Healthcare industry BW

The females choose their mates

Charles Darwin regarded swordtails (Xiphophorus) as the perfect way of explaining his theory of sexual selection. Among these fish, it is the females and the length of the sword – a conspicuous extension of the caudal fin – that determine the mating partner. The team of researchers led by evolutionary biologist Dr. Gerrit Begemann at Constance University is using swordtails to investigate the development of traits that evolved by sexual selection. Their major focus is the molecular mechanism of growth control in the caudal fin. Or put more simply: why do these fish have swords?

Swordtails are small freshwater fish that nowadays can be found in many aquaria around the world. Together with the closely related platy fish, the genus Xiphophorus has 24 species. However, the research of Professor Axel Meyer, renowned evolutionary biologist from Constance, showed back in the 1990s that platy fish lost their swords during evolution.

The criteria that determine the choice of a mating partner have for a long time remained unknown. However, it is now known that females find the entire length of males attractive.

Dr. Gerrit Begemann is investigating the evolution of developmental mechanisms on swordtails. (Photo: Keller-Ullrich)

Apparently, body size indicates the "fitness" of the mating partner. However, if the female has to choose between two males of equal size, then the attractiveness of the sword, i.e. caudal fin, will determine the female's choice. The stimulus of the caudal fin, which also differs in colour from the fish's body, is so strong that even platy females chose a male swordtail if they have to make a choice.

Although the caudal fin increases the male swordtails' attractiveness to female fish, the sword also has a range of disadvantages. The sword makes swimming difficult and also involuntarily attracts the attention of enemies. Nevertheless, the male swordtail beauties manage to court female fish, which regard the size and colour of the fins as a sign of "good genes". Thus, the progeny inherit the favourable genetic traits of the parents, which means that male progeny will develop long swords and the female progeny develop a liking for this particular trait. Thus, this selection system could be maintained over many generations and evolution led to increasingly longer swords.

Looking for signalling pathways

It is assumed that the swordtail genes accumulated mutations that led male fish to develop longer caudal fins than the females, explained Gerrit Begemann. The researchers from Constance are now investigating the molecular processes that regulate the growth of the sword and are hoping to gain insights into the rules of evolution.

Swordtails drawn by Charles Darwin (left) and photographs (right) (Photo: Begemann)

"If we are able to discover the genetic switches that enable swordtails and platy fish to grow fins of different lengths, this will provide us with important insights into the kind of mutations that have led to the development of these complex reproduction systems," explained Begemann.

In the meantime, Begemann's research group have succeeded in showing that testosterone plays an important role in the growth of the swords. If testosterone is added to the water in which the fish are kept, platy fish will also develop a sword, albeit a small one. Testosterone alone will not turn platy fish into swordtails, but the experiment shows that platy fish still possess parts of the genetic programme that enables them to develop swords. That is why the Constance biologists are looking for genes that might potentially be activated by testosterone. As the search for such genes is rather like looking for a needle in a haystack, the researchers have been looking for similar mechanisms that have already been thoroughly investigated. In zebrafish, several genes are known that are responsible for the regeneration of damaged fins. Such genes are also involved in the development of fins. "We were therefore looking for genes that were already known from zebrafish research," explained Gerrit Begemann.

The researchers found that the activity of the transcription factor msxC, which also promotes cell division and hence growth in other tissues, and that of a fibroblast growth factor receptor (FGFR) correlate with sword growth. "This does not provide us with an unexpected gene, but at least helps us increase our knowledge about such phenomena," said Gerrit Begemann.

Regulation makes the difference

The researchers also found that the system that regulates the growth of the sword in swordtails, also accounts for other differences. Swordtail males and females not only differ due to the presence of the male sword, but also through the shape of their anal fin. The male gonopodium is a testosterone-induced tubular modification of the anal fin that the males use to fertilise the eggs in the body of the females. Swordtails are viviparous fish. In evolutionary terms, the gonopodium is older than the sword. The researchers assume that the same genes code for gonopodium and sword, but are differentially regulated. They found that in juvenile males, as well as during testosterone-induced sword development, expression of the transcription factor msxC is markedly upregulated in the sword.

In the case of gonopodium and swordtail caudal fin, evolution does not manifest itself through the alteration of proteins. “It is not only the genes, but also the switches in front of the genes that can undergo changes,” explained Gerrit Begemann. The ancestors of modern swordtails most likely had a developmental programme that led to the development of gonopodia when the animals reached sexual maturity, i.e. when they fell under the influence of testosterone. Evolution then led to the activation of this “growth module” in the caudal fin, which means that genes such as msxC and FGFR came under the regulatory control of the sex hormone testosterone.

In order to show how the growth of the fins is controlled and what leads to their typical shape and colour, Gerrit Begemann’s colleagues transplanted individual sword rays from the lower to the upper side of the caudal fin and discovered that the sword also grew out from the upper part of the fin. It is assumed that a single fin ray triggers the growth of neighbouring rays, in which signalling molecules migrate from one cell to another. This is another of Begemann’s research goals. “We now know what to look for. We have to look for diffusing signalling molecules that are produced by the swords and are able to determine the growth and pigmentation of their direct environment.”

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Further information

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