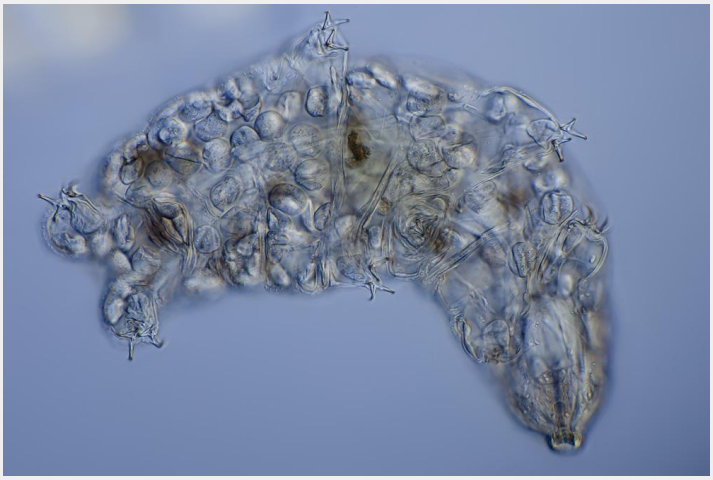
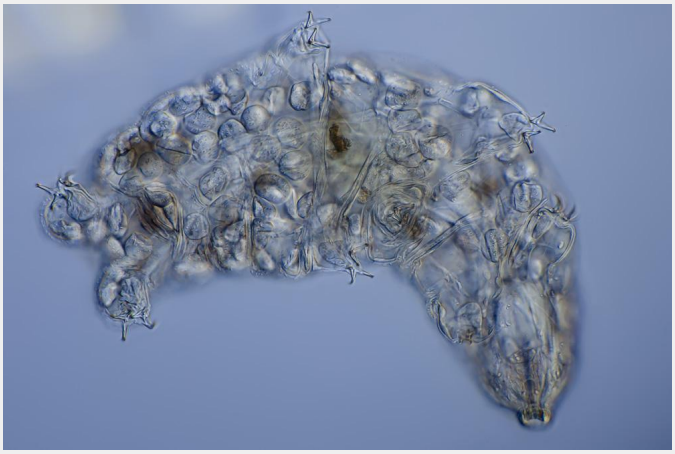
Physiology of Phylum Tardigrada



Kaylyn Flanigan

Physiology is the study of how an organism functions
The branch of biology that deals with the function and processes of a living organism

Introduction



In Invertebrate Zoology this week, our class was given a picture of this organism and we had to guess to which phylum it belonged.

I initially thought it was a nematode based on its body shape; I was wrong. I began looking in our textbook around the nematode chapter. Just before it was a chapter on Tardigrades and Onychophorans. I found an anatomical depiction of a tardigrade that matched the organism on the board.

The mystery was solved, this organism belongs to phylum Tardigrada!

Physiology is the study of how an organism functions
The branch of biology that deals with the function and processes of a living organism
Animal physiology is the scientific study of the life-supporting properties, functions and processes of animals or their parts. The discipline covers key homeostatic processes, such as the regulation of temperature, blood flow and hormones.

Bob Blaylock

Mangus Manske

Bobanny

Water-bears, moss-piglets, tardigrades must live within an area that provides a film of water
This includes moss, lichens, terrestrial plants, marine and freshwater[3]

This film of water is necessary to an active life. Eating, breathing, reproducing depends on the presence of the film of water[3]

Tardigrades can live anywhere on the planet encountering extremes. These extremes include super freezing, intense heating, radiation, dehydration, lack of oxygen, and immense pressure[1]

Extreme survivorship is an accolade only reserved for some species of terrestrial tardigrades; marine species do not change as rapidly and thus lost the ability to tolerate extreme abiotic fluctuations[9]

Strategies to mitigate extreme abiotic factors

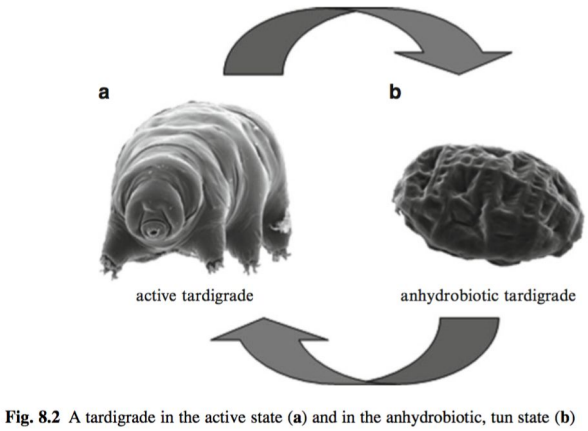
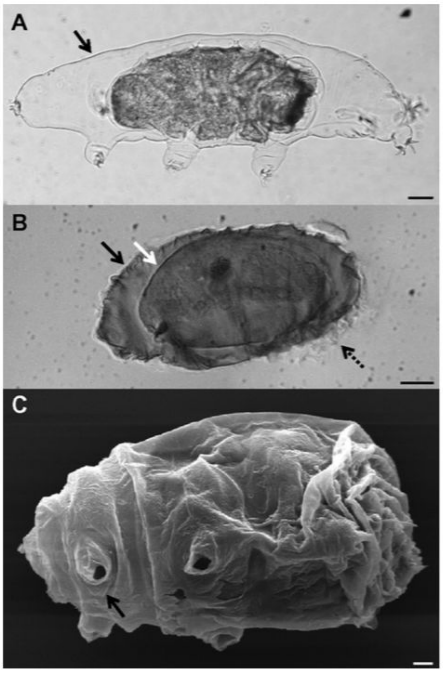


