"With immunosuppression, we can get long-term survival," White says. "I can envisage a scenario where, 12 months from now, our data will have achieved the 'comfort factor' where we think we are justified in going to clinical trials in humans." DAF in the transgenic hearts may inhibit complement proteins from attacking endothelial cells, so that platelets never come into contact with subendothelial clotting factors.

Other researchers at the congress praised Imutran's advance, but called White's timetable overoptimistic. "This work potentially makes an important contribution, but it certainly does not indicate to me that we are ready to use these transgenic hearts clinically," says MGH's Sachs. "We still have to worry about delayed rejection and [long-term] T cell immunity." Sachs is also concerned because some of the donor pigs had unexpectedly low levels of an antigen that binds to XNAs. This could have helped avoid hyperacute rejection. White responds that data on antigen levels are "not robust," and the contrast between healthy transgenic hearts and unhealthy control hearts is "amazing."

Many researchers believe that only a combination of donor- and recipient-based therapies, both pharmaceutical and genetic, will eventually make xenotransplantation routine. "This is a big problem, and people are going to have to work together to solve it," says Sachs. "The exciting thing is that every step looks as if it is amenable to being dealt with. I believe it eventually will work."

–Wade Roush

ATMOSPHERIC RESEARCH

Lofty Flashes Come Down to Earth

Walter Lyons had a mystery right in his backyard, which lies at the foot of the Rocky Mountains and commands a view over the Great Plains. So last summer he threw a little garden party, inviting over a few friends and colleagues—16 research groups in all, with their instruments—to help him solve it. The mystery was what could be creating the menagerie of exotic flashes that can be detected from his yard as they light up the atmosphere high above giant thunderstorms on the plains. And last summer's gathering at Lyons's home on Yucca Ridge near Fort Collins, Colorado, along with research efforts from other vantage points, has gone a long way toward providing an answer.

"There's so much data it's almost overwhelming," says Lyons, a meteorologist at Mission Research Corporation's ASTER Division in Fort Collins. Most of the observations are still being digested, but they are already showing how exceptional lightning strokes that drain storm clouds of huge amounts of electrical charge could spark the flashes. By analyzing spectra of the flashes and measurements of their timing, researchers have traced two different mechanisms for setting the upper atmosphere aglow, one driven by a quick pulse of energy from the lightning stroke and the other by a slower change in the atmosphere's electric field.

A year ago, observations from Lyons's yard and elsewhere had shown that the flashes come in forms ranging from carrot-shaped "red sprites" at altitudes of 40 to 90 kilometers to a fainter, broader glow at still higher altitudes (*Science*, 5 August 1994, p. 740). Analyzing the data, Dennis Boccippio and Earle Williams of the Massachusetts Institute of Technology and Lyons found that the sprites, at least, coincide with the huge, positively charged cloud-to-ground lightning bolts from the biggest thunderstorms (*Science*, 25 August, p. 1088). Although that pointed to lightning as the sprites' ultimate cause, researchers did not know the mechanism.

The colors of the sprites offered a clue, however. Rare visual sightings and color video images of these brief flashes had shown that they have a red hue reminiscent of the aurora. That suggested that the light of a sprite, like that of the aurora, comes from oxygen or nitrogen molecules excited by collisions with high-energy electrons. Now two groups—Stephen Mende of Lockheed Palo Alto Research Laboratory in California and his colleagues working at the Fort Collins site and Davis Sentman and colleagues at the University of Alaska, who made their observations from the top of Colorado's Mount Evans—have recorded spectra of sprite light and found that its source is molecular nitrogen excited by electron collisions.

But how could lightning only 5 to 10 kilometers above the ground unleash electrons at altitudes 10 times higher? One possibility relied on the 100-microsecond pulse of electromagnetic energy broadcast by a lightning stroke. Moving upward at the speed of light into thinner regions of the atmosphere, it might eventually be able to rip electrons from atmospheric molecules and accelerate them unhindered by too many collisions with other molecules.

S. B. MENDE AND R. L. RAIRDEN

High lights. Changes in the atmosphere's electric field above a thunderstorm spawned these sprites.

Researchers had also considered a slower, "electrostatic" mechanism that depends on the charge a cloud induces in the atmosphere above it as it electrifies before unleashing a lightning stroke. The cloud's own charge is annihilated when the lightning suddenly transfers upwards of 1000 coulombs of charge to the ground, while the field above the cloud lingers. And because the field is no longer nullified by the cloud charge, for a few milliseconds it's strong enough to ionize molecules and accelerate the resulting electrons.

Measurements of the precise timing of lightning strokes and flashes now imply that both mechanisms may be at work—in different parts of the upper atmosphere. Mende and his colleagues found that sprites lag the huge positive lightning strokes triggering them by several milliseconds. That's much longer than it would take for the electromagnetic pulse from a lightning stroke to arrive at the altitude of a sprite. But the timing is about right for the slower electrostatic mechanism, notes Williams.

Electromagnetic pulses could still have a role, however, in the fainter, broader flashes sometimes recorded at around 90 kilometers in the lowermost ionosphere. Working in Lyons's yard, Hiroshi Fukunishi of Tohoku University and his colleagues found that these flashes appeared less than 1 microsecond after the lightning—about the right interval for an electromagnetic pulse to reach the ionosphere. The finding also fits theoretical calculations made by Umran Inan and his colleagues at Stanford University, who had pointed out that a pulse was far more likely to trigger a flash in the ionosphere, where molecules are already ionized, than at the lower altitudes where sprites appear.

Although researchers have tentatively sorted out mechanisms for two upper-atmosphere phenomena, many questions remain. Theorists have yet to publish even a hand-waving explanation of yet another species of flash, the "blue jets" that explode from storm-cloud tops. And the menagerie of middle-atmosphere flashes may contain even more strange beasts. There will be plenty more work for the next yard party on Yucca Ridge.

–Richard A. Kerr