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A short review on tardigrades – some lesser known taxa of polyextremophilic invertebrates

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Abstract. Tardigrades are polyextremophilic small organisms capable to survive in a variety of extreme conditions. By reversibly suspending their metabolism (cryptobiosis – tun state) tardigrades can dry or freeze and, thus, survive the extreme conditions like very high or low pressure and temperatures, changes in salinity, lack of oxygen, lack of water, some noxious chemicals, boiling alcohol, even the vacuum of the outer space. Despite their peculiar morphology and amazing diversity of habitats, relatively little is known about these organisms. Tardigrades are considered some lesser known taxa. Studying tardigrades can teach us about the evolution of life on our planet, can help us understand what extremophilic evolution and adaptation means and they can show us what forms of life may develop on other planets.
Key Words: tardigrades, extremophiles, extreme environments, adaptation.

Rezumat. Tardigradele sunt mici organisme poliextremofile capabile să supravieţuiască într-o varietate de condiţii extreme. Suspendandu-şi reversibil metabolismul (criptobioză) tardigradele pot să se usuce sau să îngheţe şi, astfel, să supravieţuiască unor condiţii extreme precum presiuni şi temperaturi foarte scăzute sau crescute, variaţii de salinitate, lipsă de oxygen, lipsă de apă, unele chimicale toxice, alcool în fierbere, chiar şi vidul spaţiului extraterestru. În ciuda morfologiei lor deosebite şi a diversittii habitatelor lor, se cunosc relativ puţine aspecte se despre aceste organisme. Tardigradele sunt considerate a fi o categorie mai puţin cunoscută de organisme. Studiul tardigradelor ne poate invăţa despre evoluţia vieţii pe planeta noastră, ne poate ajuta să inţelegem ce reprezintă evoluţia şi adaptarea de tip extremofil şi ne poate arăta ce forme de viaţă se pot dezvolta pe alte planete.
Cuvinte cheie: tardigrade, extremofile, medii de viaţă extreme, adaptare.

Introduction. Unlike humans and most of the organisms on Earth, some creatures are more flexible in the habitats where they feel comfortable. Different from all living organism adapted to "normal" environments, there are organisms adapted to extreme, at the far edge of the normal conditions chosen in the course of evolution by most of the organisms living today.

Organisms which inhabit extreme environmental conditions are called extreme lovers or Extremophiles (from Latin *extremus* meaning "extreme" and Greek *philiā* (φιλία) meaning "love"), term first used in 1974 by R. D. MacElroy.

A more exact definition of this term defines an extremophile as an organism that thrives in and may even require physical or geochemical extreme conditions that are detrimental to most life on Earth (Rampelotto 2010). These environments are inhospitable for other organisms named mesophiles or neutrophiles as they live in more moderate environments.

Generally, microorganisms are known to be Extremophilic. Extremophiles may belong to any of the three domains: Archea, Bacteria and Eukarya. Most known extremophiles are microbes, both Archaebacteria and Eubacteria and their viruses represent extremophilic genera (Bhawshar 2011). Extremophiles have been found in the most unlikely places: around seething volcanic vents at the bottom of the oceans, in caves that have been cut off from the outside world for millions of years, and in deserts where it hardly ever rains.

There are many different classes of extremophiles that range all around the globe, each corresponding to the way its environmental niche differs from mesophilic conditions: Acidophile, Alkaliphile, Cryptoendolith, Halophile, Hyperthermophile, Hypolith, Lithoautotroph, Metallotolerant, Oligotroph, Osmophile, Piezophile, Polyextremophile, Cryophile, Radioresistant, Thermophile, Thermoacidophile, Xerophile (see Figure 1).

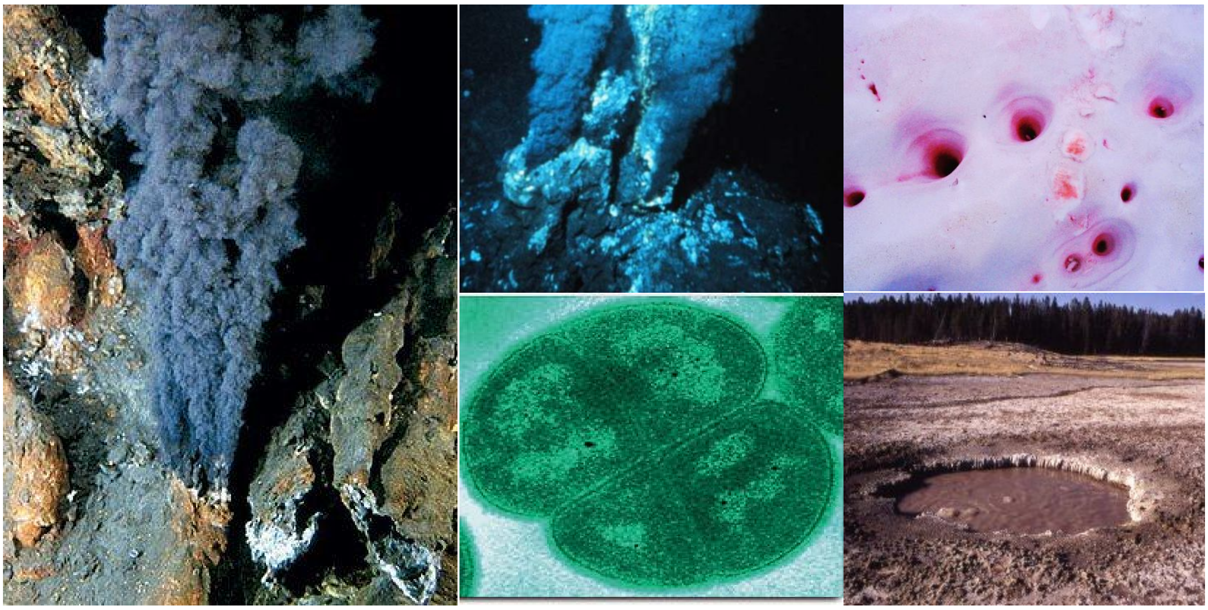


Figure 1. Extremophiles: Thermophiles, piezophiles, radioresistants, cryophiles, acidophiles and their environment (retrieved 11.01.2011, from http://www.descopera.ro).

