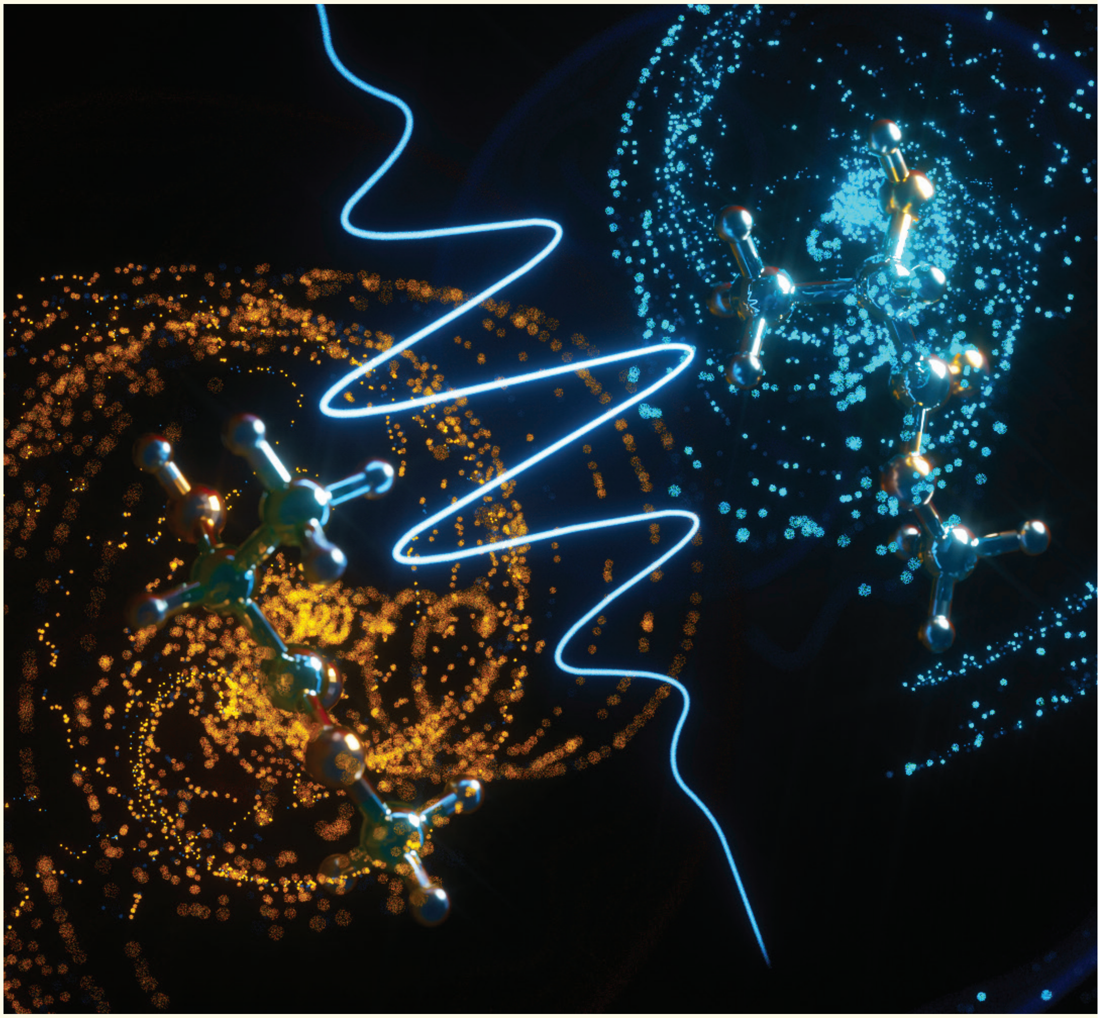
A right-handed molecule is coaxed to behave like a left-handed one

Electrons in a chiral molecule, if excited by ultrafast light pulses, can give the molecule entirely different properties.



AN ELECTRIC CURRENT that surrounds a chiral molecule with a clockwise directionality (blue) can, when pumped with an ultrafast UV pulse, reverse to a counterclockwise orientation (yellow) in less than 10 fs, the time scale at which most chemical reactions occur. (Image from Ella Maru Studio Inc.)

The controlled substance methamphetamine has the same chemical formula as the active ingredient in several over-the-counter nasal decongestants. The only difference between the two chemical compounds is their handedness—the compounds are mirror images of each other.

That's just one example of how handedness matters. In medicine and many other biophysical contexts, right-handed and left-handed versions of a molecule have different reactivities. Now Francesca Calegari, with the German Electron Synchrotron, and colleagues have used ultrafast pump–probe spectroscopy to study how the motion of electrons in chiral molecules affects reactivity. They found that after a molecule is excited with a light pulse that lasts just a few femtoseconds, it can show a response that's consistent with its chiral counterpart despite there being no change to its molecular structure.

To pump a molecule with a pulse of light that lasts just a few femtoseconds or less, you typically need extreme-UV radiation. An XUV laser carries such a high amount of photon energy that the target is ionized before it's measured by the electron probe pulse, perhaps a few hundred femtoseconds later. The pump pulse's ionization alters the molecule's electronic state and prevents the study of electron dynamics in various photochemical processes. The lack of ultrashort, nonionizing radiation has also limited investigations into how electron dynamics may control chirality in molecules. To study electrons in chiral molecules, Calegari and colleagues turned to a new laser technology that Calegari helped develop.

The technology produces UV laser pump pulses that last just 2 fs, and their photon energy is low enough that the molecules aren't ionized. At that time scale, the nuclei of chiral methyl lactate molecules are essentially frozen and only their electrons are photoexcited. After the UV pump pulse, a circularly polarized near-IR probe pulse hits the molecules. Because the probe is a chiral pulse of light—its electric field rotates either clockwise or counterclockwise around the propagation axis—the left-handed and right-handed versions of the molecules interact differently.

The interaction between the circularly polarized pulse and the molecule causes the photoexcited electrons to emit either in a forward or backward direction relative to the light's propagation axis. Calegari and colleagues found that the direction reverses at a time scale of less than 10 fs, which is an indication of the molecule switching its chiral response to light. The next step is to investigate whether specific molecular orientations can be selected for with the technique and used to control various chemical reactions. (V. Wanie et al., *Nature* **630**, 109, 2024.)

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