# Symmetry

Photo: Fermilab

People say that nothing is perfect. I beg to differ. The notion of symmetry is both perfect and nothing—a combination that gives it unreasonable effectiveness in physics.

Summing up 50 years of progress in fundamental physics, David Gross recently concluded: "The secret of nature is symmetry." (As for nothing, see below.)

Everyone gets seduced by symmetry in one form or another, whether it's the symmetry inherent in snowflakes or snail shells, kaleidoscopes or decorative tiles. But in physics, symmetry is more than just a pretty face. As Emmy Noether showed, there are symmetries behind every fundamental law.

This makes sense, because a symmetry describes what doesn't vary even as things change—the solid truth beneath the superficial difference. Einstein, who first made symmetry central to physics, exposed a wealth of these pseudo-differences—including those between energy and matter, space and time. (As Einstein so often pointed out, his theories aren't so much about things that are relative as things which are invariant.)

The late Frank Oppenheimer even cited the Golden Rule as an example of symmetry: If you do unto others as you'd like others to do unto you, and the doer and doee change places, it shouldn't make a difference.

Of course, a snowflake is symmetrical in that you can rotate it 60 degrees without making a discernible difference. But if you rotate it 5 degrees, the symmetry is shattered. To a physicist, the puddle the snowflake melts into is much more symmetrical: snowflakes can be individuals, but drops of water all look alike.

Turning snowflakes into drops of water is essentially what the Large Hadron Collider (LHC) at CERN in Geneva will be trying to do—melting matter to reveal underlying symmetries.

If supersymmetric particles turn up at high energies, for example, it will mean that bosons and fermions—which seem like apples and oranges—have fallen off the same family tree. Each quark will have its squark; each photon its photino—a perfectly symmetrical team. The symmetry lost when the universe cooled will be, for the moment, restored.

Even more beautiful symmetries appear at even higher energies. Heat up the universe to big bang temperatures, and the wildly diverse family of forces turns into one. String theory, with its tangled 10-dimensional topologies, is more symmetrical still; with so much room to move about, there are ample ways for the same thing (the string) to appear in radically different forms (quarks, gravity).

Alas, the universe we know isn't very symmetrical. Somewhere along the line, it lost its symmetries—if not its innocence—like water freezing into ice. Today, the whole thing is embarrassingly unbalanced: Time goes only one way; gravity isn't a bit like the weak force; there's matter, matter everywhere, but not a drop of antimatter in sight.

"Beauty in; garbage out," Gross puts it. (Though we shouldn't complain, since the garbage is us.) What happened to all that lovely symmetry?

Part of the blame almost certainly goes to the Higgs field—that unseen influence that makes even our vacuum unsymmetrical, giving particles different masses. With luck, the LHC will knock a piece of it into a detector. On a different front, those busy *B* physicists are searching for hints of the mechanisms that make matter different from antimatter.

Of course, having a mechanism only explains how—not why. Why does water freeze into crystals? Since ice is the lower energy state, it's as natural as flowing downhill. Perhaps the universe is the same—a cosmic drop of water that froze into an asymmetrical but still rather appealing snowflake.

In fact, our universe could once have been so symmetrical that it amounted to nothing at all. "Nothing" is as perfect a symmetry as you can imagine, since there's nothing you can do to it that makes a difference. This nothing would have been unstable, however—like a pencil balanced perfectly (which is to say, symmetrically) on its tip. And that means—as Frank Wilczek has put it—the answer to the question "Why is there something rather than nothing?" would simply be that "nothing" is unstable.

So even if nothing is perfect, all the rest—I'm happy to say—is not. We owe everything to our imperfections.

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