Fig. 8.2 A tardigrade in the active state (**a**) and in the anhydrobiotic, tun state (**b**)

Ralph Schill, 2010

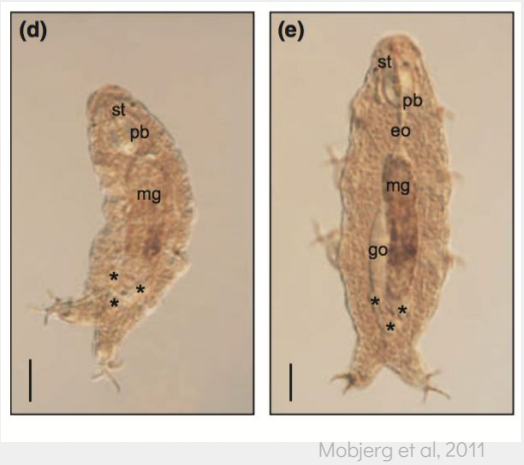


Guidetti, R. 2011.

There are three strategies that help the tardigrade mitigate extremes that it is well-known for[10]. Under some extreme conditions the tardigrade can actually mitigate these factors while still in its active state (fig. 8.2 a). These extremes include radiation, freezing, heating, changes in salinity, and drops in oxygen concentration[1]. In the crytobiotic state (tun state) tardigrades can tolerate anhydrobiosis (dehydration) and extreme amounts of pressure (fig. 8.2 b)[1,7]. In the cyclomorphic strategy (Guidetti, 2011 - ABC) some species can tolerate freezing based on seasonal morphs[1].

Tolerating extremes in **active state**

1. **Radiation:** make DNA repairing proteins & damage suppressor proteins[1,4]
2. **Freezing:** make ice-nucleating agents (INAs)[1,8]
3. **Heating:** make heat shock proteins, vitrify (to make glass) sugar to maintain important molecules, use molecule shields (LEAs)[1,5,6]
4. **Salinity:** osmoregulate - maintain body water relative to solute concentrations outside cell[1]



Mobjerg et al, 2011

H. crispae osmoregulating - swollen (e)

Tolerating radiation in active state:
- Use of DNA repairing proteins[1]
- Use of damage supressor proteins[4]

Tolerating freezing in active state:
- Entering cyclomorphic state (seasonal morph)[1]
- Synthesizing ice-nucleating agents (INAs)[8]

Tolerating heating in active state:
- Use of heat shock proteins (HSPs)[1,5]
- Vitrification (transition to amorphous solid) of trehalose[6]
- Late embryogenesis-abundant proteins ("molecular shields")[5]

Tolerating changes in salinity in active state:
- Osmoregulate: maintaining body water relative to solute concentrations outside of cells[1]

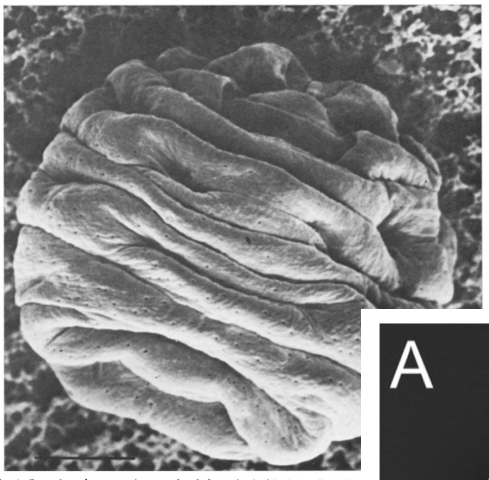
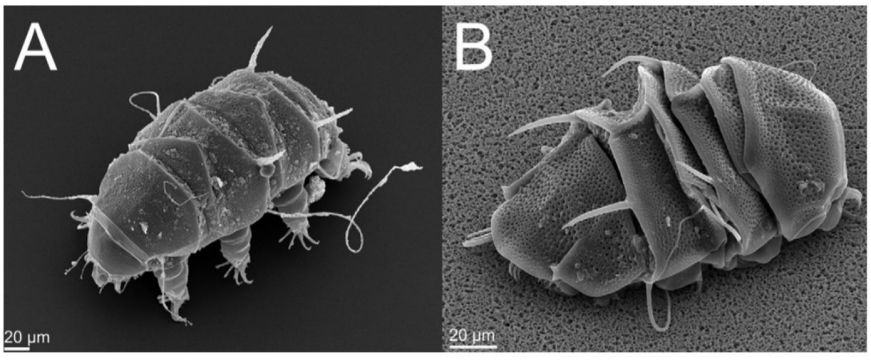


Fig. 1. Scanning electron micrograph of the anhydrobiotic tardigrade, The animal has contracted to form the so called "tun". The bar indicate

Walz, B. 1979

Tolerating extremes in **cryptobiotic (tun) state**

1. Dehydration (anhydrobiosis)[1,2]
2. High pressure[1,2]



Wełnicz

Fig. 1. Scanning electron micrographs of *Echiniscus granulatus*. Dorsal view of (A) active and (B) tun state.

