modation appears to be permanent.

"Since they both perform similar functions in terms of making [leaf] membranes leaky, it seems both reasonable and interesting" that ozone and ethylene could interact, according to botanist Joseph Sullivan of the University of Maryland in College Park. Heck says he is unconvinced, largely because his research with other plants indicates that many days of exposure produce more damage than one-day exposures.

— J. Raloff

Will livestock drug cause dung crisis?

Dung beetles and earthworms don't tend to get a lot of respect — except when they're not around. Ecologically, these invertebrates provide a valuable housekeeping service. Not only do they break down and carry away dung, but in the process they also aerate soil and enhance the ability of water to percolate into the ground. For these reasons, growing veterinary use of the drug ivermectin in livestock to control parasites — such as roundworms — could have unintended environmental repercussions. A new British study shows that the drug, excreted in the feces, can exert a dramatic insecticidal effect on dung fauna.

While feces of nontreated calves were immediately colonized by dung beetles in the field — sometimes by hundreds per "pat" — and later by earthworms, the dung of ivermectin-treated animals remained largely devoid of such invertebrates, according to a report in the June 4 NATURE by zoologists Richard Wall and Les Strong of Bristol University in England. Within 100 days, the researchers say, the control pats had "largely disappeared," whereas the drug-containing dung samples "were still largely intact." This situation could spell a serious, impending problem, especially to livestock farmers, Wall believes, because "for every pat [of dung] you have, you reduce available pasture land; cows won't graze up to the edge of their cow pat."

Bill Hill, a spokesperson for the Rahway, N.J.-based MSD-AGVET (a division of Merck & Co.), the drug's maker, says there have been no anecdotal reports from ivermectin users of problems with dung degradation. Moreover, he says, because the drug is registered only for infrequent administration by injection or as a paste, its effects on dung beetles would be limited to feces passed in the few days after each treatment. But Wall says while that may be true today, it would not be true if the drug were administered from a controlled-release implanted pellet, which he says is now under development — an application that would shed the drug into the feces daily for months.

— J. Raloff

Superconductivity and quantum mechanics

The new high-temperature form of superconductivity that is currently setting the physics world on its ear may also illustrate the problems of applying quantum mechanics to small numbers of objects, Edward Teller of Lawrence Livermore (Calif.) National Laboratory told the Loyola Conference on Mathematical and Interpretational Problems in Relativistic Quantum Theory, meeting in New Orleans last week.

Quantum mechanics makes statistical predictions, and the statistics are most easily understood when applied to ensembles of large numbers — millions, billions — of individuals. Classical mechanics, which usually governs the macrocosm, makes absolute predictions for individuals. Somewhere, somehow, the two must come together, a serious question that has been largely avoided. Teller suggests that because superconductivity in these high-temperature materials is accomplished by the action of only a few electrons — far fewer than in the long-known low-temperature form — this may be a place where the statistical and the individual shade into each other.

Electrical conduction of any kind depends on the substance having a supply of electrons that are not tightly bound to given atoms but free to drift through the material. Ordinary metals have such conduction electrons in great abundance, but the new superconducting materials are ceramics with far fewer free electrons in them. As Teller says, "If you put together a barium oxide, a copper oxide and an yttrium oxide and cook them together in the right proportions, you don't get superconductivity. But cook at 950°C for an hour and cool it. The oxygen has gone up from 6.5 to 7. You don't get superconductivity either. Stop a little too soon [so that the proportion of oxygen is 6.9], and you get superconductivity. Anybody can do it."

The 6.9 means that in an occasional cell of the crystal, an oxygen present in other cells is missing. The omissions seem randomly distributed. This missing oxygen ion leaves behind two electrons, says Teller, and these add crucially to those contributed by other atoms, particularly the copper, to make the superconducting effect go. The oxygens that are present are also critical, as they are the intermediaries that make the electrons behave in a superconducting way.

To get superconductivity, electrons must cooperate in pairs, called Cooper pairs. The pairs obey a different statistical law from single electrons, making resistanceless passage possible. In low-temperature superconductors the pairs form through an interaction with an acoustical wave in the crystal lattice called a phonon. As an electron proceeds through the crystal, it draws the atomic nuclei toward itself. As it passes, the nuclei move back to their previous position. Thus the lattice ripples as the electron moves along. A proper interaction between two such ripples brings the electrons into a Cooper pair. Characteristically the members of a pair are a few hundred angstroms apart, Teller says.

In the high-temperature superconductors, he suggests, it is not an acoustical vibration of the lattice, but a vibration of oxygen atoms at frequencies characteristic of light — ultraviolet to be precise — that makes the Cooper pairs. The mobile electrons are particularly those extracted from a certain orbital level of the copper atoms, and they move preferentially in what crystallographers call the *y* direction, thus accounting for the strong tendency for supercurrents in that direction that experiment has found. These electrons form Cooper pairs with members in adjacent unit cells.

The electrons are not evenly distributed. There is a probability for them to prefer certain locations to others, and these locations form a kind of checkerboard three-dimensional pattern through the crystal. The preferred locations along a given line are offset from those in adjacent parallel lines so as to form a stable three-dimensional "superlattice," in which the absolute positions are unknown but the positions relative to each other are known. In this structure the electrons move in "lockstep." A slight disturbance of the superlattice will produce a lot of current for very little energy.

The "optical" quality of the high-temperature superconductivity can make the Josephson effect appear at temperatures above those where resistanceless conduction sets in, Teller proposes. In the Josephson effect a supercurrent passing through a slightly insulating junction between two superconducting contacts generates a radio wave. Some experimenters have found the Josephson effect at temperatures as high as 260 kelvins in these materials, and some have claimed that that means superconductivity is present. However, actual resistanceless current flow has not been confirmed above 100 K.

Low-temperature superconductors are fully superconducting when the Josephson effect appears. In the high-temperature materials, Teller believes, a combination of the optical frequency of the vibrations and a variation of the photoelectric effect can produce a Josephson effect at temperatures above those where true resistanceless flow begins. As Teller puts it, "The electrons are not yet moving in lockstep; conductivity is not yet zero, but a dozen or 100 are correlated" — enough to make a Josephson effect.

— D. E. Thomsen