Mathematicians describe tendril perversion

The twisting tendrils of climbing plants have intrigued biologists for well over a century. A tendril can coil first in one direction and then in the opposite direction. This phenomenon, called perversion, also shows up in kinky telephone cords.

Now, mathematicians have shown that such reversals of direction result from the curviness inherent in tendrils and cords.

By solving mathematical equations that describe the idealized behavior of thin, flexible rods such as telephone cables or licorice sticks, Alain Goriely of the Université Libre of Brussels and Michael Tabor of the University of Arizona in Tucson show that putting such a rod under tension can spontaneously generate left-handed and right-handed twisting behavior.

"We are modeling the vine tendril as a thin elastic rod, and our results suggest that's not a bad physical representation," says Tabor. The findings appear in the Feb. 16 Physical Review Letters.

"I am repeatedly amazed at the range of applications of the theory of the deformation of elastic rods, from DNA to climbing plants," says Ellis H. Dill of Rutgers University in Piscataway, N.J. "They've shown that this interesting phenomenon, climbing plants, is explainable by classical physics."

The rods behave this way "because of the elastic nature of the substance, independent of any [specific] molecular structure," he adds.

The key to the reversal of twist, Tabor says, is a property called intrinsic curvature. "If you take your phone cord and stretch it out, it's straight," he says. "If you let it go, it has loops. So you would say it naturally wants to have loops."

Goriely and Tabor figured out the importance of intrinsic curvature by finding solutions to Kirchoff's theory of thin elastic rods, a 100-year-old set of equations. Solving the Kirchoff equations was very difficult, however. To do so, the two mathematicians developed some new analytical techniques and used computer algebra (SN: 3/22/97, p. 176).

The results show how to build what Tabor calls a twistless spring—a spring that starts by coiling one way and then reverses, and thus has a net twist of zero. Both vine tendrils and telephone cords form such springs.

"Here's the funny thing," Tabor says. "The vine is locked on two ends. It has no twist in it, yet it would really like to be like a spring, to absorb motion. . . . It winds up one way, and then it changes direction and winds the other way. The right-handed twist and the left-handed twist cancel."

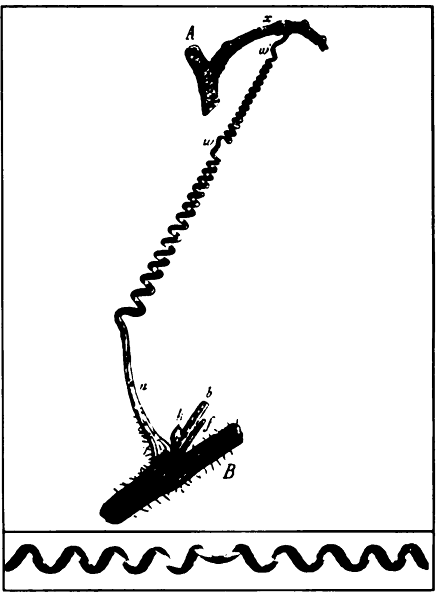
The two different directions of twist represent two different solutions to the Kirchoff equations. Each solution describes a different state, and these states alternate back and forth.

Cycling among different states has been predicted mathematically for a wide range of systems that have suitable symmetry. For example, animals can, in principle, switch between right-footed and left-footed gaits. Such cycling has been observed only rarely in nature.

"In systems with symmetry, it's one of the things you expect to have happen," says Martin Golubitsky of the University of Houston in Texas. "I have been sitting around with colleagues for the past 2 years muttering about why we don't see these cycles, because mathematically we know they're there.

"I am happy to see it come about in this really pretty physical manifestation," he adds. "We learn something about the mathematics by seeing how it is realized in the physical system." —*M.N. Jensen*

Goriely, Tabor/ Physical Review Letters



Tendrils of Bryonia dioica *(top), a plant in the squash family, exhibit perversion in this 1875 drawing from J. Sachs'* Text-book of Botany. *The bottom half of the tendril coils one way, while the top half coils in the opposite direction. Close-up of a telephone cord (bottom) shows the junction of the right-handed and left-handed coils.*

Polymer blend takes on printed pattern

Computer chips can be fabricated so easily now, they practically manufacture themselves. In a new study, researchers show they're a step closer to making that a literal statement.

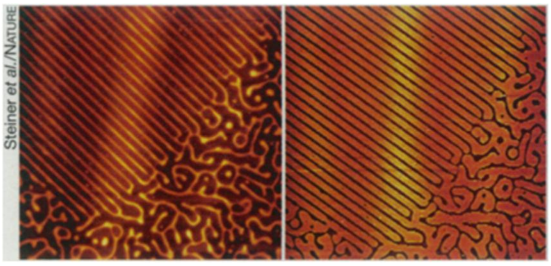
A group at Konstanz University in Germany has developed a quick and simple way to deposit two polymers in an intricate pattern onto a gold wafer. In this technique, described in the Feb. 26 Nature, the two polymers arrange themselves on the gold's surface.

The researchers first stamp a pattern onto the wafer using microcontact printing, a technique developed by George Whitesides of Harvard University and his colleagues. The method works "like a rubber office stamp," imprinting a patterned layer of organic ink just one molecule thick onto the gold, says study coauthor Ullrich Steiner.

Steiner and his coworkers then place onto the stamped gold a blend of two polymers—polystyrene and polyvinylpyridine—in a small amount of solvent. The polymers don't mix readily, and they separate as the solvent evaporates. The polyvinylpyridine sticks preferentially to the bare gold, forcing the polystyrene to collect on top of the stamped parts.

The resulting polymer films could serve as masks for lithography—a chip-manufacturing process that requires some parts of a chip to be protected while other portions are etched away. Microcontact printing alone can't produce useful lithographic masks because the ink films are too thin, Steiner says. He believes that the combination of microcontact printing and polymer patterning—both of which are cheap, simple, and fast—will provide an alternative to standard lithography methods.

Steiner et al./Nature



A pattern stamped onto part of a gold wafer causes a two-polymer mixture to separate into orderly lines. Where no underlying pattern exists, the polymers separate randomly (left). Dissolving one polymer leaves the other as a dark pattern on the gold surface (right).

He suspects, however, that his technique won't be capable of making chips with very small features (SN: 11/8/97, p. 302). So far, it seems that the polymer lines must be 1 to 2 micrometers wide. "If you make narrower lines, is the polymer pattern able to follow that?" asks Alamgir Karim of the National Institute of Standards and Technology in Gaithersburg, Md., who is studying the physics of how polymer blends separate.

The technique may work very well for producing low-cost, all-plastic devices—"throwaway electronics," Steiner says. To assess that potential, he and his group are currently testing the technique with blends of conducting and light-emitting polymers. —*C. Wu*