The Amazing Tardigrade

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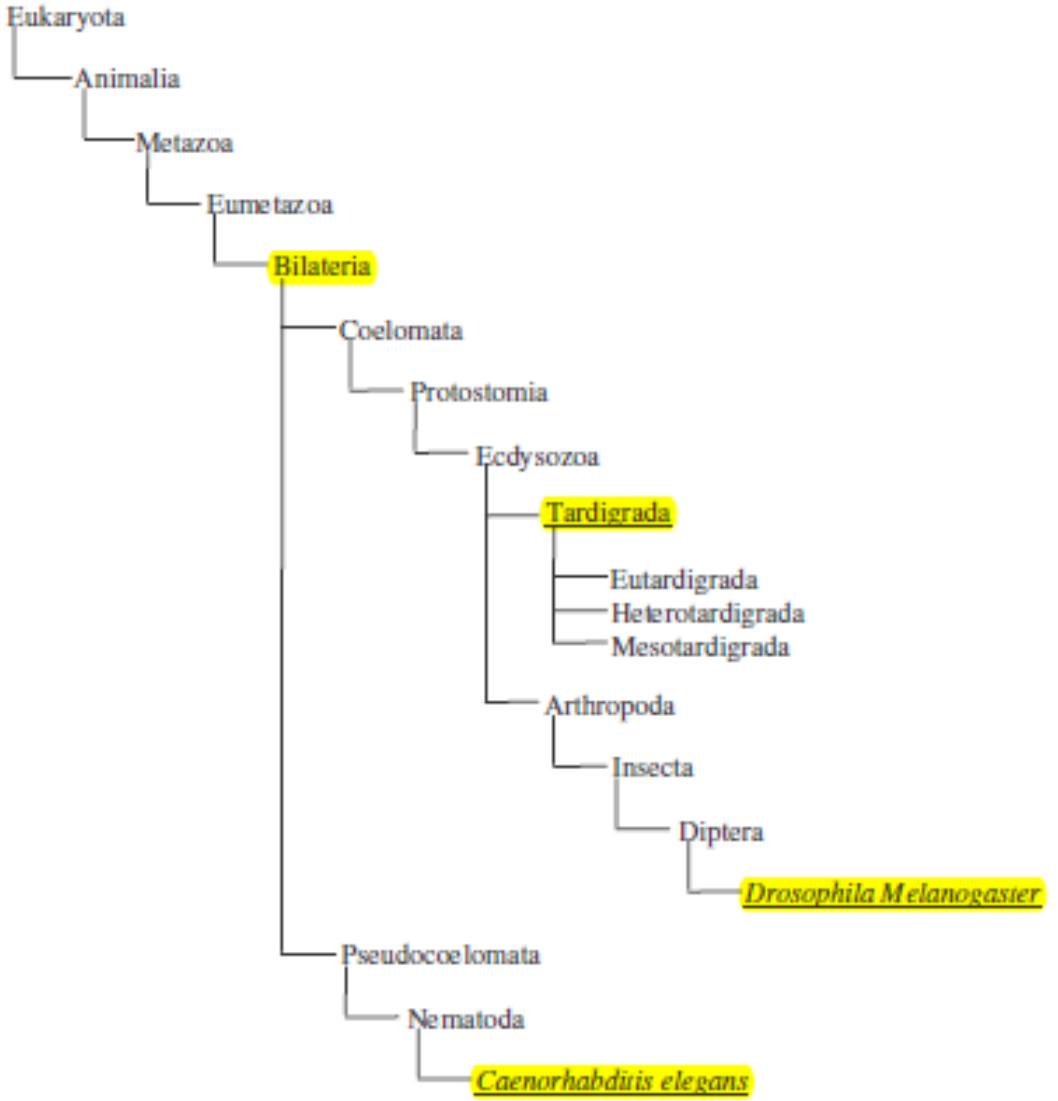
Where on Earth?

- Originally aquatic, but thrive in zones of hardship
  - Few competitors
  - Less predators
- Most are normal
  - Freshwater and semi-aquatic terrestrial habitats
- Some are not
  - Hot springs, ocean trenches, mountain-tops

What is it?