But some life forms are up to multiple challenges, and manage to resist extreme conditions of various types like ultraviolet radiations, vacuum, high temperature fluctuations, etc.

One of the most extreme and impressive extremophiles are the tardigrades (see Figure 2), a phylum of microscopic animals among which there are many poliextremophile species.

Figure 2. Tardigrade - Water bear (retrieved 11.01.2011, from http://waterbear.bioapps.biozentrum.uni).

1.1 What are Tardigrades? Tardigrades, or "water bears" are microscopic invertebrates that require water in their environment.

The first tardigrades were dicovered in the XVIIIth century and up until now, hundreds of species were described. But only in the last decades biologists have started to discover the fantastic abilities of these small creatures with eight legs named, in english and german, „water bears". The german reasearchers that have studied them showed that they look like some small bears because of the way they move.

Tardigrades were first described by Johann August Ephraim Goeze in 1773 (*kleiner Wasserbär* = little water bear). The name Tardigrada means "slow walker" (*tardi* - slow, *grade* - walker) and was given by Lazzaro Spallanzani in 1777. The name water bear comes from the way they walk, reminiscent of a bear's gait. They are also commonly known as moss piglets.

1.1.1 Tardigrade Taxonomy and Phylogeny. Tardigrades are often referred to as some "lesser known taxa" (Nelson 1991 cited by Romano 2003) of invertebrates. Recent DNA and RNA sequencing data indicate that tardigrades are the sister group to the arthropods and *Onychophora* (Blaxter et al 2003). Some scientists consider they form their own phyla, *Phylum Tardigrada* (proposed by Ramazzotti in 1962 cited by Romano 2003) (Figure 3).

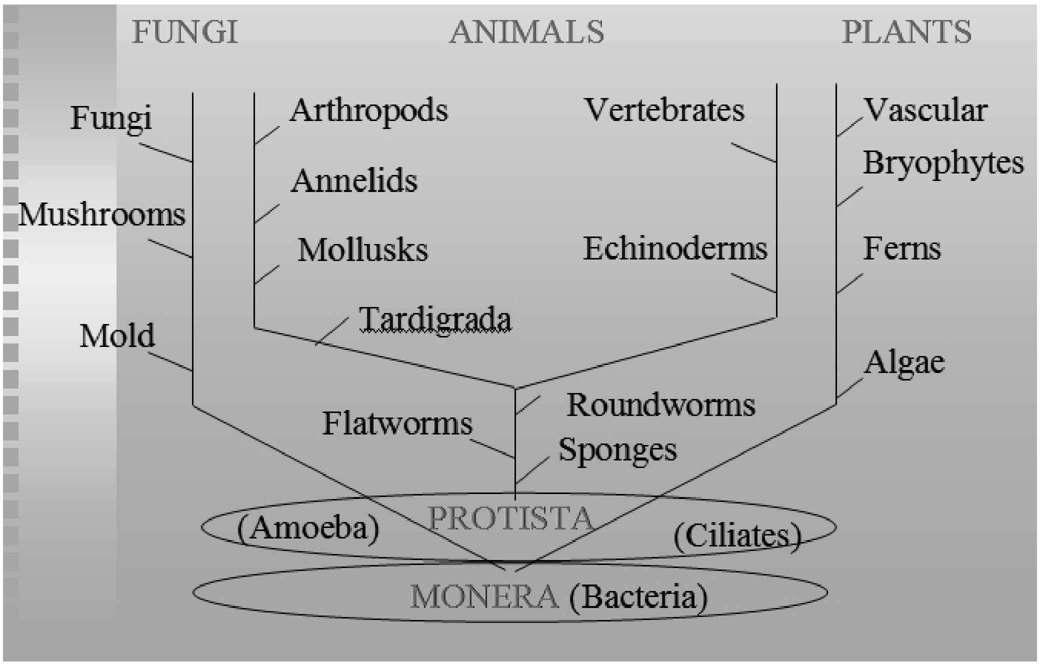


Figure 3. Clasification of Tardigrada as a different phylum among the superior category of Animals (Miller, retrieved 11.01.2011, from http://serc.carleton.edu)

Marcus (1929) aut cited by Romano (2003) established the major taxa within the phylum Tardigrada splitting the group in two, forming the classes: Heterotardigrada (armoured tardigrades) and Eutardigrada (naked tardigrades) (Figure 4).

What is sure is that they are an old group of animals (the oldest known fossils come from mid Cambrian, ca. half a billion years ago), and that they belong to the mega-clade Ecdysozoa (moulting animals).

More than 1,000 species of tardigrades have been described (Guidetti & Bertolani 2005 cited by Degama et al 2010), however it is estimated that the total number of tardigrade species may exceed ten times as many.

The tardigrades represent a successful group of animals – in flourishing existence after about 600 million years of evolution – that could hold keys to the patterns and mechanisms by which animal body plans evolve (Goldstein & Blaxter 2002).

