

A NEW ORDO OF TARDIGRADES FROM THE HOT SPRINGS OF JAPAN (FURU-YU SECTION, UNZEN)

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TWO FIGURES

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A. INTRODUCTION

The Tardigrades or, as they are called in English, the water-bears, belong to the group of animals known in science as anabiotic animals. That means that these animals possess the faculty of leading a latent life even under the most adverse conditions of cold and heat and drought. In this state of life the resistance against extreme temperature and other bad influences of the environment is enormous. They survive even in liquid helium ($-269^{\circ}\text{C}.$) which is by expansion brought to the extreme temperature of $-271.5^{\circ}\text{C}.$ They can endure for a short time degrees of $150^{\circ}\text{C}.$ +, and a difference of over 400 degrees by sudden transition from the electric stove heated up to $150^{\circ}\text{C}.$ to liquid hydrogen ($-252.8^{\circ}\text{C}.$) does not kill them. We have exposed them to X-rays of a dosis mortal for many other animals and pathogenic bacteria, to ultraviolet and radium rays, to 1000 atmospheric pressure, without doing any harm to them. Even in a vacuum of X-rays they could live 20 months (Details you find in No. 4 of Literature). To this wonderful power of resistance the Tardigrades owe their world-wide distribution. In the latent state of life the animal's body shrinks as the water evaporates, and it becomes like a ball or, as we may call it, like a little barrel, in order to reduce the surface to a minimum. Tardigrades live generally in mosses and lichens on walls and rocks and barks of trees; but by their faculty of leading a latent state of life in cases of adverse conditions, they have been described from many other places of our planet. We discovered them even in the deserts, in the desert-like hills between Jerusalem and the Dead Sea in Palestine, in the Atacama Desert in North Chile, in the South of Australia near the Nullarbor Plain and in the Sahara Desert near

Luxor and Cairo. Recently we could prove that many of them live in the desert-like places of North China. They have been found in the depth of the Lake of Geneva at 150 metres; they are recorded from the altitudes of the mountains as the Alps, the Himalaya and the Andes. We collected them from 5,200–5,600 metres in the Andes of Peru, and they were found even at the altitude of 6,600 metres in Bolivia. Some Tardigrades live in fresh-water, and generally they do not possess the marvellous power of the so-called “anabiosis”, the faculty to lead a passive or latent life. From the sea only very few species are known. Only one of them is capable of being dried up with the environmental algae, giving up all movements and living like a terrestrial animal a latent life for some days.

Thermophile Tardigrades have never been recorded up to this date. In the end of May this year we passed by Unzen Park in order to collect some thermophile Nematodes from the hot springs. We were very much surprised to find among them also Tardigrades, the first ones found in hot springs.

B. DESCRIPTION OF THE NEW ORDO AND CLASSIFICATION

According to Marcus, who has revised and classified all Tardigrades known up to this date (1936), the Tardigrades are divided into two principal orders, the *Heterotardigrada* and the *Eutardigrada*. The first group is distinguished by the cirrus lateralis and the clava on both sides of the body. The pharynx is without the so-called bacilla or komma, but fitted with some chitinous thickenings. Toes and claws are equal, and each claw is separated completely from the neighbouring claws. Vasa Malpighii are not known. The *Eutardigrada* do not possess lateral appendices. The pharynx contains a number of bacilla or grains; the stylets are of convex shape. The claws are divided into a main and a smaller branch, which are connected on the basis. There can be distinguished a rectal gland and vasa Malpighii (cf. figure I).

The new order may be placed between the *Heterotardigrada* and the *Eutardigrada*. We call it *Mesotardigrada*. The animal possesses a cirrus lateralis, but no clava. Lateral spines are four in number on both sides of the body, on b, c and d according to the nomenclature given by Thulin (7) and adopted by all specialists. The pharynx contains bacilla, but no komma. Toes and claws are nearly equal, with exception of the outer ones on both sides, which are a little longer than the inner ones, but there is no distinction between the main and side

