

A simple generic key to the Bdelloid rotifers

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Summary

Rotifers of the Order Bdelloidea occupy a vast number of natural habitats, from ice to soil, lichens to mosses, freshwater interstitial to saltwater sands, from the tropics to the Antarctic. Because of their apparently cosmopolitan presence, an understanding of their taxonomy is critical, especially since more and more ecologists are confronted with the need to identify them in sampling regimes. Since descriptions such as 'rotifer sp.' or 'bdelloid sp.' are becoming more and more unacceptable in a modern species list, this paper presents a relatively simple numerical key that will allow non-experts to identify most common bdelloid rotifers to genus. Although the Order is in much need of revision at species level, the current generic names and criteria will probably persist through any such revision, and thus generic-level identifications produced with this key will likely be accurate in the future as well.

Introduction

ACCURATE identification of Bdelloid rotifers can be very difficult. Literature on rotifer taxonomy seldom discusses details of the Bdelloids in common terms. Works that deal with the taxonomy of the Order in any detail are usually large, technical, and aimed at specialists. As a result, there are very few references of note occupying the 'middle' ground between the amateur and specialist.

When presented with the identification, non-specialists turn to the existing taxonomic references, but this difficult chore is compounded in three ways. (1) the subtleties of acceptable specific features, (2) concurrent questions about what is a true species in a completely parthenogenetic group of animals, and (3) the difficulties of bdelloid rotifer handling. Suitable identifications are also hindered by the extreme amount of time usually required of the investigator in the attempt to wade through the subtle specific elements for good identifications. As a result, "bdelloid sp." too often shows up on microfauna lists.

The entire Order Bdelloidea (bdelloids) consists only of female rotifers. There are no known males. In one sense this simplifies the chore of identification, since there is only one gender for which to accumulate identification elements. Without males, however, acceptable species identifications must rest on phenotypic

comparisons or genetic tests, since cross-breeding or inbreeding does not occur and cannot be induced.

The proper identification of bdelloids requires that they be viewed *in-vivo*, which in turn requires special care and handling of the animals and the medium. Bdelloids are particularly sensitive to changes in temperature, light, oxygen content, and vibrations, so these factors must be controlled to be successful.

The customary use of a high-intensity light-source for microscopic examination may need to be altered while viewing bdelloids, since the heat generated by the light source may provoke animal contraction. Likewise, physical vibrations in the water, on slide or watch-glass, created by focusing or by moving the mechanical stage, may induce contraction. If the animal stays contracted for more than a few minutes, it is not likely to recover for some time. If this occurs, the viewer may be forced to wait for the rotifer to recover from the agitation, or seek another example for identification.

Background

A short history of the research, and a partial listing of references available, begins with the many works of Murray (1902–1913) and Bryce (1892–1929). They combine to assume the most significant baseline information used for the later works on taxonomy and ecology of Remane (1932/33) and Voigt (1957). Subsequent works by Bartos (1951) in English, and Donner (1965) in German, are the most recent and most detailed compilations of significance. Additional efforts include Koste & Shiel (1986) discussing Australian bdelloids as a part of a series on Australian rotifers, and the six works of Haigh (1963–1971) that discuss New Zealand bdelloids. These later works are among the last comprehensively to examine the taxonomy, ecology and systematics of the Order. Non-taxonomic research in the order is described by Bateman & Davis (1980), Ricci (1987), Zullini & Ricci (1980), and others.

The current state of understanding is augmented by virtual works such as the Aydin Örstan bdelloid web page at <http://members.aol.com/bdelloid1/deloid.htm>. Örstan discusses the entire

group with very useful diagnostic keys, photos, drawings and ecological data.

Discussion

Bdelloid rotifers can be found in almost any temporary or permanent wet environment. Many are considered aquatic, flourishing in the benthos or littoral of ponds and streams, while others occupy terrestrial habitats such as moist soil, mosses, leaf litter and lichens. These rotifers are notable for their ability to resist severe environmental changes to their habitat. The process and morphology of their ability to resist dehydration (anhydrobiosis) is documented in Jacobs (1909), Rahm (1926), Ricci (1987) and Umezawa (1958) to mention a few. Only a relatively small number of specific bdelloid rotifers have been actually documented performing anhydrobiosis, (*Philodina roseola*, *Adineta vaga*, *Macrotrachela musculosa*, *Mniobia magna*, *Macrotrachela quadricornifera*, *Habrotrocha constricta*, *Philodina acuticornis odiosa*, *Mniobia russeola*) under special, slow drying conditions (Gilbert, 1974), yet the process is logically extrapolated for the rest of the Order by their reappearance in the moss, lichen and soil habitats in which they often occur.