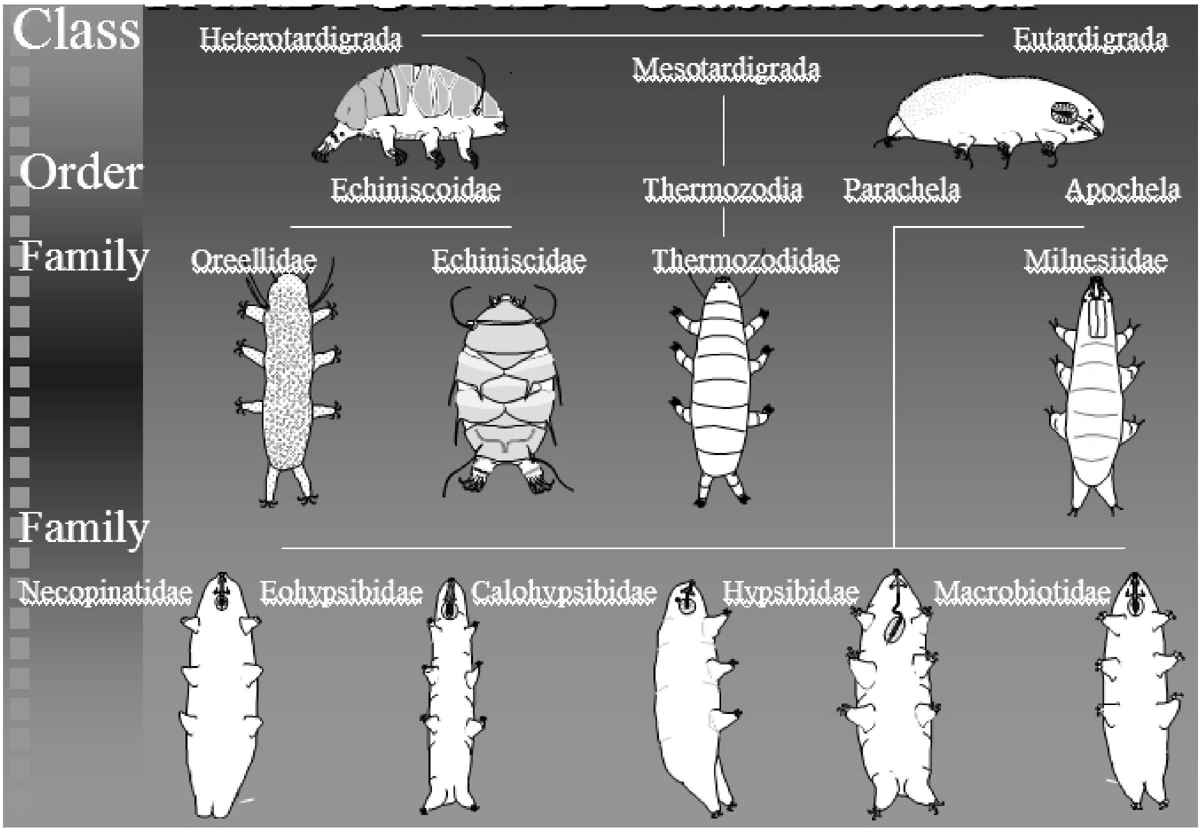


Figure 4. Classification of tardigrades (Miller, retrieved 11.01.2011, from http://serc.carleton.edu).

1.2 Characteristics of Tardigrades

1.2.1 Anatomy and morphology. These bilaterally symmetrical micrometazoans with cylindrical body are generally flattened on their ventral side and convex on their dorsal side, and average 250-500 µm in length as adults (see Dewel et al 1993 cited by Romano 2003, for detailed morphology). The biggest adults may reach a body length of 1.5 mm (0.059 in), the smallest below 0.1 mm. Freshly hatched larvae may be smaller than 0.05 mm. The species *Echiniscoides sigimunde* from European and Asian coastal habitats is the largest known to science.

They come in the variety of colours (transparent, white, red, orange, yellow, green, purple, black). Respiration occurs by diffusion.

They have an external cuticle, built up from a protein compound called an albuminoid different from the chitin that comprises the insect cuticle. Tardigrades undergo ecdysis or moulting of the exoskeleton (outer skin made of cuticle).

Tardigrades are what is called eutelic, meaning there is a fixed number of cells in the body of an adult of any given species. Some tardigrade species have as many as about 40,000 cells in each adult's body, others have far fewer (Kunihiro & Masato 1998; Kinchin 1994). Their body is segmented and they possess eight legs. Their body is composed of 5 somewhat indistinct body segments including a cephalic segment and four trunk segments each supporting a pair of legs. Each appendage ends with claws (figure 5) ranging from four to eight in number. The first 3 pairs of legs are directed ventrolaterally and are the primary means of locomotion, while the 4th pair is directed posteriorly and is used primarily for grasping the substrate (Romano 2003).

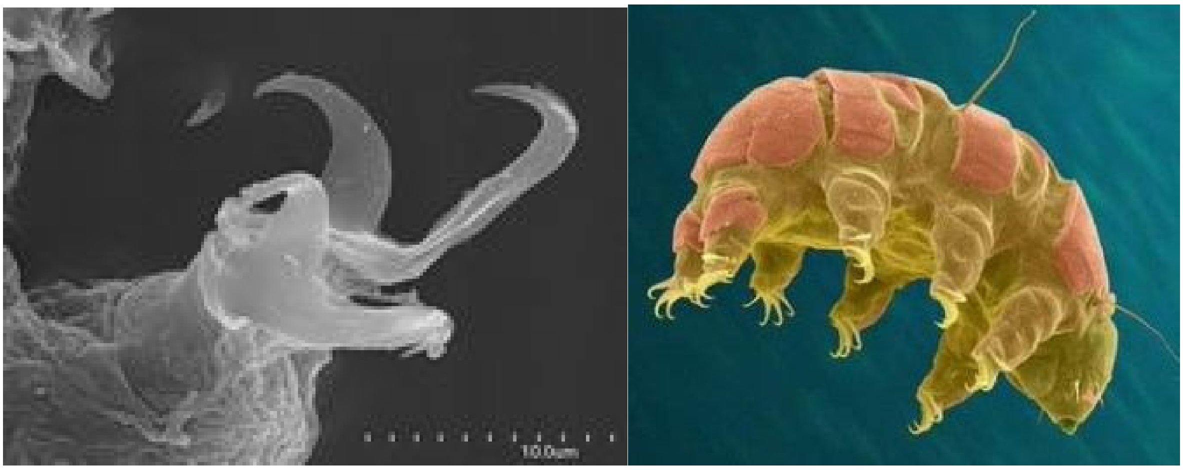


Figure 5. Right: Claw of an Eutardigrade tardigrade (Miller, retrieved 11.01.2011, from http://www.astrobio.net); Left: Structure of a tardigrade organism (retrieved 11.01.2011, from http://www.astronoo.com).

A tardigrade presents the following structural features (Figure 6): nervous system with light sensitive spots, full digestive and excretory systems, complex mouth & pharynx system, well developed muscles, no respiratory or circulatory systems. Respiration occurs by diffusion. They have a relatively large brain and a well developed nervous system with a double suboesophagal ganglia and 4 further ganglia along the body. Being small they have no need of, and therefore have no, gaseous exchange system and no blood system. Most of the body cavity is a haemocoel but there is a true coelom around the gonads. Many species possess a pair of rhabdomeric pigment-cup eyes, and there are numerous sensory bristles on the head and body (Greven 2007).

