what role the chytrids are playing" in the wild. He and others question whether something hasn't changed in the frogs' environment to weaken their resistance and promote the chytrid.

While U.S. researchers argue about the chytrid's role, in Australia, Speare, Aplin, and others are waging a campaign to try to stop it. They're tracking the fungus's spread, identifying susceptible species, and planning captive breeding programs. And even skeptical U.S. researchers are urging field precautions, in case herpetologists themselves are spreading the fungus via wet boots or collecting gear. Chytrid specialist Longcore, who named the new genus, notes that she brought a non–disease-causing type of chytrid from Puerto Rico home to Maine in the wet mud on her boots.

Despite all such efforts, Speare and others fear that in Australia, the disease "will be spread like the plague" through new populations. At least, Aplin says, this time scientists will be able to watch one of these sudden declines in action, rather than discovering it after it's all over: "We've caught it this time close to the beginning." And that may provide answers to the many questions that still surround this strange frog killer.

–VIRGINIA MORELL

FROG DECLINES
▶ DEFORMITIES

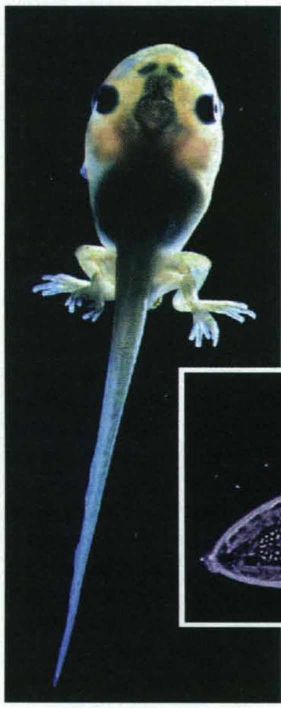
A Trematode Parasite Causes Some Frog Deformities

The cysts formed by the trematode lead to abnormal limb development in California frogs; whether trematodes cause the deformities elsewhere remains to be seen

It was a disturbing sign that something might be going terribly wrong in the environment: Frogs with extra legs, missing limbs, and twisted jaws were popping up in ponds across the country. First spotted by schoolchildren in Minnesota in 1995, the famous malformed frogs, together with reports of declining frog populations worldwide, sparked concerns that the animals might be falling victim to some type of environmental degradation—a change that might even threaten human populations. The discoveries touched off a million-dollar-plus hunt to find the culprit, whether natural or humanmade. Two reports published in this issue now point to a natural cause for at least some of the frog abnormalities.

On page 802, a team led by a recent Stanford graduate describes results indicating that infection by a trematode, a kind of parasitic flatworm, is at fault. The researchers based this conclusion on experiments in which they showed that they could exactly duplicate the kinds of limb abnormalities and other deformities seen in California by infecting tadpoles with the trematode, which goes by the genus name *Ribeiroia*. Some experts say that this work, together with a second study reported on page 800 that may exonerate certain chemicals suspected of causing the abnormalities, has now elevated parasites to the top of the list of possible causes for the frog deformities across the country. "This is *the* best experimental evidence showing a cause for the limb deformities in amphibians," says Andrew Blaustein, an ecologist at Oregon State University in Corvallis, who has studied whether ultraviolet light could explain the deformities.

Others caution, however, that *Ribeiroia* infections may not explain the different patterns of frog deformities seen outside of California, especially in the Midwest. "I do not believe that there's a single cause" for the deformities, says herpetologist Mike Lannoo of Indiana University School of Medicine in Muncie. Still, many experts are saying that after several years of frustration it's a relief to finally get some hard evidence for what might be happening to the frogs.



Seeing double. This metamorphosing tadpole owes its extra legs to *Ribeiroia* trematodes *(inset)*, which are about 500 micrometers long.

CREDITS: (LEFT TO RIGHT) STEVEN HOLT, STOCKPIX.COM; S. SESSIONS/HARTWICK COLLEGE

Since the first malformed leopard frogs made headlines in Minnesota, deformities in at least 12 species of frogs and salamanders have been reported in Canada, Vermont, and 32 other states, often at rates of 8% or more, much higher than the rate of 1% or less expected in healthy populations. Investigators have pursued three main theories about what might be causing the problems: chemicals such as pesticides, increased ultraviolet light because of ozone destruction, or parasites (*Science*, 19 December 1997, p. 2051).

