Inside JEB is a twice monthly feature, which highlights the key developments in the *Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

ELECTRIC PERSPECTIVE


Picture provided by Jacob Engelmann

Vision probably isn't much use if you live in sluggish, muddy waters. So several species of West African fish have opted for an alternative view. They perceive the world through a weak electric field, emitted by an electrical organ near the fish's tail. Jacob Engelmann says that most analyses of the electrical images perceived by these fish have focused on the electric field cast over the body surface, but explains that this does not square with the elephantnose fish's behaviour or physiology. According to Engelmann, the electric fish uses its trunk-like structure, known as the Schnauzenorgan, to probe soft sandy river bottoms and the Schnauzenorgan is covered in electro-sensitive cells. Engelmann suspected that he should measure the electric field near to the Schnauzenorgan to get a better sense of the field from the fish's perspective (p. 921).

But measuring electric fields around the fish's head was going to be tricky: elephantnose fish can whip their Schnauzenorgans back and forth at speeds up to 800° s^{-1} and they have a complex head shape. Engelmann would have to design a precise measuring system, as well as carefully immobilising the animal, to accurately plot the electric field around its head. Teaming up with Roland Pusch and engineer Axel Mickenhagen, Engelmann designed and built an electrode that could simultaneously measure all three components of the electric field at precise positions to glimpse what the elephantnose perceives.

Plotting the electric field in planes around the fish's head, Engelmann quickly realised that it looked almost like a classic dipole field, but elongated along the head. The Schnauzenorgan also appeared to funnel the field along the proboscis's surface, just like his colleague Angel Caputi had suggested. And when the team gently moved the Schnauzenorgan to one side and remeasured the field, they saw that the field followed it. Engelmann admits that he was stunned by this discovery and explains that this allows the fish to distinguish the presence of novel stimuli from distortions, caused by their activity, by using their anatomy rather than colossal amounts of brain power.

Next the team wondered how objects would distort the field around the Schnauzenorgan to produce an electrical image. Placing small metal and PVC cubes or spheres close to the Schnauzenorgan, Pusch and Engelmann painstakingly recorded the distorted electrical fields and found that they were very different from the fields recorded near the fish's body. Electric field measurments at the fish's trunk give a misleading view of the field perceived by the electrosensitive Schnauzenorgan.

Finally Engelmann teamed up with Kirsty Grant, Michael Hollmann and João Bacelo to measure the density of electroreceptors on the proboscis to find out which region of the Schnauzenorgan is most sensitive to electric fields. Sabine Nöbel also tested the sensitivity of the Schnauzenorgan by recording the electric organ's discharge rate when presented with an electric dipole at positions near the Schnauzenorgan, and found that it was most sensitive at the tip. Which was the exact spot where Grant, Hollmann and Bacelo had recorded the highest electroreceptor densities.

10.1242/jeb.017814

Pusch, R., von der Emde, G., Hollmann, M., Bacelo, J., Nöbel, S., Grant, K. and Engelmann, J. (2008). Active sensing in a mormyrid fish: electric images and peripheral modifications of the signal carrier give evidence of dual foveation. *J. Exp. Biol.* **211**, 921-934.

FISH'S EXPENSIVE ELECTRIC SERENADE

It's easy to see how a deep voice or massive muscles can communicate fitness, but whether electric fish can send the same message with crackling electric discharges wasn't clear. Philip Stoddard, from Florida International University, knew that at night male *Brachyhypopomus pinnicaudatus*'s electric buzzes were bigger and longer than the females. But why were the nocturnal males so much louder than the females when they also run the risk of attracting predators? Could the crackling communications convey information about a male's condition that could improve his chances of attracting a mate? Stoddard's student, Vicky Salazar, explains that this could be the case if the males were investing significant amounts of energy in their electric communications. But everyone assumed that the signal's metabolic cost was negligible, so the team decided to measure the metabolic cost of male and female electric discharges (p. 1012).

Salazar took on the challenging job of designing a respirometer that was watertight, so that she could accurately measure the animal's oxygen consumption, and transparent to the fish's electric discharge. Eventually she came up with a sealed unglazed ceramic tube that the nocturnal fish could rest in contentedly during the day as she recorded their metabolic rates.

Next Salazar had to devise a way of partitioning out the discharge's metabolic cost from the fish's routine costs. Fortunately the team already knew that metomidate, an anaesthetic, would only sedate the fish, and a curare analogue, flaxedil, would silence the fish's electric organ discharges. By sequentially administering the drugs, Salazar could systematically shut down different components of the fish's metabolic budget and dissect out the discharge's cost. Having recorded the fish's electric organ discharges after administering the metomidate, Salazar quickly removed the fish from the tube, injected it with curare, and returned it to the respirometer before measuring its standard metabolic rate. Fortunately the effects of both drugs wore off quickly after the experiment, and the fish soon recovered and began firing off again.