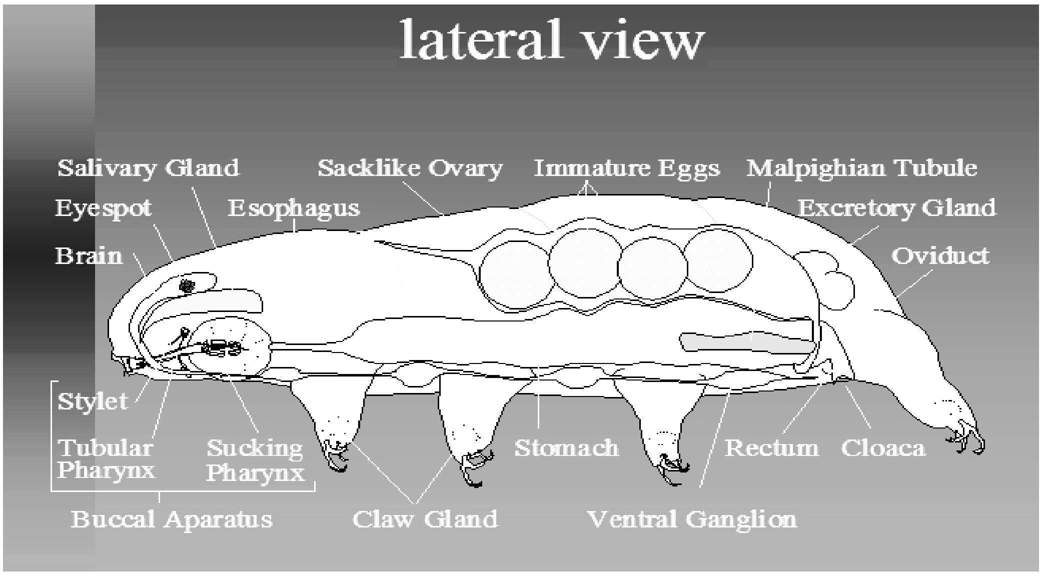


Figure 6. Stucture of a tardigrade from a lateral view (Miller, retrieved 11.01.2011, from http://serc.carleton.edu).

1.2.2 Feeding. Tardigrades are all suctorial feeders (Figure 7). They have two sharp stylets within their oral cavity which they use to pierce the cells of their food, the fluids are then sucked out of the cell using the muscular pharynx as a pump. They feed on fluids of plants (mosses, liverworts, and lichens), animals (protozoans, rotifers, nematodes, larvae, and other small invertebrates) and bacteria. In some cases, the whole organism is ingested.

Detritus may also be a major nutrient source of some species. They are prey to amoebas, nematodes.

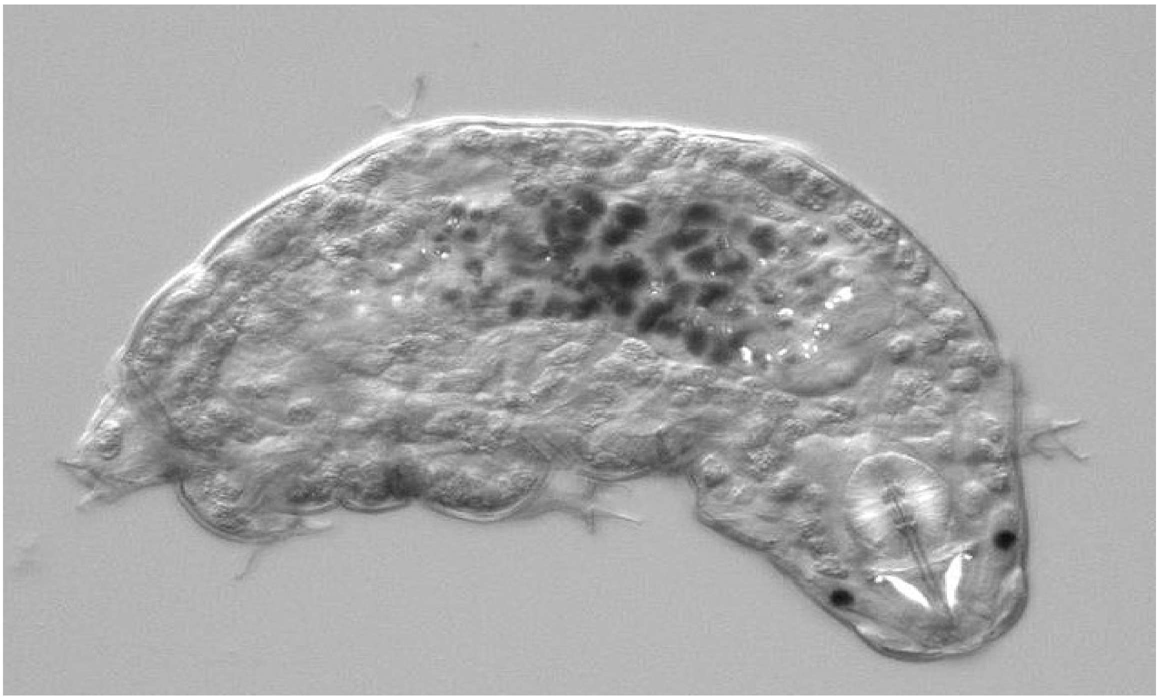


Figure 7. *Hypsibius dujardini*, view of feeding animal. Dark material in digestive tract is *Chlorococcum* algae (Gabriel W., retrieved 11.01.2011, from tardigrades.bio.unc.edu).

1.2.3 Reproduction. Water bears show a variety of reproductive strategies. They can reproduce both parthenogenetically (asexual) as well as sexually. Tardigrades are gonochoristic, meaning they are either male or female, though in some species only females have been found, these species are presumed to be parthenogenetic. Otherwise females (which usually are in a bigger number than males) tend to lay their eggs (Figure 8) inside their old cuticles. As they moult, these eggs are then fertilized *in situ* by one or more males. Females lay from 1 to 30 eggs at a time (Figure 9).

