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Emerging Insights into Directed Assembly: Taking Examples from Nature to Design Synthetic Processes

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There is considerable interest in controlling the assembly of polymeric material in order to create highly ordered materials for applications. Such materials are often trapped in metastable, non-equilibrium states, and the processes through which they assemble become an important aspect of the materials design strategy. An example is provided by di-block copolymer directed self-assembly, where a decade of work has shown that, through careful choice of process variables, it is possible to create ordered structures whose degree of perfection meets the constraints of commercial semiconductor manufacturing. As impactful as that work has been, it has focused on relatively simple materials neutral polymers, consisting of two or at most three blocks. Furthermore, the samples that have been produced have been limited to relatively thin films, and the assembly has been carried out on ideal, two-dimensional substrates. The question that arises now is whether one can translate those achievements to polymeric materials having a richer sequence, to monomers that include charges, to three-dimensional substrates, or to active systems that are in a permanent non-equilibrium state. Building on discoveries from the biophysics literature, this presentation will review recent work from our group and others that explains how nature has evolved to direct the assembly of nucleic acids into intricate, fully three-dimensional macroscopic functional materials that are not only active, but also responsive to external cues. We will discuss how principles from polymer physics serve to explain those assemblies, and how one might design a new generation of synthetic systems that incorporate some of those principles.