Despite the flurry of activity, however, no lab had grown a batch of frogs under environmentally relevant conditions and produced the same deformities seen in wild specimens of the same species—until now. Pieter Johnson began this project 2 years ago for his undergraduate thesis at Stanford, with ecologist Paul Ehrlich as his adviser. Johnson investigated some ponds about 45 minutes south of Palo Alto where up to 40% of emerging Pacific treefrogs had deformities, mostly extra, partial, or missing hindlegs. The water tested free of chemical pollutants, but he noticed that the ponds with deformed frogs always had planorbid snails, a first host for *Ribeiroia* trematodes. "That was a pretty substantial clue" that trematodes might explain the deformities, Johnson says.

That idea fit with a proposal developmental biologist Stanley Sessions of Hartwick College in Oneonta, New York, had made years earlier. In work published in 1990, Sessions had shown that he could induce extra legs in salamanders by implanting beads in their developing limbs, presumably because the beads move cells around. Noting that the cysts formed in infected hosts by trematodes could exert the same kind of mechanical forces as the beads, Sessions suggested that the worms could also cause limb deformities.

By the time he graduated last June, Johnson had dissected hundreds of frogs and found that they did in fact have trematode cysts clustered around their extra limbs. But he hadn't done any experiments exposing tadpoles to the parasites. "I couldn't let go that close" to a solution, he says. So he teamed up with two friends, Kevin Lunde and Euan Ritchie. They all spent the summer "working pretty intensely," Johnson recalls, often from 10 p.m. to dawn so they could catch the parasitic worms when they emerged from the snails and use them to infect the frogs.

After several false starts, the team began infecting tadpoles with *Ribeiroia* and watching them develop into adults. The results were "almost painfully textbook," Johnson says. Higher doses of the trematode produced more deformities, and the mix of multiple legs, partial and missing limbs, fused skin, and other oddities was very close to that seen in the frogs in the field. Johnson thinks the cysts may cause deformities by changing the positions of cells in a developing limb, as Sessions's beads apparently did, and may also produce some chemical that mimics a hormone.

The Johnson team's findings don't mean that some chemical in the environment couldn't be at work too, but in the accompanying report, Sessions offers evidence that seems to rule out at least one type of chemical that has been linked to the frog deformities: retinoids. Sessions compared the abnormalities in 391 preserved, multilegged Pacific treefrogs from California and Oregon to those known to be induced in the lab by retinoids. More than 90% of the time, for example, the chemical produces a "proximal-distal duplication," such as a new limb coming out of the elbow rather than the shoulder. The retinoids also cause only certain mirror-image limb duplications. Although Sessions found many specimens with other kinds of mirror-image duplications, none had proximal-distal duplications. "Retinoic acid gives you particular morphologies, and we just don't see that with the frogs," says Sessions.

Developmental biologist David Gardiner of the University of California, Irvine, who has been studying retinoids as a possible cause, disagrees, saying they are still in the running. "What the published literature says retinoids do and don't give you," he says, isn't clear-cut. Other researchers say that differences in the abnormalities seen in midwestern and eastern frogs also point to other causes besides parasites. Few have the extra legs seen in California, for example. And although some of the animals have cysts, so far nobody has found *Ribeiroia* in the midwestern frogs. In addition, Carol Meteyer, a wildlife pathologist at the U.S. Geological Survey in Madison, Wisconsin, says she has dissected hundreds of metamorphosing tadpoles from the affected ponds, and the cysts she has found do not appear until after the frogs' limb buds had developed—too late to do the damage Johnson describes.

But Lannoo and many others think parasites should be looked at more closely, even in those locales where chemicals are also suspected. "I don't for a minute think this is going to explain everything," says David Wake, director of the University of California, Berkeley's Museum of Vertebrate Zoology. But he adds that it's "a warning not to put all of your eggs in one basket" when trying to pin down the cause of the frog deformities.

