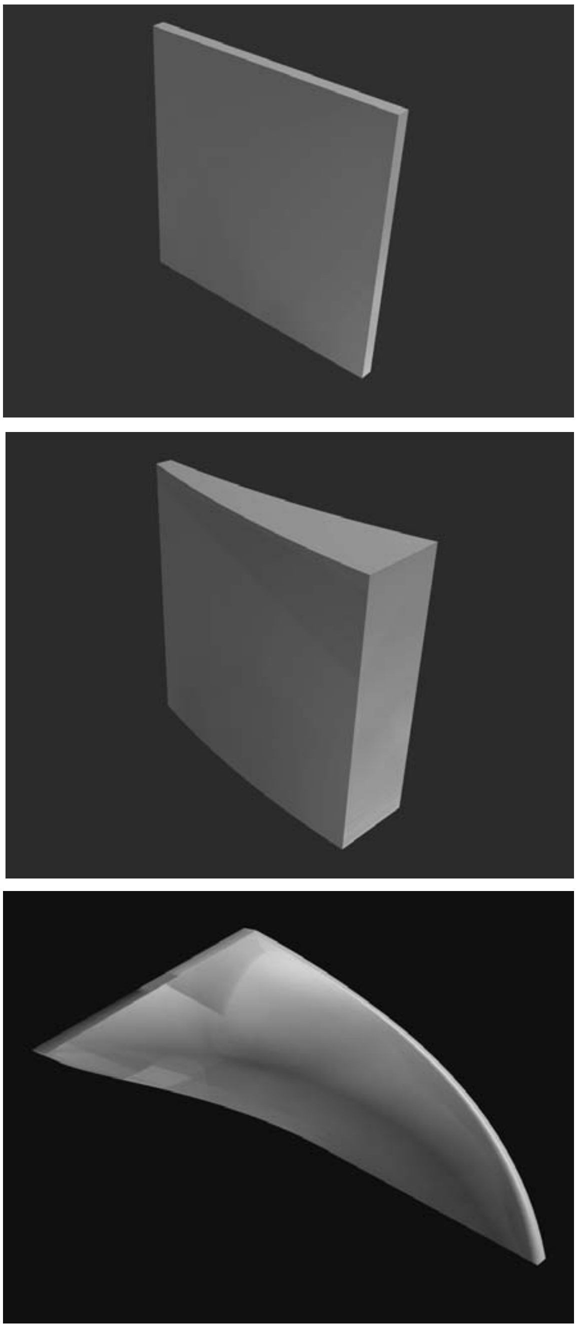

Fig. 1–3: Top, an object with no transformations applied; center, two the same original objects with only one, but different, transformation applied to each of them; down, an object with two transformations applied

face subdivisions. The surface subdivision can further control the shape or proportions of resulting objects (fig. 7).

Cohesive transformations result in merging multiple objects into one larger entity. This can be achieved by attaching 'adhesive' properties into objects, but also by capturing these objects in a space bubble through the use of space warps. An example is a metaball or meta-object that behaves similarly to mercury, a liquid, with strong cohesive forces and its molecules seek to minimize surface tension. Space warps are another way of forced cohesion. They are particularly effective with objects using dynamics and with particles (fig. 8, 9).

