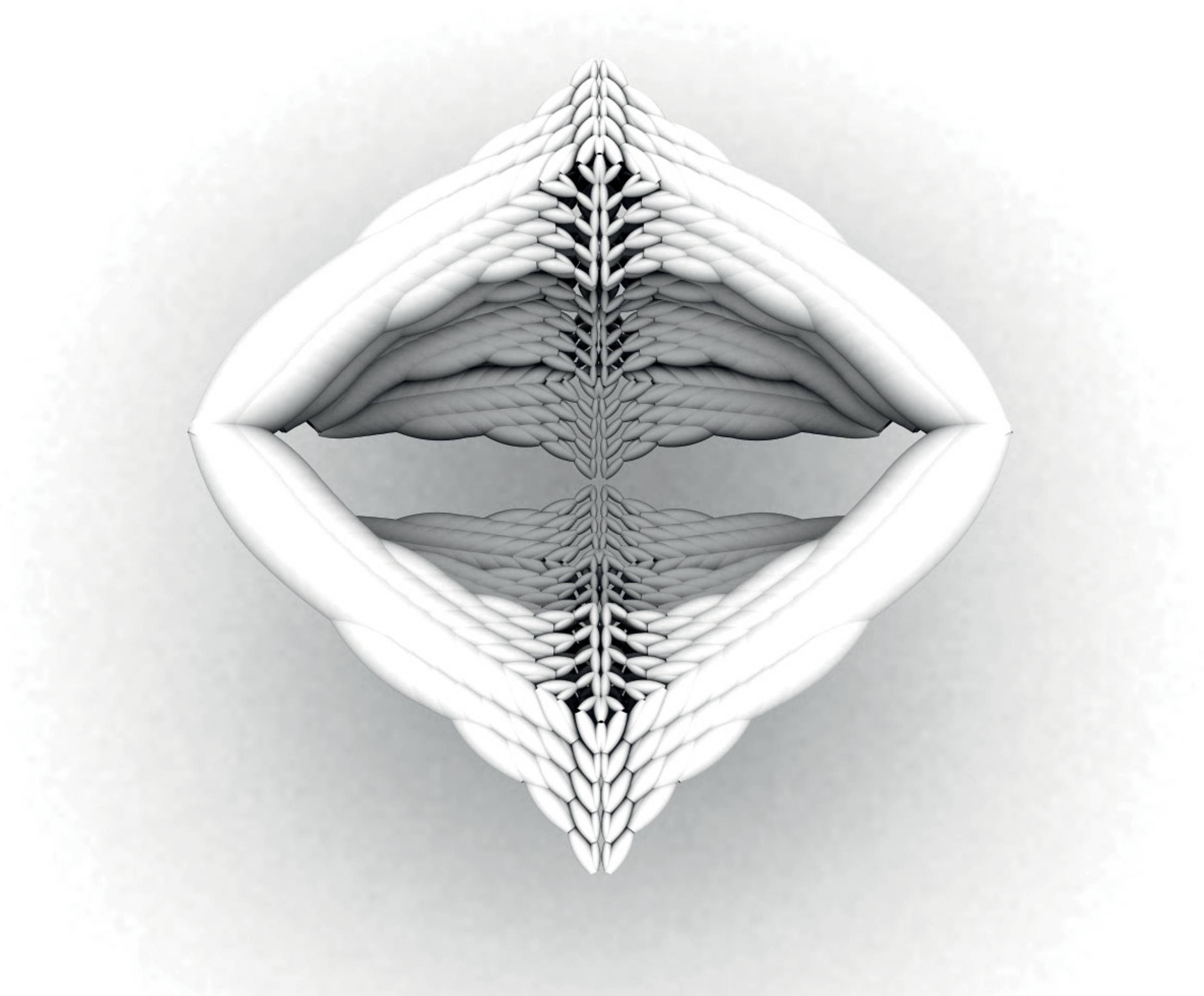
