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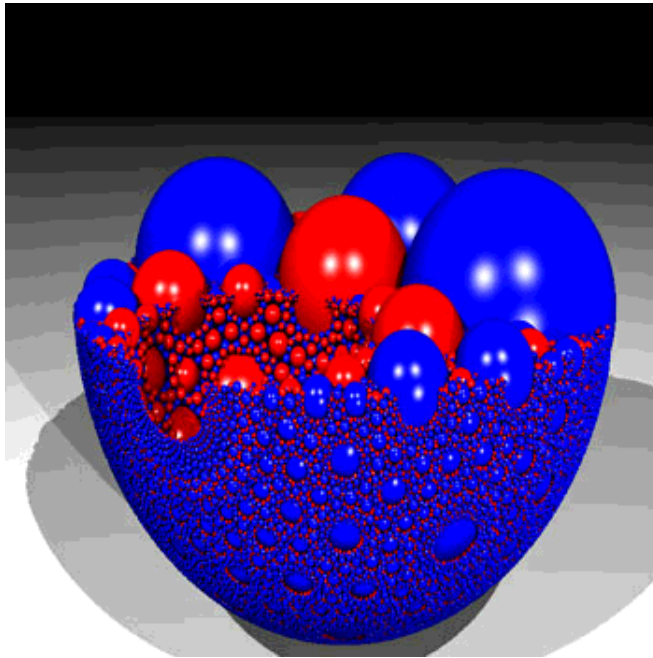
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## One Good Turn Deserves Another

Here's a thought that may make your head spin: It's possible to pack spheres together so that they all roll smoothly and no two rub against each other. The geometrical oddity works as a universal ball bearing--at least in theory.



**Let's roll.** Turn any of the spheres in this universal bearing, and the others will rotate freely, too.

CREDIT: HANS HERRMANN

"space-filling bearing," the researchers envisioned a large sphere with six smaller spheres arranged inside as if they were on the corners of a regular octahedron. The six spheres touched the bigger sphere but not each other. The researchers then filled the empty spaces with smaller copies of the original spheres using a geometrical technique called inversion, which works a bit like reflection in a mirror.

Repeating the process produced an infinite number of ever-smaller spheres, much as reflections between two nearly parallel mirrors generate infinitely many images. If the radius of the first six corner spheres was just right, then all the inversions worked together to produce a pattern with no overlaps or inconsistencies, as the group reports in the 30 January issue of *Physical Review Letters*. Moreover, the

Generally, tightly packed objects can't roll against one another without causing friction somewhere. Imagine pennies lying flat on a table and pressed edge to edge. To avoid slipping and friction, neighboring pennies must turn at the same rate in opposite directions. However, any three pennies forming a little triangle cannot all rotate in opposite directions, so two of them must slide against each other. Such conflicts can be avoided, however, if instead of pennies, the plane is covered with disks of an infinite variety of sizes in certain patterns, as theoretical physicist Hans Herrmann of the University of Stuttgart in Germany and colleagues demonstrated in the 1980s.

Now, Herrmann, Reza Mahmoodi Baram, and colleagues have found a three-dimensional arrangement of spheres that performs a much tougher trick: If one of them turns any which way, the rest will always rotate smoothly, even as they spin around different axes. To construct the

researchers showed that this particular arrangement would never jam, no matter how any one of the spheres turned.

"It's quite a surprise that this is possible," says Ronald Peikert, a computer scientist at the Swiss Federal Institute of Technology in Zurich. "At first it appears impossible in three dimensions because there are too many points of contact, too many places for things to go wrong." Peikert notes that the same inversion technique could be used to create bearings that fill the gap between two flat surfaces, which might make the abstract idea a little more relevant to real-world situations, such as, perhaps, the movement of tectonic plates at a rock-filled geological fault.

--ADRIAN CHO

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