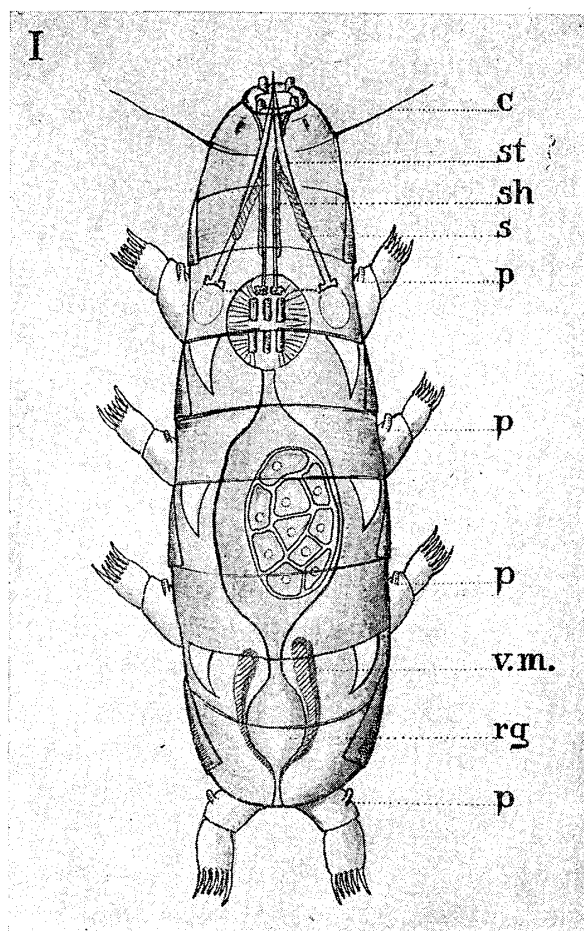


Figure I. *Thermozodium esakii*
nov. gen. nov. sp. $\times 180$

c—cirrus lateralis
st—stylet
sh—sheathholder
s—sheath of the stylets
p—papillae
v.m.—vasa Malpighii
rg—rectal gland

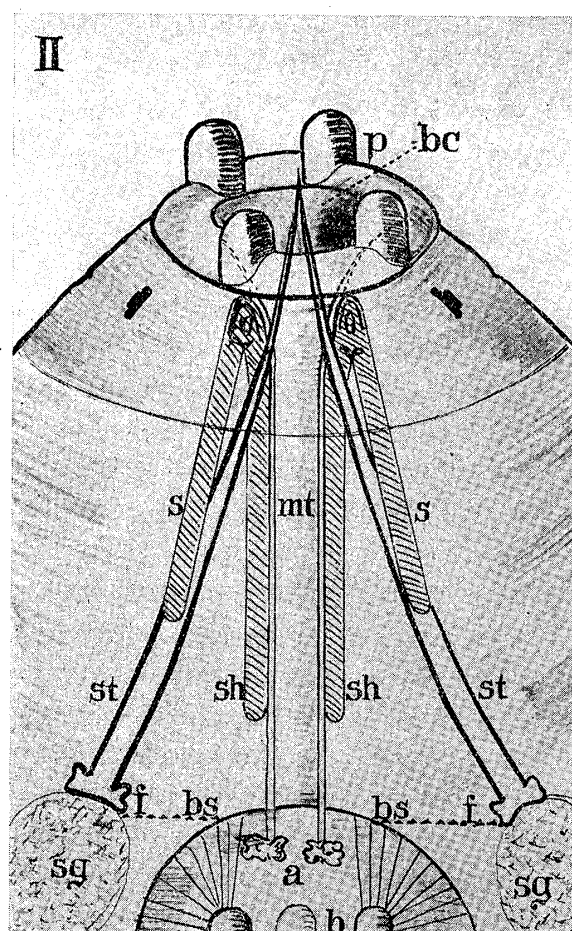


Figure II. The anterior part of
Thermozodium esakii. $\times 650$

p—papillae
bc—buccal cavity
mt—mouth tube
st—stylet
s—sheath of the stylets
sh—sheathholder
f—furca
bs—bearer of the stylets
a—apophyses
b—bacilla
sg—salivary glands

To R. Fth. J. Schmerbach O. S. B. I am indebted for his kind aid in drawing these figures.

branches of the claw. Besides the well visible anus one can distinguish a rectal gland and the vasa Malpighii (nearly invisible).

C. DESCRIPTION OF THE NEW FAMILY, GENUS AND SPECIES

The cuticle is transparent, and granulated plates can not be distinguished, but the margin is at four points (above the four appendages) folded and thickened, but not granulated. Filaments are on "a" as a cirrus lateralis. The mouth-opening is fitted with two pairs of papillae. The opening itself is relatively wide. The four pairs of appendages are provided each with 6 or 8, in one case even with 10, claws which possess small pointed papillae (cf. I p). Claws are as described above under B; more details are given in the German description in the "Zoologischer Anzeiger" in press. If the enlargement is sufficient, little spines may be seen on the basis of each claw (by oil-immersion). There are strong spines on each side of the body just under the first three pairs of appendages.