- Between a worm and a fly
- Relatives of the most widely researched model biological systems:
  - Fruit flies
  - Nematode worms

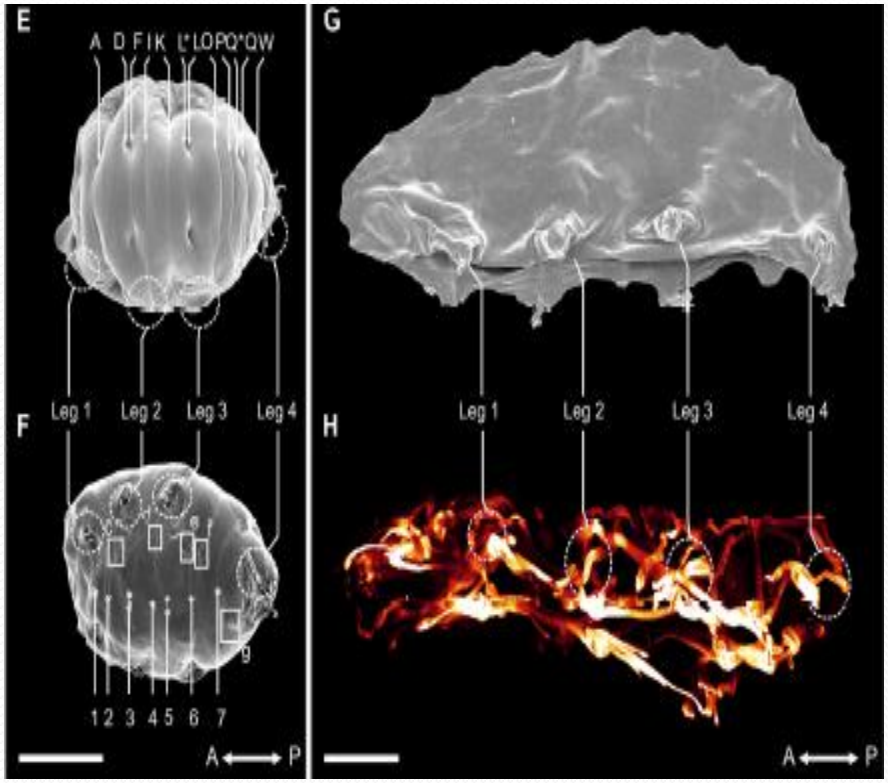


Adaptations

- Small, have tissues and organs, easy to grow and study in the lab (0.5 mm)
- Thrive in habitats where they can exercise special abilities
  - Anhydrobiosis (entering the tun state) includes:
    - Up to 97% water loss
    - Up to 1/3 size reduction
    - Transition in a few minutes to few hours
- In a dehydrated state, species can withstand
  - Physical hardship: cold, vacuum, UV, gamma, and heavy ion irradiation
  - Chemical hardship: acidic, basic, and high salinity

