KEYNOTE ESSAYS

TOWARDS A MATERIAL ECOLOGY

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That matter is secondary to shape constitutes the fallacy of design after craft. By nature, and in its rite, the practice of craft is informed by matter, its method of fabrication, and by the environment.

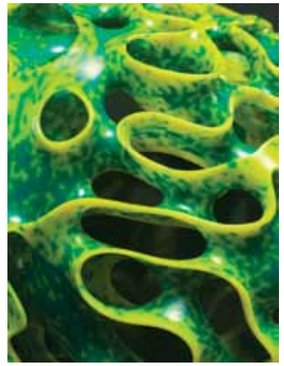
As in Nature, when creation *begins* with matter, *morphogenesis,* or the generation of form, is a process engendered by the physical forces of Nature. Similarly, in the framework of this essay, *Material* is not considered a subordinate attribute of form, but rather its progenitor. Such is the story of form told from the point of view of matter, and it begins, unsurprisingly, with form's predicament.

Over the long trajectory of architectural design history, the design and production of artifacts has been characterized by a growing separation between form and matter. In contradistinction to *craft* in which material and form are organically intertwined into a tradition of making, modern design and production have historically evolved away from this integration, or in its absence, towards the compartmentalization of form-making as a process independent of its sources in material knowledge. At least since the Renaissance, with the emergence of architectural theories, form generation has become somewhat of a self-directed and autonomous body of knowledge. Within architecture and industrial design, the most culturally sensitive of the productive design fields, form has grown in both eminence and temporal precedence in the design process to the point that the condition of *form preceding materialization* has become normative and virtually intuitive in contemporary design culture. With the exception of few pioneering cases in contemporary design, the secularization and debasement of the material realm has become axiomatic. Materiality has become, within the logic of the modernist tradition, an agency secondary to form.

The Industrial Revolution lay open the door to machine-based manufacturing and mass production. The creation of form was now to be conceived and created by the power of industrial automation, detached and independent of environmental forces and influences. The values promoted by ancient crafts (not unlike Nature's way), pronounced by the integration of material substance and construction methods, once within the province of the craftsman, were abandoned while in their place emerged a design practice based on values of mass production. Fast, cheap, repetitive and modular building types and parts were synonymous with Ford's visionary dream. Industry's victory aside, it appeared as if design's propinquity to ancient crafts and its design expressions as portrayed by vernacular forms of design was now doomed lost; and with it the intimate context of material technologies. Eventually, this non-material approach to the design and the automation of construction were to be reinforced under the command of computer aided design and engineering.

The Digital Revolution, which marked the shift from analog to digital technology, has transformed the designer's drafting board into a digital canvas. Form, it seemed, was now divorced completely from the physical reality of its manifestation. This new design space afforded much liberation in formal expression, but it has also broadened the gap between form and matter, and made the hierarchical and sequential separation of modeling, analysis and fabrication processes infinitely more pronounced.

The implementation and broad absorption of enhanced computational design tools in architectural practice has, since the early nineties, motivated a renaissance of the formalist project in architecture; geometrically complex shapes became emblems of creativity in digital design environments and supported the design mastery of complex geometries in form-generation. This formal and geometric design orientation has also addressed "free form" design and architecture along with their enabling technologies as part of the larger design phenomenon of "non-standard" form.



Today, perhaps under the imperatives of growing recognition of the ecological failures of modern design, inspired by the growing presence of advanced fabrication methods, design culture is witnessing a *new materiality.* Within the last decade in both industrial design and architecture, a new body of knowledge is emerging within architectural praxis. Examples of the growing interest in the technological potential of innovative material usage and material innovation as a source of design generation are developments in biomaterials, mediated and responsive materials, as well as composite materials. With the growing relevance "materialization", new frontiers of material science and digital fabrication are supporting the emergence of new perspectives in architectural and industrial design. Thus the role of digital design research as the enabling environment of the transformation to a new age of material-based design in various design disciplines has become the cutting edge of computational design research. Here we are at the cusp of a new paradigm inspired by the Troika structure of craft, at the interaction of Materials Science, Digital Fabrication and the environment.