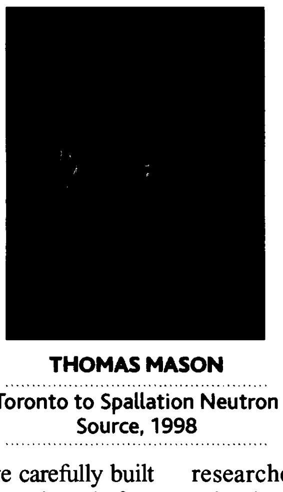
–JOCELYN KAISER

SCIENTIFIC COMMUNITY

Headhunters Stalk the Halls of Physics

Bidding wars are breaking out in academe as prestigious institutions vie for the top researchers in high-profile areas of physics and astronomy

Nothing is permanent but change, said the Greek philosopher and physicist Heraclitus. Academic physics departments are discovering this truth all over again. Like star athletes and top business executives, high-profile physicists and astronomers have become the object of bidding wars, leading to a chaotic mobility from which some academics believe only a handful of the most prestigious and best funded institutions can benefit. One shell-shocked department chair, Paul Langacker, quips that he has a new motto for enticing prospective faculty members: "The University of Pennsylvania—where Princeton and Harvard come to recruit."

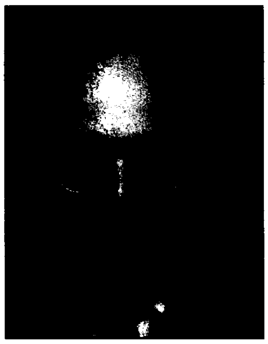


THOMAS MASON
Toronto to Spallation Neutron Source, 1998

Langacker says that although researchers have every right to move, the accelerating pace threatens to destroy small groups that universities such as his own have carefully built up in emerging subfields—sometimes before the Princetons and Harvards saw the trend. Others think the aggressive recruiting actually has benefits, as it spreads ideas around and encourages collaboration. But there is one universal feeling when a star walks out the door, says Pekka Sinervo, chair of physics at the University of Toronto: "It hurts. There is no way that it can't hurt."

Sinervo and others at Toronto got a strong taste of that hurt in 1997 and 1998. First, Scott Tremaine—a former director of the Canadian Institute for Theoretical Astrophysics with joint appointments in physics and astronomy—left to become chair of the Astrophysical Sciences Department at Princeton. Long a force in areas ranging from celestial mechanics to cosmology, Tremaine, who turned down an initial offer from Princeton and then changed his mind 6 months later, says Toronto mounted a "very effective countercampaign" to keep him. It was not effective enough, however, and Sinervo was determined to do even better when the phone started ringing in late 1997 for one of his department's best young researchers: Thomas Mason, a materials scientist widely known for his studies of high-temperature superconductors.

Now 34, Mason was named one of "100 Canadians to watch" by *Maclean's* magazine in its 1 July 1997 issue for his structural studies of novel superconductors using neutron scattering. But he let it be known that he would entertain offers in the United States because of what he saw as insufficient support for such research in his department and because Canada's premier neutron facility—the Chalk River reactor—is aging and poorly funded. Interest materialized posthaste from the University of California, San Diego, and Los Alamos National Laboratory in New Mexico; but it was an offer to become scientific director of the planned $1.36 billion Spallation Neutron Source (SNS) at Oak Ridge National Laboratory in Tennessee that really grabbed his attention.



PAUL STEINHARDT
Pennsylvania to Princeton, 1999

Toronto quickly offered to bump Mason's salary up to six figures, to spend $400,000 on a new helium-liquefaction plant—crucial for Mason's work—and to hire a new faculty member in the same area. "It's by no means been a tradition at Toronto that we can react as nimbly as we did," says Sinervo. "In the end, the offer they made me actually addressed all of the concerns I had initially," says Mason. But by then, the once-in-a-lifetime chance to influence scientific priorities at SNS, along with a substantially more generous financial package and other benefits, induced him to leave the university just 5 years after he arrived. "I got tenure the week I left," he says.

In spite of Toronto's losses, the University of Pennsylvania's Langacker might envy the national boundary that separates Toronto from prestigious, deep-pocketed American

CREDIT: (LEFT) OAK RIDGE PHOTO; (RIGHT) PRINCETON UNIVERSITY