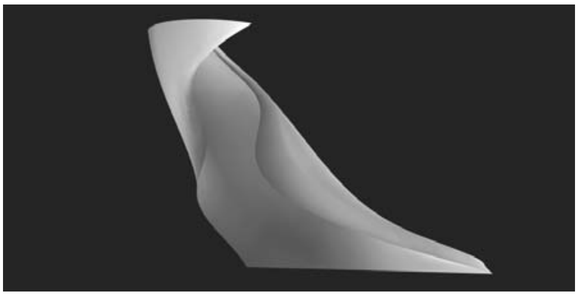

Fig. 4: The original object with two transformations, Bend and Twist applied

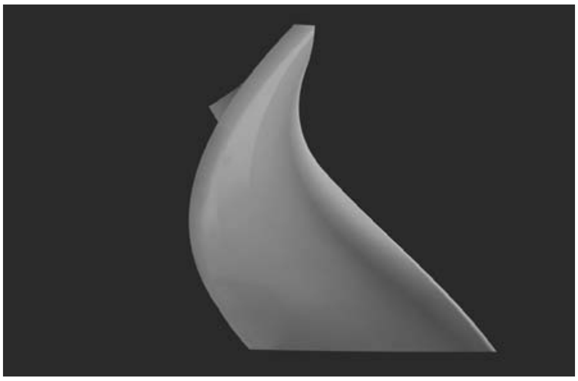

Fig. 5: The same object transformations applied in different orders, compared to the previous illustration

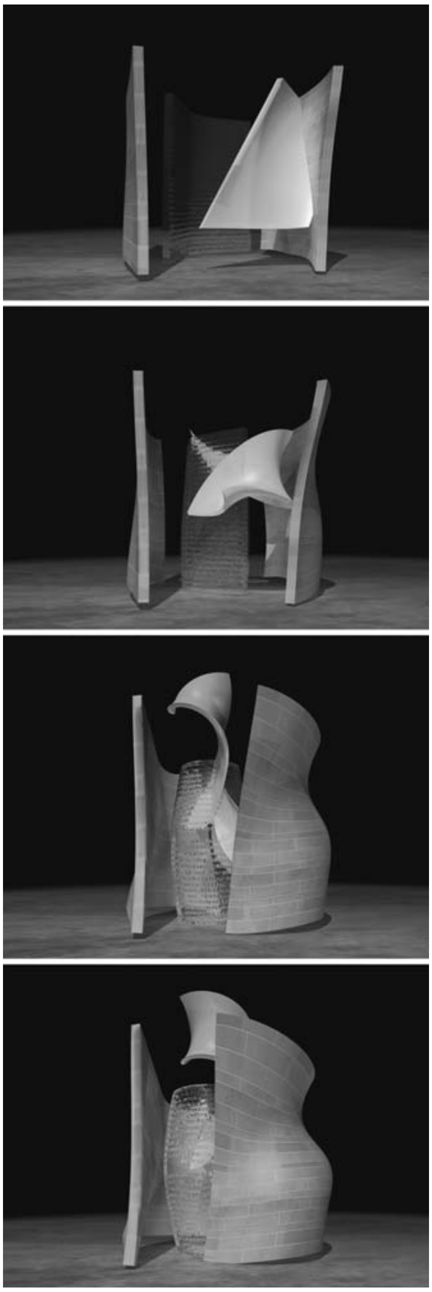

Fig. 6: Stages of a form evolution using exclusively continuous transformations

Fig. 7: Destructive transformations in conjuncture with continuous transformations applied to a single object result in a rich visual landscape; three stages of an evolution