The body appears transparent or of a slightly reddish colour. Reserve corpuscles are lacking. The eye-spots are black in colour.

From the mouth-opening, where the strong long stylets (II st) are often to be seen piercing through, leads the buccal cavity (II bc) to a chitinous tube, the mouth-tube (II mt), which is relatively wide and as long as $\frac{1}{4}$ of the whole length of the body. It ends into the pharynx and is there provided with some chitinous thickenings called apophyses (II a). The forked end of the stylets is "furca" (II f). By sufficient enlargement one may see also the sheath-holder, the sheath of stylets (cf. I and II sh and s) and the bearer of the stylets (II bs), almost invisible. The pharynx possesses besides the just mentioned apophyses two series of "bacilla" nearly equal in length (I and II b).

The stomach is always filled with the just masticated contents of the cells of algae. There is one ovary generally with 6 to 10 eggs. These eggs are put in the moulted cuticle. Rectal glands, salivary glands and the so-called vasa Malpighii are to be seen by sufficient enlargement (I rg, v. m. and II sg).

Length of the body: 360 to 490 μ excluding the fourth appendage.

D. SOME NOTES ON THE BIOLOGY AND ECOLOGY OF THE
NEW TARDIGRADE

About the mode of life of the first thermophile Tardigrade under description, we do not know very much. The animalcule lives always in a very damp and hot environment. The temperature was found to be 39.8°C. to 41.7°C. measured with two thermometers. But I am not sure if the temperature is constant throughout the year. The

guide-book, issued by the Japanese Gov. Railways, gives it to be 65°C. or 149°F. for the "Enryaku-yu" in the Furu-yu section of Unzen Park, but this is the temperature of the hot spring itself. The animalcules are living in the algae in the little overflowing stream of the hot spring, where the minerals of the water have produced some incrustations. One moult was found among the other individuals, but nothing is known about the "larvae" or young ones. Adult animalcules were found in possession of 6.8 and 10 claws. The small number of claws is generally a sign of the younger Tardigrades.

The "Enryakuyu" which is not very far from the point where we collected the algae, is a acid hydrogen sulphide vitriol spring. According to the cited guide-book, the radio-activity is 1.19 Mache's units. The analysis given by the Hygienic Laboratory of Nagasaki Pref. in 1909, gives in 1 kilogram of the water :

Free sulphuric acid	1,2887	grams
Aluminium sulphate	0,3986	"
Ferrous sulphate.....	0,2539	"
Silica	0,2450	"
Calcium sulphate	0,0656	"
Sodium sulphate	0,0613	"
Magnesium sulphate	0,0516	"
Potassium sulphate.....	0,0172	"
	<hr/>	
	2,3819	"
Free hydrogen sulphide	0,0035	"
	<hr/>	
	2,3854	"

Besides these, there are small quantities of free carbon dioxide, free hydrochloric and phosphoric acids, and a trace of ammonia.

Nothing is known about the faculty of these animals to lead like other Tardigrades a latent state of life. They probably do not have such faculty, according to our knowlegde of the fresh-water Tardigrades living in humid atmosphere. Encystments were not observed.

The name *Mesotardigrada* was given to the new order, and the new family may be called *Thermozodiidae*, as the new genus bears the name *Thermozodium* derived from the Greek "Thermozodion" which means a small animal living in the water. The specific name *esakii* is given in honour of Prof. Dr. T. Esaki, Entomologist in the Kyushū Imperial University.

The author wishes to thank especially Prof. Dr. N. Yatsu, Zoologist

of the Tokyo Imperial University, for his aid and kind permission of using the library of the Institute, and Dr. C. Zirn of Kobe, for his interest and help to facilitate these studies.

E. NOTE ON JAPANESE TARDIGRADES IN GENERAL

The Tardigrades are distributed in the whole world; they are not uncommon in Japan also. The first worker on Japanese Tardigrades was the German physician F. Richters. He recorded (cf. Lit. 6) two species: *Echiniscus elegans* Richters 1907 and *Macrobiotus intermedius* Plate 1889. The present author mentioned a new species called *Hypsibius choucoutiensis* Rahm 1937 in Lit. 4 and 5. The mosses in which this species was discovered, had been collected in Tokyo and kept in the Herbarium of the Fan Memorial Institute of Peiping.

