VI Tardigrades

In 1773, a German pastor, Johann August Ephraim Goeze (1731-1793), was the first to describe a new animal in the book "Herrn Karl Bonnets Abhandlungen aus der Insektologie": "… *strange because of its extraordinary anatomy and at first glance its appearance has a strong resemblance to a little bear. It is because of this I will name them small water bears*…" Goeze also included the first drawing of a tardigrade in this book (Fig. VI.I).

Six years after the publication of Goeze, the famous naturalist Lazzaro Spallanzani (1729-1799) made the first scientific description of the water bear. Since then they have been called tardigrades. The name refers to the animal's slow movements (Lat. *tardus* - slow, *grado* - walker).

The group of tardigrades is quite old. Two fossils are known from amber which trapped the creatures and was formed in the Upper Cretaceous period which was 60 – 80 million years ago. Another specimen has been discovered in amber which is approximately 92 million years old. There are also a few specimens known from the mid Cambrian (around 550 million years ago), which have been attributed to a stem-group of the water bears.

The number of known tardigrade species has been increasing steadily over the last decades. In 1972, 301 water bear species were known and had been catalogued, with the number increasing to 531 by 1983, 960 by 2005, and today we know more than 1,000 different species of tardigrades from all over the world. Tardigrades can be found in a variety of habitats including marine, brackish, freshwater and terrestrial ecosystems, ranging from the deep sea to the highest mountains, as well as in many extreme environments ranging from the coldest to the hottest and driest places.

Terrestrial tardigrades mostly live in patches of moss or lichens (Fig. VI.II): they can be up to just over 1 mm in size. They have a cylindrical body with four pairs of clawed legs (Fig. VI.III). Marine tardigrades are often less than 0.5 mm in size, and can have various different appendages in place of claws. The body of tardigrades can also carry appendages. Not much is known about their feeding behaviour in general, although it is known that many tardigrades are carnivorous or at least omnivorous. They typically hunt protozoans, rotifers, and nematodes, living within the same habitat. Within seconds, they pierce their long and sharp-edged stylets into the prey and suck the body fluids. Small prey can be eaten completely (Fig. VI.IV). Although some species have eyes, they are generally poor and do no appear to be used for hunting. Herbivorous tardigrades are able to pierce the cells of moss or green algae whereby they can feed by sucking out the cellular fluids.

Sexual reproduction or mating takes place, but observations are really rare. However, many species are parthenogentic (i.e. the ovum does not require fertilisation to develop into a new individual); therefore no males are known. This may be an evolutionary advantage for colonisation of new habitats as a single female is able to establish a new population. Many tardigrades lay freely single eggs with a miscellaneous egg-shell morphology (Fig. VI.V). But there are also species which lay egg clutches into the exuvium after molting. The embryonic development varies between a few days to several months, depending on species, but all animals molt continuously throughout their life time which varies also between a few months and a couple of years.

Due to their ability to enter a cryptobiotic state (similar to an extreme form of hibernation whereby all metabolism stops) at any developmental stage, tardigrades are capable of surviving extreme conditions for very long periods of time and are able to extend their lifespan significantly.

Drying of cells and whole organisms generally leads to massive damage of cellular properties, which usually results in cell death and, consequently, death of the organism. However, this is not the case of tardigrades. They have the remarkable ability to circumvent such problems by retracting their legs and entering a form known as a tun (from the German word "Tönnchen") (Fig. VI.VI) during periods of desiccation. This is an ametabolic state; a state without visible signs of life. In this state they are able to survive exposures to extreme temperatures over 100°C, they are freezing tolerant and can also survive ionizing radiation, and high pressure. Tardigrades have even been shown to be able to survive in the vacuum of open space. A number of tardigrades were exposed to the vacuum of space in a low earth orbit for 10 days. It was found that on return to earth many of the organisms survived and laid eggs which hatched normally. Currently, the longest known observation of an extended lifespan in the tun state was 20 years.

Due to the fact that tardigrades show extraordinary tolerances to a range of physical extremes they are now being used as a new model organism to study mechanisms of preservation in several fields of research and applied technologies. Tardigrades may eventually tell us something fundamental about the nature of life itself.

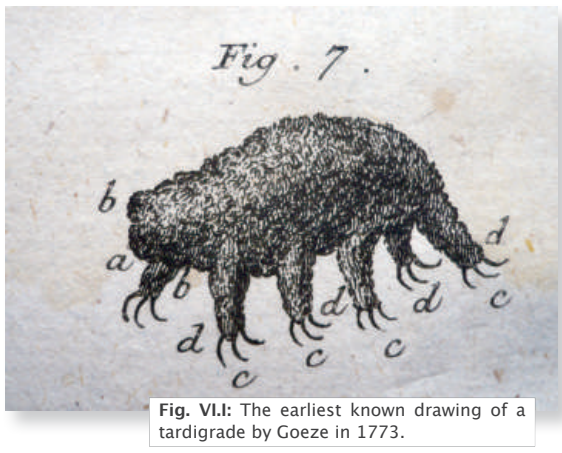

Fig. VI.I: The earliest known drawing of a tardigrade by Goeze in 1773.

