Nudibranch Defense Using Stolen Hydroid Polyps

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Martin R, Walther P. 2002. Effects of discharging nematocysts when an eolid nudibranch feeds on a hydroid. Journal of the Marine Biological Association of the UK, 82: 455-462.

Nudibranchs, or sea slugs, represent one of the many diverse lineages of the gastropod molluscs. Having lost their shells, nudibranchs soft bodies are extremely vulnerable to predators, and they are preyed upon by a variety of fish, crab, turtle, and sea star species as well as other nudibranchs. As they have lost the hardened shell which most other gastropods rely on, sea slugs have evolved a numbers of other ways to protect themselves. Some species rely on camouflage or aposematic coloration to either hide from or warn away predators. Others produce debilitating toxins or irritating acids or derive from their prey. A subset of nudibranch species known as the Aeolids feed on hydroid colonies and integrate the nematocysts into their own cells, storing them in the cerata and giving any predators that touch them a painful sting. The exact method by which the nudibranchs ingest the nematocysts and move them through their body to the cerata is unknown. It is a complex question, as the nudibranchs must be able to ingest and move the nematocysts without them firing, since the stinging cells would both be useless as a defense mechanism after it has fired and it would undoubtedly not be good for the animal to have nematocysts firing inside it.

In 2002, Martin and Walther set out to determine a possible mechanism for the successful ingestion and redistribution of nematocysts by nudibranchs. Building off of previous work, they proposed two hypotheses for the nudibranchs' ability to avoid triggering the nematocysts when they ingested them: either the nudibranch's epithelial and digestive cells are protected by specialized elements that prevent damage from fired nematocysts, or nudibranchs are somehow able to prevent the hydroid from firing the nematocysts in the first place. Many species of nudibranchs have been shown to possess a certain kind of cell, known only as a "special vacuole", throughout their body walls and digestive tissue, and the researchers were curious to see if the vacuoles might play a role in protecting the nudibranch while it feeds. The authors focused on the nudibranch species *Cratena peregrina* and the colonial hydroid it feeds on, *Eudendrium racemosum*. *E. racemosum* feeds with tentacles and defends itself with cnidophores, which can be distinguished from the feeding tentacles as they are club-shaped, as well as being wider and thicker. In addition, the cnidophores are armed with larger, more densely packed nematocysts (12.07 x 4.73 µm) of a different structure than the feeding tentacles (8.64 x 3.59 µm). *E. racemosum* forms large colonies of individuals and *C. peregrin*a can often be found living in and amongst the colony on which it grazes. The nudibranch relies on the polyps it extracts from the hydroid for defense, as they will fire into any unlucky predator that comes in contact with the sea slug's cerata.

The researchers exposed isolated cerata of the nudibranchs to pieces of hydroid tentacle and cnidophore and froze them at high pressure. They also prepared a selection of SEM slides of cerata exposed to tentacles or cnidophores. Finally, the authors tested a group of nudibranchs that fasted for several days and then were fed hydroids. Afterward, the nudibranchs were killed and the contents of their digestive tracts and stomachs were examined.

From their experiments with the isolated cerata, the researchers were able to see that interaction with the tentacles was not enough to damage the nudibranchs epidermis. However, contact with the hydroids' defense structures (cnidophores) resulted in damage to the epidermis as well as damage to the nerves and muscles. The “special vacuoles” released their contents, which proceeded to adhere to the cnidophores, once the epidermis was ruptured. When the digestive tracts of the nudibranchs were examined, 4 of the 5 specimens had higher numbers of intact nematocysts compared to discharged nematocysts, with one having 70 intact and only 5 discharged (Fig 1). The walls of most of the digestive tract and stomach are lined with “special vacuoles” and the researchers hypothesized that they may enable the nudibranch to process the nematocysts without incurring injury to themselves.

