says. "The problem we have now is that none of the possibilities look very likely."

When they bagged element 118, the Berkeley team was in a hot race with a group at the Joint Institute for Nuclear Research in Dubna, near Moscow. But Gregorich doesn't think the rivalry was responsible for the error. "In '99, things did go fairly quickly," he acknowledges, noting that researchers felt pressure to complete their work rapidly before other labs could perform similar experiments. "But we're trying to get away from the rivalry aspects of the different labs. It's pretty much a different generation of scientists from when there was a lot of rivalry in the '70s."

Hofmann says that Dubna's observations of elements 114 and 116 suffer from uncertainties similar to those of the Berkeley experiment, but their results have an internal consistency that gives him more confidence in the Dubna data. He praises the Berkeley team's candor, and, along with the rest of the heavy-ion community, hopes a fuller accounting will reveal what went wrong. Dieter Ackermann, also of GSI, says, "The problem now for me is that I need an explanation."

–CHARLES SEIFE

ENTOMOLOGY

First Light on Genetic Roots of Bt Resistance

For the last 5 years, farmers, particularly cotton growers, have been able to reduce their use of chemical pesticides by planting crops genetically engineered to make insecticidal proteins from the bacterium *Bacillus thuringiensis* (Bt). But insects can adapt to these natural toxins, just as they do to synthetic chemical pesticides. For example, some populations of diamondback moths, a devastating pest of cabbage and related crops, are no longer bothered by sprays of Bt bacteria used by organic farmers. This has raised worries that extensive use of the modified crops will lead to widespread resistance that could render both the crops and the Bt sprays useless. Now scientists have taken a big step toward understanding how Bt resistance arises—a key to predicting the occurrence of such resistance.

In work reported in this issue of *Science*, two teams, one led by Linda Gahan of Clemson University in South Carolina and David Heckel of the University of Melbourne in Australia and the other by Raffi Aroian of the University of California, San Diego, have identified the first resistance genes for Bt. "It's a huge leap forward," says Bruce Tabashnik, an entomologist at the University of Arizona, Tucson. The most practical payoff may be an easy DNA test for detecting resistance in insect pests; this could help alert farmers to burgeoning resistance in time to stop planting Bt crops and switch to chemical pesticides for a while.

For their experiments, which are described on page 857, Gahan and Heckel used a lab strain of the tobacco budworm that was developed by Fred Gould of North Carolina State University in Raleigh. This strain, known as YHD2, resists the Bt toxin designated Cry1Ac, which is present in a genetically modified cotton produced by Monsanto Corp. of St. Louis.

In 1997, the Gahan-Heckel team, working with Gould, obtained evidence indicating that the gene responsible for the budworm's Bt resistance is located on chromosome 9. After narrowing the location of the putative gene, which they called *BtR-4*, the team checked that stretch of the chromosome for known genes that code for proteins that bind the Bt toxin. Resistance might reside in one of those genes, they thought, because of the way Bt toxins kill—by binding to cells in the midguts of insects that eat them, causing the cells to burst. A mutation that could prevent that binding, either directly or indirectly, could thus confer Bt resistance.

Lab studies have identified two classes of proteins that bind to Bt: the aminopeptidases, enzymes used by insects to help digest proteins in their gut, and cadherins, some of which are located on cell surfaces and are involved in cell adhesion. Heckel and Gahan quickly ruled out two aminopeptidase genes, as they weren't located on the same chromosome as *BtR-4*.

So the researchers turned to the cadherins. They used the polymerase chain reaction to isolate a fragment of a cadherin gene that mapped to the same location as *BtR-4*. The fact that the cadherin gene maps to the same area as *BtR-4* provides "almost irrefutable evidence" that it's the Bt resistance gene, Tabashnik says. "The odds of that being a coincidence are essentially nil."

The pair went on to show that this cadherin is made in the right place to confer resistance—the budworm's midgut. What's more, the researchers have evidence that the gene has been inactivated in the resistant YHD2 budworm strain. In that lab strain, but not in nonresistant budworms, the gene's coding sequence was interrupted by the insertion of a retrotransposon—a bit of movable DNA that can jump from place to place in the genome. Such an insertion would likely disable the gene, presumably preventing the Bt toxin from latching onto —and killing—the cells of the budworm's midgut. Finding such a disabling mutation was "totally unexpected," says Heckel, as insecticide targets are usually very important to the insect and can't tolerate such large changes.

Because large mutations such as retrotransposon insertions are easy to detect, researchers should be able to develop a rapid test for this type of resistance to Bt. But a single test won't suffice. "Insects can have more than one mechanism of resistance," explains Ian Denholm of the Institute of Arable Crops Research's Rothamsted Experimental Station in Harpenden, United Kingdom. Indeed, that message is brought home by the Aroian team's paper, which appears on page 860.

Aroian and his colleagues study Bt resistance in the roundworm *Caenorhabditis elegans*, which like insects suffers intestinal damage from Bt toxins. Last year the group located five genes, dubbed *bre* for Bt resistance, that when mutated confer resistance to a Bt toxin called Cry5B. Now they have cloned one of those genes, *bre-5*, and confirmed that blocking its activity, as a mutation might do, does in fact make the worm resistant to Cry5B and also to Cry14A.

The BRE-5 protein turned out to be an enzyme called β-1,3-galactosyltransferase, which adds carbohydrates to lipids and proteins. Aroian's team has evidence suggesting that such carbohydrate addition to the Bt protein receptor is needed for toxin binding in the gut. The researchers also showed that losing the enzyme creates resistance. "It's an important mechanism to understand," Aroian says, because losing the enzyme could be an effective way to gain resistance to many Bt toxins at once. If it works this way in insects, a mutation in the enzyme might help insect pests defeat the next generation of genetically modified crops, which are being endowed with multiple Bt toxins to help prevent resistance.

–ERIK STOKSTAD

Nipped in the bud. DNA tests could help detect genes that allow the tobacco budworm and other insect pests to resist Bt toxins.

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