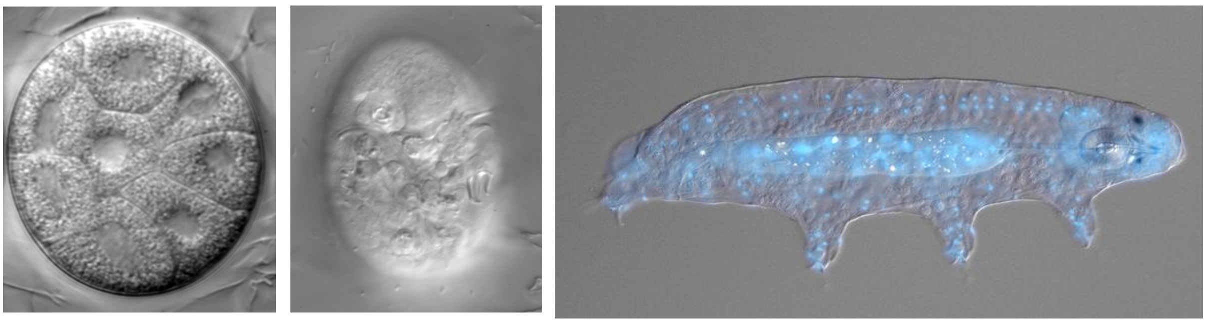


Figure 8. *Hypsibius dujardini.* Right: view of an embryo, slightly flattened; Middle: an embryo that has developed its claws, still inside its eggshell; Left: stained hatchling, lateral view (Gabriel W., retrieved 11.01.2011, from tardigrades.bio.unc.edu).

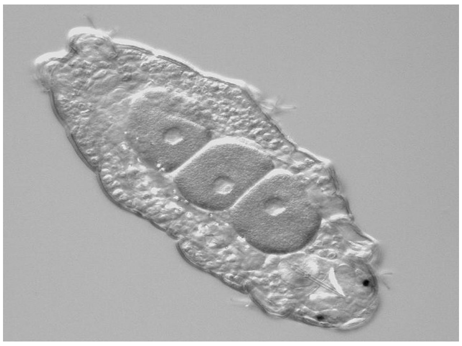
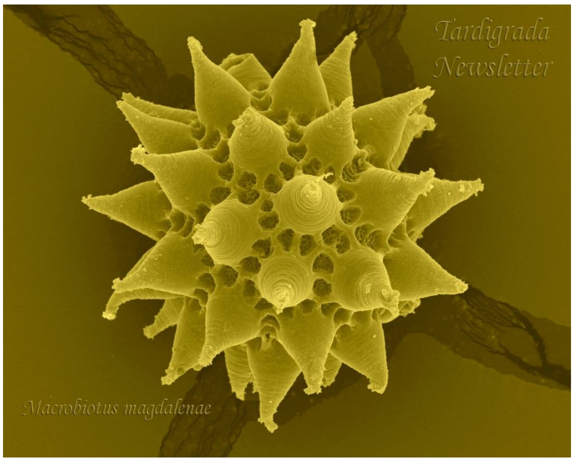


Figure 9. *Hypsibius dujardini*, view of gravid female with three large oocytes visible (Willow, retrieved 11.01.2011, from tardigrades.bio.unc.edu).

Some species lay richly ornamented eggs and the ornamentation may be unique to the species (Figure 10). The eggs hatch after no more than fourteen days, with the young already possessing their full complement of adult cells. Growth to the adult size therefore occurs by enlargement of the individual cells (hypertrophy), rather than by cell division. There is no metamorphosis, though young tardigrades may look slightly different to adults.



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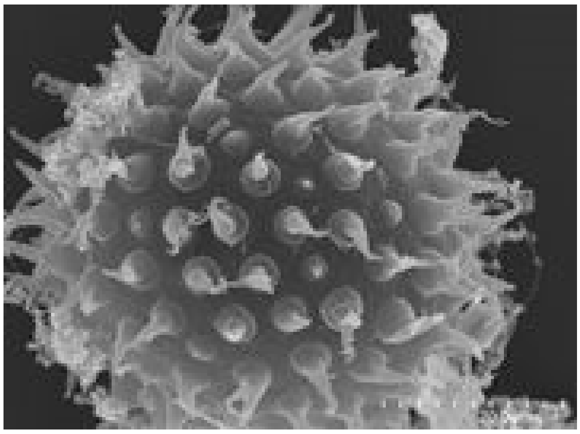

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Figure 10. a. *Paramacrobiotus magdalenae* (Michalczyk & Kaczmarek 2006) egg, Scanning Electron Microscope (SEM) (Michalczyk, retrieved 11.01.2011, from www.tardigrada.net); b. Tardigrade egg (Mitchell, retrieved 11.01.2011, from http://serc.carleton.edu); c. An egg of a tardigrade from the Eutardigrade class (Miller, retrieved 11.01.2011, from http://www.astrobio.net).

Despite their peculiar morphology and amazing diversity of habitats, relatively little is known about these tiny animals.

1.3 Where do they live? Tardigrades can be found in almost every habitat on Earth and on all continents. Species have been sighted from mountain tops (above 6 km above sea level) to the deep sea (7 km below sea level), from Ecuador and tropical rain forests to the Antarctic.

Active tardigrades require water in their environments and can be found in three main habitats; marine water, fresh water and terrestrial habitats (Kinchin 1994; Nelson 1991; Ramazzotti et Maucci, 1983 cited by Romano 2003). All tardigrades are considered aquatic because they need water around their bodies to permit gas exchange as well as to prevent uncontrolled desiccation (Bordenstein 2008). They can most easily be found living in a film of water on lichens and mosses, algae as well as in sand dunes, soil, sediments, rooted aquatic vegetation and leaf litter (Figure 11).

Figure 11. Right: Coloured scanning electron micrograph (SEM) of *Echiniscus testudo*, a marine tardigrade (retrieved 11.01.2011, from http://www.sciencephoto.com); Left: Tardigrades can be found in and easily collected from moss (Wikimedia Commons, retrieved 11.01.2011, from http://serc.carleton.edu).