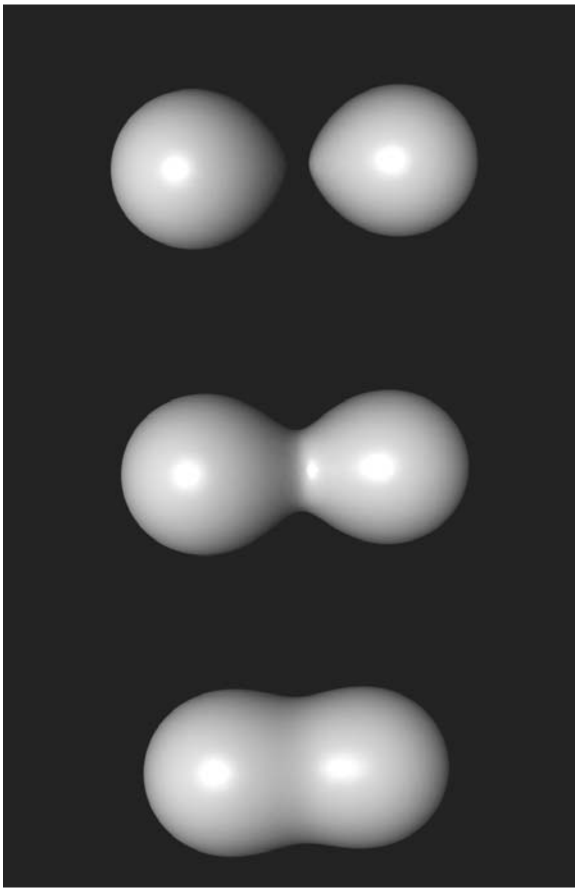

Fig. 8: Behavior of two meatballs

Fig. 9: Metaball particle system trapped in a space bubble

Animation – interpolation and extrapolation of static states

While using form transformations is a new and effective way to derive designs, even greater design possibilities are achieved by animating those initial, static forms with the use of space warps, morphs and form modifiers. Since most transformations are parameter based, it is easy to animate numeric values of these parameters and study evolution of forms. This is usually executed by defining critical static states of a form, also called keyframes as an analogy to traditional animation process, and interpolating these values as well as spatial positions and properties into in-between forms. While morphing forms we identify moments in an animation that have interesting design opportunities and we can retrieve the parameters that define the transformation's particular states for further refinement. We can also register the object's particular state and output as a static, transformed form that no longer relies on changing parameters. This newly shaped form becomes a seed for another process. Its simpler existence as a 'flattened' transformation stack, reduces the complexity of the object's definition, but is not critical in terms of the object's visual definition.

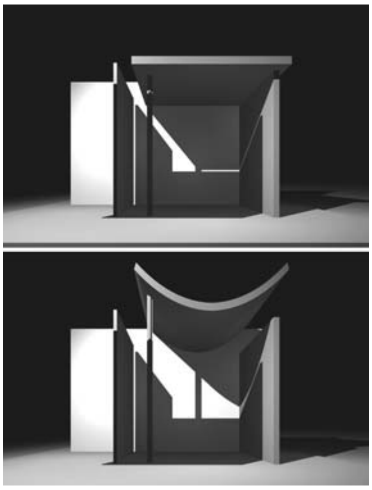

Fig. 10: Animation a building envelope allows for in-depth lighting studies

Since many of these parameter driven functions behave in a non-linear way, the results of these animations as well as the in-between stages are often unpredictable even though there are no random values introduced. This is perhaps the strongest element in this approach since it allows for the creative leap—mutation to occur. It also introduces strong and effective explorative components into architecture, in a similar way as physical model explorations can also bring surprising new discoveries. However, in this case it happens in a much more pronounced way and with greater intensity.

Tectonic animations can also be used as study tools. While it is common to employ digital technology in performing light and shadow studies for a static architectural space or a building, with this approach, we can animate the envelop of a building with changing window apertures arriving at the most desirable lighting scenarios (fig. 10).

This effectively repositions the question from what is the best lighting scenario for a particular design, to what is the best design that effectively uses existing lighting possibilities.

This compounding strategy can be brought to another level of design thinking where any form can be subsequently deformed and be used as a seed for another design. Consequently, through the parallel processing of ideas and designs, we often talk about a class of all possible solutions or about tendencies the solutions are gravitating towards, and less about geometric absolutes. Geometric absolutes that are seen as static and finite design solutions, as well as designs that start obeying probabilistic rules rather than definite and predictable patterns.

With an introduction of animation into design, two classes of transformations emerge: form and space deformers. Form deformers change the object's geometry, which is a permanent change even if it only exists for a short period of time. This new form is an attribute of an object and is not location dependant. Form deformers are reacting only with particular objects and do not interfere with other objects that are in the same locality.

Space Deformers, also called Space Warps, are the properties of space and affect any object that is within a space unless specifically excluded from the operation. They allow transformations that are only relevant to space or context not a particular object. Furthermore, their influence is location-in-space related, which means that the form of an object is dependant on the location within a space warp and will change if the object is moved (fig. 11).

This distinction, to form and space deformers, is particularly applicable for architecture since space deformers can be seen as the design context or environment. Ability to assign properties to space, not much different than in real life, allows for global treatment of design. It also creates favorable conditions for simulations of form mutations and dynamic systems.

