frontiers FOR YOUNG MINDS

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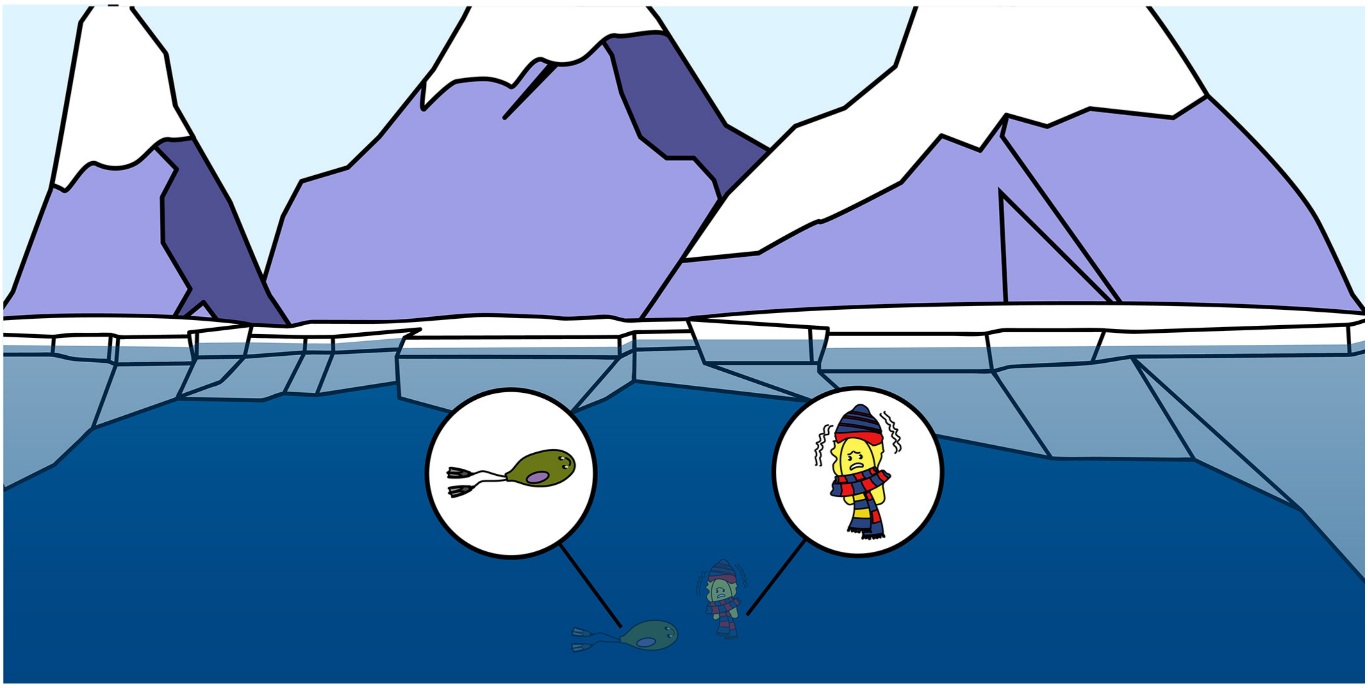

AN ANTARCTIC ALGA THAT CAN SURVIVE THE EXTREME COLD

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YOUNG REVIEWER:

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Microscopic algae are tougher than you might think. Some can even survive the extreme cold. In this article, we describe one of the coolest algae of all, the Antarctic green alga called *Chlamydomonas* sp. UWO241. This one-celled super-organism lives deep in the frigid waters of a remote and permanently ice-covered lake in Antarctica. How does this little alga thrive in such a barren and unwelcoming place? Well, dive into this article to learn how studying the genome of UWO241 is helping scientists better understand this amazingly hardy alga.

LIFE IN A LAKE AT THE BOTTOM OF THE WORLD

There are better places to call home than Antarctica. But apparently the green alga *Chlamydomonas* sp. UWO241 did not get the memo (Figure 1). This tiny, egg-shaped, single-celled organism, which has

Figure 1

Light microscope image of multiple *Chlamydomonas* sp. UWO241 cells.