It is thought that tardigrades are so widely distributed because they are carried by the wind. Their eggs, cysts, and tuns are light enough to be distributed by wind, floating plants or animals for great distances. This theory seems to be supported by the discovery of tardigrades on remote volcanic islands, where they could only have been deposited by wind or birds.

Their presence in the extremely cold environments from the poles (5m below solid ice, as low as -80 °C) is of high importance as sometimes they represent the only organisms able to populate these areas. The limno-terrestrial tardigrade fauna in Antarctica and the sub-Antarctic islands is currently represented by two classes with 17 genera and approximately 48 species (Convey & McInnes 2005 cited by McInnes 2010).

1.4 Tardigrades in Extreme Environments. Tardigrades are polyextremophiles. One of the main reasons for which water bears are so intensly studied, is their ability to survive in a variety of extreme conditions.

When they are in the active stage (ex. when they crawl around, eat and reproduce) they are no tougher than any other animal (Figure 12). However, when conditions worsen water bears can dry or freeze - this peculiar form of existence is called cryptobiosis (or anabiosis). When cryptobiotic, their metabolism is undetectable. In this anabiotic stage they can be exposed to very high X-ray radiation of 570 000 rads, very high pressure or vacuum, they can withstand temperatures as high as over plus 150°C and as low as minus 272.8°C (almost absolute zero). Tardigrades have been known to survive the following extreme conditions also: freezing and/or thawing processes, changes in salinity, lack of oxygen, lack of water, excessive concentrations of CO, CO_2, N_2, H_2S, some noxious chemicals, boiling alcohol, low pressure of a vacuum.

Eutardigrades show excellent tolerance to starvation and it has been reported that they survive several weeks of starvation (Ramazzotti et Maucci 1983). Tardigrades can also resist in the vacuum of the outer space (Jönsson et al 2008).

Terrestrial tardigrades are well adapted to extreme environmental changes in their microhabitats and well known for their capabilities to survive for several years in an anhydrobiotic (lack of water) or cryobiotic (low temperature) state. In the anhydrobiotic state they can endure experimental conditions of low or high temperatures as well as immersion in organic solvents, or exposure to high doses of radiation and hydrostatic pressure (Westh et al 1991; Ramløv et Westh 1992; Westh et Kristensen 1992; Seki et Toyoshima 1998; Ramløv et Westh 2001; Horikawa et al 2006; Jönsson et Schill 2007; Jönsson et al 2008; Ono et al 2008; Hengherr et al 2009 cited by Reuner et al 2010). A longevity of 20 years has been reported for the species *Echiniscus testudo* stored under laboratory conditions (Jørgensen et al 2007 cited by Reuner et al 2010). Some species are known to survive for more than 100 years in a cryptobiotic state.

Figure 12. Right and left: Scanning electron micrograph of adult tardigrades (*Hypsibius dujardini*) (Gabriel W., retrieved 11.01.2011, from tardigrades.bio.unc.edu); Center: Close up (retrieved 11.01.2011, from http://www.atlibertytosay.com).

Under more natural conditions they have the capacity to survive unfavourable periods by complete desiccation. In this anhydrobiotic state the tardigrades do not show measurable metabolism and form the so-called tun state (Baumann 1922 cited by Reuner et al 2010). Moreover, the tun is resistant to extreme pressures and temperatures (low/high), as well as radiation and vacuum (Horikawa et al 2006; Hengherr et al 2009; Jönsson et al 2008; Jönsson et Schill 2007; Wright 2001 cited by Förster et al 2009).

1.5 How do they do it? Tardigrades are capable of reversible suspension of their metabolism and entering a state of cryptobiosis (Keilin 1959; Ramazzotti et Maucci 1983 cited by Förster et al 2009). Anton van Leeuwenhoek first documented cryptobiosis in 1702. Tardigrades have drawn the majority of the attention that they have received from this quite unique quality apparent through all species of tardigrades.

During this process, metabolism lowers to 0.01% of normal or is entirely undetectable and the water content of the body decreases to less than 1%.

Latent states (cryptobiosis, including encystment, anoxybiosis, cryobiosis, osmobiosis and anhydrobiosis) enable tardigrades to withstand unfavourable environmental conditions (Nelson et Marley 2000). Each of these states represents the reaction to the changes within an external factor (environmental extreme condition): slow changes in the environment, reduction in oxygen, freezing, increased salinity respectively loss of water.

Unlike other types of cryptobiosis, anoxybiosis involves the uptake of water and the animals become turgid. Revival time is directly proportional to duration of the dormant state.

Cryobiosis is a form of cryptobiosis which is initiated by a reduction in temperature and involves the ordered freezing of water within the cells. The studies done by Somme in 1995 and 1996 have helped to develop a greater understanding of the mechanism tardigrades use to survive extreme temperatures. Cryobiosis allows tardigrades to tolerate rapid freezing and thawing cycles and allows for tardigrades in Arctic and Antarctic habits to withstand the temperature changes which occur (Wright 1992 cited by Lindahl & Balser 1999).

Osmobiosis is a form of cryptobiosis initiated by a decreased water potential due to increased solute concentration in the surrounding solution. Upon immersion in non-ambient saline solutions tardigrades commonly contract rapidly into a tun. Some tardigrades are found in the marine intertidal zone and can tolerate changes in the salinity of the water.

The most common type of cryptobiosis studied in tardigrades is anhydrobiosis, a form of cryptobiosis initiated by desiccation.

Tardigrades can survive many environmental extremes by converting themselves into a 'tun' (Figure 13). Tun formation, a vital part of the process, results in a body that is constricted and folded. Wax extrusion covers the surface and may help to reduce transpiration (water loss by evaporation). This involves them pulling in their legs to give their body a cylindrical shape and then shutting down all their metabolism and exhibit almost zero metabolism. Only tardigrades regularly return to life again from this state.

They perform this miracle by replacing the water in their membrane lipids with a sugar called trehalose. Different species have different survival characteristics. Revival from this state typically takes a few hours but is dependent on how long the tardigrade has been in the anhydrobiotic state (Somme 1996 cited by Lindahl & Balser 1999).

