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# Toward Immunogenetic Studies of Amphibian Chytridiomycosis: Linking Innate and Acquired Immunity

Amphibian species around the world have been declining rapidly over the past several decades, with one-third or more of the 6,300 species currently threatened with extinction. The skin disease chytridiomycosis is a leading cause of these declines, particularly in the humid tropics of northern Australia and Central America. In an article in the April issue of *BioScience,* USGS scientist Dr. Jonathan Richmond and colleagues Anna Savage and Dr. Kelly Zamudio at Cornell University and Dr. Erica Rosenblum at the University of Idaho reviewed the preliminary evidence supporting a role for acquired immune defenses against chytridiomycosis.

**Management Implications:**

- Immunogenetic data promise to answer key questions about chytridiomycosis susceptibility and host-pathogen co-evolution.
- Targeted investigation of genes controlling acquired immune responses, as well as those that functionally bridge the innate and acquired immune systems, are needed.
- Evolutionary processes are important to consider for amphibian conservation management.

The pathogen responsible for chytridiomycosis, *Batrachochytrium dendrobatidis* (*Bd*), shows high virulence and transmissibility, and typically spreads in a wave-like fashion across landscapes. Fungal spores disperse through water or moist soils and infect the external mouth parts of tadpoles and the outer layer of skin in adult amphibians. Disease symptoms of infected individuals include irregular increase in number of normal skin cells, lethargy, poor righting reflex, convulsions with extended limbs, and ultimately death in most cases. The means by which the disease causes death is not known, but it may interfere with oxygen exchange and osmoregulation. The sudden emergence of *Bd* as a vertebrate pathogen produced a flurry of research on the causes for its host switch to amphibians (chytrids typically feed on dead or decaying organic matter) and rapid spread around the globe. Environment was immediately pegged as one of the principal drivers of the epidemic; the fungus thrives in moist humid habitats, particularly at high elevation sites in the tropics, and also in temperate areas where seasonal temperature flux produces windows of opportunity for fungal growth and replication.

Immunogenetic studies are key to understanding amphibian susceptibility to chytridiomycosis. Here, an infected lowland leopard frog *(Lithobates yavapaiensis)* near Muleshoe Ranch in Arizona, January 2009, has likely died from chytridiomycosis. Acute die-offs have occurred throughout Arizona in recent years. Photo by J. Richmond, USGS.

However, researchers immediately noticed that not all species or populations respond the same way to infection, even when they occur in the same habitats; some experience acute die-offs several days post-infection, others suffer declines but some individuals survive, and still others tolerate infections without developing clinical signs of disease. These observations, in addition to the fact that chytridiomycosis is a skin disease, led to several studies on antimicrobial peptides that are commonly secreted in amphibian skin. These peptides constitute a rapid, first line of defense against a variety of infectious microbes, and form one component of the so-called 'innate' immune system. The results of these studies have shown that differences in the type of peptides produced by different species can indeed affect how an individual responds to infection, providing one line of evidence that helps to explain why some amphibians differ in susceptibility.

While investigations of innate immune defenses are important and justified, other attributes of the immune system may also provide critical defenses against *Bd* infection. In particular, innate defenses typically act as triggering mechanisms to stimulate 'acquired' or 'adaptive' immune defenses, which take longer to develop and are more specific to certain types of pathogens or parasites. Acquired defenses involve cascading interactions between a specialized set of molecules that recognize and attack invading pathogens or parasites. Genes encoding these molecules are some of the most polymorphic and ancient in the vertebrate genome, and variation in the DNA sequences of these genes may hold critical information on why some individuals fall victim to chytridiomycosis while others survive. To date, investigations on immunity to this disease have been restricted to innate defenses only, but several interesting preliminary studies suggest that acquired defenses are activated in the aftermath of *Bd* exposure.

*Richmond, J. Q., A. E. Savage, K. R. Zamudio, and E. B. Rosenblum. 2009. Toward immunogenetic studies of amphibian chytridiomycosis: Linking innate and acquired immunity. BioScience 59:311–320.*