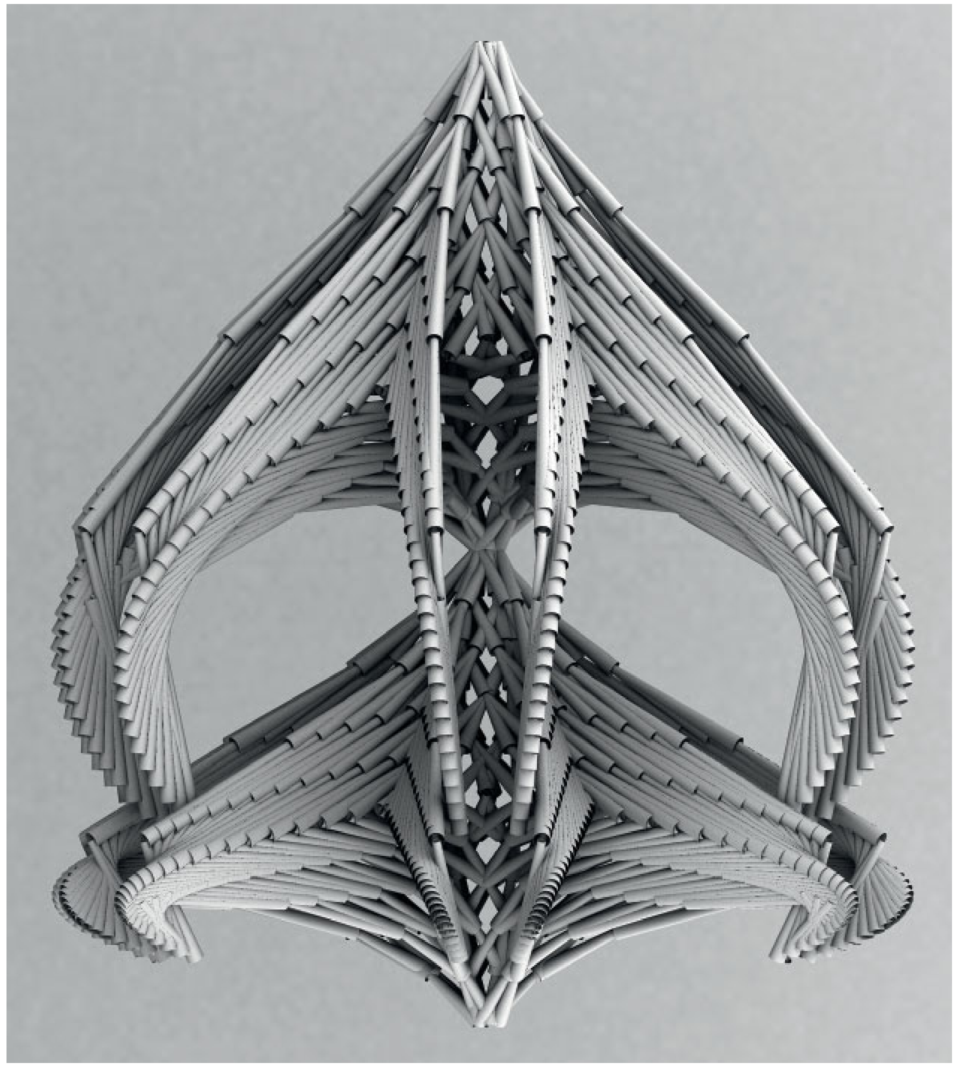
PROTO-DESIGN



