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NEWS AND VIEWS

PERSPECTIVE

Complexity and context of MHC-correlated mating preferences in wild populations

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There is now substantial and growing evidence for a role of the major histocompatibility complex (MHC) in shaping individual mate preferences. In view of both its codominant expression and its function in immune response, it is often expected that females aim to avoid inbreeding or maximize offspring MHC-heterozygosity by selecting as mates those males which share fewest or no MHC alleles with themselves. However, it is becoming increasingly clear that this view is over-simplistic: not only is MHC dissimilarity just one of several (perhaps many) criteria important in mate choice decision-making, extremely MHC-dissimilar males may be avoided, and furthermore, specific alleles or combinations might be preferred if they bestow particular advantages. These points are raised in two papers in this *Molecular Ecology* issue, in which patterns of reproductive success in tiger salamanders (*Ambystoma tigrinum*) and three-spined sticklebacks (*Gasterosteus aculeatus*) are each inconsistent with a generalized preference for MHC dissimilarity. Together, these studies demonstrate several adaptive reasons for decision rules that do not necessarily result in maximizing mate dissimilarity.

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Much of the early work on MHC-associated mate preferences was based on laboratory studies, notably mice, and hence, often involved relatively inbred individuals. Females were often found to prefer males with whom they shared fewest alleles (e.g. review in Jordan & Bruford 1998). In more natural conditions, MHC-disassortative preferences have also been reported in several taxa, and coupled with studies finding lower homozygosity than expected under random mating, the prevailing view has been that mate choice followed a simple but effective decision rule emphasizing MHC dissimilarity (e.g. Penn & Potts 1999). More recently, researchers have recognized that nonadditive benefits accruing from selection of dissimilar partners are modulated by additive benefits to be gained from choice of mates scoring highly on other desirable traits (e.g. Roberts & Gosling 2003). Furthermore, in terms of nonadditive benefits, the most genetically complementary mates may not always be the maximally dissimilar ones. Specifically at the MHC, the effects of thymic selection on T-cell repertoires (Nowak *et al*. 1992), and strongest resistance to multiple parasite load in individuals with intermediate levels of individual genetic diversity (Wegner *et al*. 2003), may lead to the optimal mate-choice solution being an intermediate level of dissimilarity between mates (Reusch *et al*. 2001; Jacob *et al*. 2002; Milinski 2006).

Eizaguirre *et al*. (2009) draw just this conclusion in sticklebacks. Using an elegant design, they set up mate-choice experiments in controlled but near-natural conditions using enclosures located in breeding grounds on the shores of Lake Großer Plöner in Germany (Fig. 1). Six enclosures provided protection from predators for 90 fish, but fine mesh exposed them to local parasites. Eggs were regularly collected from nests and typed for paternity assignment, thus enabling inferral of female mate choice. Although mating appeared random with regard to genetic background (based on microsatellites), mating was found to be nonrandom with respect to MHC in every enclosure. Interestingly, the observed mating distributions were statistically different to those expected under either extreme similar or extreme dissimilar mating preferences, consistent with an intermediate strategy.

Fig. 1 Enclosures located in stickleback (*Gasterosteus aculeatus*) breeding grounds on the shores of Lake Großer Plöner, Germany. Photo credit: Christophe Eizaguirre.

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Fig. 2 Eggs of the tiger salamander (*Ambystoma tigrinum*) in a breeding chamber and, below, an adult pair. Photo credit: David Bos.

In their study, Bos *et al*. (2009) trapped wild tiger salamanders (Fig. 2) while migrating to breeding sites and allowed them to mate before returning them once oviposition occurred. Similarly to the sticklebacks, genetic background assessed by microsatellites did not predict reproductive success, but mating patterns were associated with MHC. Here, MHC-similar males sired more of a focal female's offspring than did dissimilar males. Since there is no homozygote excess in this population, as would be expected under a general MHC-similar preference, Bos *et al*. argue that, as in the stickleback case, the data are consistent with a preference for intermediate levels of similarity.

The consistency of these conclusions, based on two very different systems but each with wild-caught individuals and thus avoiding problems associated with inbred populations, makes for a convincing case: avoiding extreme MHC dissimilarity may be a robust feature of MHC-associated mate choice. But do females actively choose intermediately dissimilar males or do observed mating patterns reflect a trade-off between MHC dissimilarity and other desirable traits which serves to dilute an underlying dissimilarity preference? In MHC-congenic mice, for example, there is evidence that females simultaneously assess good gene traits and genetic similarity, weighting these criteria according to variability in each among the males available to a given female (Roberts & Gosling 2003). Similarly, female spotted salamander (*Ambystoma maculatum*), preferences based on relatedness to males are modulated by male body size (Chandler & Zamudio 2008). In tiger salamanders, Bos *et al*. thus investigate this context-dependency on the robustness of their finding that MHC-similar males are preferred. In addition to MHC, they find that male tail length, which may be condition-dependent and thus reliably signal male quality, also predicts reproductive success. They therefore carried out two further analyses; they compared mating outcome in trials in which (i) there was smaller-than-average difference in tail length between the two males that a female chose from, and (ii) where there was a larger-than-average MHC dissimilarity in the two males. Each case provides conditions in which a disassortative preference might have become more evident if females indeed favour it, but in neither did they find emerging evidence for a more explicit dissimilarity preference: females indeed appeared to avoid very dissimilar males.

In sticklebacks, however, reproductive success was also predicted by male size and parasite load (Eizaguirre *et al*. 2009). Relatively large males harboured fewer numbers of the monogenean parasite *Gyrodactylus* and were more likely to have a specific MHC haplotype, F10. Even after correcting for size, F10 males appeared to have a particular advantage through lower *Gyrodactylus* burden and a higher probability of reproducing. Together with the previously described results, there is suggestion here that MHC-type confers both additive and nonadditive benefits and that female stickleback used both absolute and relative criteria during mate choice. Although this does not rule out the possibility that females can optimally satisfy both criteria, at least in free-ranging individuals, it could be that success of intermediately dissimilar males in these limited-choice experiments reflects a trade-off between them.

Patterns of mating in wild populations are not simple, nor should we expect them to be so — they reflect a number of complex interactions between traits which each confer different benefits and costs (Roberts *et al*. 2006). The two studies in this issue demonstrate how careful researchers must be when interpreting the role of MHC in mating preferences, understanding how these may reflect trade-offs between specific benefits arising in terms of parasite resistance against potential costs of disrupting co-adapted genes, while also considering a complex suite of other desirable traits. More such studies in wild populations are needed to fully understand the decision rules underlying these trade-offs and their fitness consequences, but the emerging pattern is that MHC-correlated mate choice is not always explained by choosing the most dissimilar mate.

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