**From microscopic algae to kelp forests**

Multicellular life is one of the most astonishing wonders on Earth, but why and how does it arise in the first place? We exposed single-celled algae to predators and watched them evolve into multicellular life in real time. Within a year, these algae formed groups of cells to avoid being eaten. However, this incipient multicellular form comes with a cost.

|  |  |
| --- | --- |
| Macintosh HD:Users:Kimberly:Downloads:K1-01-cropped.jpg | Macintosh HD:Users:Kimberly:Downloads:20170815-B211_2.jpg |

Photo credits: Joshua Borin

By Kimberly Chen | Postdoctoral Fellow, Matthew Herron | Senior Research Scientist

Although many of the discussions on the evolution of multicellularity tend to focus on animals and plants, other groups of organisms such as fungi, slime molds, different groups of algae, cyanobacteria and myxobacteria are also multicellular. To date, there are at least 25 independent origins of multicellularity in the history of life. What are the critical steps for single-celled ancestors to evolve into organisms consisted of multiple cells? What are the advantages of being multicellular organisms?

Unfortunately, known transitions from single-celled to multicellular organisms trace back hundreds of millions of years ago. The oldest fossil evidence of cyanobacteria-like organisms date back 3 to 3.5 billion years ago, while land plants did not appear until 500 million years ago. It is hard to know what happened that far back.

We used a single-celled, free-swimming green alga (Chlamydomonas reinhardtii) to replay life’s tape in the laboratory. Becoming multicellular is about becoming bigger. One possible driver for the evolution of multicellularity is predation, as it favors increased size. The predators we used in our experiment are filter-feeding ciliates. Despite being unicellular, these ciliates are larger and graze on small algae by sweeping them into their mouths with hairlike structures. We cultured some algae with predators and some without over a year to test the possibility that whether predators can drive the evolution of multicellularity.

By the end of the evolution experiment, some cultures grown with predators had become multicellular. The evolved multicellularity is achieved via the modification of cell cycle. Single-celled algae normally multiply by a process called multiple fission, where a cell goes through one to three divisions to produce two, four or eight daughter cells. These daughters then hatch out of the mother cell to start the cycle again. In the evolved multicellular algae, we did not observe the last hatching step when cell cycle is about to complete.

Instead, each daughter cell continues its cell cycle, leading to multicellular clusters we observed. Strictly speaking, cells in each cluster are descendants of a mother cell, and are genetically similar to each other. As clusters continue to grow bigger, they reach a limit and start to release propagules (e.g. single cells or small clusters). In case a mutation has arisen in a cluster and causes defects or reverts one of its cells to the single-celled state, it will become separate during propagule formation. Selective pressures like predators therefore can favor the increase of clusters over single cells or defects.

The evolved multicellular colonies form obligately in normal growth conditions without predators. This may come with a price. In nature, single-celled algae swim with their flagella towards light for photosynthesis. Nevertheless, the evolved multicellular structures trap individual cells within mother cell wall despite the fact that the flagella of each cell are present and active. The multicellular clusters do not show noticeable movement. Such a drawback may be mitigated in the laboratory, since we culture these algae in an incubator with an ample supply of lights. They might not be so lucky in nature.

From this experiment, we have learned that multicellularity can evolve readily in response to predation. This initial transition, although being a key step towards more complex life, does not seem to require organisms like green algae to evolve something new. Rather, this can be accomplished through the modification of existing cell cycle. The multicellular algae that evolved in our experiment also provide opportunities for further evolution experiments. For example, will they be able to regain the ability to swim? Can they evolve a division of labor, with cells becoming specialized to perform different tasks? These questions are under our current investigations.

Original articles:

Herron M, Borin J, Boswell J, Walker J, Chen K, Knox C, Boyd M, Rosenzweig F & Ratcliff W. *De novo* origins of multicellularity in response to predation. *Scientific Reports*. (2019) 9:2328. <https://doi.org/10.1038/s41598-019-39558-8>

Boyd M, Rosenzweig F, Herron M. Analysis of motility in multicellular *Chlamydomonas reinhardtii* evolved under predation. *PLoS ONE*. (2018) 13(1): e0192184. https://doi.org/10.1371/journal.pone.0192184