Fish fathers exhibit signatures of 'baby brain' that may facilitate parental care behavior

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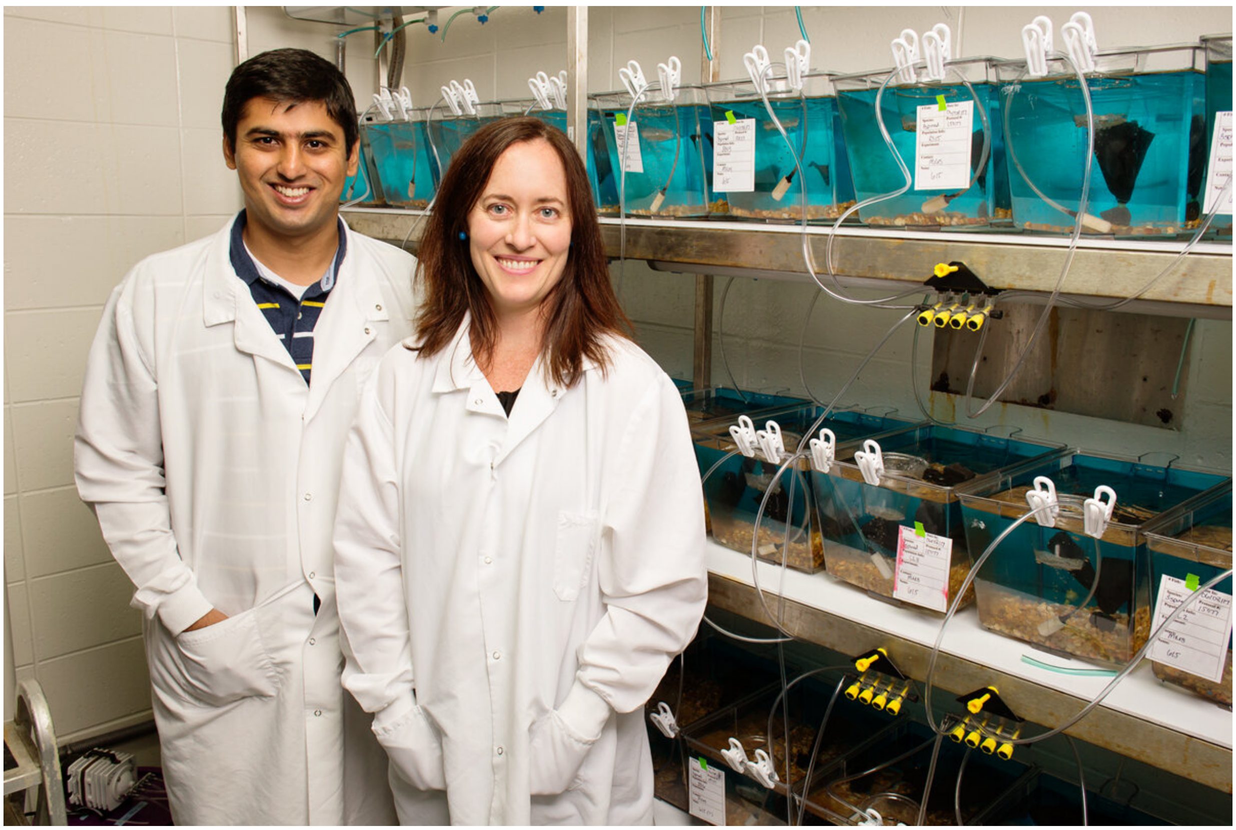

University of Illinois animal biology professor Alison Bell, right, with graduate student Abbas Bukhari. Credit: University of Illinois

Many new parents are familiar with terms like "baby brain" or "mommy brain" that hint at an unavoidable decline in cognitive function associated with the hormonal changes of pregnancy, childbirth, and maternal caregiving. A new study of parental care in stickleback fish is a reminder that such parenting-induced changes in the brain and associated shifts in cognition and behavior are not just for females—and they're not just for mammals either.

Work led by Alison Bell, a professor of evolution, ecology and behavior at the Carl R. Woese Institute for Genomic Biology at the University of Illinois at Urbana-Champaign, found that transition to fatherhood is accompanied by a host of changes in gene activity in the brain. The study, published in *Nature Communications*, focused on male sticklebacks because they, rather than female sticklebacks, provide parental care to eggs and fry. Graduate student Abbas Bukhari was first author of the study.

