The goal of molecular electronics is the construction of electronic circuit elements (such as transistors and diodes) from individual molecules (1, 2). The molecules of interest have dimensions on the order of a few nanometers, whereas with conventional photolithography, the smallest structures that can be prepared are on the order of 100 nm (3). Therefore, molecular electronics potentially allows a greater number of circuit elements to be packed on a chip than is possible with conventional methods (4). Mainstream electronics companies such as Hewlett-Packard, Motorola, and IBM are pursuing research and development projects in molecular electronics (5).

However, the development of this technology requires electrical contact to the molecule to be made (1, 6). To study the electronic properties of a macroscopic circuit element, such as a resistor, one simply connects electrical leads to each end of the device. How can one connect electrical leads to each end of a molecule? On page 113 of this issue, Qin et al. describe a potentially versatile method, on-wire lithography, for accomplishing this task (7).

Currently, two general approaches are used to make electrical contacts to individual molecules (1). In the first approach, one end of the molecule is connected to a conductive surface, and the ultrathin tip of a scanning-probe microscope is used to make contact to another part of the molecule. However, it can be difficult to find a single molecule on a surface and to know how much force to apply to make good electrical contact (6).

The second approach entails fabrication of a nanometer-scale gap between two electrodes, followed by insertion of the molecule into the gap (1). In one such method, a gold nanowire is prepared that is thick at its ends but thin in the middle (8). When an electrical current passes through this wire, the thin part of the wire breaks to create the gap. In an alternative strategy, a thin metallic bridge is created across a pit in a silicon wafer (9). The wafer is then strained in order to break the bridge at the thinnest point along its length. Such methods typically require experimental finesse and sophisticated modern microfabrication facilities, and often yield only a small number of functional devices (8).

What would be the ideal device for fundamental studies in molecular electronics? Ideally, the device would be micrometers in length, such that it could be easily manipulated and positioned. Somewhere along its length, this micrometer-scale structure would have a reproducible, nanometer-scale gap. Finally, it should be possible to prepare the device by a simple and versatile method that allows mass production and provides convenient and reproducible control over the size of the gap. The ability to have different metals on either side of the gap would also be useful (10).

On-wire lithography yields devices that have the potential to satisfy all these criteria (7). The requisite micrometer-scale structure is a microwire (360 nm in diameter and 5 μm in length) prepared by template synthesis (11). In this method, cylindrical pores in a membrane are used as templates to prepare wires and tubes that typically have micrometer-scale lengths and nanometer-scale diameters. Methods such as electroplating or chemical polymerization are used to deposit the wires or tubes in the pores. Because the membrane pore densities are high (see the figure), it is easy to make large numbers of these structures. In addition, the pores have uniform diameters, resulting in correspondingly uniform tubes and wires, and the pore diameter can be varied at will. After preparation, the wires or tubes can be liberated by dissolving the template membrane, and manipulated by simple solution-based processing methods.

In on-wire lithography, a segmented microwire—in the simplest case, a long gold segment connected to a very short silver segment connected to another long gold segment—is electroplated into the pores of a commercially available alumina template. Template-based electroplating of such segmented wires is well established (12, 13), and electronic measurements on segmented nanowires have been reported (14). The gap is prepared by dissolving the short silver segment. Electroplating provides a reproducible and...
Food Web Ecology: Playing Jenga and Beyond

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Naturalists have long noted that the distribution, abundance, and behavior of organisms are influenced by interactions with other species (1). Motivated in part by Paine’s (2) work in the rocky intertidal zone and May’s (3) theoretical work on the relationship between the complexity and the stability of ecosystems, the study of food webs gained momentum in the late 1970s and early 1980s (4). These studies precipitated a convergence of different approaches—mathematical treatments, descriptive work, manipulative field studies, and a formal treatment of energy flow and matter. This in turn allowed mapping of the interrelationships among the structure of an ecological community, its stability, and the processes occurring within the ecosystem—that is, the construction of a food web (5).

Over the past decade, new issues arising in ecology, such as environmental change, spatial ecology, and the functional implications of biodiversity, require a different view of ecosystems and ecological research (6). The food web approach, with its focus on static structure and reliance on stability or persistence of species, seemed ill-equipped for analyzing these more dynamic topics. Indeed, the often-used metaphor for the relationship among species, community structure, and stability was that of a stone arch with the loading forces among stones (species) representing interactions among species, and the “keystone” representing the species that had the dominant role in regulating structure and stability of the community. But many ecologists now view such a static representation of biological communities as inappropriate. Moreover, food web descriptions have been criticized for incompleteness because they do not fully account for all the species and links that are present, and because they generally ignore spatial and temporal variability. For these reasons, food web approaches have rarely been applied to current environmental issues.

The metaphor of the static arch might better be replaced with the metaphor of the structures built during a variation of the game Jenga (see the first figure, caption). Simple rules of balance and energetics govern the stability of both arch and Jenga structures, but unlike an arch, a Jenga structure is constantly changing, with additions and deletions of stones, and its stability at any moment depends on the importance of a given ingoing or outgoing stone’s contribution to the structure. By realizing that dynamics are key to understanding complex structures, we can see stable food webs not as static entities, but as open and flexible Jenga-like systems that can change in species attributes, composition, and dynamics. Recent food web studies have incorporated data on spatial and temporal dynamics. Here, we highlight a few examples of such studies and discuss their implications for environmental management.

Over time, food webs change in species composition and in population life history parameters and abundances, and individual organisms within the web change in growth, size, and behavior. Dynamic relationships among different levels of the biological hierarchy govern food web structure and stability. Field observations and theoretical models show that environmental heterogeneity creates subsystems...