However, injecting the curare analogue when the fish became active at night was perilous. Salazar explains that the fish's electric discharge pattern became disturbed when she switched on her headlamp so that she could see to inject them. She tried to shield the fish with a red filter, but then she ran the risk of injecting herself. Realising that the nocturnal experiments were too hazardous, Salazar changed tack. She abandoned the respirometer tube, recording the metabolic rates of a pair of active fish in a tank, before calculating the metabolic cost of each individual's nocturnal electric discharges based on models of her daytime recordings.

Calculating the electric discharge's metabolic cost, Salazar realised that it cost the males dear. According to Salazar, the males invested anything from 11% up to a colossal 22% of their metabolic rate in their crackling serenades. However, the females hardly exerted themselves at all, expending a minimal 3% on electric discharges. And when Salazar compared the males' physical condition with the amount of effort they put into their electric hum, she realised that the males were probably broadcasting information about their condition too. The fattest and healthiest males could well use their big electric buzzes to entice females to mate with them while warning smaller males to steer clear.

10.1242/jeb.017806

Salazar, V. L. and Stoddard, P. K. (2008). Sex differences in energetic costs explain sexual dimorphism in the circadian rhythm modulation of the electrocommunication signal of the gymnotiform fish *Brachyhypopomus pinnicaudatus*. *J. Exp. Biol.* **211**, 1012-1020.

HOW HORSES GALLOP UP HILL

Biomechanics studies of galloping have a long and august history. In 1878 Eadweard Muybridge's photographs of a galloping horse, taken with 24 cameras at Stanford University, proved what the human eye could not see: that the galloping animal becomes airborne for a brief instant during each stride. Since then, horse biomechanists have used increasingly sophisticated technologies to resolve the complexities of galloping, including high speed film, force plates and treadmills. More recently Kevin Parsons, a vet from The Royal Veterinary College in Hertfordshire, UK, working with Thilo Pfau and Alan Wilson, have developed a system of accelerometers, worn by horses and coupled with GPS, to accurately measure horses' stride patterns to find out how the animals gallop up slopes (p. 935).

But scientists aren't the only people intrigued by galloping horses. Parsons explains that the horse racing industry is keen to understand how horses negotiate different terrains and surfaces; 'they want to know how exercising on inclines affects the forces on horses' legs because higher forces can cause injuries', he says. Working with a world famous trainer, the team travelled to Somerset to test out their accelerometer set-up on elite galloping thoroughbreds to find out how the animals modify their gait while ascending a slope.

According to Parsons he was up before dawn each day to collect data as the horses and their jockeys went out for training runs. Parsons explains that his data collection had to fit in with the horses' training regime and adds that 'the jockeys aren't negotiable; we needed the horses to gallop on the track, and the horses won't gallop unless the jockey's there'. Taking advantage of this, Parsons attached a GPS system to the jockey's hat to track the horse's location, as well as gluing accelerometers to all four of the animal's hooves, before the horse joined a chain of thoroughbreds heading out to the track. Then it was a case of keeping his fingers crossed; 'If one accelerometer failed, the data set was useless' he remembers.

Fortunately after a week at the stables, Parsons returned to The Royal Veterinary College with almost 5000 galloping strides to analyse. Correlating the jockey's GPS location with the time each hoof spent in contact with the ground, Parsons was able to distinguish between strides on the flat and strides as the horse climbed. Parsons admits that manually transcribing each hoof beat was tedious, but eventually he was able to calculate the forces on each leg and found that the back legs generated more force to power the horse up the hill than the front legs. Parsons suspects that this information could help trainers working with injured animals to reduce the forces on injured forelimbs during rehabilitation.

Knowing that trotting horses reduce their stride frequency as they ascend an incline, Parsons calculated the gallopers' stride frequency and was surprised to see that it had increased; the ascending horses were swinging their legs faster, just like a human runner. Parsons suspects that there could be two explanations for the increase. Either the leg contacts the rising ground more quickly at the end of each swing, or the elastic tendons in the horse's leg stores more energy to catapult the leg forward more quickly.

10.1242/jeb.017798

Parsons, K. J., Pfau, T. and Wilson, A. M. (2008). High-speed gallop locomotion in the Thoroughbred racehorse. I. The effect of incline on stride parameters. *J. Exp. Biol.* **211**, 935-944.

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