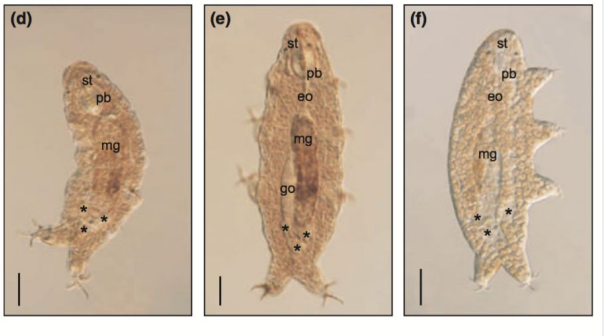
Tolerating anhydrobiosis (dehydration):

- Species will bring their legs in and curl their body laterally to form a ball[1]
- Metabolism will decrease to 0.01% of active metabolism[2]
- 97% of water is expelled from the body[9]
- Trehalose (disaccharide - sugar - carbohydrate) is produced in some species to form a matrix around their membranes, DNA, and proteins to avoid breakdown[1,5]
- Other species produce TDPs (tardigrade-specific intrinsically disordered proteins) to avoid desiccation[11]

Tolerating extreme amounts of pressure:

- Active tardigrades cannot survive >200 MPa[7]
- Tun tardigrades can survive 600 MPa[7]
- Due to tun state being more compact (?)
- Also, DNA repair proteins and matrix forming trehalose could play a role[2,7]

Tolerating extremes in **cyclomorphic** state



Mobjerg et al, 2011

(f) is the freeze-tolerant morph.

Halobiotus crispae exhibits cyclomorphosis - depending on the season, it will have a different phenotype[1]

Tolerating freezing in cyclomorphic state:

- H. crispae has a freeze-tolerant morph that occurs seasonally[1]

Similarities

1. Dehydration → tun state
2. Radiation is mitigated better in active state; pressure is tolerated better in a tun state[1,7]
3. The length of time spent in the tun state is correlated with the amount of DNA damage[1]

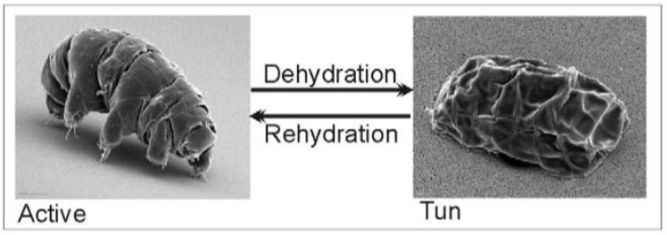


Figure 1. SEM images of *M. tardigradum* in the active and tun state. Tardigrades are in the active form when they are surrounded by at least a film of water. By loosing most of their free and bound water (>95%) anhydrobiosis occurs. Tardigrades begin to contract their bodies and change their body structure into a so-called tun.
doi:10.1371/journal.pone.0009502.g001

Schokraie, et al.

Radiation[1,5]

1. *Richtersius coronifer* (after >1,000 Gy, tardigrade becomes sterile)
    a. Desiccated: 1,000 Gy
    b. Hydrated: 5,000 Gy
2. *Milenesium tardigradum*
    a. Desiccated: 5,000 Gy
    b. Hydrated: 8,000 Gy

Differences (a few...there are many)

1. Tactics for maintaining homeostasis varies with species
    a. *Macrobiotus sp.* synthesize trehalose (disaccharide) but it is not measurable in *Milnesium tardigradum*[1,5,6]
    b. Some species produce trehalose while others create tardigrade-species disordered proteins to mitigate desiccation[1,2,11]
2. Different species synthesize different bioprotectants
    a. Some species utilized heat-shock proteins while others rely on DNA repair machinery and LEA proteins that act as "molecular shields" against denaturing proteins[1,5]
3. Tolerances for each extreme (dehydration, temperature, pressure, irradiation) have different limits based on species
    a. *Echiniscus testudo* has a longer cryptobiotic life expansion than *Richtersius coronifer*[1]
    b. *M. tardigradum* can withstand higher irradiation without consequences than *R. coronifer*[1]
    c. *M. tardigradum* had the greatest recovery after extreme warming than any other species[6]

There are many species-specific differences across the phylum

Works Cited

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