Language of Mutations

The concept behind *Formal Mutations* brought this transformative design methodology a step further where the process of change is paralleled to other processes like those found in nature and evolution. As a result design, methodology has to account for the *creative error*—a *mutation* which helps a designer to break away from the obvious and predictable while setting the design on unexpected but meaningful trajectories. This can be achieved by introducing chaotically behaving functions into design or by compounding multiple simple rules that behave like switches enabling individual transformations.

Formal Mutations, an example of a non-linear design process, relies on generating new design forms from previously created forms. If established as a part of a generative process, an element of reiteration is introduced into design. A present design state can only be seen in the context of the immediately preceding state. While evolving a form from a generation to generation there is an opportunity to introduce elements of noise or imperfections that can push designs in unexpected directions. Even in a simplified model of behavior where there is no mutation or contamination introduced, we can observe the development of great variations in forms. This connection between the resultant forms and the particular methods can be as surprising and unpredictable as relationship between visual representation of the Julia Set and the equation that created it: $Fc(z) = z2 + c$, where c is a complex parameter.

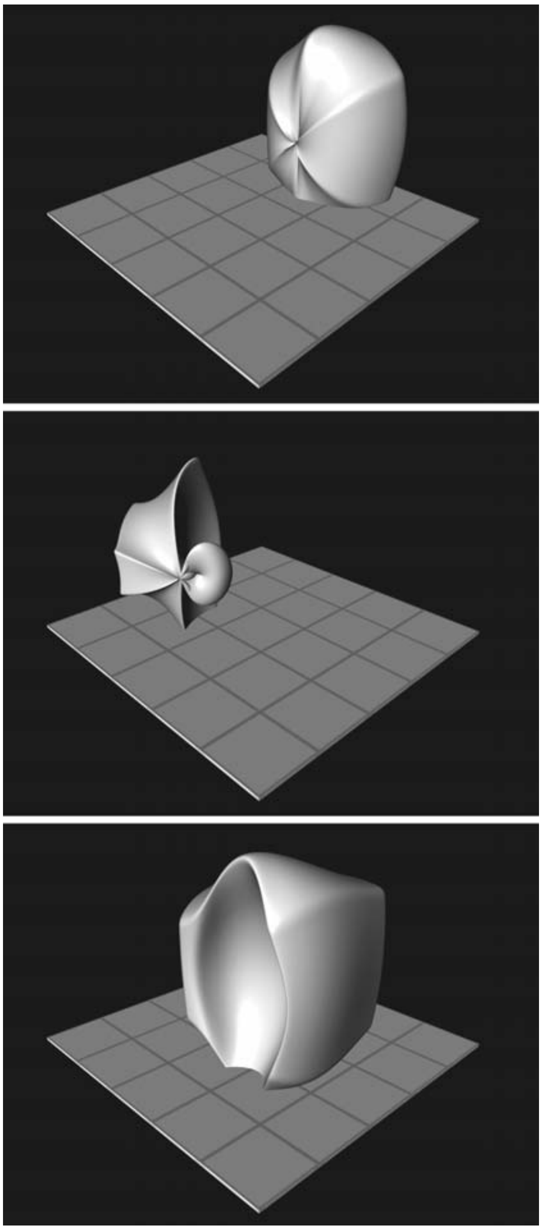

Fig. 11: Behavior of an object as its location-in-space changes

Non-linear processes, especially those employing dynamics such as cloth deformations or particles, are defined by their immediately preceding states. As such, they tend to carry some residual values in discontinuities or deformations, called here *traces*, from iteration to iterations. Traces, such as flexion, often result from the inertia present in the material's physical properties. In such situations, the speed changes in the dynamics system can proceed faster than the material's ability to react to the change, leaving a discreet trace from the action. These traces can manifest themselves by *tears, folds*, or other surface imperfections (fig. 12).

