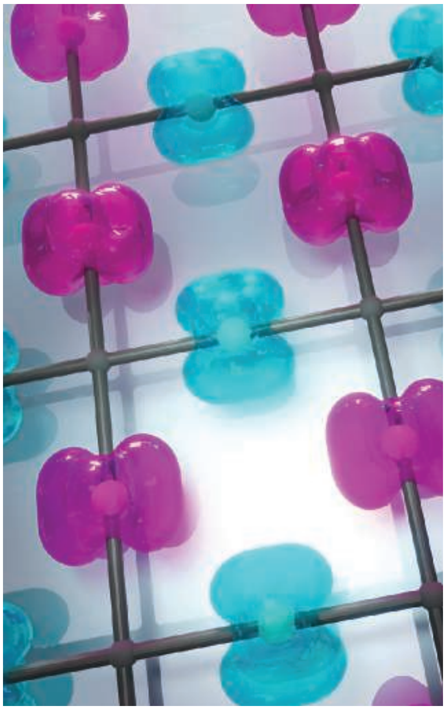

ILLUSTRATION: LIBOR ŠMEJKAL & ANNA BIRK HELLENES

In an altermagnet, neighboring electrons spin in opposite directions (colors) but sit in atomic-scale structures with different orientations (shapes).

A new type of magnetism emerges

For 98 years, physicists knew of two types of permanently magnetic materials. Now, they've found a third. In familiar ferromagnets such as iron, unpaired electrons on neighboring atoms spin in the same direction, magnetizing the material so that, for example, it sticks to a refrigerator. Antiferromagnets such as chromium have zero overall magnetism, but they possess an atomic-scale magnetic pattern, with neighboring electrons spinning in opposite directions. Novel altermagnets—hypothesized 5 years ago—share aspects of both. Neighboring electrons spin in opposite ways, ensuring zero net magnetism, but on a deeper level, the materials resemble ferromagnets, too. This year multiple groups demonstrated that split personality.

Theorists distinguish the two older kinds of magnetism by imagining what happens if time runs backward. They envision a crystalline material's most energetic electrons as occupying a 3D "Fermi surface" in an abstract space whose axes are the components of the electrons' momenta. In an antiferromagnet, electrons spinning, say, "up" have a Fermi surface that happens to be identical to that of those spinning "down." Reversing time flips the spins. But the coinciding Fermi surfaces still look the same, preserving so-called time-reversal symmetry.

In a ferromagnet, up electrons outnumber down electrons and have a bigger Fermi surface that surrounds the smaller one for downs. Reverse time and spins and the Fermi surfaces change places, a "breaking" of time reversal symmetry that had been the hallmark of ferromagnetism.

Altermagnets have equal numbers of up and down electrons, but peculiarities in the structure of the material itself result in more complicated Fermi surfaces for the up and down electrons that break the symmetry, too. Imagine two identical ovals intersecting at 90°. Because the ovals are the same size the material has no net magnetism. But reverse time and spins, and the ovals swap orientations, a detectable difference. Of course, experimental physicists can't reverse time, but this year multiple groups measured the Fermi surfaces and saw the telltale split in materials such as manganese telluride and chromium antimonide. Potentially numerous, altermagnets might make ultrafast magnetic switches in electronics. *—Adrian Cho*

Organelle discovery adds an evolutionary twist

Some bacteria manage the feat, but until this year, no eukaryote—an organism with a complex cell, such as plants and animals—was known to "fix" nitrogen from the atmosphere, turning it into ammonia, which plants can use to make proteins and other essential molecules. That changed with the discovery of "nitroplasts," unique nitrogen-fixing compartments in the cells of marine algae. In addition to demonstrating how much we still don't know about the evolution of cellular complexity, this finding and related work hint at the possibility of future crops endowed with nitroplasts that would enable them to fertilize themselves.

DNA studies showed the newfound organelle arose about 100 million years ago from a partnership between the marine algae and nitrogen-fixing cyanobacteria. Algal cells took up these bacteria, which eventually lost enough genes and biochemical abilities that they depended on the algae to survive, and now reproduce on the algae's timetable. This makes them one of the few known endosymbiotic organelles—those that originated from a once-independent microbe—to become incorporated into another organism's cells. Chloroplasts, which enable plants to convert sunlight to energy, and mitochondria, the internal powerhouses for all eukaryotic cells, share a similar origin story.

Researchers have begun to unravel how the nitroplast precursor made itself at home in cells by studying nitrogen-fixing structures inside diatoms, tiny silica-encased algae. Diatom fossils indicate they began to host nitrogen-fixing cyanobacteria much more recently—about 35 million years ago. The bacteria haven't transferred any of their own genes to their host cells, suggesting they represent an earlier stage of nitroplast evolution and aren't yet incorporated as organelles.

A novel organelle, the nitroplast (circular object, lower right), was discovered in the marine alga *Braarudosphaera bigelowii*.

Harnessing such knowledge to improve agriculture won't be easy. For now, crops derive their fixed nitrogen from fertilizer, or from the symbiotic nitrogen-fixing bacteria that live on the roots of beans and other legumes. Clues to endowing more crops with their own source of nitrogen could come from another discovery this year: a diatom that harbors nitrogen-fixing bacteria distantly related to ones active in the roots of legumes. Learning how this partnership works could point the way to putting nitroplasts into crop plants. *—Elizabeth Pennisi*

RNA-based pesticides enter the field

Insecticides can be a blunt weapon, killing innocent species along with pests. This year, the U.S. Environmental Protection Agency (EPA) approved what could be a solution: an RNA-based pesticide spray tailored to a gene in its intended target. Proponents believe this new, precise approach will be safer than existing chemicals and could work for many pests. The first RNA pesticide product takes aim at the Colorado potato beetle, which has evolved resistance to existing chemicals and causes half a billion dollars in lost crops per year around the world.

Invented by the company GreenLight Biosciences, Calantha interferes with a gene unique to the beetle. When larvae chew on leaves that have been sprayed, the RNA blocks expression of a key protein, and they die within days. This mechanism, known as RNA interference (RNAi), is a natural process that most cells use to regulate gene expression and to defend themselves from viruses.

Unlike current commercial insecticides, ones based on RNA interference target a specific pest.

After the discovery in 2007 that double-stranded RNA can cross the gut lining of insects and efficiently kill them, researchers tried to turn RNAi into a weapon against bark beetles, mosquitoes, and other insects. A genetically modified variety of corn that makes its own RNA to kill corn rootworms came on the market in 2023. GreenLight is now developing another pesticide to kill the varroa mite, a notorious scourge of bee hives.

Researchers now hope to adapt RNAi to kill moths and other so-called lepidopteran insects, which include some of the most damaging crop pests, such as the diamondback moth and the fall armyworm. Unlike beetles, however, lepidopterans have gut enzymes that easily destroy RNA before it can harm them. One potential answer, packaging RNA inside a tiny protective shell, has become a hot research area.

Insects and other pests are notorious for quickly evolving resistance to toxins, and researchers are already wondering how long it will take natural selection to thwart RNA insecticides. Lab tests have revealed the Colorado potato beetle and the corn rootworm can evolve resistance to RNA, if exposed to high enough doses. Like all inventions that try to take on nature, RNA insecticides will have to be used responsibly to keep their edge. *—Erik Stokstad*

PHOTOS: (TOP TO BOTTOM) TYLER COALE; EDWIN REMSBERG/VWPICS VIA AP IMAGES