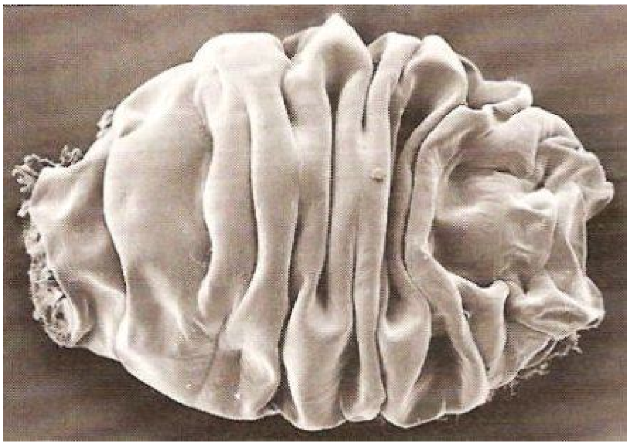
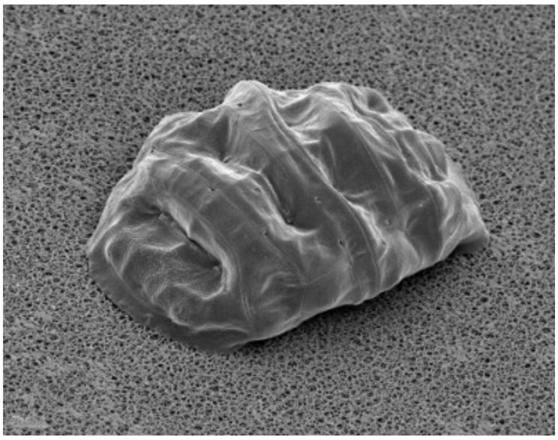

Figure 13. Right: The water bear *Adorybiotus coronifer* in a state of cryptobiosis (retrieved 11.01.2011, from http://www.diagonale-groenland.asso.fr); Left: tardigrade in anhydrobiosis (retrieved 11.01.2011, from http://cires.colorado.edu).

This amazing ability of the tardigrades can be found even in their egg form. Although little is known about egg dormancy in tardigrades, their ability to survive desiccated for a long time has been found (Altiero et al 2009).

In order to recover without any apparent damage, tardigrades have evolved effective adaptations to preserve the integrity of cells and tissues in the anhydrobiotic state (Neumann 2009).

One mechanism is somehow linked to a specialized category of cells, the storage cells. These cells are potentially important in mediating the protection of the other tissues by, for example, producing protective metabolites. The high variability in number and size of the storage cells reflects the versatile role these ‘organs’ play in the life of the tardigrade (Reuner et al 2010).

Desiccation tolerance is also correlated with an increase in the antioxidant potential in several organisms, but the regulation of the antioxidant defense system is complex and its role in desiccation-tolerant organisms is not yet firmly established. Having an antioxidant metabolism could represent a crucial strategy to avoid damages during desiccation in anhydrobiotic tardigrades (Rizzo et al 2009).

Proteins member of different heat shock protein families and LEA group 3 might play important roles in surviving extreme conditions (Schokraie 2010).

Tardigrade genomes invest in stress-specific adaptations, this includes major sequence related protein clusters, functional clusters for stress as well as specific regulatory elements in mRNA (Förster et al 2009).

Vitrification too is assumed to play a major role in the survival of anhydrobiotic organisms during exposure to extreme temperatures, and consequently, the glass transition temperature (Tg) is critical to high temperature tolerance.

1.6 Tardigrades in the outer space. Tardigrades' physiology makes them so tough that they can also resist in the outer space (Figure 14). After they dehydrate they exhibited rates of survival close to the individuals that have never left the laboratory. Therefore they have been included in the Top 10 Things Launched Into Space in 2008.

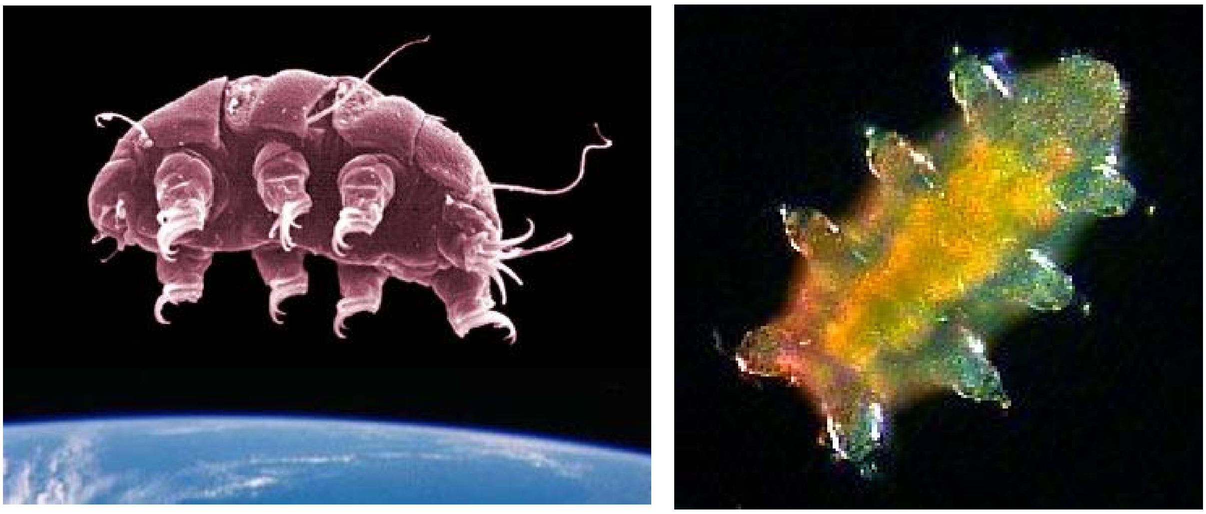

Figure 14. Right: Tardigrades are able to resist in the harsh conditions of the outer space (Google Images, retrieved 11.01.2011, from http://carlygoogles.blogspot.com); Left: NASA's Astrobiology site cites the tardigrade as an example of an 'extreme animal' (Mach M., retrieved 11.01.2011, from http://www.preoccupations.org).

