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# COLD-LOVING BACTERIA CAN SURVIVE IN THE ICE

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Did you know that there are many places on Earth that are frozen all year round? Can you imagine living your whole life in the bitter cold of snow and ice? Well, not only can some tiny microbes live comfortably in the cold, but many kinds of bacteria call such harsh places home! Just as a polar bear needs a thick coat to survive in the cold, these bacteria have their own ways of keeping themselves comfortable in the harsh environment. Scientists have found that these bacteria can teach us a lot about life in our solar system and that they are extremely useful in many industries.

## SURVIVAL IN EARTH'S COLDEST PLACES

Did you know that our Earth is quite a frozen planet? In fact, about half of Earth's land environments are seasonally or permanently covered in snow or ice! Brrr! From the North Pole to the South Pole, from the ice caps on mountaintops to icebergs floating on the sea, cold habitats are everywhere, and they make up the frozen part of the Earth called the **cryosphere** (Figure 1) [1].

**CRYOSPHERE**

Places on the Earth where water is frozen as ice or snow.

**Figure 1**

The various forms of snow and ice that make up Earth's cryosphere (Figure created with BioRender.com).

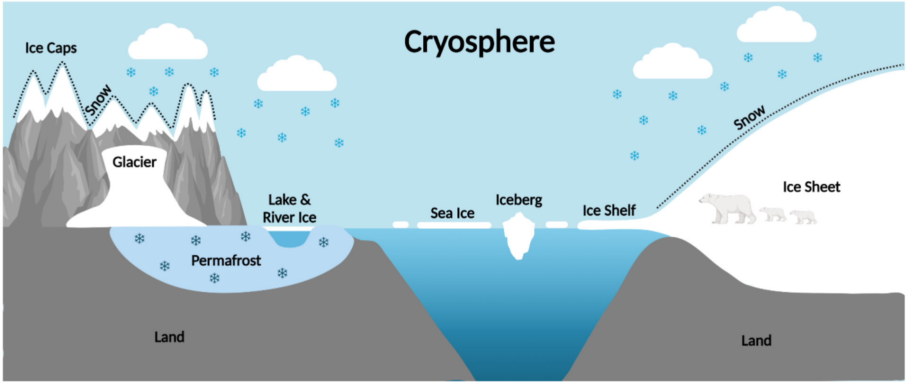


Figure 1

**MICROBES**

Living things that are very small and can only be seen through a microscope. Examples of microbes are bacteria, algae, protozoa and viruses.

Temperature plays an important role in determining whether living things can survive. Extremely cold temperatures in the cryosphere make it especially challenging for **microbes** to survive. In a cold environment, it is very difficult to find water, which is essential for life, because most of the water turns into solid ice. Most organisms (except humans) do not have a way of melting the ice in such cold places. It is also difficult for organisms to find food and generate energy in the cryosphere, because the chemical reactions that keep living things alive happen more slowly in the cold [1, 2]. However, unlike polar bears or whales, microbes—which are the smallest living organisms and can only be seen through a microscope—do not have a thick layer of fur or fat to keep themselves warm. Given these challenges, it seems almost impossible that microbes can survive in frozen environments.

## BACTERIAL LIFE IN THE ICE

**PSYCHROPHILES**

Microbes, especially bacteria, that have adapted to life in cold environments. The term comes from the Greek "psychros" meaning "cold and frozen" and "philia" meaning "loving."

Frozen environments were once thought to be lifeless. Scientists initially thought that microbes in frozen environments were brought there by the wind and were "asleep" due to the cold. However, they later found that permanently frozen environments contain a lot of living microbes! Some of these microbes were found to have adapted in special ways (over a long period of time) to survive in the snow and ice. These microbes are called **psychrophiles**, which means "cold-loving" in Greek. Psychrophiles are largely bacteria but can also include other microbes [1].

Microbes cannot survive in solid ice. So far, all the communities of psychrophiles found within ice, from ice sheets to glaciers, survive inside very tiny veins of liquid water trapped in the ice when it forms (Figure 2). This means that these psychrophiles must have come from the surrounding environments, such as the air, snow, or the surface of the oceans (in the case of sea ice) and were trapped in the ice veins at some point.

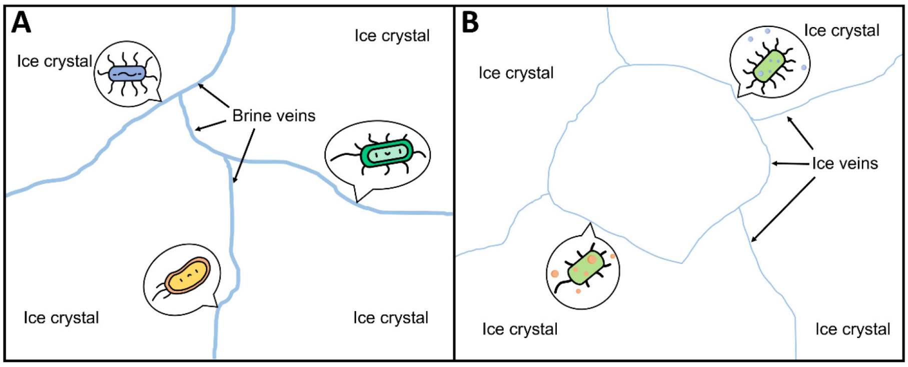


Figure 2

**Figure 2**

Psychrophiles in ice veins. **(A)** In sea ice, the ice veins are filled with a salty water and are called brine veins. **(B)** In glacier ice, the ice veins are much smaller, and therefore usually contain smaller psychrophiles.

