Fishing for Behavioral Determinants

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Animals display a wide range of complex behaviors, but it has been challenging to dissect the underlying genetic basis for behavioral differences between species. Social grouping has evolved in several species such as fish, which form both shoals and schools. Shoals are simply groups of fish, while schools require more complex behavior including coordinated body position and synchronized movement between all members of the school. In a recent report published in *Current Biology*, Drs. Anna K. Greenwood and Catherine L. Peichel (Divisions of Human Biology and Basic Sciences) together with their collaborators demonstrate that in threespine stickleback fish two components of schooling behavior, the motivation to form schools and the fishes' ability to position itself within the school, are influenced by different regions in the stickleback genome, a critical step towards understanding the complex relationship between genetics and behavior.

To investigate genetic contributions to behavior, Greeenwood, *et al*. focused on two populations of sticklebacks: strong-schooling marine sticklebacks and weakly-schooling lake sticklebacks. Crosses between these two populations generated hybrid fish with a wide variety of schooling behaviors. Intriguingly, schooling tendency traits such as time spent schooling did not correlate with schooling position traits such as body orientation in these hybrid fish. The ability to separate these two traits in hybrid fish suggested that distinct genetic loci influenced these behaviors. To test this hypothesis, Greenwood, *et al*. employed quantitative trait locus (QTL) mapping to map these two traits to the stickleback genome. In this assay, DNA is isolated from the fish of interest and genotyped using a single nucleotide polymorphism (SNP) array with markers distributed across the stickleback genome to detect genetic differences between fish. Fixed differences were then correlated to the different phenotypes to identify genomic regions associated with the different behaviors. The researchers found that some traits associated with schooling tendency mapped most strongly to chromosome 20, although this association was only suggestive. In contrast, some traits associated with schooling position mapped strongly to chromosomes 4 and 17.

A previous study from the Peichel laboratory in these same hybrid sticklebacks had demonstrated that some anatomic determinants of the lateral line (Wark, *et al*., 2012) map to the same genomic regions associated with schooling position. The lateral line is a sensory organ, in many ways similar to the auditory organs of the ear, that detects vibrations in the surrounding water. Several studies have demonstrated that the lateral line impacts social grouping in other fish species. Importantly, no

lateral line QTL overlapped with schooling tendency QTL, providing further evidence that schooling position and schooling tendency are governed by distinct genetic elements.

Behavioral traits are often highly variable, making the genetic control of behavior difficult to study. However, this study by Greenwood, et al. demonstrates that it is possible to identify discrete regions of the genome that are associated with different behaviors in vertebrates. Their identification of a lateral line anatomy QTL overlapping with a schooling position QTL makes intuitive sense, as lateral line differences may impact the ability to detect neighboring fish in the school. Excitingly, this discovery paves the way to investigate the impact of individual genes on complex behaviors, as one of the genomic regions contains a gene called *Eda* that they suspect plays a role in schooling behavior. "To test this, we have generated transgenic [lake sticklebacks] that ... have a more marine-like lateral line anatomy. We're currently in the process of testing the schooling behavior of these transgenic fish to see if their schooling body position is more like marines," said Dr. Greenwood.

Greenwood AK, Wark AR, Yoshida K, Peichel CL. 2013. Genetic and neural modularity underlie the evolution of schooling behavior in threespine sticklebacks. *Curr Biol* 23(19):1884-8.

See also: Wark AR, Mills MG, Dang LH, Chan YF, Jones FC, Brady SD, Absher DM, Grimwood J, Schmutz J, Myers RM, Kingsley DM, Peichel CL. 2012. Genetic architecture of variation in the lateral line sensory system of threespine sticklebacks. *G32*(9):1047-56.

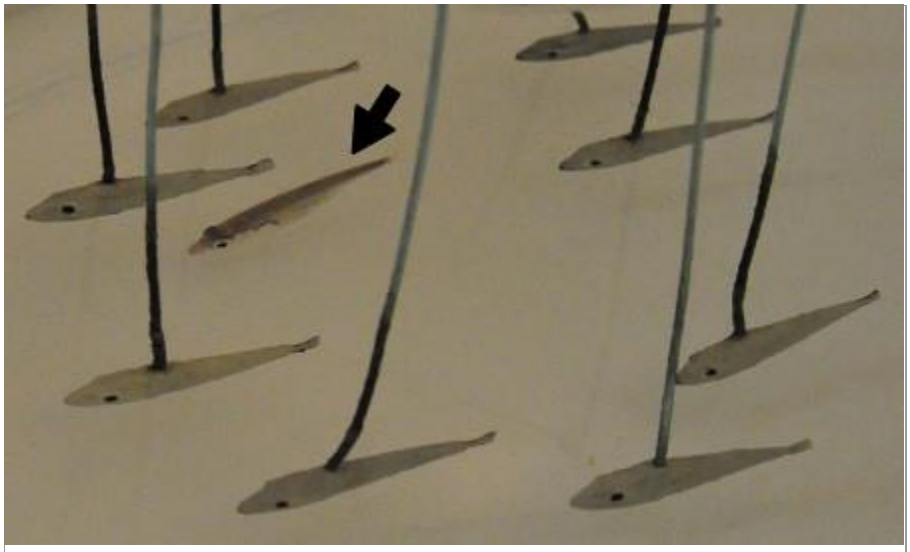

Image courtesy Dr. Anna Greenwood.

A marine threespine stickleback (arrow) schooling with model fish.