ARCHITECTURE'S PRIMORDIAL SOUP AND THE QUEST FOR UNITS OF SYNTHETIC LIFE

Neri Oxman, Tropisms, Massachusetts Institute of Technology (MIT), 2006
Design for an inflatable furniture piece based on parallel rewriting logic. The underlying geometry is determined by an L-system algorithm guiding the growth direction of the overall structure. Cell size and distribution are determined by the anticipated load triggering inflation.

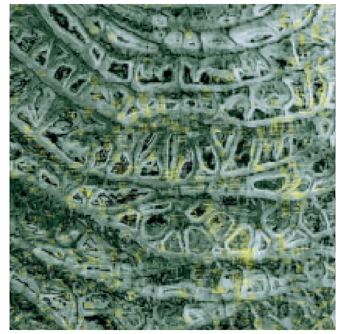


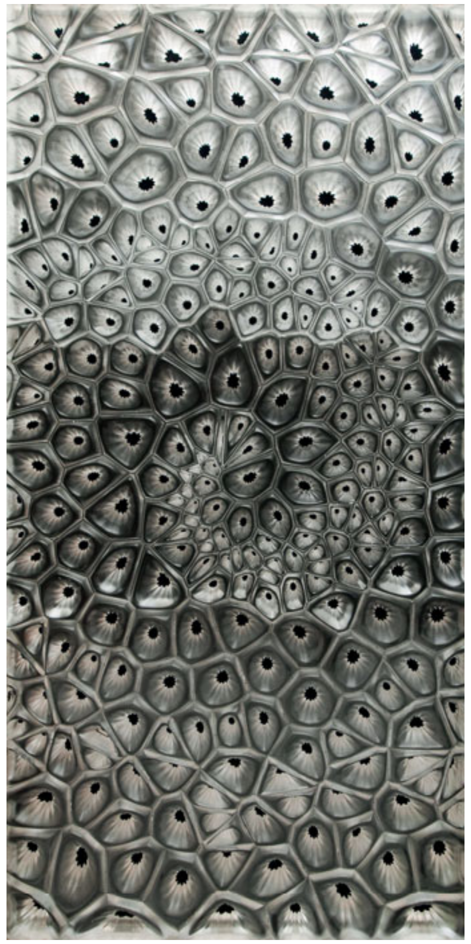
Standfirst to come: Neri Oxman, PhD, Sony Corporation Career Development Professor, Assistant Professor of Media Arts and Sciences, Mediated Matter Group, Director, Massachusetts Institute of Technology Standfirst.

Neri Oxman, Stalasso, Museum of Science, Boston, Massachusetts, 2010
Parts and wholes: an exploration into the relationship between cellular units and their assembly within a site-specific, light-refracting surface. All cells are computed as a consistent tissue corresponding to local conditions through the local manipulations of each uniquely defined cell.

Neri Oxman, Fatemaps, Museum of Science, Boston, Massachusetts, 2008
Natural micro-structural 2-D tissues are visualised, analysed and reconstructed into 3-D macro-scale prototypes by computing hypothetical physical responses. An object-oriented finite element application is used to determine material behaviour according to assigned properties and performance such as stress, strain, heat flow, stored energy and deformation due to applied loads and temperature differences.

The interaction between the directional morphology of the specimen and the tensor direction produces physical effects that emphasise the tissue's spatial texture in different ways. The resulting model is six-dimensional and includes 2-D information (X, Y), out of plane deformation (Y), elastic stress (S), strain (S) and temperature flux (T). The tissue is then reconstructed using a CNC mill and metal/steel and wood composites. Anisotropic in nature, grain directionality and layering are informed by the analysis, resulting in laminated structural composites that respond to given ranges of energy and loading conditions.





Questions regarding the units of digital design have been at the centre of the discipline since its inception.[1] From masonry bricks to multi-dimensional voxels, architectural design is possessed with the search for synthesis. Motivated by new scientific discoveries, such enquiries are now advancing new ways of thinking and making architecture. Such is the case of protocells, hypothesised to have been pre-genomic blueprints for the units of life made of inanimate matter. Following the discovery of protocells, their contribution to spontaneous generation[2] and to the emergence of life on earth, designers are now seeking the synthetic design counterpart to basic science.[3] Pertaining to a gene's-eye view of the built environment, wherein a material unit might incorporate data that is inclusive of its assembly, behaviour, decay and regeneration, what might the proto-brick of the future look like?

Parallel to, and inspired by the contemporary discourse in synthetic biology, a bottom-up approach to design is indeed one of the key characteristics of design inspired by performance.[4] In this approach, a units-based strategy is commonly devised and encrypted in order to correlate between form's material properties and its environmental milieu.

Material-Based Design Computation was developed at the Massachusetts Institute of Technology (MIT) as the theory and method by which to relate units of matter to units of performance in the generation of form.[5] According to this approach, material properties are considered intermediary agents mediating environmental impetus with material response,[6] such that inanimate matter might contain the information for its behaviour and evolution, not unlike protocells. This method assumes complete synergy between geometry, physical matter and energy.[7]

Such synergy can only be achieved if and when the various processes of design will have been integrated to allow modelling, analysis and fabrication to occur simultaneously in parallel fashion not unlike the behaviour of living organisms.[8] The systems assume that each and every cell comprising the whole is in constant flux as it remodels and evolves under environmental pressures: call it proto-design.

The explorations below, part of the Material-Based Design Computation project, illustrate three approaches for the definition of a proto-design unit from the modelling, analysis and fabrication perspectives respectively. However, it is only when these are combined into a single process that we may begin to speculate on the generation of a synthetic protocell.

Geometric Protocells: Tropisms
Devoid of sensor-actuator technologies, geometrically defined units comprise – within the scope of illustrated experiments – the simplest method for achieving bottom-up design. These units are parametrically defined as they contain curvature data, but do not typically designate and predict physical properties and material behaviour. In the case of Tropisms (MIT, 2006), a load-sensitive pneumatic furniture system, each geometrical component is designed to optimally inflate and deflate upon sitting and standing respectively. The assembly logic of all cells determines the overall form its assembly would take as behaviour control and accommodation are geometrically defined and exercised.

