Genetically engineered protein is a versatile quantum sensor

In noisy biological environments, the fluorescent protein can pinpoint subcellular structures and detect magnetic field changes.

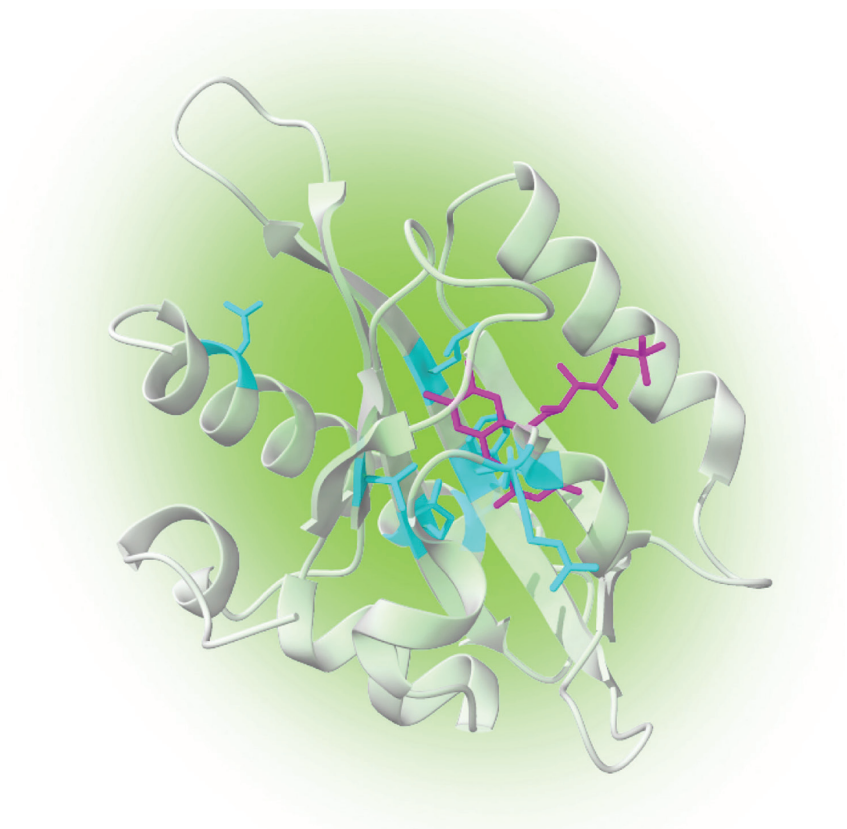
By Alex Lopatka

When researchers study biological processes in cells, it helps if they have nanoscale sensors to take measurements. One approach is to carefully build and embed sensors into cells. (For an example with nitrogen–vacancy centers, see the 2020 *PT* story "Nanodiamonds shine as subcellular thermometers.") Another option is to exploit the biological machinery that's already there. Because of advances in genetic engineering, researchers can assemble protein sensors *in situ* by manipulating the proteins' DNA. Now Gabriel Abrahams and Harrison Steel, both at the University of Oxford, and their colleagues have engineered a fluorescent and magneto-responsive protein that has boosted magnetic-sensing capabilities.[1]

Abrahams and colleagues started with a well-known and biocompatible fluorescent protein and engineered it to have magnetic-sensing properties.[2] Then, using a technique called directed evolution, they mutated the protein, screened the resulting variants for the ones with the highest sensitivities to magnetic field strength, and then repeated the process several more times. (To read more about directed evolution, see the 2018 *PT* story "Chemistry Nobel winners harnessed evolution to teach old proteins new tricks.")

The researchers found a protein, which they named MagLOV 2, that at room temperature in living cells exhibits optically detected magnetic resonance. By shining a laser on the protein, they could excite two electrons, which develop spins that are quantum mechanically linked. The protein's fluorescence signal depends on what spin states the electrons are in. Because the spins are influenced by magnetic fields, a resonant RF field can, on demand, drive transitions between the spin states.