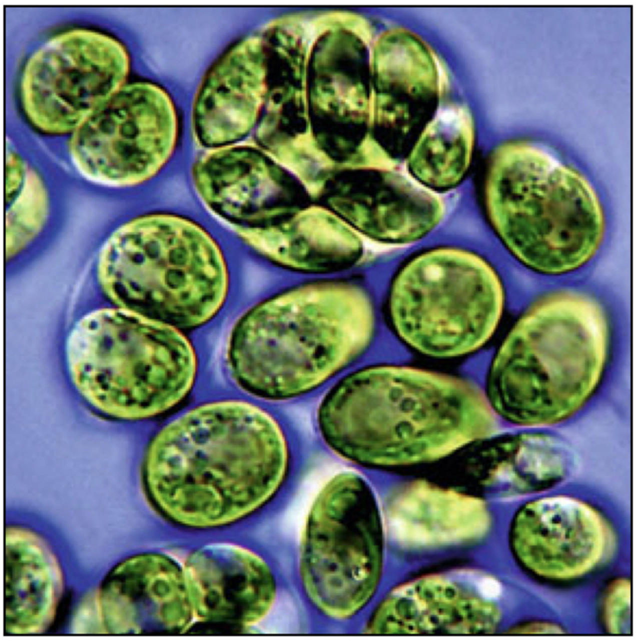

Figure 1

Figure 2

(A) Map of Antarctica showing where Lake Bonney is located (Image credit: NASA Earth Observatory) **(B)** Image of Lake Bonney, with mountain and glacier in background (Image credit: Wikimedia-Commons, 2021).

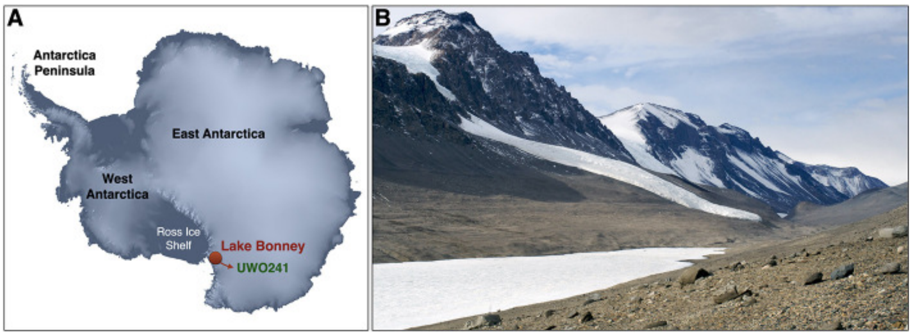

Figure 2

two antennae-like structures called flagella for swimming, lives in the frigid waters of Lake Bonney, Antarctica (Figure 2A). If you are planning a summer vacation, best to skip Lake Bonney. This relatively small lake is found in a frozen desert called the McMurdo Dry Valleys and it is surrounded by desolate mountains, glaciers, and the vast, endless expanses of the Earth's southern-most continent (Figure 2B). If that were not enough, Lake Bonney is permanently covered in five meters of ice, thicker than the height of a basketball net. UWO241 exists in the near-freezing liquid water, 17 meters beneath the frozen surface (Figure 3), and no one knew it was there until researchers discovered it a few decades ago [1].

PSYCHROPHILE

An organism that grows well in colder temperatures (below 15°C) but dies at warmer temperatures (>18°C).