Desiccation State

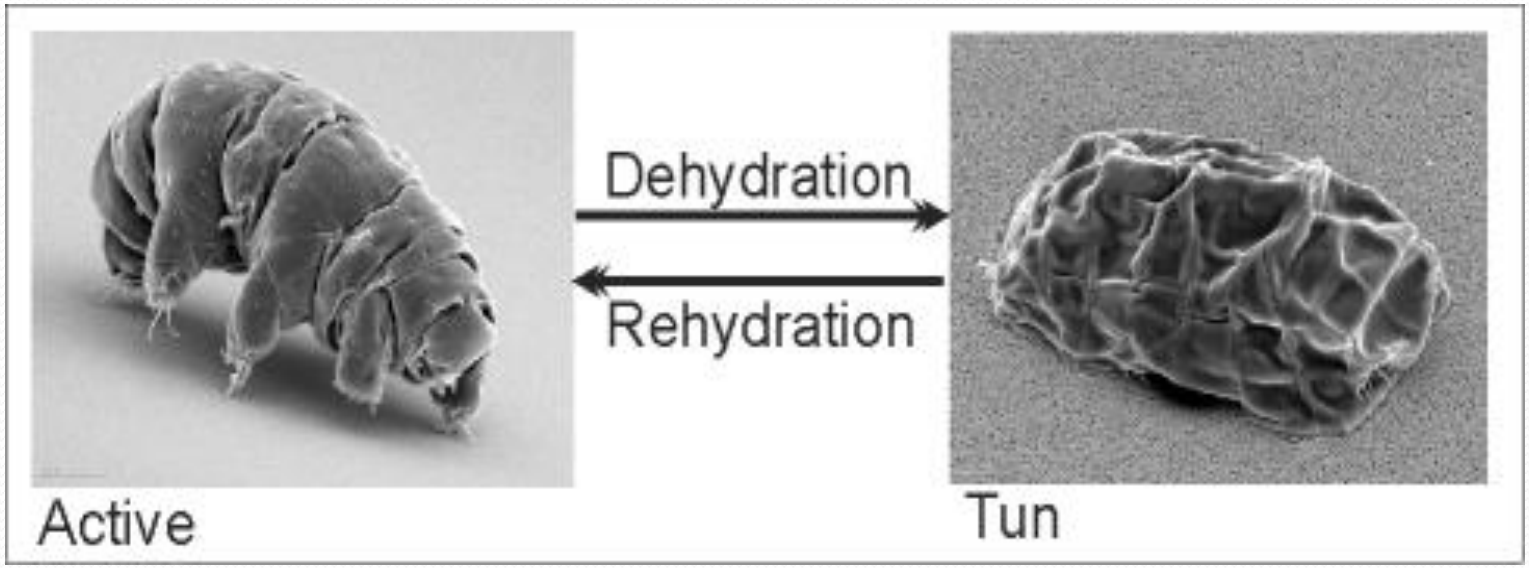
- Metabolism is minimized (<0.01%) but still ongoing
- Mitochondria function is needed
  - Oxygen and ATP required for tun formation
  - 6 months without oxygen: Echiniscoides species member was found naked! (without a cuticle)
- New shape requires active musculature



Richtersius coronifer

Changing Cuticle Composition

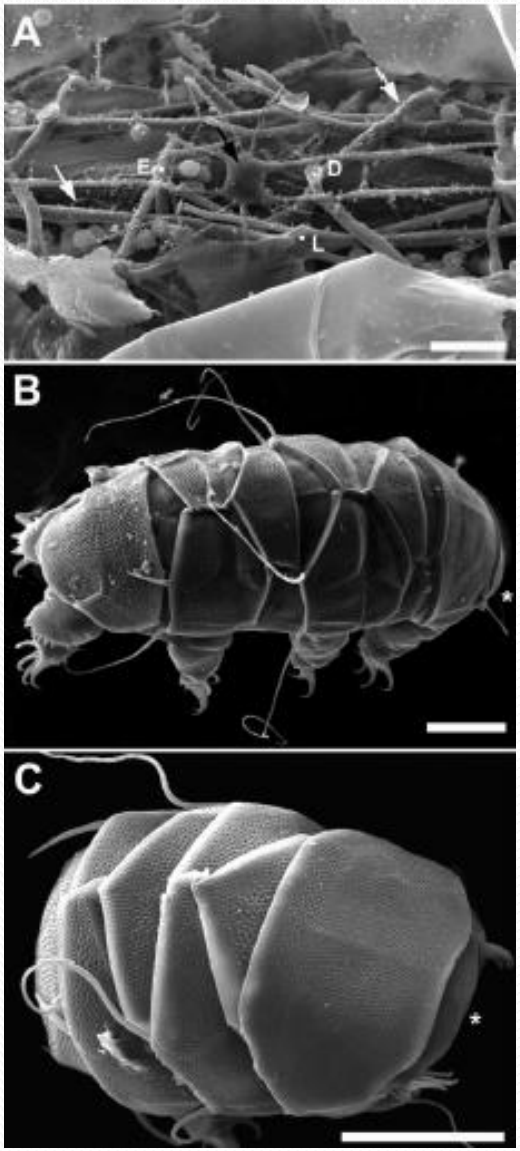
- Species: Bertolanius volubilis
  - Type 1: Winter to next Summer
  - Type 2: Summer and Fall