In September 2007, tardigrades were taken into low Earth orbit on the FOTON-M3 mission and for 10 days were exposed to the vacuum of space. After they were returned to Earth, they were analyzed for survival and reproductive potential, and for damage on DNA.

The Tardigrade Resistance to Space Effects (TARSE) project, part of the mission LIFE on FOTON-M3, analyzed the effects of the space environment on desiccated and active tardigrades (Rebecchi 2009). Another project part of this mission was Tardigrades in Space (TARDIS) one of the first research project to evaluate the ability of tardigrades to survive under open space conditions.

The aim of these projects is to see if these animals, as the first ever, are able to cope with the extremely dry conditions of deep vacuum and the harmful solar and galactic radiation up there. In the past, several biologists have suggested that tardigrades may be one of the few animals that have a chance to come back alive after a trip in real space. At a more mechanistic biological level, exposure of organisms to space conditions will reveal how living cells react to the potentially very stressful impact of space parameters (Figure 15).

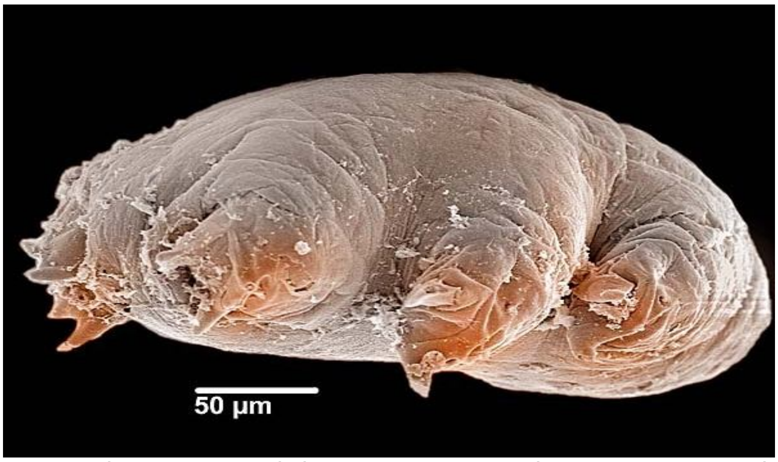

Figure 15. Dried-up water bears survived the open space conditions - vacuum, ultra-violet radiation from the sun and cosmic radiation, most of them being revived with a drop of water (retrieved 11.01.2011, from http://www.vyoos.com).

The results showed that microgravity and radiation had no effect on survival or DNA integrity of active tardigrades. Some characteristics did not differ between the animals in space and the control animals on Earth. During the flight mission, tardigrades molted, and females laid eggs. Several eggs hatched, and the newborns exhibited normal morphology and behavior (Jönsson et al 2008).

The space vacuum and cosmic radiation did not affect their survival or reproduction at all. What this means is that these animals can either protect their cells from expected damage of the extremely dehydration impact of space vacuum, or that they can repair damage that arise in some way (Jönsson 2008).

This way, these organisms will be important sources of knowledge for how to generate the space ecosystems that will be necessary for the more permanent human establishments in space that is envisaged today (the TARDIS project).

There is a theory that even suspects these organisms might be extraterrestrial as they have extremely unusual properties. Some authors (Vettner 1990 cited by Mach) have claimed that the tardigrades might have developed on distant planets as evolution wouldn't create those extreme properties without need. The water bears seem to be among those few organisms on earth that might travel across the universe without any modification as they can survive high levels of radioactive radiation, withstand a vacuum (when in dry state), have no problem with temperatures as low as -273°C, they might survive elevated temperatures (100°C) when diving from space into the atmosphere and their dry state persists for many years without food, water and oxygen. Further points mentioned are the lack of clear relations to other zoological phyla and the scarce fossil findings of tardigrades. Plus the fact that they can exist in vacuum mean that other organisms might have a tun-like state, drifting through space in search of new worlds to thrive on.

But as Martin Mach, the author of the article suggests, these are just theories. There is a lot of interests for these organisms and there is still a lot to learn about them.

1.7 Uses of tardigrades. The cryptobiotic properties of tardigrades helped scientists to develop so called 'dry vaccines'. In such vaccines water is replaced with trehalose (a non-reducing sugar used by water bears to protect their tissues and DNA during cryptobiosis). Dry vaccines don't require refrigeration and thus can be delivered and stored at room temperature in the most remote developing countries in the world. Other possible applications of the knowledge that we can obtain from tardigrades, are in the field of transplantology. It could be a way to preserve intact organs for months or even years and then bring them back to life by simply adding water (Michalczyk L.).

A combination of transcriptional, proteomic and metabolic approaches with bioinformatics tools can provide a better understanding of gene regulation that underlie the biological functions and physiology related to anhydrobiosis. The development of this concept will raise exciting possibilities and techniques for the preservation and stabilization of biological materials in the dry state (Ralph 2009).

Conclusions. Under sheets of ice, in hot springs, on mountain tops or in the sediments from the deep of the oceans, and even in space, tardigrades survive, as to demonstrate us all what extremophilic evolution and adaptation means. Tardigrades are survivors par excellence, the best in the animal kingdom.

Water bears are at the same time among the most unknown and the most fascinating creatures on earth. The ability to bring these fascinating creatures living into the laboratory is currently the biggest stumbling block to advancing knowledge (Roberts 1998).

Although scientists don't really know what their limits are, most of them, they are the toughest animals on the planet. They are the first animals known to be able to survive the harsh combination of low pressure and intense radiation found in space and are known for their virtual indestructibility on Earth. They have been shown to survive some of the harshest battery of tests and environments. If organisms can thrive under such hostile conditions, the reasoning goes, then maybe life exists elsewhere in the Universe (Gross 2002).

There is no doubt that tardigrades could travel to the stars amongst the dust on a piece of rock were the earth ever to be destroyed.

Studying tardigrades and extremophiles in general helps us know the way life works in these conditions that we may consider extreme, but, in the same time, they can teach us a lot about the nature of life itself. Starting with the most elementary bricks, extremophiles can help us understand what form of life may develop on other planets of our solar system, and also in the much further galaxies. The world of extremophiles has thus become a key field of study also for astrobiologists (Novey 2009).

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