The results of Martin and Walther's study indicates that, at least in this species, there is some specialization of the digestive tract that enables the nudibranchs to ingest the nematocysts without them firing. Additionally, sea slugs are at least somewhat protected from their prey, although not completely. One aspect of the hydroids that the researchers found peculiar was the arrangement of their defensive structures; not all of the cnidophores possess the larger nematocysts that were able to damage the nudibranch. The researchers tested the effects of contact with the hydroid's defenses by exposing small pieces of nudibranch cerata to hydroid tissue. Might there be another element to the nudibranchs' prey selection that couldn't be reproduced by the researchers, for instance strategies they may use to avoid the particular sections of the hydroids that can damage them? Martin and Walther also discussed the possibilities of further research in examining how the nematocysts, once ingested, were installed in the cerata. One possible hypothesis is that only immature nematocysts don't fire, and that they finish developing inside the cerata. How might we track what happens to the nematocysts between ingestion and installation in the cerata?

Finally, it is worth considering a broader implication of this behavior. The nudibranch *C. peregrina* is able to not only evade its preys' defense mechanisms but also to utilize those defense mechanisms for its own benefit. In order to do that, it has had to adapt so that it can ingest nematocysts, which ordinarily destroy tissue on contact. How might a complex behavior like that have evolved?

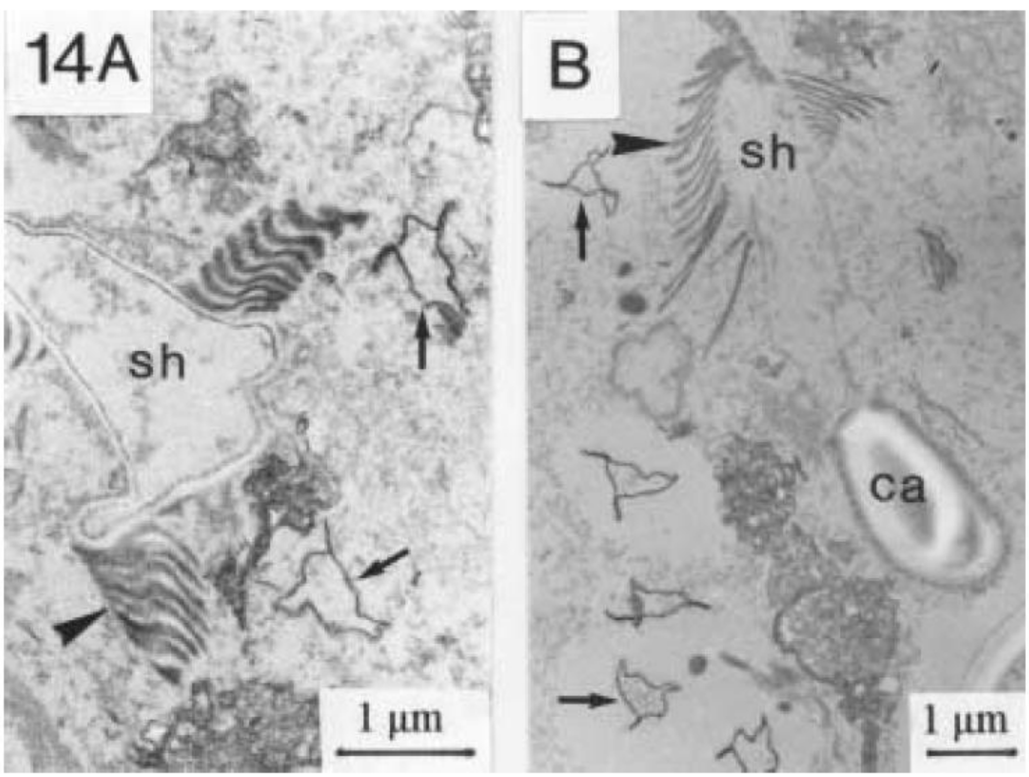

Figure 1: Electron micrograph image of stomach contents, mainly parts of discharged nematocysts: shafts (sh), barbs (arrow heads), threads (arrows), and capsules (ca).