Analysis Protocells: Fatemaps
Mesh discretisation processes allow the designer to subdivide a continuous mathematical domain into a set of discrete sub-domains referred to as elements and represented as singular geometrical entities. Lattices and triangulations are common rationalisation discretisation techniques, where quadrant and triangulated elements may respectively wrap the surface area or volume of the object. These structural meshes are used by engineers to simulate structural loads, analyse their distribution and predict any potential displacements that may arise. More recently, engineers have been utilising mesh-free algorithms to rationalise 3-D form in the process of translating it from the digital domain to its material manifestation via appropriate fabrication routines. Such mesh-free methods eliminate some, or all, of the traditional mesh-based view of the computational domain and rely on a particle view of a field problem.

When inverted, these analytical tools may be put into synthetic purposes of form generation. Mesh-free methods can then be viewed as continuous fields of particles that may potentially carry material data as they 'grow' a structure. This is the case with Fatemaps (Museum of Science, Boston, 2009, a study exploring natural tissue reconstruction using artificial materials.

Perfect alignment between form and material behaviour may be considered by calibrating the size, shape and proximity of the element to the size and shape of the material unit from which the form is to be fabricated.

Neri Oxman, Raycounting, Museum of Modern Art (MoMA), New York, 2008
Raycounting is a method for originating form by registering the intensity and orientation of light rays. In this process, form generation is guided by fabrication constraints and material properties. 3-D surfaces of double curvature are the result of assigning light parameters to flat planes. The algorithm calculates the intensity, position, frequency, polarisation and direction of one, or multiple, light sources placed in a given environment, and assigns local curvature values to each point in space corresponding to the reference plane and the light dimension. These parameters are then interpreted as 3-D printed material particles in the construction of the physical prototype.

Imagine the case in which the size of a mesh-free particle, applied for the purpose of form generation informed by light performance, precisely matches the size of an imaginable powder molecule, or – more realistically speaking – a material aggregate providing for the substance of the 3-D printing process.

Fabrication Protocells: Raycounting
Imagine the case in which the size of a mesh-free particle, applied for the purpose of form generation informed by light performance, precisely matches the size of an imaginable powder molecule, or – more realistically speaking – a material aggregate providing for the substance of the 3-D printing process. Such is the design motivation behind Raycounting (MoMA, 2008), the form of which is mediated by environmental and structural constraints.

The maxel unit9 can be thought of as an intermediary representation linking the digital form to its physical manifestation, particularly when rapid fabrication processes are considered. In this respect, the maxel provides for a lower-limit material definition establishing the degree of granularity required to manifest the 3-D details of the design. From here it is relatively easy to imagine the implications of using maxels as the units for calibrating voxels and printing powder. The designer would then be generating 3-D form using the precise units applied to describe its physical manifestation, not unlike protocells.

To conceive of design as the 'dry path' of biology in the generation of synthetic form requires designers to find the formula to describe matter as generative. To do this, they must first abandon the conceptual structure of a divided and hierarchical process separating the analytic and the synthetic, and arrive at their ultimate integration. A new philosophy of design is slowly emerging which anticipates and supports the merging of matter and energy on the way to proto-design.

Notes
1. N Oxman, 'Material-Based Design Computation: Tiling Behavior', *ACADIA 09: reForm Building a Better Tomorrow, Proceedings of the 29th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA)*, 2009, pp 122–9.
2. Philip P Wiener (ed), 'Spontaneous Generation', *Dictionary of the History of Ideas*, Charles Scribner's Sons (New York), 1973.
3. C Zimmer, 'Origins: On the Origin of Eukaryotes', *Science* 325 (5941), August 2009, pp 666–8.
4. M Weinstock, *The Architecture of Emergence: The Evolution of Form in Nature and Civilisation*, John Wiley & Sons (London), 2010.
5 N Oxman and the Massachusetts Institute of Technology Department of Architecture, 'Material-Based Design Computation', doctoral thesis, 2010.
6. For example, consider force as an environmental impetus, extension as a material response, and stiffness as the material property that mediates the two.
7. Cellular digital units must scale with variable gradients; if illumination is changing rapidly, then the computational unit must be small enough to capture this gradient.
8.The human bone is a great example illustrating the integration of growth, analysis and remodelling as an integrated process.
9. A maxel is defined as a physical voxel. See 'Material-Based Design Computation', op cit.