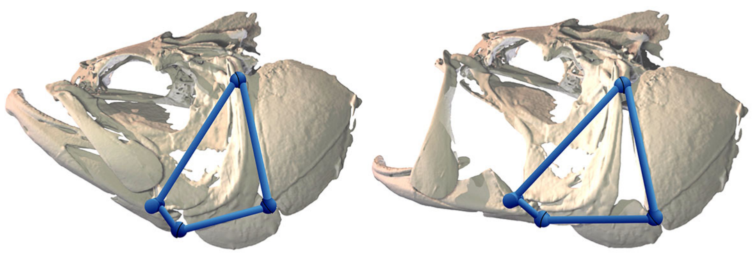
INSIDE JEB

How largemouth bass pucker up to slurp



The bone structure in a largemouth bass head with the bar model overlaid. Photo credit: Ariel Camp and Aaron Olsen.

It might look as if a largemouth bass is simply puckering up for a kiss when it slurps up a tasty morsel, but the routine motion is an extremely sophisticated and coordinated manoeuvre. 'The mouth and throat of fish are built from over 15 mobile bones', says Aaron Olsen, from Brown University, who explains that the animals rapidly unfold the intricate bone network to expand their mouths and suck in water; Ariel Camp likens the movement to unfurling an umbrella. The bones are so well connected that even a dead fish can pop its mouth open if you gently rotate the opercular bone covering the gills. Based on the bone structure, scientists were able to build simulations that successfully reproduced many aspects of the movement, but they failed to accurately reproduce the movement of the lower jaw. As Camp had previously collected high-speed X-ray movies that allowed her to follow the motion of the elaborate bone structure in minute detail, Olsen and Elizabeth Brainerd began the complex challenge of simulating the movements of the bones relative to each other in an attempt to reproduce the jaw swinging motion.

After identifying the key bones (the suspensorium and interoperculum) that link the operculum to the lower jaw, Olsen then represented each structure as a rigid rod, and linked all four together with hinge joints to form a quadrilateral structure (known as a four-bar linkage), before rotating the rod that represented the operculum to see how the movement propagated through the bones to swing the jaw open. However, the simple model failed to reproduce the inward swinging motion of the jaw bone that accompanied the downward rotation that Camp had seen as the fish opened its mouth.

In the next simulation, Olsen and Brainerd wondered whether the joints at both ends of the interoperculum might rotate in three dimensions, like a ball-and-socket, so they replaced the hinge joints at the ends of the interoperculum with more mobile ball-and-socket joints, but this also failed to reproduce the correct jaw movement. And when they replaced all of the hinges with ball-and-socket joints, the simulated motion of the flexible system was more realistic, but still did not recapture the true jaw motion. It was only when the team placed ball-and-socket joints at the operculum–suspensorium joint, the operculum–interoperculum joint and the interoperculum–lower jaw joint, while retaining a simple hinge at the lower jaw–suspensorium joint, that the simulation most closely mimicked the jaw bone's inward and downward rotations. However, Olsen admits that the team was surprised by how much the lower jaw swings inward as it opens, and they suspect that it may also twist a little, suggesting that there may be some give in the ball-and-socket that links it to the interoperculum.

So there is more flexibility in the joints that link the opercular to the jaw bone than had been thought previously, and the team is hoping that their new approach could help them to better understand how other suction feeders rapidly expand their mouths while vacuuming up food.

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Olsen, A. M., Camp, A. L. and Brainerd, E. L. (2017). The opercular mouth-opening mechanism of largemouth bass functions as a 3D four-bar linkage with three degrees of freedom. *J. Exp. Biol.* **220**, 4612-4623.

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Harnessed ants learn the hot way

A harnessed ant with open mandibles. Photo credit: Paul Devienne, Laboratoire d'Ethologie Expérimentale et Comparée.

The sudden appearance of a smell can instantly comfort us or make us uneasy. Pleasant smells may trigger happy childhood memories, and smells we find unpleasant may set us on edge and drive us to avoid whatever is malodorous – sometimes for reasons we don't fully understand. This reaction to smell is not unique to humans. Insects rely heavily on their attraction to and repulsion by smells, based on their past experiences. 'We usually think that insects are little robots, following rules that are innate, and they're not plastic in their behaviour,' says Patrizia d'Ettorre, at the University of Paris 13, France, 'but, this is absolutely not true. They do learn a lot.' For decades, honey bees were the insects we turned to for insights into learning and memory. However, d'Ettorre is convinced that ants, being more diverse in ecology and life history than honey bees, will open up a broader view into the mechanisms behind learning and memory. Her team, including researchers from the

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University of Toulouse, France, wanted to study aversive conditioning in ants – training them to associate an otherwise neutral smell with an unpleasant experience. The problem? 'This has not been done so far with ants,' d'Ettorre says. Why not? 'I think it's because it's difficult', she laughs, 'We really had to be stubborn to make this work.'

Lucie Desmedt, a Master's student in d'Ettorre's lab, set to work on a way to train carpenter ants to learn and remember a new unpleasant odour association. She placed individual ants into a harness and presented them with one of two natural odours. To help the ant learn a bad association with the odour, she touched the ant's back legs with a hot probe, an experience not unlike that which an ant would encounter walking on open ground in the summer. This unpleasant sensation caused the ant to open its mandibles wide in an aggressive display.

Desmedt tested the ant's ability to learn in two contexts. She trained one group to associate a single odour with the heated probe. For the second group, she provided the ants with two odours, one associated with a dab of the hot probe and another where no heat was applied. She then tested the ant's ability to remember the negative association by presenting the 'hot' odour, or the other odour, to each ant 10 min later and watching the ant's reaction.

Not surprisingly, the ants learned a negative association with the hot odour after just a few trials. And, mandibles wide, they displayed their discontent when they encountered the hot odour again 10 min later. Also, the ants learned and remembered best when they were presented with the additional odour (that was not accompanied with heat), which is similar to the behaviour of ants trained with food rewards and for honey bees and *Drosophila*. d'Ettorre suspects that it is easier for the animals to learn to remember the odour that is associated with the uncomfortable experience when it is trained in parallel with a second odour, and says 'The stimulus is more relevant', probably because they have another experience to compare it with. In other words, context makes a difference.

With a successful new way to train ants, d'Ettorre lists potential future projects: 'We can now study mixtures of odours; we can use a pharmacological approach to study the dynamics of memory, the underlying brain circuits that are working in different types of learning…'. And she hopes to continue to pursuing the nitty gritty of those learned smell associations that treat or torment animals of all sizes.

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Desmedt, L., Baracchi, D., Devaud, J. M., Giurfa, M. and d'Ettorre, P. (2017). Aversive learning of odor–heat associations in ants. *J. Exp. Biol.* **220**, 4661-4668.

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