Abrahams and colleagues demonstrated that when the fluorescent MagLOV 2 is exposed to magnetic and RF fields, it can be used to measure the locations of proteins in cell cultures and of other structures embedded in a 3D volume. The protein sensor is less



▲ The AsLOV2 protein, illustrated here, was used as a precursor to develop the MagLOV 2 protein through directed evolution. The parts of the AsLOV2 structure that were mutated to make MagLOV 2 are highlighted in blue and purple. MagLOV 2 is more sensitive to magnetic field effects than AsLOV2 and can be used as a quantum sensor. (Image adapted from ref. 1.)

sensitive to light scattering by biological tissue than other fluorescence-based sensors, so it could outperform various localization techniques, such as fluorescence-modulated tomography.

Abrahams and colleagues also determined that in the presence of other magnetic chemical species, MagLOV 2 exhibits a decreased sensitivity to magnetic field effects. By quantifying the protein's response to those effects, researchers could use the new quantum sensor to identify magnetic-signal-generating molecular species, such as free radicals and metalloproteins, which are critical in physiological processes such as cell signaling, immune responses, and metabolism. PT

References

1. G. Abrahams et al., "Quantum spin resonance in engineered proteins for multimodal sensing," *Nature* **649**, 1172 (2026).
2. R. F. Hayward et al., "Magnetic control of the brightness of fluorescent proteins," https://zenodo.org/records/11406498.

Reduced pandemic emissions contributed to atmospheric methane surge

A drop in nitrogen oxide emissions led to fewer hydroxyl radicals in the atmosphere to oxidize the methane.

By Sarah Wells

During the pandemic shutdowns that began in early 2020, the anthropogenic emissions of certain pollutants, such as nitrogen oxides, dropped—which contributed to improvements in air and water quality. Nonetheless, the concentration of atmospheric methane surged. From January 2021 to January 2022, methane levels increased by 17.7 ppb, according to NOAA data,[1] the largest annual increase in the roughly 40 years that NOAA's Earth system research laboratory has measured methane (see figure 1). By 2023, the annual rate of increase had fallen back to 8.6 ppb. To put that in perspective, the total concentration of atmospheric methane was about 1950 ppb as of last fall, and every 1 ppb increase is equivalent to 2.8 million metric tons of methane entering the atmosphere.

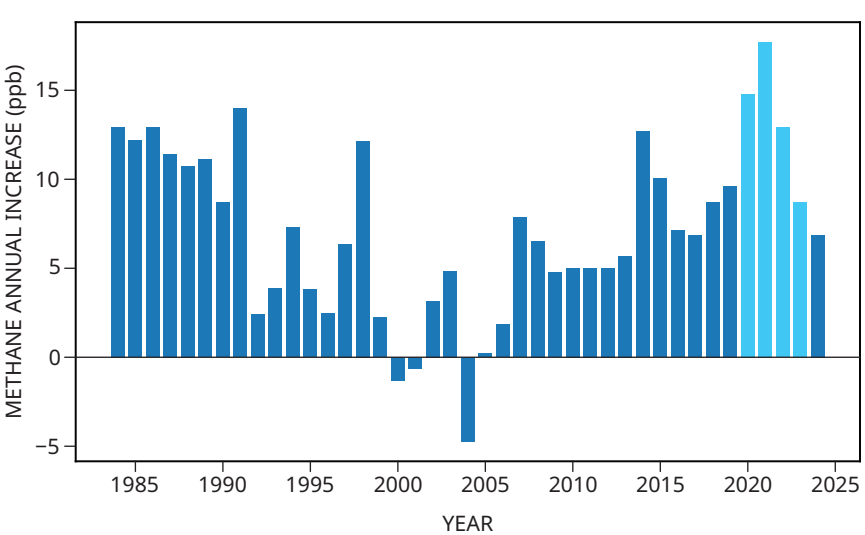


Figure 1. In 2021, the annual rate of increase in atmospheric methane concentration reached its highest level in the nearly 40 years of NOAA measurements. Methane levels change from year to year because of a variety of factors, including changes in anthropogenic and biogenic emissions levels and the capacity of methane sinks like hydroxyl radicals. (Image adapted from NOAA.)