**BRINE VEINS**

Tiny channels between sea-ice crystals filled with very salty water, containing the salt that was not incorporated when the ice crystals formed.

Ice veins within different frozen habitats create very different environments for psychrophiles. Let us look at two examples: sea ice and glacier ice. Sea ice is frozen seawater that floats on the surface of the ocean, grows in winter, and shrinks in summer. Under non-freezing conditions, seawater contains water, dissolved salt, nutrients, and numerous tiny microbes. When seawater freezes, only the water can form the ice crystal, while the dissolved salt, microbes, and small amounts of water are left out of these crystals. These then become trapped in tiny liquid channels called **brine veins**, which are extremely salty and therefore difficult to live in. During the freezing winter months, trapped psychrophiles can survive in these small brine veins (Figure 2A). When the ice melts in the summer, the psychrophiles must go back into the ocean, which means that they must be able to adapt to a changing environment [3]. That is hard work!

In contrast, glaciers are bodies of frozen freshwater formed from the accumulation of snow that, over time, is compressed into ice. The weight of all that heavy buildup of ice and snow presses down on the lower layers of the glacier, causing any ice veins that form in these layers to be extremely small (Figure 2B). This means that bacteria that survive in glacial ice veins are typically very tiny and they have to stay there for a really long time, maybe even millions of years! So far, scientists have found evidence of bacterial DNA from 500,000-year-old ice, but we are still learning about these bacteria and are still not sure how long bacteria can stay alive in ice [1, 3].

## HOW DO PSYCHROPHILES PROTECT THEMSELVES FROM THE COLD?

Just as you would put on a thick winter coat or rub your hands vigorously to keep yourself warm on a winter night, our psychrophilic friends also have ways to survive in cold conditions (Figure 3) [4]. One of the most basic challenges to living in the cold is that everything takes more time, including nutrient movement and important chemical reactions (To understand this, try placing a teabag in cold water, and another in hot water—you will see that the tea spreads more slowly in the cold water.). Therefore, to get enough food from the water around them, many psychrophiles increase the number of transporters on the cell surface, which actively grab nutrients from the surroundings.

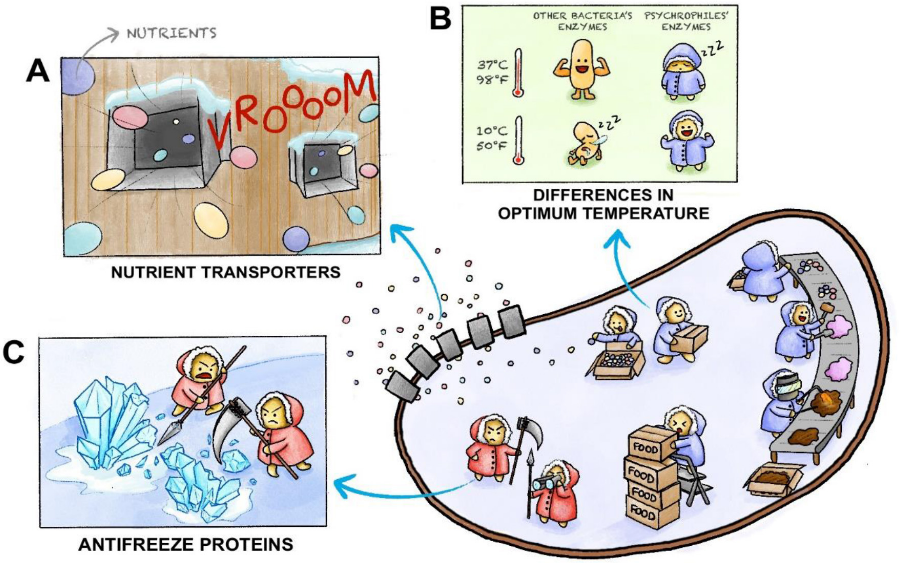


Figure 3

**Figure 3**

Unique features of psychrophiles help them live in extremely cold environments. **(A)** Psychrophiles have nutrient transporters that help them grab nutrients from the cold environment, where things move slowly. **(B)** Psychrophiles have cold-active enzymes that can do their jobs in the cell at low temperatures. **(C)** Psychrophiles have antifreeze proteins that prevent ice crystals from forming and damaging the cell.