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Fig. VI.II: A tardigrade of the species *Paramacrobiotus kenianus* sitting on a moss leaf.

Fig. VI.III: The tardigrade *Echniscus granulatus* has relatively long appendages and strong claws.

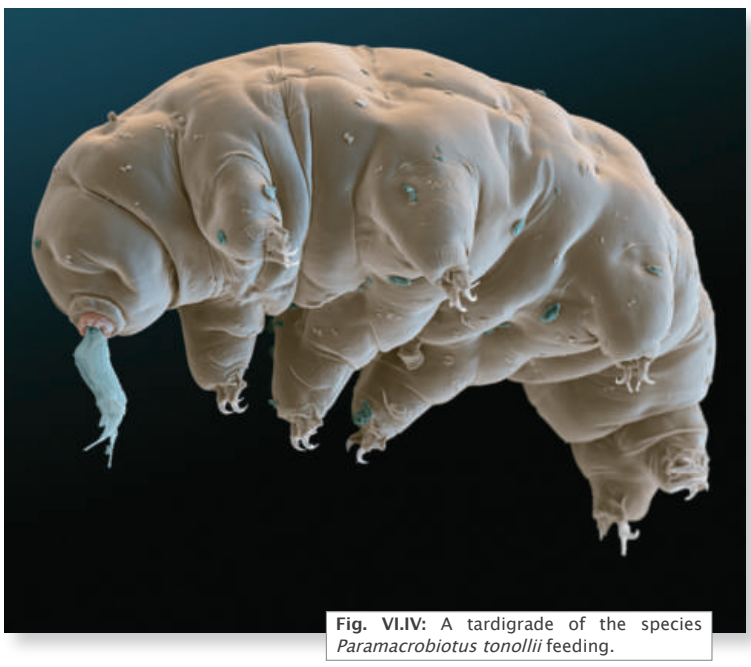

Fig. VI.IV: A tardigrade of the species *Paramacrobiotus tonollii* feeding.

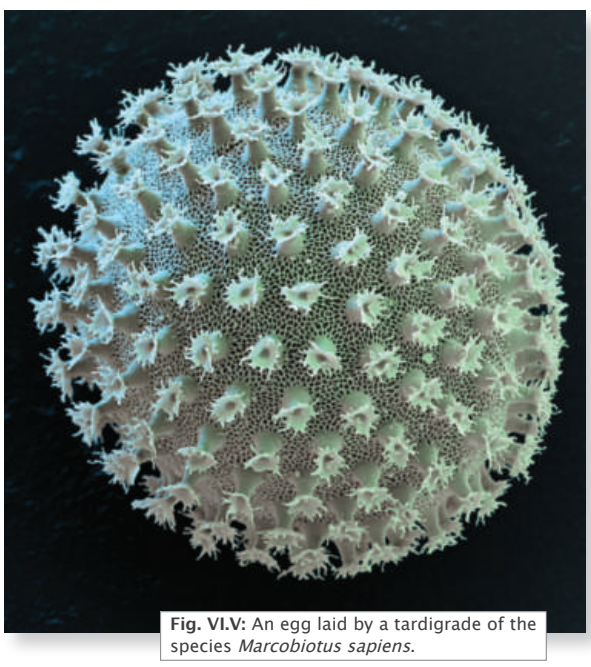

Fig. VI.V: An egg laid by a tardigrade of the species *Marcobiotus sapiens*.

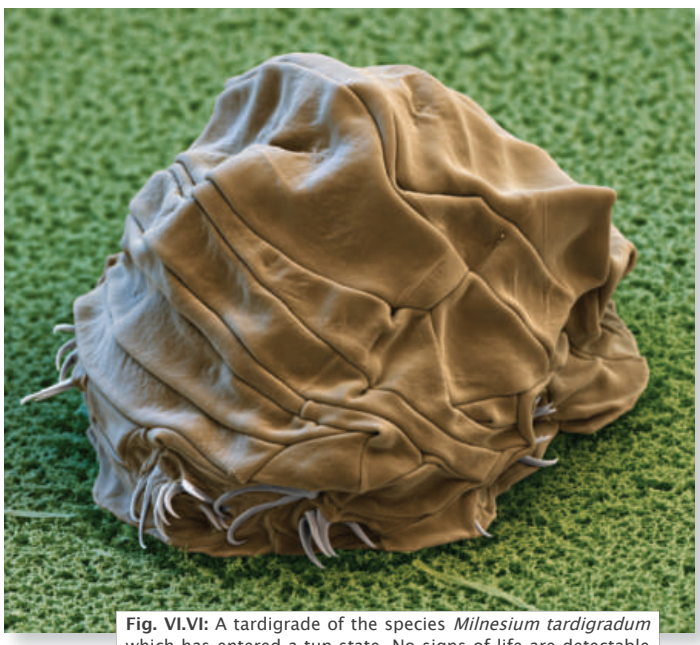

Fig. VI.VI: A tardigrade of the species *Milnesium tardigradum* which has entered a tun state. No signs of life are detectable while tardigrades are in this state, although they are capable of revival when environmental conditions again become suitable.