Card Trick: the Black Queen from Hearts Helps Explain Reductive Evolution in Life

Marcia Stone

The newly devised Black Queen Hypothesis (BQH) attempts to explain how evolutionary processes sometimes simplify microorganisms, according to J. Jeffrey Morris and Richard E. Lenski at Michigan State University (MSU) in East Lansing and Erik R. Zinser at the University of Tennessee in Knoxville.

For example, when *Prochlorococcus* species long ago jettisoned a costly but critically important survival gene, the genetically reduced survivors swept their more-encumbered ancestors from the oceans. Details appear in the March/April 2012 *mBio* (3(2):e00036- 12. doi:10.1128/mBio.00036 -12).xx "The Black Queen here refers to the Queen of Spades, which players in the game of Hearts try to avoid because it's so costly," Lenski says. This card-game metaphor helps one to visualize how reductive evolution can make microbes with streamlined genomes among the most successful on Earth.

The lost *Prochlorococcus* gene that these researchers study is *katG,* which protects some but not other species in the *Synechococcus-Prochlorococcus* clade from hydrogen peroxide, a byproduct of photooxidation. Even sterile filtered sea water exposed to sunlight in the laboratory accumulates enough hydrogen peroxide in a few hours to kill cultured axenic *katG*deficient *Prochlorococcus* strains. Although exposure to hydrogen peroxide in the wild should be similarly costly, it is not, according to these researchers. Neighboring organisms protect *Prochlorococcus*, which carries "less genetic baggage," reducing its requirements for energy or nutrients, "which are in short supply in the open ocean," Morris says.

"Genomic streamlining requires that the lost genes are dispensable for the organism in its natural environment," Zinser says. "That turns out to be true for *Prochlorococcus* because other bacteria in the community protect their own interiors with *katG*-encoded catalase-peroxidase-a primary defense against hydrogen peroxide- and enough peroxidase activity leaks out to protect all the cells in their immediate vicinity. In this way, some marine microbes act as unintentional ‘helpers,' protecting the vulnerable majority -the ‘beneficiaries'-as a side effect of helping themselves."

"Leakiness" is a pivotal feature of the BQH, but it is also necessary that the "public goods" produced are energetically or nutritionally vital to nearby cells as well as to the producers."Anyfunction that is both leaky and costly to perform is a potential target for gene loss," Lenski says. Inorganic nutrient acquisition, nitrogen fixation, and biofilm matrix deposition meet these criteria, and are currently being investigated within theBQH framework.

The phenomenon of cells protecting neighbor cells is neither altruistic nor self-enriching, according to the BQH. Nonetheless, both producer and recipient sometimes benefit from the association. "For example, the heterotrophic helpers probably depend on *Prochlorococcus* for carbon, so if genome reduction enables their beneficiary to increase its rate of organic carbon production, then the helper community also benefits greatly from the relationship," Morris says. "Thus, the relationship between *Prochlorococcus* and its helpers is . . . mutualistic."

"This elegant hypothesis touches on the well-known ecological concepts of commensalism,mutualism, or parasitism, and provides a framework to test some underlying assumptions about their evolution in microbial communities," says Anton Post at the Marine Biological Laboratory (MBL) in Woods Hole, Mass.

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