Programmable Matter

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The design of programmable matter seeks to achieve performative articulation through the vicissitudes of increasingly minute and multi-hierarchical scales of material formation. Often, this design pursuit triggers a discussion and examination of natural systems, implicit throughout the work in this chapter and explicit in the work of Körner's "Bioinspired Kinetic Curved-Line Folding" and Huang's "Durotaxis Chair." To address the conceptual nature of the research documented here, though, it is necessary to define the relationship between natural and artificial (architectural) systems. This is best captured by George Jeronimidis, an expert in biomimetics and composite structures, who provides a general understanding of biological formation that can be appropriated to programmable matter: "morphogenesis of biological organisms— the animation of geometry and material that produce form."[1]

Yet, to discuss this comparison also demands the discussion of how concepts of morphogenesis are applied to the formation of architectural systems. Jeronimidis points out the need for developing a *technological transformation*. Instead of enacting a replication or representation of biological formation, often referred to as biomimicry, computational design becomes a manifold process of investigating the specifics of a natural system, transforming those logics into codified methods, and enacting such methods within other constraining and contextual systems.

Referred to more appropriately as *biomimetics*, it is the integration of the specific contextual parameters for material processing and performative parameters that defines the distinction between computationally generative processes and morphogenesis. Even though both natural and artificial systems are often referred to as bottom-up processes, certain material parameters and methods of formation will impose top-down constraints. Biological structures are formed, extraordinarily, from only four basic polymer fibers,[2] while in manufactured material systems, a constrained *morphospace* based on material and manufacturing parameters always exists.[3] The work in this section exemplifies various approaches for how to define and implement this distinction between natural and artificial systems, and the means by which emergent and top-down conditions are negotiated.

Pineda and Ramirez-Figueroa each address the transformation of biological systems to design logics. Both Pineda's crystallographic material symmetry and Ramirez-Figueroa's exploration of bacterial spores unfurl natural ordering systems as design generators. Schleicher and Nicholas both discuss the opportunities afforded by higher-order design systems. Schleicher hybridizes form finding and form conversion to explore bending-active behavior as a meso-scale tiling condition. The interdependencies of multi-scale material operations are explored through Nicholas's incremental sheet forming.

The research by Sharmin, Wang, and Ramsgaard Thomsen confront material design, shifting from the manipulation of homogenous materials to the explicit formation of material differentiation through textile design. Yu, Huang, and Retsin do so through means of 3D printing, while Wit explores the negotiation of bespoke shape generation and fabrication through robotic winding of carbon fiber. Comparatively, these various avenues of research test the extensiveness by which differentiated performance is designed and materialized in morphologically based systems that are completely seamless in nature.

1. George Jeronimidis, "Biodynamics," *Architectural Design* 74, no. 3 (2004): 90–95.
2. Jeronmidis cites the four polymer fibers as cellulose in plants, collagen in animals, chitin in insects and crustaceans, and silks in spiders' webs.
3. A *morphospace* is a multi-axial graph which houses the descriptions of forms both real and possible. Cited from George R. McGhee Jr., *Theoretical Morphology: The Concept and its Applications* (New York: Columbia University Press, 1999).

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