Cover illustration

Chameleon of the sea

Ambush predators possess the advantage of surprise and, when coupled with speed, are devastatingly successful. Speed and accuracy require adept sensory mechanisms, most commonly vision, and excellent vision usually requires large eyes especially among the vertebrates. But evolution has found creative, often unique, solutions for the smaller vertebrates that survive in the highly competitive world of predation. The sandlance, *Limnichthyes fasciatus*, has just such a unique solution.

L fasciatus is no more than 20–40 mm in length and hides in the loose sand of the shallow reefs of the Indo-Pacific. Using creative adaptations, this benthic predator will explode from its camouflaged hide among the coral rubble in a brief and extremely rapid sally to attack small planktonic prey.

Most fish have all the refractive power of their eye concentrated into a round crystalline lens (*BJO* covers May 2002 and Oct 2004) with little or no refractive effect from the cornea since the refractive index of the cornea and seawater is approximately the same. *L fasciatus*, though, has a very thick cornea representing approximately one seventh of the diameter of the approximately 1 mm long eye, as can be seen from the figure on this page. This fish, unlike any other, has a cornea with an embedded lenticle that functions as a lens with approximately 180 dioptres of accommodative potential that can be unleashed in a fraction of a second by the use of a striated retractor cornealis muscle. Corneal accommodation is seen in many birds, but is unique to this fish in the piscine world (Pettigrew JD, Collin SP, *J Comp Physiol A* 1995;**177**:397).

The crystalline lens is peculiar as well, at least for a fish. The lens of the sandlance is flattened. The combination of a corneal lenticle with a flattened, but hyperopic, lens creates a magnified image on the fovea. Although the optics are complicated and beyond the scope of this essay, the nodal point is moved forward and separated from the axis of rotation allowing monocular parallax. This displacement of the nodal point and separation of the nodal point from the axis of rotation create a significant displacement of the image on the retina, and thus creates monocular parallax. Most vertebrates must move their head or even their body to gain monocular distance cues through parallax. Such animals as a robin or pigeon bob their heads do this, but the sandlance merely moves its eye to achieve the same degree of parallax. Because of this unique system, it can function perfectly well, monocularly, as an ambush predator in a three dimensional world and because of the nature of its visual system can dissociate its optokinetic response from one eye to another.

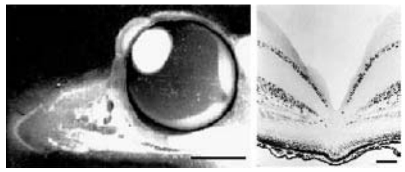

Figure 1 Note the corneal lenticle, the size of the lens, and the convexiclivate fovea. (From Collin SP, Shand J. In: Collin SP, Marshall NJ, eds. *Sensory processing in aquatic environments* 2003:139–69. Courtesy of Springer, New York.)

The almost exclusively cone retina consists of a peculiar matrix of a single cone surrounded by four double cones. The ganglion cells are tightly packed with a foveal density of 150 000 cells per mm^2 which is the highest among all the fish species studied and rivals the highly specialised retinas of birds (Collin SP, Collin HB, *J Comp Neurol* 1988;**278**:226). The fovea is convexiclivate, meaning that it is steep walled with a deep central depression as can be seen in the figure. This anatomical arrangement probably provides image magnification because of the difference in the index of refraction between vitreous and retina combined with the steep curvature of the sides of the foveal pit.

The eyes move independently, and alternately (to avoid the simultaneous acquisition of different prey by each eye that could lead to the fish theoretically splitting itself down the middle). The animal burrows slightly below the sand with only its eyes exposed, and waits, and scans with both eyes—independently. Once a planktonic prey species, such as a copepod, comes into striking distance, *L fasciatus* will waste little time in its attack. Over these short distances of a few body lengths, its speed is a humbling 4 metres/s. This is approximately 200 body lengths/s and makes the sandlance's strike for all the world like the strike by the chameleon's tongue. Coupled with an oral ''cage'' that allows the fish to engulf prey if it is not exactly on target or if the prey should move erratically, this species rarely misses.

Interestingly, it can, and does, target prey monocularly because of its unique optics, which resemble those of a chameleon and are substantially different from our own. The monocular movements of *L fasciatus* contain the familiar rapid saccades to an eccentric anatomical position to locate potential prey, but what follows that saccade is an independent monocular drift back towards a more neutral position. In most animals, the oculomotor system has fast saccades to prevent a slow blurring or destabilisation of the image, but the slow drift in the eyes of the sandlance is a distinct departure from the norm and probably occurs because of a passive relaxation of the extraocular eye muscles (Fritsches KA, Marshall J, *Curr Biol* 1999;**9**:292).

This remarkable little fish should remind you of another ambush predator, the chameleon, because of numerous similarities such as camouflage, rapid accurate targeting of small mobile prey, corneal accommodation, telescopic optics with a forward movement of the axis of rotation of the eye, monocular range finding, and extreme non-synchronous ocular movement. Now if *L fasciatus* could only change colour!

I R Schwab, S P Collin, J D Pettigrew
University of California, Davis, Sacramento, CA, USA; irschwab@ucdavis.edu

Pictures by S P Collin, Department of Anatomy and Developmental Biology, and J D Pettigrew, The Vision, Touch and Hearing Research Center, School of Biomedical Sciences, University of Queensland, Brisbane, Australia. Visit the website for a video of this creature (http://bjo.bmjjournals.com/supplemental).

Chameleon of the sea

I R Schwab, S P Collin and J D Pettigrew

Br J Ophthalmol 2005 89: 4
doi: 10.1136/bjo.2004.057240