this unusual behavior to construct "spintronic" devices that switch on or off in response to electrons' spin, rather than merely to their charge, as electronic de-

vives do Similarly, at the small size of a nanotube, the flow of electrons can be controlled with almost perfect precision. Scientists have recently demonstrated in nanotubes a phenomenon called Coulomb blockade, in which electrons strongly repulse attempts to insert more than one electron at a time onto a nanotube. This phenomenon may make it easier to build single-electron transistors, the ultimate in sensitive electronics. The same measurements, however, also highlight unanswered questions in physics today. When confined to such skinny, one-dimensional wires, electrons behave so strangely that they hardly seem like

electrons anymore

Thus, in time, nanotubes may yield not only smaller and better versions of existing devices but also completely novel ones that wholly depend on quantum effects. Of course, we will have to learn much more about these properties of nanotubes before we can rely on them. Some problems are already evident. We know that all molecular devices, nanotubes included, are highly susceptible to the noise caused by electrical, thermal and chemical fluctuations. Our experiments have also shown that contaminants (oxygen, for example) attaching to a nanotube can affect its electrical properties. That may be useful for creating exquisitely sensitive chemical detectors, but it is an obstacle to making single-molecule circuits. It is a major challenge to control contamination when single molecules can make

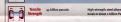
a difference.

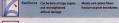
Nevertheles, with so many avenues of development under way, it seems clear that it is no longer a question of whether nanotubes will become useful components of the electronic machines of the future but merely a question of how and when.

Properties of Carbon Nanotubes

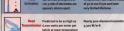
Going to Extremes PROPERTY SINGLE-WALLED BY COMPARISON NANOTUBES







Current Estimated at a billion amps Copper wires burn out at about Carryling per square centimeter smillion A/cm*





Cost S1,000 per gram from Gold was selling for about BuckyUSA in Houston S10/g in October

The Authors

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Further Information

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