assembly on the left side with the assembly on the right side. Complete, correctly structured assemblies are derived by recursively applying the replacement rules *R* to the initial thing *S*. The language specified by the grammar consists of all the assemblies of terminal things that can be derived in this fashion.

Formal grammars commonly apply to vocabularies of words and tell you how to put together complete and correct sentences, but they are not limited to this. They can apply to many different sorts of things and tell you how to put together useful assemblies of them.

In the case of a grammar for a programming language, the things to be put together are recognizable symbols, the replacement rules have one-dimensional strings of symbols on their left and right sides, and these rules derive complete and correct expressions in that language. In the case of a two-dimensional shape grammar, the things to be put together are two-dimensional shapes, the replacement rules have two-dimensional assemblies of shapes on their left and right sides, and they derive complete and correct graphic designs. In the case of three-dimensional architectural grammars, the nonterminal things to be put together are construction lines and the like, the terminal things to be put together within skeletons of nonterminals are actual architectural components, and the replacement rules derive complete and correct compositions of these components—in other words, designs in the architectural language that the grammar specifies.

Decades ago, for example, George Stiny and I published a formal grammar, in this format, for the famously beautiful villas of the great Italian Renaissance architect Andrea Palladio.* It derives all of the known villa designs by Palladio, together with large numbers of convincing fake Palladian villas. (Or, you might say, it derives all the villas that Palladio might have designed if he had lived longer and had more clients.) Furthermore, it provides a cogent explanation of the underlying principles of Palladio's villa architecture. Since then, numerous architectural grammars have been written for other bodies of design work.

One of the most important functions of an architectural grammar is to capture the principles or modularity and hierarchical organization that characterize works in some particular architectural style. In the precisely defined and widely used language of classical architecture, for example, a column has a base, a shaft, and a capital. The capital decomposes further into a hierarchy of components—different for Doric, Ionic, and Corinthian—and so on. Moving up the hierarchy of subassemblies, regularly spaced columns form colonnades. Then columns, entablatures, and pediments form porticos. Eventually, all the components and subassemblies fit nicely together to constitute complete, grammatical, classical compositions. These compositions can, like sentences, be parsed into named parts.

From a geometric or CAD system perspective, the components and subassemblies of a building are discrete shapes that can be transformed and assembled to produce larger spatial compositions. From a supply chain and construction perspective, they are material elements

* George Stiny and William J. Mitchell, "The Palladian Grammar," *Environment and Planning B*, vol. 5, no. 1, 5–18 (1978).