Non-bdelloid species (those of the other major class of Rotifera, Eurotatoria (Monogononta)) also sometimes suddenly reappear in open permanent or temporary waters after a long stretch of dryness. The mechanism responsible for their presence can be attributed to an equally significant survival phenomenon of laying resting or 'resistant' eggs, prior to, or during environmental stressful conditions such as the evaporation of their water habitat. This phenomenon is thought to be an extension of their ability to reproduce parthenogenetically, which includes episodes of males appearing and joining with females to produce 'resting' eggs and a new generation of parthenogenetic females.

There are too few rotifer taxonomic references properly to support bdelloid rotifer identifications for the non-specialist. Ongoing research by interested ecologists, environmentalists and other biological workers has suffered from a lack of suitable references to assist even the simplest of bdelloid rotifer identifications. Works such as Pennak (1978) offer a modicum of help, but the arrangement of key elements can sometimes be confusing, and some primary elements of identification are not visible without the application of suitable and often difficult

treatment techniques. Donner (1965) is the preferred, and possibly the most authoritative work on bdelloid rotifers, but published only in German. Use of other keys such as that by

TABLE 1
Generic Identification Elements

1.	Rostrum imperfectly developed
2.	Rostrum non-retractile
3.	Wheel organ (ciliated field) prone and flat
4.	Wheel organ ring, with dorsal and ventral breaks
5.	Upper (dorsal) lip undivided
6.	Upper (dorsal) lip bilobed, or divided
7.	Pedicels rudimentary, or absent
8.	Pedicels well developed
9.	Trochal disc inset, between 2 horn-like processes
10.	Trochal disc between hoodlike expansion of upper lip
11.	Throat distinct
12.	Gullet absent
13.	Rami protrusile
14.	Lumen wide
14a.	Lumen absent, where food pellets fill body cavity
15.	Lumen narrow
16.	Food in pellets (do not mistake oil droplets for food)
17.	Food NOT in pellets
18.	Abdominal transverse cuticle folds correspond to body segments
19.	Abdominal transverse cuticle folds numerous, NOT corresponding with body segments
20.	Foot long, slender
21.	Foot short, stout
22.	Foot ending in sucker-like plate, disc or discs
23.	Foot glands in longitudinal series
24.	Foot glands in transverse series
25.	Foot shorter than pre-intestinal part
26.	Toes 2
27.	Toes 3
28.	Toes 4
29.	Spurs 1
30.	Spurs 2
31.	Spurs long
32.	Spurs short
33.	Spurs modified or absent
34.	Cuticle coarse, leathery, bumps, spines, plates or knobs
35.	Viviparous (able to see young forming inside mother)
36.	Oviparous
37.	Commensal
38.	Limnetic (free-swimming)
39.	Anhydrobiotic (found in moss)
40.	Eyes generally absent
41.	Eyes cervical or in neck, rarely absent
42.	Eyes in rostrum or rarely absent
43.	Trophi aberrant
44.	Sometimes in 'bottle' secretion shell

Koste & Shiel (1986) (for Australian fauna), although adequate for genera, can be misleading for species if used for other parts of the world, since rotifers in general are now being acknowledged to be endemic to a larger extent than previously thought (Ricci, 1987). Relying on experts for bdelloid rotifer identifications can also be difficult, since such people are all too few.

The Key

This paper is designed to be a non-specialist identification key, aimed at the individual researcher in need of an identification tool for bdelloids.

Tables 1 & 2 will allow a worker to have a reasonable chance of getting a bdelloid identification down to genus, but not to species. It does not follow the traditional 'key' structure, but it does follow a key-code format that will prove useful to those who attempt to get past the all too pervasive 'bdelloid sp.' they find themselves obligated to report in the literature.

This key (the combination of Tables 1 and 2) has been patterned after one used by Frank J. Myers, subsequently shared with Louis

Dorsey of Philadelphia, Pennsylvania, during their cooperation in rotifer research. Modifications to the Myers key were made by Albert E. Turner III, in his unpublished aborted attempt to revise the Order. Noticeable elements of important characters are taken from Bryce (1910), Bartos (1951) and Donner (1965).

The Tables are arranged into Generic Identification Elements (Table 1), and the Numeric Key of genera based on Table 1.

