CHEMISTRY

Does Life's Handedness Come From Within?

New results suggest that the weak nuclear force may be the source of the left-right bias of amino acids and other biomolecules

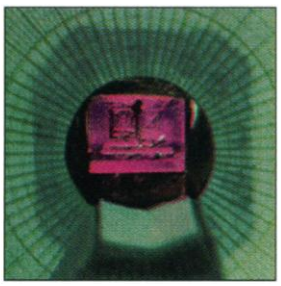
RICHMOND, VIRGINIA—Even for molecules, life isn't evenhanded. Molecules that are essential to life, such as amino acids and sugars, can come in two mirror-image versions, like a left and right hand. Yet biology views these near twins as Cain and Abel, embracing one while shunning the other. Left-handed amino acids are the building blocks of all proteins and thus serve as the cornerstone of life. Their right-handed brethren, meanwhile, just don't fit into the scheme of things.

Researchers have been struggling for decades to explain how life acquired this bias, without success. But at the International Symposium on Cluster and Nanostructure Interfaces meeting here 2 weeks ago, a team of researchers from the United States and New Zealand reported preliminary results indicating that its source might lie in the heart of molecules themselves—in the so-called weak force that operates within the nuclei of atoms. If the new work holds up, "it will have a tremendous impact on science," says Peru Jena, a physicist at Virginia Commonwealth University in Richmond.

Over recent decades, researchers have ranged far and wide looking for a phenomenon—astronomical, electromagnetic, or nuclear—that could have imprinted this handedness, or chirality, on nature. "It's really an open problem that people have looked at since the 1950s," says Joshua Jortner, a chemist at Tel Aviv University in Israel. Perhaps the most popular recent contender has been rays of circularly polarized light from supernovae, for example. These light waves fly in a corkscrew fashion, spinning either clockwise or counterclockwise as they go. And researchers have shown that such light can skew chemical reactions toward producing one particular chiral molecule at the expense of its twin. But supernovae and other astronomical sources would generate both the left and right spinning forms equally and so would be unlikely to produce an imbalance in organic molecules.

Another candidate, the weak nuclear force, has seemed to be a long shot. The weak force governs the radioactive decay of a neutron in the nucleus of an atom into a proton and an electron, and the force has a handedness: The decay always produces an electron with a left-handed spin. Because the weak nuclear force is the only chiral fundamental force in nature, it was tempting to link it to the handedness of biomolecules. "But it's like a phantom," says Jortner. "There has really been no evidence, because the effect is so weak."

Chemical physicist Robert Compton and organic chemist Richard Pagni of the University of Tennessee, Knoxville, along with other researchers at UT, Oak Ridge National Laboratory, Berea College in Kentucky, and the University of Canterbury in Christchurch, New Zealand, set about trying to find some evidence. They turned to a type of salt called sodium chlorate, which forms chiral crystals, normally yielding left- and right-handed ones in equal numbers. These crystals contain arrangements of atoms that spiral either clockwise or counterclockwise through the crystals. Environmental factors can influence the direction of those spirals, however: If a solution of sodium chlorate is stirred, the crystals it produces will all be of one chiral type.



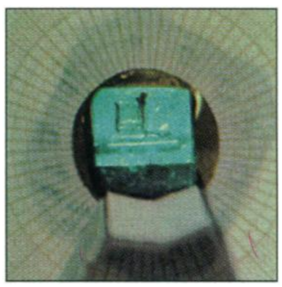
Compton and his colleagues wondered if lefty electrons produced by radioactive decay could produce the same effect. They weren't disappointed. When the researchers bombarded a solution of sodium chlorate with left-spinning electrons—from a source of radioactive strontium—they wound up with an excess of right-handed crystals. And when they hit the solution with positrons—positively charged counterparts to electrons, which have the opposite spin—an excess of left-handed crystals formed.

"It's a very, very interesting experiment," says Roger Hegstrom, a chemist at Wake Forest University in Winston-Salem, North Carolina. But puzzling as well: Hegstrom's calculations—which only look at the effect of the lefty electrons—show that beta decay electrons should alter the crystallization of only about 1 out of 1 million experiments. Yet in Compton's experiment, "every single batch went in the same direction. That's quite significant" and can't be explained by current theory, Hegstrom says. But Compton points out that as the electrons hit the salt solution, they give off left-handed circularly polarized light, which can increase the chiral selectivity.

Still, Compton is quick to note other questions as well: "Whether this [process] is involved in the generation of chirality in amino acids is pure speculation." However, he notes, electrons produced by radioactive decay are ubiquitous in the natural world, whereas the positrons that would cancel out their handedness are not. And that difference could have set the ball of prebiotic chemistry rolling toward a handed bias.

The group also went on to show another way the weak nuclear force might have tipped chemistry toward a particular handedness. In the sometimes quizzical world of quantum mechanics, electrons not only orbit the nuclei of atoms but sometimes actually pass right through the center in a process called tunneling. As they tunnel through the nuclei, these electrons encounter the weak nuclear force, which can alter their energy content slightly. And because chiral pairs start with slightly different electronic structures, their electrons tunnel with different spins. In theory, the nuclear encounters should alter electrons' overall energy, by as much as 1 part in 1 trillion.

This subtle difference is easiest to see in heavy atoms, so the researchers synthesized a pair of propeller-shaped chiral molecules with heavy iron atoms at their core. They then turned to a sensitive detection technique called Mössbauer spectroscopy, which fires a steady stream of photons—all of which carry the same amount of energy—at target molecules. If those incoming photons have just the right amount of energy, they are absorbed by the propeller's iron atom, which then kicks out a less energetic photon that is detected. The researchers found that the opposite-shaped



Bias revealed. Polarized light produces different colors when scattered by chiral crystals of sodium chlorate.

