*The wish to escape the human condition, I suspect, also underlies the hope to extend man's lifespan far beyond the hundred-year limit. Hannah Arendt, philosopher. The Human Condition, 1958 (source).*

**This month's theme: Tardigrades**

## What are tardigrades?

Tardigrades, also known as water bears, are microscopic invertebrates measuring between 0.1 and 1 mm in length and have 8 legs. Discovered in 1773, they inhabit a wide range of environments, including oceans, freshwater bodies, and terrestrial ecosystems such as mosses, lichens, and soil. 1380 species of living tardigrades have been recognized worldwide to date. Despite their small size, tardigrades play important ecological roles in nutrient cycling and microbial regulation within their habitats.

Tardigrades are best known for their extraordinary survival abilities: They have survived several mass extinctions, flown into orbit, and landed on the Moon. They can survive for 20 months at -200°C , in immense pressures, the vacuum of space, and toxic substances. Some species (in the genus *Paramacrobiotus* for instance) are 1000 times more resistant to UV and X-ray radiation than humans and can even survive without oxygen for several days. Their unique physiological adaptations make them a subject of interest in scientific research, particularly in astrobiology, genetics, and environmental studies.

**How do they survive everything?**

Tardigrades owe their extreme resilience to several biological adaptations. One of their main survival strategies is cryptobiosis, a state in which they almost completely shut down their metabolism in response to extreme environmental conditions. In this state, tardigrades lose 99% of their body water and curl into a desiccated form called a tun, allowing them to survive extreme dehydration (anhydrobiosis), freezing temperatures (cryobiosis), high salinity (osmobiosis), and lack of oxygen (anoxybiosis). For instance, in a 2016 study, Japanese researchers were able to recover and reproduce an Antarctic tardigrade retrieved from a moss sample frozen for over 30 years.

A key factor in their survival is the production of bioprotective proteins, known as Tardigrade-Specific Intrinsically Disordered Proteins (TDPs). These proteins replace water inside their cells and form a protective gel-like structure that prevents damage to sensitive biological molecules, such as DNA and proteins. When conditions become favorable again, tardigrades can rehydrate and return to normal activity within hours.

Tardigrades also possess highly efficient DNA repair mechanisms that help them survive high levels of radiation, which would typically cause lethal mutations in other organisms. In addition, some species produce pigments that act as a shield against harmful ultraviolet radiation.

These remarkable adaptations make tardigrades one of the most resilient life forms on Earth. Their ability to survive in space has attracted significant scientific interest, especially in the fields of astrobiology and biotechnology, where researchers study their unique survival mechanisms for potential applications in medicine, food preservation, and space exploration.

**Application for science and longevity**

- Cancer therapy

The Tardigrade Damage Suppressor Protein (Dsup) has been identified as a key factor in the tardigrade's ability to protect its DNA from damage caused by stressors such as radiation and dehydration. Research has shown that when Dsup is introduced into human cells, it helps regulate genes involved in DNA repair and transcription. A study found that the expression of Dsup increased antioxidant levels and restored key parameters altered by UV exposure, such as pollen tube length, position of the male germ unit, and expression of stress proteins (tubulin, HSP70). These results suggest that Dsup could enhance pollen resistance to UV-B and improve plant tolerance to solar radiation. This protein could play a vital role in protecting human DNA against environmental damage and may have therapeutic applications in cancer treatment, where DNA repair mechanisms are crucial for the efficacy of therapies. Chemotherapy and radiotherapy often induce DNA damage in healthy cells, which limits their success and causes harmful side effects. By applying tardigrade-derived proteins or genes to human cells, researchers could potentially enhance the cells' ability to repair DNA, making them more resilient to the damaging effects of cancer therapies. This could help increase the effectiveness of treatments while minimizing harm to healthy tissues.

- Cryopreservation

Cryopreservation, the process of preserving cells, tissues, or organs at low temperatures, is another area where tardigrade research has applications. Tardigrades are capable of surviving extreme desiccation (drying out), a process that is similar to cryopreservation. By studying the genes responsible for their stress resistance, researchers are working on improving cryopreservation techniques for human cells, tissues, and organs, which could revolutionize organ transplantation and the preservation of genetic material.

- Astrobiology

As extremophile organisms, tardigrades can survive in space. In 1964, it was first suggested that tardigrades could serve as model organisms for space research due to

their extraordinary resistance to radiation. Over the years, studies on their cryptobiosis revealed even greater resilience, particularly in space conditions. Several space missions, such as FOTON-M3 in 2007 and the Endeavour mission in 2011, explored how tardigrades survived space stressors like microgravity and radiation. The final space research involving tardigrades was the Phobos Life Project, which aimed to test the survival of organisms during an interplanetary flight, supporting the panspermia theory. Unfortunately, the mission ended in failure when the spacecraft crashed in 2012.
Furthermore, this organism has shown remarkable resilience to sustained extreme pressures, enduring up to 74,000 atmospheres—equivalent to a descent of 180 km toward Earth's core. This surpasses the pressure needed to form diamonds. Despite such intense conditions, the structure and integrity of their cells remain unchanged.

The ability of tardigrades to enter cryptobiosis not only makes them well-suited for surviving long cosmic journeys but also opens the possibility of exploring whether they could survive and thrive on other planets.

- Longevity

Another potential use of tardigrades as a model could be to investigate how they age when they enter cryptobiosis. The “sleeping beauty” hypothesis suggests that tardigrades may not age during this dry state, even if it has not been fully explored. Recently, this hypothesis has been tested by subjecting a group of tardigrades to alternating periods of freezing at -30°C and feeding at 20°C. The results showed that the frozen tardigrades lived twice as long as the control group. This study represents the first experimental evidence that tardigrades reduced ageing during cryobiosis.

**Tardigrades are not the only ones to practice cryptobiosis**

Like tardigrades, some bdelloid rotifers can enter cryptobiosis to survive extreme conditions, including prolonged freezing. A study published in 2021 revealed that a bdelloid rotifer from the genus *Adineta*, extracted from Siberian permafrost and radiocarbon-dated to approximately 24,000 years BP, was successfully revived. Genetic analysis confirmed its classification and demonstrated that it could resume reproduction by parthenogenesis in a laboratory setting. This discovery represents the longest documented case of survival in a frozen state for a multicellular organism, highlighting cryptobiosis as a remarkable biological strategy that enables certain life forms to withstand extreme environments and remain dormant for thousands of years.

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**The good news of the month: We understand more about the life of supercentenarians.**

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Maria Branyas Morera died in 2024, aged 117 years. She agreed to be already examined to study her exceptional health during her lifetime. A study published as a preprint in February shows that she had almost a "child's gut microbiome". Her genes protected her from cardiovascular, neurodegenerative, and metabolic diseases.

The lead author of the article Manel Esteller says that the record-breaking supercentenarian suggests that, under certain conditions, aging and disease can be decoupled. This is, of course, sadly, for a limited time and for a small group of people. But our knowledge progress to make this possible for more people for longer.

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For more information

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