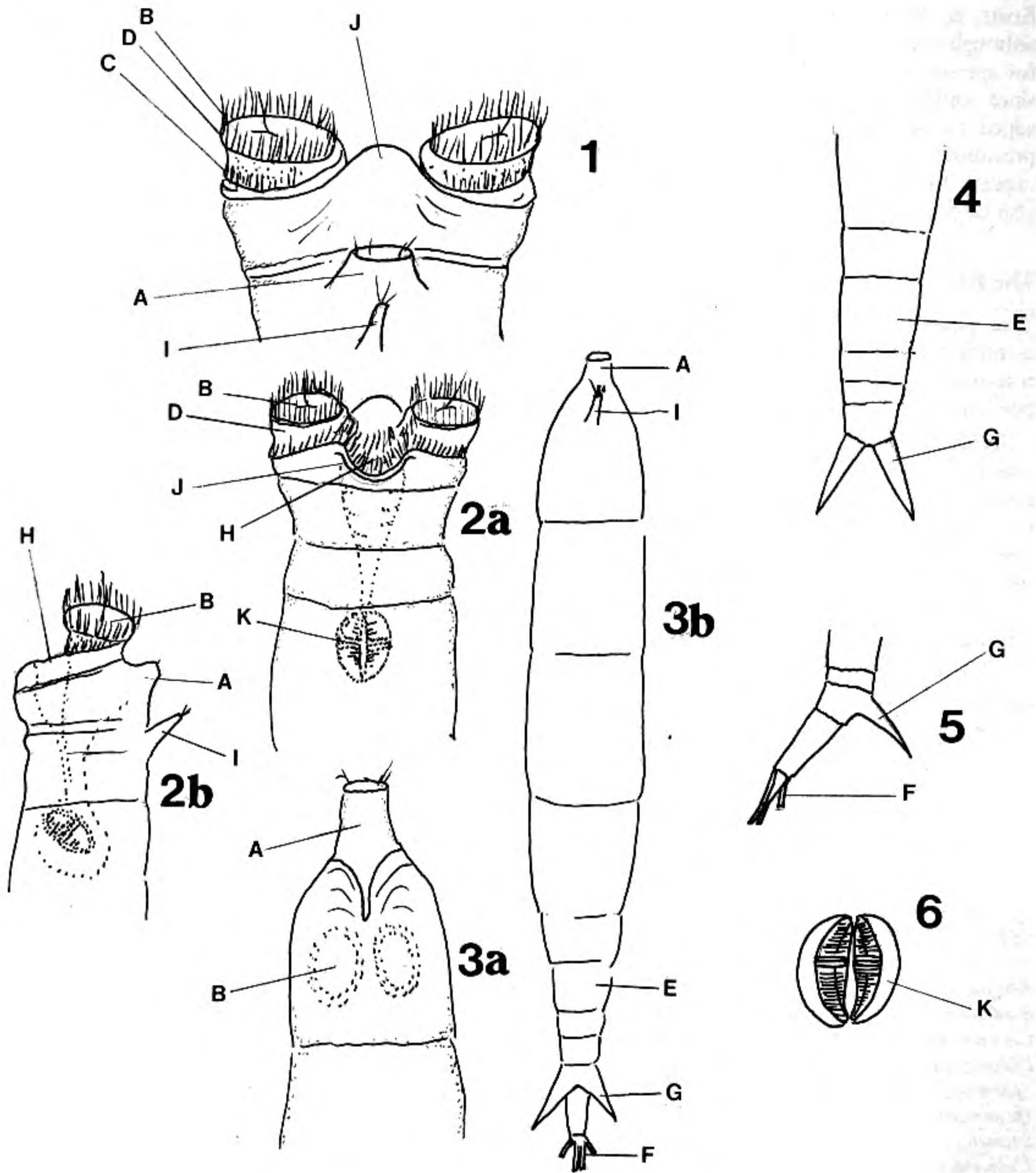
A simplistic diagram of important bdelloid identification elements can be seen in Figures 1–6. The most 'common' bdelloid rotifers that investigators are likely to encounter are worm-like animals that possess two distinct anterior ciliated wheel-bodies or discs (Figures 1 & 2). The first wheel-body sits on short or long, usually separated pedicels, accented by cilia around the top (sometimes with a mid-placed sensory hair) and is called the trochus. (Some diagnostic characteristics of the trochus include breadth and distance between pedicels, relative thickness, height above secondary wreath (cingulum) and proportion in breadth to head.) The second wheel-body rests on the base or lower lip of the pedicel, and is called the cingulum. These can

