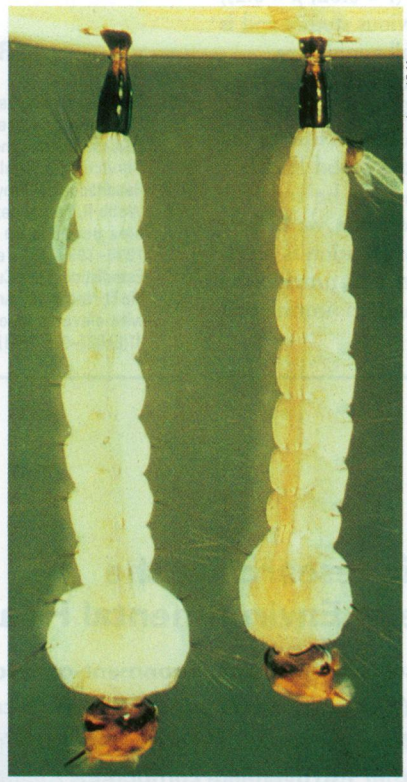
As we constantly become more and more nearly lords of creation, there is nothing so much to be feared as ourselves, yet we know so little about fearsome us.

Howard Zahniser, quoted in *John Muir and His Legacy*, 1970

Last Supper for Mosquitoes

The same pond scum that nourishes young mosquitoes soon may deliver their death blow. A newfangled version of the common algae chlorella has been bioengineered as a mosquito larvicide. The larvicide's effect comes from a hormone that shuts down digestion. Because the hormone occurs in mosquitoes naturally, researchers believe the new larvicide poses none of the environmental risks of older methods. "It's a natural hormone," explains John Bennett, chairman and CEO of Insect Biotechnology, a Chapel Hill, North Carolina-based corporation that has licensed the larvicide technology from the University of Florida in Gainesville, where it was developed. "This is a green product—safer than chemical pesticides used today."



Leonard E. Munstermann

Languishing larvae. A new strain of chlorella may prevent mosquito young such as these *Aedes aegypti* larvae from growing up to become disease carriers.

Dov Borovsky, a biochemist at the Florida Medical Entomology Laboratory in Vero Beach, discovered that in nature, trypsin modulating oostatic factor (TMOF), a peptide hormone, normally shuts off the production of stomach enzymes in mosquitoes after a blood meal has been digested. Young larvae that were fed the hormone stopped digesting food prematurely and quickly starved to death.

Borovsky and his colleagues packaged his mosquito "diet pill" in the freshwater chlorella algae favored by waterborne larvae. The hormonal protein gene is incorporated in the DNA of the genetically altered chlorella.

Borovsky claims that TMOF is effective against most species of mosquitoes, including those that transmit dengue fever, yellow fever, St. Louis encephalitis, eastern equine encephalitis, and malaria.

TMOF has yet to be tested in the field. Bennett expects to begin small field trials within the next four months and continue until the EPA's requirements for registration are satisfied. But already the new larvicide is creating a stir in the mosquito-control community. Since word of his development hit the Internet, Borovsky has received calls from people as far away as China, India, and Singapore.

"We could sure use alternatives," says Andrew Spielman, a professor of tropical public health at the Harvard University School of Public Health in Cambridge, Massachusetts. "If you could have a transgenic alga that expresses the [TMOF] protein, it would be very attractive."

The most commonly used mosquito larvicides in the United States, according to Spielman, are *Bacillus thuringiensis* ssp. *israelensis* (Bti) and the growth hormone methoprene, sold under the brand name Altosid. Both are considered environmentally safe, although studies suggest they kill some nontarget aquatic insects. "We found that with long-term, high-level applications, some midges [gnat-like flies] are affected," says Nancy Read, the technical leader of a study of the effects of larvicides for the Metropolitan Mosquito Control District in St. Paul, Minnesota.

Another possible drawback of Altosid and Bti is resistance. "When you're using only one or two insecticides, the probability of resistance is strong," says entomologist Kelly Johnson of Ohio University in Athens. "An arsenal of more tools is better." Borovsky says he's heard of Altosid resistance problems in several mosquito-control districts in Florida.

In many developing countries, the larvicide temophos, sold as Abate, is often used because it costs considerably less than Bti and Altosid. But the broad-spectrum organophosphate weakens the food chain by killing other waterborne arthropods and copepods.

Borovsky believes his larvicide is a safer choice, not only because the hormone occurs naturally in mosquitoes, but also because its pond life is limited. The genetically altered variety of chlorella is believed to carry the hormone only through a few generations, lasting a total of 3–4 weeks. "The gene we put in is not stable, so eventually the dividing chlorella will kick it out," Borovsky says. "You don't want something [like that] to stay in the water forever." Spielman and Johnson agree. "I think it could be a good delivery system if there's tight control over the chlorella," Johnson says.

Spielman cautions that mosquitoes might develop resistance to TMOF as they apparently have to methoprene. Borovsky points out, however, that methoprene is an analog that binds to a different receptor than does the natural form of the hormone. He doubts mosquitoes will resist his chlorella larvicide because it contains the same hormone they produce naturally.

A significant limitation of Borovsky's larvicide is that chlorella grows only in fresh water. Borovsky is experimenting with other delivery vehicles that can be used in saltwater marshes. He is also investigating the digestion-regulating hormones of budworms, diamondback moths, and other pests. He expects his research to one day greatly lessen the need for chemical insecticides. "Insects are regulating their digestive enzymes," he says. "We are looking at these regulators. I see that in the 21st century we're going to control most of these pest insects through natural hormones."

The Threat of Meth

In January 1996, a large mobile home in Aquanga, California, burst into flames after a home methamphetamine lab exploded. Kathy James, her son Jimmy, and two men managed to scramble out, but trapped inside and suffocating to death were James' three younger children. Then, in September 1997, toxic fumes from a home lab killed little Joseph Carnesi in a Phoenix, Arizona, apartment as he slept on a couch. These are just two of many such incidents graphically illustrating the growing environmental health danger of the home meth labs that have sprung up across the country in recent years.