"The male stickleback defends the territory, he builds the nest, he attracts a female to spawn . . . and the nest is everything to him: it's where his babies are, it's the center of his territory," Bell said, describing the changes experienced by stickleback fathers. "Then the eggs hatch after about a week; he's still defending a territory, he's still protecting his kids, he still has a nest, but all of a sudden he's interacting with his offspring in a different way compared to when they were just eggs."

In some ways, a male stickleback is quite like any other new parent; he must abruptly shift his behaviors from focusing on his own biological needs to prioritizing the protection and care of his relatively helpless young. Stickleback fathers fan to circulate water past their fertilized eggs, keep the nest clean, protect the young from predators, and retrieve wandering fry that stray from the nest. They must exhibit nurturing behavior toward their offspring while still mounting a rapid aggressive response toward intruders that may pose a threat.

Despite this dramatic behavioral transition, stickleback fathers are distinguished from their mammalian counterparts whose neural response to parenthood has been extensively studied: females who gestate their young and lactate to feed them—physiological events that are accompanied by well-documented suites of swift hormonal changes. Yet Bell and her colleagues knew that even though stickleback dads do not experience these events, dramatic physiological changes were still occurring.

"The cues that these dads are getting, they are exogenous, they're not inside his body; these are eggs that are in his nest," Bell said. "It's something that's happening exogenously and socially."

The researchers set out to discover what changes occur in the stickleback telencephalon (similar to our cerebrum) and diencephalon (a brain region that helps regulate hormonal signaling) in association with stickleback male parental care. To characterize the fish brain's response to fatherhood, they measured gene expression—that is, they quantified which genes in the genome were being used to make the proteins they encoded, and how often. To get a complete picture of how fatherhood changed the stickleback brain, they examined gene expression before spawning occurred, after the male began tending his eggs, and at three points throughout the hatching process.

Using statistical analyses tailored to their experimental setup, Bukhari, Bell and their coauthors identified a set of genes whose expression was altered by one or more of these transitional phases of stickleback parenting. They took a closer look at which genes were responding and what functions they might be performing in the paternal brain, and they noticed some familiar players.

"Genes associated with mothering like oxytocin and prolactin and galanin, these are things you read about in the vertebrate mammalian literature all the time, and now they were popping up in our data set," Bell said. "That's part of why we thought it would be really interesting then to compare to mouse."

Oxytocin plays roles in social bonding as well as in directing labor, while prolactin promotes milk production—functions strictly associated with mammals. Yet fish have their own closely related versions of these hormones, as well as of galanin, a hormone that helps regulate aggressive behaviors toward young in adult mice. Changes in genes used for production of these signaling molecules or their receptors in the fish fathers was an intriguing indication that fish and mammal parents might be more molecularly similar than one might predict.

Bukhari designed a method to meaningfully compare the neural responses of the relatively disparate stickleback and mouse genomes. The team was surprised by what this analysis revealed.

"There was overlap... between these stickleback paternal care genes and the mouse maternal care genes," Bell said. "It's surprising to think that the same molecular mechanisms could be involved in parental care in a fathering fish and in a mothering mammal."

Bell suggested that their data on gene activity related to galanin signaling might indicate a mechanism preventing fathers from consuming their own offspring. Comparison of their data to previous studies of gene expression related to aggression in stickleback fish revealed that many of the genes responding to parental care responded oppositely to conflict with an intruder, perhaps contributing further to the appropriate modulation of aggression while caring for young.

"Genes that were going up after a guy has a fight, those are the ones that are going down while he's caring for kids," Bell said.

Although "mommy brain" is often associated in popular culture with a loss of cognitive function, the stickleback study, like other animal and human research, suggests a more nuanced picture in which hormonal signaling and external cues help prepare male and female brains for parenthood via behavioral changes rather than deficits.

"A long time ago in our evolutionary history, these changes were happening for dads in the most powerful way, as it happens for mammalian moms. I feel like that takes a little bit of the edge off the sexist connotations of 'mommy brain'," Bell said. "It's no wonder it is such a transformative experience. I just think that it's happening to dads too."

More information: Syed Abbas Bukhari et al, Neurogenomic insights into paternal care and its relation to territorial aggression, *Nature Communications* (2019). DOI: 10.1038/s41467-019-12212-7

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