TABLE 2
A Numeric Key of genera based on Generic Identification Elements

GENUS	Generic ID Elements	Additional Characteristics
<i>Adineta</i>	2 3 <u>20</u> 27 33	large ventral ciliated field
<i>Bradyscela</i> *	2 3 <u>21</u> 27 33	papillae for toes
<i>Ceratotrocha</i> *	5 7 9 14 16 36 40	
<i>Didymodactylos</i> *	12 13 15 17 <u>26</u>	
<i>Zelinkiella</i> *	15 17 22 24 <u>35</u> <u>37</u>	commensal on sea cucumbers
<i>Dissotrocha</i>	6 11 15 17 18 <u>28</u> <u>31</u> <u>34</u> 35	usually cuticular spines, sometimes plates
<i>Embata</i>	6 15 17 28 31 36 <u>37/38</u>	corona wide, usually free swimming or commensal
<i>Habrotrocha</i>	5 8 <u>14a</u> <u>16</u> <u>27</u> 36 <u>44</u>	usually on mosses
<i>Macrotrachela</i>	5/6 <u>15</u> <u>17</u> <u>25</u> 27 <u>34</u> 36 40	
<i>Otostephanos</i>	<u>4</u> 5 8 14 <u>16</u> 36 40	
<i>Mniobia</i>	15 17 <u>22</u> <u>23</u> 25 36 40	sucker-like disc vice toes
<i>Philodina</i>	6 11 15 17 <u>28</u> 32 36 <u>41</u>	
<i>Philodinavus</i> *	2 28 43	
<i>Pleuretra</i>	6 11 15 17 19 28 <u>34</u> 36 40	armor-like dorsal cuticle
<i>Rotaria</i>	6 15 17 <u>27</u> 35 <u>42</u>	
<i>Scephanotrocha</i>	5 7 <u>10</u> 14 <u>16</u> 36 40	
<i>Abrochtha</i> *	12 13 15 17 28	
<i>Anomopus</i> *	15 17 20 <u>22</u> 23	foot ends in discs
<i>Henoceros</i>	28 <u>29</u> 43	corona absent, large, fat toes

* = rare or monotypic.

Underlined numbers () are primary elements.



KEY: A: Rostrum; B: Wheel Organ; C: Cingulum; D: Pedicel; E: Foot; F: Toe; G: Spur; H: Mouth Area; I: Antenna; J: Lip and K: Trophi.

- FIG. 1. Dorsal view of adult female 'generic' bdelloid rotifer head (not contracted).
 FIG. 2a. Ventral view of adult female 'generic' bdelloid rotifer head (not contracted).
 FIG. 2b. Left lateral view of adult female 'generic' bdelloid rotifer anterior half (not contracted).
 FIG. 3a. Ventral view of adult female 'generic' bdelloid rotifer anterior half (contracted).
 FIG. 3b. Dorsal view of adult female 'generic' bdelloid rotifer (contracted).
 FIG. 4. Dorsal view of adult female 'generic' bdelloid rotifer foot.
 FIG. 5. Lateral view of adult female 'generic' bdelloid rotifer foot.
 FIG. 6. Dorsal view of generic rami bdelloid trophi.

generally be seen when the animal is observed feeding or swimming and are collectively referred to as the corona. Ventrally, the animal's mouth catches food swirled into it by the corona's ciliary action. (The animal's treatment of food, ie formation into pellets or not, can be diagnostic.)

The presence, absence and location of eyes, presence of a ventral and/or dorsal lip, shape and size of dorsal rostrum (proboscis) and dorsal antenna compose many of the key elements to the anterior anatomy of the bdelloid rotifer. Posterior elements consist of false toes called spurs, foot segments and true toes, which are all diagnosed by shape, size and number (Figures 3b, 4 & 5). Their bodies are pseudosegmented and extremely telescopic, which can conceal the nature of their cuticle, which by itself can be diagnostic (look and feel, number of longitudinal or transverse folds, pseudo-armature such as spines, bumps, warts, hooks etc., and secreted, bottle-like shell).

Both the presence of two trochal discs (absent in *Adineta*, *Henoceros*, *Philodinavus*, and *Bradyscela*) and their leech-like creeping motion are mostly key to initially identifying the observed animal as a bdelloid rotifer. The jaws (trophi) are ramate type (Fig 6), and are key features for initially identifying the order (with the exception of *Henoceros*, *Abrochtha*, and *Anomopus*). The number of teeth, shape of rami and striae in each trophi may also be diagnostic. Their design facilitates the functional grinding of detritus, small algae and bacteria for food. These identification elements described, however, apart from the trophi, are usually only visible in the live animal. When seen dead or preserved, bdelloids can be easily overlooked as detritus or the egg of a worm or crustacean. Once suspected of being a bdelloid rotifer, only the well-trained eye is likely to ascertain even the genus of a semi-contracted animal.

Use of the Key

The use of the key involves locating and isolating the rotifer in question, and attempting to assign as many of the numbered Generic identification elements from Table 1 as possible to the animal. (Use Figures 1-6 and the Figures legend to assist in identifying physical characteristics noted in Table 1.) Once this is done, consult Table 2 for the diagnosis of the Bdelloid rotifer under observation. The underlined identification elements are primary to the animal's identity.

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