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The arsenal of paramecium

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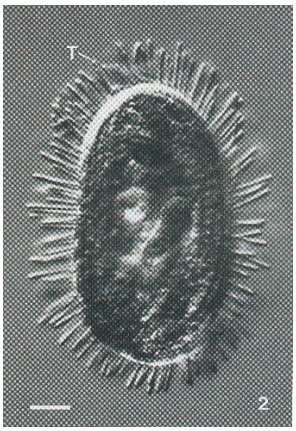
Harpoons are not only man's invention. *Paramecium* has also developed quite a sophisticated harpoon-like means of defence: trichocysts. The Algerian protozoologist Emile Maupas (1842-1916) had already observed trichocysts through a light microscope in the 19th century and noted an "explosion so instantaneous [at the cell's surface] and so fast that it was quite impossible to follow the transformation of the spindle-shaped rod into a fine needle".

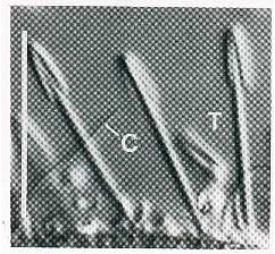


An angry *Paramecium*

Courtesy of Robert Peck

Trichocysts are carrot-shaped exocytotic vacuoles, 3 to 4µm long with a diameter of 1µm and surmounted by a tip about 2µm long. They are docked, by the thousands and at regular intervals, around the inside of the cell membrane. A carrot is not a harpoon though. The peculiarity of a trichocyst is its contents, which is what Maupas observed. These bio-harpoons are full of trichocyst matrix proteins (TMPs) which are bound together in a para-crystalline structure reminiscent of the para-crystalline structure of tropomyosin, itself involved in muscle contraction.

In times of peace, there is a spontaneous exocytosis rate of 2 to 3 trichocysts per minute. However, when *Paramecium* is attacked, the compact crystalline structure shoots out of the cell and is propelled by its own decondensation. One shot takes less then a millisecond! It then adopts a second more relaxed and irreversible crystalline conformation, which has lengthened by a factor of 8 (25-35µm) and is stable. "This is one of the aspects which is so extraordinary", says Dr Robert Peck, a protozoologist at the University of Geneva, "one same protein structure which adopts two different crystalline structures. There could be high interest here for chemists and polymer research." The general effect is one of a harpoon being fired. What is more, electron microscopy has shown that this peculiar ammunition actually takes on the conformation of a harpoon at its tip…



Harpoon-shaped trichocysts

Courtesy of Robert Peck

Scientists are now making efforts to understand TMPs on the molecular level. There are more than 100 different kinds in one same trichocyst, which are produced by several different multigene families. TMPs are synthesized as 40-45kDa precursors, which are processed to 15-20kDa polypeptides by proteolytic maturation. Each precursor molecule gives rise to two mature polypeptides. It has been argued – on the sole basis of logistics – that all TMPs

may have evolved from one same gene, simply because *Paramecium* needed to renew its arsenal, and fast. Peck is sceptic. “There is little similarity among the primary sequences”, he says, “however it is true that their secondary structures are amazingly similar.” Indeed, TMPs may well share a unique protein structural organisation in *Paramecium*: probably a 4 alpha-helical antiparallel bundle suggested by the heptad repeats in the primary sequence.

What triggers off these biological missiles? In an attempt to understand, Harumoto et al. observed the logic of war between *Dileptus* and *Paramecium*. *Dileptus* likes to eat *Paramecium*. *Paramecium* does not like to be eaten. When *Dileptus* becomes offensive, it makes a first hit with its proboscis. *Paramecium*’s immediate reaction is an explosive release of trichocysts from the site of hit. This simultaneous discharge of its artillery is not a salute but allows *Paramecium* to ward off the predator possibly by uprooting the cilia on the proboscis and by pushing *Dileptus* away. Concomitantly, the rapid firing of trichocysts synchronously propels *Paramecium* away from danger. Needless to say, the faster the reaction, the less chance *Paramecium* has of being eaten.

Astonishingly, there is no attack when *Dileptus* simply brushes past *Paramecium*. Trichocysts are only launched once *Dileptus*’ tentacle has made firm contact with its opponent. Battle can be laborious. Indeed, one sole discharge of trichocysts may not be sufficient to ward off a predator. With an additional proboscis prod, *Paramecium* sends off yet another batch of missiles. The lives of a *Paramecium*, though, are few: a second prod at the same site causes swelling of the prey. And if *Dileptus* continues to attack unrelentingly at the same spot, *Paramecium* simply disintegrates, which must surely be a disagreeable metamorphosis to go through.

Paramecium cannot frighten off all predators. “It is the same with humans”, comments Peck, “take any weapon, it can be offensive for some yet harmless to others. It all depends on the type of protection you have.” For instance, another predator, *Didinium*, seems to have perfected its offensive artillery and a launched trichocyst is simply ignored. Perhaps then, *Paramecium* should now turn to more sophisticated weaponry.

Cross-references to Swiss-Prot

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Trichocyst matrix protein T1-B, *Paramecium tetraurelia* : Q27180
Trichocyst matrix protein T2-A, *Paramecium tetraurelia* : Q27173
Trichocyst matrix protein T2-B, *Paramecium tetraurelian* : Q27174
Trichocyst matrix protein T2-C, *Paramecium tetraurelia* : Q27181
Trichocyst matrix protein T4-A, *Paramecium tetraurelia* : Q27182
Trichocyst matrix protein T4-C, *Paramecium tetraurelia* : Q27176

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