CREDIT: FROM A. HOLDEN AND P. SINGER, *CRYSTALS AND CRYSTAL GROWING* (ANCHOR BOOKS DOUBLEDAY & COMPANY INC., GARDEN CITY, NEW YORK, 1960) propellers absorbed photons of slightly different energies, suggesting that the weak nuclear force in their cores had altered the iron's energy levels.

Compton says his team's experimental results are in line with theory. According to calculations, "the presence of the chiral electroweak force produces a shift in the energy levels of chiral molecules very close to this number that we're getting," he says. Still, he adds, the work is preliminary, and his team has yet to do essential experiments to rule out possible artifacts.

Could such an energy difference have an impact on the origin of biomolecules? Possibly, says Compton. Other calculations show that the same effect would give left-handed amino acids a slightly lower overall energy than their right-handed brethren, which would favor their chemical production. But because the difference is so small, and thus the preference for the left-handed amino acids so weak, Compton believes that at this stage it's more likely that the spinning electrons given off by radioactive decay are responsible for biology's choice of handedness. If so, researchers may have finally found the source of nature's chiral bias: not light from the depths of space, but subtle forces in the very heart of matter. —ROBERT F. SERVICE

ECONOMIC DEVELOPMENT

A Shifting Equation Links Modern Farming and Forests

New studies of deforestation around the world suggest that high-tech agriculture can be either culprit or savior

New research is raising questions about sustainable growth, a notion dear to both environmentalists and development specialists. Both camps have embraced the assumption that improving agricultural practices in the developing world should relieve pressure to cut down nearby forests. But when looking at more than two dozen cases of deforestation, economists David Kaimowitz and Arild Angelsen of the Center for International Forestry Research (CIFOR) in Bogor, Indonesia, noticed that the real-world equation was a bit more muddled: In Brazil, for example, a new strain of soybeans planted by farmers wound up accelerating the destruction of the tropical forest, while in the Philippines an irrigation project protected a tropical forest elsewhere on the same island.

In a book about their findings, due out next year, the duo also looks beyond these case studies to determine why agricultural development can have such differing impacts. Among the key factors they identify are how the new technologies affect the labor market and migration, whether the crops are sold locally or globally, and how profitable farming is at the boundary between cultivated land and forest. Senior environmental adviser John Spears of the World Bank calls the work "extraordinarily valuable" and says the bank is developing forest protection policies that take it into account.

Before the mid-1980s, says economist Robert Faris of the Harvard Institute for International Development, conservationists tended to be antigrowth. More recent thinking, crystallized in a 1992 world development report from the World Bank, suggested that economic development and environmental conservation could be complementary: As farmers earned more from their existing plots—thanks to better irrigation, new crops, an investment in tools, and easier access to markets—they would be less motivated to clear marginal land.

But when Kaimowitz and Angelsen examined studies presented at a CIFOR-sponsored conference last March in Costa Rica, they found that growth and conservation are only sometimes compatible. "If you think from the outset that the objectives [of development and conservation] are complementary, then you'll likely get it wrong," says Angelsen.

One important variable is how much labor an agricultural system requires, says Angelsen, now at the Agriculture University of Norway in Aas. Brazilian soybean cultivation is highly mechanized, says Kaimowitz, and large plantations of a new strain that thrives in the tropics displaced small southern Brazilian farmers who had cultivated grains, vegetables, and coffee. These farmers were forced to the agricultural frontier, where they cleared forest to eke out a living.

In contrast, projects that create employment can relieve deforestation pressure, as a project on the Philippine island of Palawan shows, says economist Gerald Shively of Purdue University in West Lafayette, Indiana. An irrigation project there, he found, drew wage laborers to newly created rice fields in the lowlands and reduced pressure to cultivate forested areas. "You've got to create opportunities elsewhere to pull people away from the forest," says Shively. Or even from farming itself: "As bad as it sounds," says Faris, "sweatshops are friends of the forest" by concentrating laborers in already developed areas. "The question is," he says, "what [forest] do you have left when you get to that point?"

Burning issue. This Indonesian forest has been slashed and burned to make way for an expanding oil palm plantation.

CREDIT: CARMEN GARCIA

Development theorists have also assumed that easier access to markets would make farmers' crops more profitable and thus allow them to farm less land and spare the forest, according to Kaimowitz. "But if you can produce twice as much, it makes just as much sense to produce more on more land," he says. As an example, he points to Nicaragua, where cattle grazing is very land intensive but profitable. Building roads to remote regions allows farmers to sell their cattle easily, with profits going to clearing more land to graze more cattle. New roads into the Amazon Basin and improved ports along the river will likewise spread soybean farming into areas that once were jungle, he predicts.

In place of the simple assumption that has guided many development projects in the past—that poverty is the cause of deforestation—Angelsen says that big plantation projects are more likely to contribute directly to deforestation than are small farmers. The challenges, he says, are to foresee how specific development strategies will impact a region's environment—displacing workers or making forest-clearing profitable, for example—and to identify projects that achieve both economic and ecological objectives.

Ultimately, says Kaimowitz, high-tech farming in the tropics should reduce the overall amount of land dedicated to agriculture, as it already has in the United States and Europe. "But that may or may not be relevant for saving the forest [today]." —LAURA HELMUTH