Material Ecology is an emerging field in design denoting informed relations between products, buildings, systems, and their environment (Oxman, 2010). Defined as the study and design of products and processes integrating environmentally aware computational form-generation and digital fabrication, the field operates at the intersection of Biology, Materials Science & Engineering, and Computer Science with emphasis on environmentally informed digital design and fabrication.

With the advent of digital fabrication techniques and technologies, digital material representations such as voxels (3-D pixels) and maxels (a portmanteau of the words 'material' and 'voxel') have come to represent material ingredients, for instance in the context of additive manufacturing processes. In other words, designers are now able to compute material properties and behavior built-in to form-generation procedures. Combined with the designer's capacity to analyze structural and environmental forces, the enabled mediation between matter and the environment through fabrication appears to be as powerful as the ethos of craft itself.

The ability to design, analyze and fabricate using a single material unit implies unity between physical and digital matter, enabling nearly seamless mappings between environmental constraints, fabrication methods and material expression (Oxman, 2010). Such unity—like that found in natural bone, a bird's nest, a typical African hut and a woven basket - might promote a truly ecological design paradigm, facilitating formal expression constrained by, and supportive of its hosting environment.

Ultimately, the faculty to author new forms of expression will depend on the craft triptych (matter, fabrication, environment) and its integration into the design practice as an undifferentiated scheme, able to process matter into shape as informed by the environment. Once achieved, architectural design will have arrived at a new ecology of and for the artificial: a *Material Ecology.*

*Based on the author's PhD dissertation:
Oxman, N. (2010). Material-based Design Computation. Ph.D. thesis, MIT

MATERIAL GENERATION

MATERIALITY AND MATERIALISATION AS ACTIVE DRIVERS IN DESIGN COMPUTATION

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Computation, in its most basic meaning, refers to the processing of information. In this way, both machinic processes operating in the binary realm of the digital, as well as material processes operating in the complex domain of the physical can be considered computational. While there is a strong bias towards the former in contemporary design, sporadic investigations of the later have also occurred in architecture. What is more rarely explored, though, is the territory where machine computation and material computation potentially overlap, where they not simply co-exist but intensely interact in the design process. Over the last ten year this has formed a central part of the design research we have pursued at the Architectural Association in London, at Harvard University and more recently at my new institute at Stuttgart University.

Contrary to most current uses of computational design and digital fabrication, this research is based on a synthesis of form, material, structure and performance in a process of integral materialisation, which finds its conceptual roots in the processes of becoming in nature: Natural morphogenesis, the process of individual growth and evolutionary development, derives the complex organisation, structure and shape of natural systems from the interaction of system intrinsic material capacities and external influences and forces. The resultant, astounding articulation, performative capacity and material resourcefulness, emerges through morphological differentiation, the summary process of each element's response and adaptation to its specific environment.

In contrast to the reciprocities characteristic for natural systems, the relation between information, formation and materialization in architecture is typically linear and, at least in regards to the genesis of form and its materialization, one-directional and hierarchical. Whereas material plays an active role in the generation of biological form, in architecture it is most commonly conceived as a passive receptor of otherwise determined shape. Since the Renaissance, the rising separation between the processes of design and making, and the subsequent development of representational design techniques based on descriptive geometry has lead to an increasing division between design methods and subsequent processes of production, fabrication and assembly. Thus far the advent of widespread and increasingly ubiquitous use of machine computation in architecture had seemingly very little effect on this condition. While the integrative character of computational design has been extensively utilized for the inclusion of programmatic, structural, environmental or economic information, material information is hardly ever considered, let alone employed, as a generative driver in design. Especially in recent years one could witness a widening conceptual gap between the generation of form in the realm of the virtual and its manifestation in the physical world, Emblematic for this schism is the strange coactive development, where the ability of digital design to generate ever more exotic shapes has been facilitated and accelerated by the ability of digital fabrication to produce them. It seems as if the age-long predominance of shape-oriented representational design techniques based on explicit geometry and their direct, conceptual extension in most contemporary CAD packages still preconditions contemporary design thinking: Even in otherwise progressive and behavior-oriented design approaches materiality is still conceived as a passive property of shape and materialization understood as subordinate to the creation of form. Based on an understanding of form, material, structure, fabrication and assembly not as separate elements or processes, but rather as complex interrelations, our research focuses on a different approach to