Lake Bonney is a lonely place for an alga. There are no penguins or fish or animals of any kind. Only microbes. Believe it or not, UWO241 does quite well in this barren habitat. One might even say that it thrives. This is because it is a **psychrophile**, which is the technical term for a

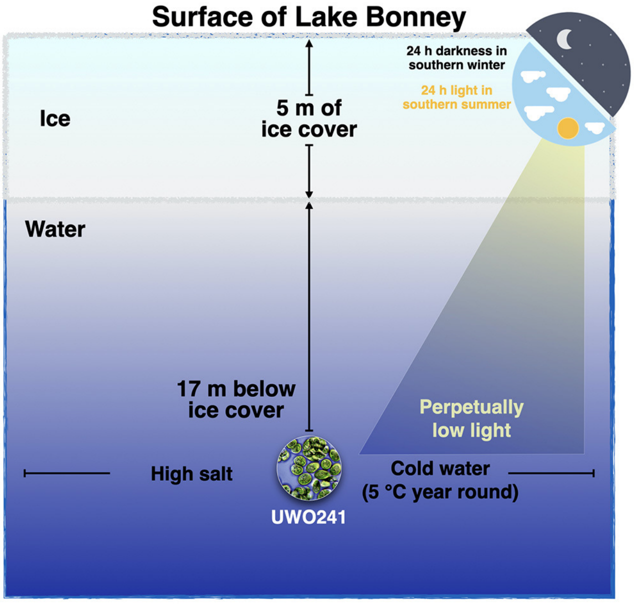

Figure 3

Figure 3
Environmental conditions in Lake Bonney.

species that is highly adapted to an extremely cold environment but cannot survive in a warmer climate [2]. You read that right: UWO241 is so acclimatized to the chilly waters of Lake Bonney that if you moved it to a more welcoming place, like lake water with a temperature that you or I would want to swim in, it would die.

SUPERHEROIC SURVIVAL ABILITIES

In addition to the cold, UWO241 must cope with a range of other severe environmental conditions, meaning it is not only a psychrophile but also an **extremophile** [2], which is a fancy way of saying it can withstand multiple kinds of extremes, like a superhero. As you can imagine, it can get quite dark in the ice-covered waters of Lake Bonney, especially during the southern winter when the sun does not rise for weeks on end. Thus, UWO241 must cope with a perpetually low-light environment, which is not ideal for an organism that makes food with the help of sunlight. The water is also very salty at the depth at which UWO241 is found, saltier than the ocean, in fact.

EXTREMOPHILE
The name given to an organism that can withstand multiple different environmental stresses, such as high salt and extreme temperatures.

How does UWO241 survive these extremes? Researchers are just starting to unravel some of the remarkable adaptations that make this alga so resilient. One of the more recent scientific breakthroughs in understanding UWO241 has come from studying its **genome**, which represents the entire DNA instruction booklet for how this alga functions.

GENOME
The complete set of genetic information needed to build an organism.

A COOL GENOME FOR A COLD ALGA

Genomes come in all shapes and sizes and represent the complete set of genetic information needed to build an organism. The UWO241 genome is about 215 million letters long, which is big for an alga, but do not forget that the human genome is 3 billion letters. Hundreds of millions of DNA letters may sound like a lot of information, but only a small fraction of it is represented by **genes**, which are short segments of DNA that code for **proteins**. Genes are often what biologists are most interested in when trying to understand an organism because they encode the miniature machines that both allow cells to work and accelerate chemical reactions. The UWO241 genome contains around 16,000 genes, which is an average number for an alga. However, close inspection of these genes and the proteins they encode shows that UWO241 is anything but average.

GENE

A short segment of DNA coding for a protein.

PROTEIN

A molecule made of amino acids, which can perform functions crucial for keeping the cell alive.

If UWO241 could talk, its first words would likely be "ice-binding protein." Indeed, this alga encodes dozens of these proteins in its genome, more than any other alga explored to date! **Ice-binding proteins** protect cells from the damage caused by freezing, and they are frequently found in organisms that live in exceptionally cold places, such as the Arctic or Antarctic [3]. It might seem to make perfect sense that an Antarctic alga like UWO241 would encode an abundance of ice-binding proteins—to keep it from freezing, of course. But keep in mind that this species lives in *liquid* water, which never drops below freezing (Figure 3). Scientists are still trying to figure out the precise role of the ice-binding proteins in UWO241. Some have suggested that the ice-binding protein genes are hand-me-downs from a recent ancestor that might have spent more time on ice than in water.

