Solving Romantic Mysteries

Would you risk your life to reproduce? Probably not, but little diatom *Pseudostaurosira trainorii* has no other choice. One important survival trick is to pick the right time to have sex, how it does that is investigated by Shinya Sato and Co.

Diatom dilemmas

*Pseudostaurosira trainorii* is Sato’s current subject of observation. If you ever have romantic troubles, just consider for a minute what *P. trainorii* has to go through in its private life.

In order to mate, *P. trainorii* has to deal with the fact that its ancestors ‘decided’ to enclose themselves in a cell wall made of hydrated silicon dioxide. That was not such a bad choice. Earth’s crust is, for example, almost one-third silicon and, additionally, it doesn’t cost more than a smidgen of ATP to precipitate it. So, diatoms have plenty of energy to mate.

In love with diatoms

When asked why he chose to work with diatoms, Shinya Sato from the Royal Botanic Garden Edinburgh has a very special answer for a scientist, “I was simply fascinated by their beauty.” Assertions like that are more often found among artists. He adds, “I remember myself as a university student, admiring diatom pictures in textbooks.”

His artistic admiration of diatoms turned into a dedicated study on the evolution of their shapes. Working under the supervision of Linda Medlin in Bremerhaven, Germany, the Japanese slowly adapted to the Western style. Not without any trouble though. “I wanted to call my PhD supervisor Medlin sensei [master], but I knew it wouldn’t work, so I ended up with a compromise and kept calling her Dr. Medlin. I still remember when I first called her Linda, I was so nervous, my heart was racing and my palms were sweaty. Of course, she accepted, and she was probably even unaware of my uneasiness. Since then I fully adapted to the European life.”

After finishing his PhD, he went to Edinburgh to work with algae expert David Mann. Together they investigate one of the deepest dilemmas in phycology. “Diatoms are one of the most successful groups of eukaryotes, having a widespread distribution and huge species richness. However, we don’t know much about their special ways of life,” admits Sato.

A new cellular structure

The lack of flagella can be explained in various ways, among them, it might just be that no one has been lucky enough to catch them under the microscope. That wouldn’t be too surprising since there are plenty of beings on earth whose sexual stages have never been observed. However, minute analyses of the gametes of *P. trainorii* revealed that the male sex cells did possess flagella, even though only on the male sex cell. The surprise comes when looking at pennates like *P. trainorii* and realising they don’t have a flagellum, anywhere! What happened to the pennate flagellum is a question of its own, but for our *P. trainorii* it means that its gametes can’t swim.

That’s romantic life for our diatom: a single cell covered with a metalloid that has to bet his life on meiosis, just to shed its valuable frustule and produce gametes that can’t even swim. How on earth have they managed to stick around since the cretaceous period?
scope, these filaments or ‘threads’ looked very similar to flagella. Had they found the evasive pennate flagellum? Shinya Sato and colleagues rushed to determine the nature of the mysterious filaments. After days of peering into the light microscope, working with the scanning electron microscope and the laser confocal microscope, the finding turned out to be even more exciting (PLoS ONE, 6(10): e26923).

The extracellular structures resembled flagella produced by the male sex cells and they contained microtubules. However, these thread-like structures couldn't beat or undulate, which makes them unable to propel the gametes. The way they help to reach the egg cells is a cellular novelty. The threads are sticky and the cells can spin to reel them, giving the male gametes the capacity to catch and draw eggs.

“Since the first observation of diatom sex cells in 1847, the only known extracellular structure was the flagellum. The threads represent a totally new structure,” Sato points out. This solves the problem of the gamete motility issue. Once the eggs are within the reach of the male threads, they will be drawn towards the sperm. This cellular love rodeo, however, doesn't yet explain how the cells take the risky decision of shedding their frustules and pulling out the threads.

The pheromone myth

Long ago early workers in the diatom field suggested a simple idea: Diatoms could be the happy owners of sex pheromones. By releasing these substances, gametogenesis will be induced and sex partners will find their way to each other, mate and live happily ever after...which in biology means form a zygote. “The experiment to test the idea was straightforward. Give a filtrate of one sex [vegetative or sexualised clones] to the other, then check for sexualisation,” Sato explains. This looks like one of those experiments that one can quickly run... and well, ever since the concept of sex pheromones was put forward during the fifties, scientists have been giving cell-free exudates of one sex to the other... and nothing happened! Sexualisation had never been induced by cell filtrates. Sex pheromones in diatoms were on their way to become a myth.

That night Shinya Sato left the lab with the filtrate experiment set up. He saw himself writing an expected negative line such as “filtrate didn’t stimulate sexualisation of the opposite sex”. But when he returned to the lab the next morning, he could not believe his eyes: “I was stunned when I noticed that the cells in the Petri dish were all sexualised by the filtrate.” After years of suspicion and speculation, evidence of sex pheromones in diatoms had finally been found.

“The reason I had the result,” he explains, “is because I used an araphid diatom, which has no vigorous motility in its vegetative stages, whereas previous researchers used motile raphid diatoms.” Sato adds, “Because the araphid diatoms cannot always establish physical contact between compatible cells during their sexual reproduction, they need the power to induce gametogenesis by cell-free exudates will enable the molecular dissection of sexualisation in diatoms. Determining the biochemical identity of the pheromones is also a question within reach.

The story of Shinya Sato is not only about solving the life cycle mysteries of the diatoms. It is also a reminiscence of the cycle of scientific life itself: there’s a time when you are a youngster looking at pictures in textbooks, and after some miles and some years, you will be the one putting the pictures in the textbooks.

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