G. Mathews has recently published two papers on Japanese Tardigrades (Lit. 1 and 2). He does not seem to have known the mentioned new *Hypsibius* from Tokyo, although the author showed him the prepared animalcules and gave him the paper in which he published the first communication on the subject. (Lit. 4). In his first paper G. Mathews records 8 and in the second one 16 species of Tardigrades, which he has found in mosses and lichens sent to him from Japan.

The author of this communication wishes to express his surprise that his name is mentioned in the first paper published by G. Mathews, who thanks him "for his kind and useful information concerning Tardigrada". It must be stated, however, that G. Mathews has never shown to the author one exact determination of a Tardigrade made by himself, although both worked during the whole winter 1936-37 in the same university by the kind invitation of the Dean of the Faculty of Science, Dr. Fth. A. Jaensch S. V. D. So the author must decline any responsibility for the above mentioned publications, which are without exaggeration the worst papers ever written on Tardigrades. They contain so many errors that we cannot mention here all of them.

G. Mathews has mixed up *Echiniscus blumi* with *testudo*, the world-wide distributed species very well known to all specialists of Tardigrades. So one may doubt with some reason, if the determination given by G. Mathews can be trusted. According to him, he has received "fifty-three samples of lichens from various parts of Japan", and studied all of them in the month of December. His first paper had been finished

and sent for publication on January 9th. The Tardigrades are, as known to all specialists, very small, and very difficult for exact determination. Especially the *Eutardigrada* are considered to be very hard to classify. During the last ten years many specialists have devoted themselves to the studies of Tardigrades, and there may be no other group of the microfauna which is better investigated than the Tardigrades. Mathews' statement: "The water-bears or Tardigrada form a group of multicellular animals little known and little studied" can hardly be justified.

The second paper published by G. Mathews is only an enumeration of already known species. There are *Echiniscus spiniger* Richters, *E. spinulosus* Doyère, *E. lapponicus* Thulin, *E. morokensis* Richters, *E. quadrispinosus* Richters, *Pseudechiniscus suillus* Ehrenberg, *Macrobiotus harmsworthi* Murray, *M. hufelandi* Schultze, *M. echinogenitus* Richters, *M. occidentalis* Murray, *Calohypsibius ornatus* Richters, *Hypsibius areolatus* Murray, *H. oberhaeuseri* f. *cranulatus* Doyère, *Diphascon alpinum* Murray, *Milnesium tardigradum* Doyère. Besides these species there is *Echiniscus blumi* Richters, very common in Japan, which is mentioned only in the first paper.

F. KEY TO THE TARDIGRADES

In the following is given a short key of the Tardigrades known up to this date. Mentioned are ordo, familia, genera and the number of species:

TARDIGRADA

I. Ordo: *Heterotardigrada*.

1. Subordo: Arthrotardigrada; 5 genera, 5 species.
 - A. Familia: Discopodidae.

Genus unicum: *Batillipes*.
 - B. Familia: Onychopodidae.
 1. Genus: *Bathyechiniscus*; species unica.
 2. Genus: *Tetrakentron*; species unica.
 3. Genus: *Halechiniscus*; species unica.
 4. Genus: *Actinarctus*; species unica.
2. Subordo: Echiniscoidae; 5 genera, 4 subgenera, 122 species.
 - A. Familia: Nudechiniscidae.
 1. Genus: *Oreella*; 2 species.
 2. Genus: *Echiniscoides*; species unica.

B. Familia : Scutechiniscoidae ; c. 119 species.

1. Genus : *Parechiniscus* ; species unica.
2. Genus : *Echiniscus* ; 4 subgenera, c. 104 species.
3. Genus : *Pseudechiniscus* ; c. 14 species.

II. Ordo : *Mesotardigrada*. Ordo nov.

A. Familia unica : Thermzodiidae.

Genus unicum : *Thermozodium*, genus nov.

Species unica : *esakii*, nov. sp.

III. Ordo : *Eutardigrada* ; 3 genera, 4 subgenera, c. 153 species.

A. Familia : Macrobiotidae ; 2 genera, 4 subgenera, 150 species.

1. Genus : *Macrobiotus* ; c. 62 species.
2. Genus : *Hypsibius* ; 4 subgenera, c. 88 species.

B. Familia : Artiscidae ; 1 genus, 3 species.

Genus unicum : *Milnesium* ; 3 species.

G. LITERATURE REFERRED TO

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