ICE-BINDING PROTEIN

A special family of proteins that help prevent organisms from freezing.

A BIOLOGICAL "BUY ONE, GET ONE FREE" DEAL

Surprisingly, the most striking feature of the UWO241 genome is not the types of genes it contains but the fact that many are duplicated. Think of it as a 2-for-1 deal. Genes that are typically present only once in other algae, they are found in multiple copies in UWO241. The numbers are quite staggering. It was shown that UWO241 has nearly a thousand very similar genes representing many different proteins. How could these duplicates help this alga survive? The answer is connected to a phenomenon called **gene dosage**—how the number of copies of a gene influences the amount of a protein that is produced. It is not as complicated as it sounds.

GENE DOSAGE

The number of copies of a particular gene.

In some circumstances, it can be helpful to produce more of a particular protein. In the extreme cold, for instance, proteins may not work as well as they should because low temperatures can interfere with their folding (a bit like trying to tie frozen shoelaces). One of the many ways to compensate for this reduction in function is just to make more protein. Simply put: if one sweater is not keeping you warm because it has holes in it, you would be better served by putting on two beat-up sweaters, on top of one another.

Is this what is happening in UWO241? Maybe. A lot of the duplicate genes encode proteins that carry out crucial cellular functions. But more work is needed, particularly experimental work on proteins, before we will know for certain whether gene dosage is helping this alga survive in the Antarctic. Moreover, it appears that some proteins in UWO241, whether they are encoded by one or multiple genes, are particularly well-suited to working in the cold [4], implying that there is not a single answer to the question of why UWO241 thrives in Lake Bonney!

FUTURE STUDIES ON UWO241

UWO241 is undoubtedly among the world's toughest algae and has a lot teach us about how microbes survive extreme environments, particularly the extreme cold. Already, we can say with confidence that its unique genome architecture, including duplicate genes, is contributing to its survival in the Antarctic. As you read this, various scientific teams are hard at work trying to understand the different ways that UWO241 has been shaped by its unique environment. It will be exciting to see what these groups uncover in the coming months and years. Research teams are also exploring the other microbes that live in Lake Bonney to see if their genomes share any similarities to that of UWO241. For now, you can rest assured that UWO241, despite living in one of the most remote and uninviting places on Earth, is doing just fine.

AUTHOR CONTRIBUTIONS

The study was conceptualized by MC, NH, and DS. The data were analyzed by MC and XZ. DS and AL drafted the manuscript. All authors commented to produce the manuscript for peer review.

ORIGINAL SOURCE ARTICLE

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REFERENCES

1. Neale, P. J., and Priscu, J. C. 1995. The photosynthetic apparatus of phytoplankton from a perennially ice-covered Antarctic lake: acclimation to an extreme shade environment. *Plant Cell Physiol.* 36:253–63. doi: 10.1093/oxfordjournals.pcp.a078757

2. Cvetkovska, M., Hüner, N. P., and Smith, D. R. 2017. Chilling out: the evolution and diversification of psychrophilic algae with a focus on Chlamydomonadales. *Polar Biol.* 40:1169–84. doi: 10.1007/s00300-016-2045-4
3. Davies, P. L. 2014. Ice-binding proteins: a remarkable diversity of structures for stopping and starting ice growth. *Trends Biochem. Sci.* 39:548–55. doi: 10.1016/j.tibs.2014.09.005
4. Cvetkovska, M., Szyszka-Mroz, B., Possmayer, M., Pittock, P., Lajoie, G., Smith, D. R., et al. 2018. Characterization of photosynthetic ferredoxin from the Antarctic alga *Chlamydomonas* sp. UWO 241 reveals novel features of cold adaptation. *New Phytol.* 219:588–604. doi: 10.1111/nph.15194

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LANGSTON, AGE: 13
My name is Langston and I am 13 years old. Some of the things I like to do include playing sports and video games. My favorite subject is math. When I grow up I want to be an architect.

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