Another *trace* example is inconsistencies in particles spatial distribution. These inconsistencies are being carried from generation to generation by the

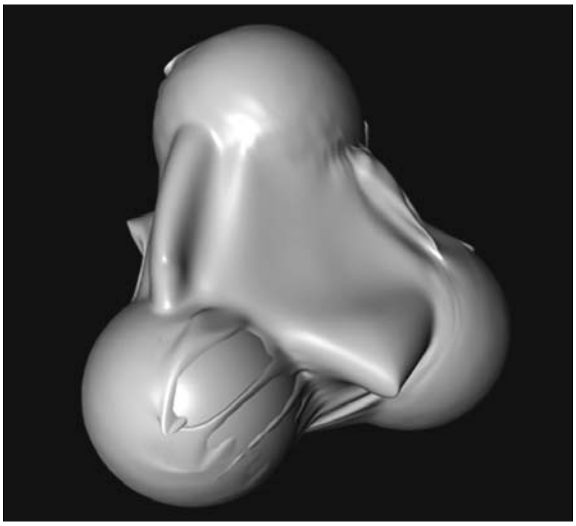

Fig. 12: Dynamic cloth deformations register traces resulting from object collisions; visible tearing and folding of surfaces

dynamic interaction between particles. Particle systems are, in many ways, what the formal mutations idea suggests. Particles are objects, which once created become freely behaving agents that can only be controlled with space deformations or other deformations that affect the entire population of objects, not just individual instances. The two control areas over particle systems are the initial conditions and global deformations.

A new set of design criteria is emerging. Terms such as *contaminations, traces, seeds, thresholds, attractors*, etc. are becoming building blocks in the design process. In this new world, chaotic functions become contaminants; residual elements and values from previous states of existence are seen as traces. Any form can be used as a seed for another architectural form while trajectories of individual evolutions—mutations disobey a simple causality.

In some aspects, this iterative process is what design has always been about. It is a process of continuous refinement, trace paper over trace paper, is present in both traditional and digital approaches to design. The difference is that digital simulations allow for more parallel processing in design through a co-development of several trajectories or multithreading in design.

These formal and tectonic possibilities are not always immediately recognizable. Often they emerge from obscure landscapes through the process of spatial mutations, and they are only noticeable when other components become activated. Since they are often interdependent, they may remain dormant while waiting for a spatial activator. These situations are particularly visible through the use of space warps and dynamics, where objects have an ability to interact and are aware of each other.

Conclusions

This paper identifies three levels of computational design as they relate to the Formal Mutation concept.

Level one, is a simple transformation of forms within the computational environment through the use of transformations. This traditional-yet-digital method brings great potential into design. It is fully interactive and enables users with a limited knowledge of computational concepts and software to engage digital design on the 'user' basis.

Level two, *formal transformations*, has all the benefits of the previous level, plus the ability to morph form transformations with animation tools that bring a new class of design possibilities. The design process is still fully interactive with design results usually escaping the preliminary expectations.

Level three, *formal mutations*, introduces randomly behaving functions into level two transformations. It relies more on particle and dynamic system that are designed to obey the laws of physics. The role of a designer shifts from being clearly interactive into a system manager that controls naturally evolving processes through arranging various starting conditions.

In this new paradigm, a designer can re-trace design steps for future revisions and reconsiderations. This goes beyond the 'undo' button and helps us not only to create new designs, but more importantly to study the design process itself. This design methodology allows for better scanning of potential design possibilities, bringing them from the realm of possible to probable to real. The second critical advantage is that it enables us to understand, explain, and produce complex designs with a set of simple rules or transformations. It is important to add that the complexity of digital designs is not seen as an aim in itself, but rather complexity is recognizing the nature of reality. These computational methods are looking for ways to address this complexity as well as to explain complex ideas and forms with the simplest language possible.

For more on this subject visit
www.FormalMutations.com

References:

George Hersey and Richard Freedman, *Possible Palladian Villas (Plus a Few Instructively Impossible Ones)*; The MIT Press, Cambridge, MA, 1992.

M. Kirschner, J. Gerhart, *The Plausibility of life, resolving Darwin's dilemma,* Yale University Press, New Haven and London. 2005.