Milnesium cf. tardigradum

Tun Formation

- Steps to desiccated state
  - Limb invagination
  - Decreased volume
  - Decreased surface area
- Shape of tun varies per species

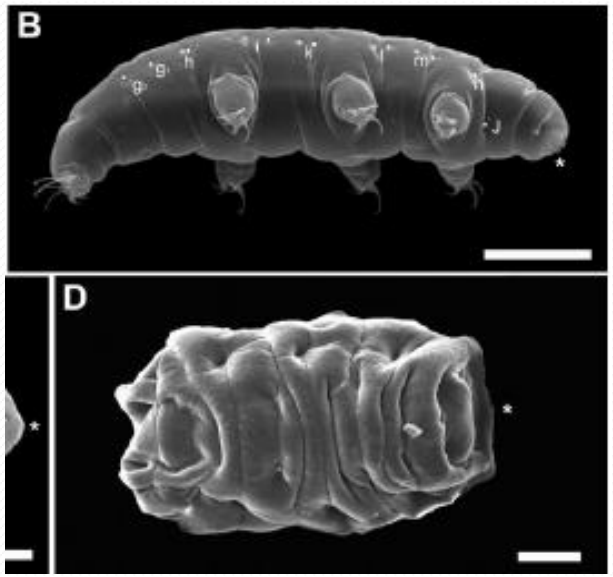


A. Muscle fibers of *Paramacrobiotus richtersi*

B. Normal state and C. Anhydrobiotic state or *'tun state' of Echiniscus testudo*

Concentration of Ions

- Ions are important to maintain
- Removal of water increases concentrations
  - This would lead to a loss of ions if a powerful ion-retentive mechanism were not in place
- Principle inorganic ions: Na^+ and Cl^-
- High Ca^{2+} concentrations used for muscle contraction
- Substantial F^-, PO_4^{3-}, and SO_4^{2-} detected in all tardigrades
- F^- found in hard tissues, bones, and exoskeletons
- Fraction of unidentified compounds
  - Related to cryptobiosis



Milnesium cf. tardigradum
A) Hydrated
D) Tun state

It's in the Genes!

Shared living strategies with brine shrimp

- Problem: Dehydration causes DNA damage
- Solution: Store chaperone codes as mRNA
  - Chaperones help protein folding
  - mRNA is unstructured and flimsy
  - mRNA is protected by cushion proteins when leaving the nucleus
- Artemia franciscana (brine shrimp) also do this
  - Accumulation of mRNA before the dispause stage

In order to prepare the tardigrades for space…

Tardigrade in a Space suit

FOTON-M3

- This is a European Space Agency mission of 2007
- Subjects: *Richtersius coronifer* and *Milnesium tardigradum*
- Experiments: UV-A, UV-B, or both
  - Space vacuum exposure
  - UV radiation dose: 7000 kJ/m^2 under space vacuum conditions
- Results:
  - All specimens survive vacuum (no impact to egg laying/hatching)
  - Most died when exposed to UV-A, UV-B, and a vacuum

DAMA Mission

- Italian Space Agency and Italian Air Force
  - Carried out on the International Space Station (2014)
- Subjects: *Paramacrobiotus richtersi* and *Ramazzottius oberhaeuseri*
- Experiment: TARDIKISS
  - Biochemical content and changes from physical stress
  - Results of vacuum exposure
    - High survival rates of all species (91%)
    - Higher number of eggs laid/hatched
    - Shorter egg development time

Sum It Up

- Tardigrades protect themselves
  - Controlled desiccation
- Mechanisms
  - Powerful molecular ion-balancing mechanism
  - Storage of chaperones as mRNA

Astrobiology Application

- Expanded scope of where life can survive
  - Novel adaptability techniques
- Applications of mRNA storage
  - Battling diseases
- Human parallel of Tardigrade desiccation state?
  - With any foreseeable technology, interstellar travel would require hibernation/suspended animation/cryptobiosis.
  - Much research is needed

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