Another problem associated with this frozen environment is ice formation. Just as 70% of the human body is made up of water, most bacteria cells are also full of water, which can easily turn into ice crystals at freezing temperatures. Ice crystals inside living cells are dangerous because they grow outward like little thorns, eventually piercing the bacteria from the inside out and killing them. Psychrophiles have therefore evolved multiple strategies to avoid this gruesome fate. For instance, they take in dissolved salts and sugars to lower the freezing temperature of water inside themselves. Some species also have special antifreeze proteins that attach to any forming ice crystals and lower their freezing point, preventing their growth. These strategies reduce the danger of living in the cold.

Psychrophiles also have **enzymes** that are different from those of non-psychrophile bacteria. Enzymes are like the factory workers inside cells. Each type of enzyme carries out an essential chemical reaction, keeping the bacteria alive and happy. Enzymes only work best within a small range of temperatures called the **optimum temperature**. For example, the bacteria that make humans sick have enzymes with an optimum temperature of about 37°C, which is the same as human body temperature. This allows these bacteria to grow and cause disease inside the human body. However, if these disease-causing bacteria are exposed to freezing temperatures, their enzymes will become inactive, causing them to "fall asleep." This is not the case for psychrophiles. To keep the psychrophiles alive at freezing temperatures, enzymes called **cold-active enzymes** have evolved,

**ENZYMES**

The workers of the cell; proteins that help chemical reaction to happen.

**OPTIMUM TEMPERATURE**

Temperature at which an enzyme performs its chemical reaction the fastest.

**COLD-ACTIVE ENZYMES**

Enzymes that work the fastest at temperatures of 20°C (68°F) or below.

which have an optimum temperature of 20°C or less [5]! Now that is a *cool* way to survive!

## WHY IS STUDYING PSYCHROPHILES IMPORTANT?

Cold habitats on Earth are very much in danger from global warming. Scientists need to quickly find out what important functions psychrophiles play in the environment, to estimate the damage that global warming will have on the cryosphere. In addition, cold environments are very common on other planets in our solar system, and many scientists study cold environments on Earth to get clues about whether life could exist on other planets [3].

Many scientists are also putting our growing knowledge of psychrophiles to use in new technologies [5]. Cold-active enzymes, for example, have already been used to increase the effectiveness of industrial processes, such as fruit processing, that take place at low temperatures (so that the fruit does not spoil). Scientists have also identified many of the active chemicals in psychrophiles that help them respond to the cold. We can use these chemicals in medicines to treat infections and even cancer. Additionally, with psychrophiles so well-adapted to surviving in harsh environments with poor nutrients, they can break down pretty much anything they get access to. This means psychrophiles might be very useful for breaking down plastics and treating waste. Psychrophiles are as useful as they are diverse!

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**SOPHIE, AGE: 12**

I am passionate about science, drawing and painting. I like manga, anime and penguins. I play the violin since when I was 9 years old. At school, my favorite subjects are foreign languages, especially French. I can speak English, Italian, and Russian.

**SPROUTS MONTESSORI, AGES: 7–10**

We are a group of students who love learning about how the world works. We hope to one day use this knowledge to make the world better for ourselves and others.

## AUTHORS

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I am a Ph.D. student at the Singapore Centre for Environmental Life Sciences Engineering at the Nanyang Technological University in Singapore. My research is interdisciplinary and uses a combination of computational and experimental approaches. I study how bacteria adapt in extreme environments, and how we can make use of them to produce useful items like biofuel. When I am not in my lab coat, I am often taking a hike in nature, enjoying a good book, practicing copperplate calligraphy, or writing letters to pen pals. *yiwenkri001@e.ntu.edu.sg

**FREDERICK REINHART TANOTO**
I am a Ph.D. student at the Singapore Centre for Environmental Life Sciences Engineering at Nanyang Technological University, Singapore. My research involves understanding how certain bacteria can cause infections in our bodies and continue to persist in the infection site for a long time. Outside of my own research, I have always been fascinated by the diversity of bacteria in the environment, both the good and the bad, and how these little creatures can have a huge impact on our lives. Oh, and I love to doodle, too! *FRED0016@e.ntu.edu.sg

**ADRIANA LOPES DOS SANTOS**
As a child, I loved to learn about the creatures I found in my grandpa's garden. Together, we would spend hours trying to discover which species they were and how they grow, what they eat, and how they live. Not surprisingly, I choose to become a biologist. While studying, I became fascinated with the invisible microbial world and its infinitely variable forms and lifestyles, especially those drifting in the ocean, called plankton. My work today involves naming and describing plankton creatures and understanding their ecological roles in the world's oceans. The study of plankton has taken me around the globe, from the Arctic to the Antarctic. Today I am also a professor at the Nanyang Technological University, teaching microbiology and hoping to inspire the next generation of microbiologists to continue uncover the wonders of the invisible world. *lopesas.ufrj@gmail.com

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