XXIV.—Scottish Tardigrada, collected by the Lake Survey.

By James Murray. *Communicated by* Sir John Murray, K.C.B., etc. (With Four Plates.)

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Introduction.

In 1905 there was published an account of the Tardigrada collected in the Scottish Lochs by the Lake Survey (6). At that date we were able to name 21 species. The subsequent work of the Survey has enabled us to add a number of species to the list.

Moreover, the wanderings of the members of the Survey over every part of Scotland offered an excellent opportunity for the study of the whole Tardigrade Fauna. A recent journey to the Orkney and Shetland Islands added much of interest to our knowledge of Tardigrada, though few of the species found were lacustrine. The work of Mr Wm. Evans in the basin of the Forth has also added much of value to our records of Tardigrada (7), (10).

Considering the large number of species now collected from all parts of the country, it is thought desirable to bring together all that is known about Scottish Tardigrada, in the hope that such a *résumé* will assist the further study of this group of animals.

The Tardigrada are now being found to be much more numerous than was long thought. A great many of the earlier species are very insufficiently described; and the more it appears that species are numerous, the more doubt attaches to the earlier descriptions. Some of these are doubtless compounded of the characters of various species which were confounded together. Many of the most important characters were neglected, under the impression that they were not sufficiently stable: the pharynx, with its system of rods, for instance, was hardly regarded before Richters, while I see no reason to suppose that the number and form of these rods is any less constant than, say, the dentition of Vertebrata.

All the Tardigrada yet found in Scotland have their ordinary habitat among moss. They appear to be generally indifferent to the situation of the moss, as the same species may be found alike among permanently moist moss, and among moss which is only intermittently moist. No doubt there are some exceptions, and certain species may affect always certain situations. Professor Richters remarks that the degree of coloration of *M. oberhäuseri* appears to depend on the exposure of the wall where they are found.

Some kinds are found in the mud of ponds and lakes when no moss may be present, but those same kinds are commoner among moss.

M. macronyx and *M. dispar* appear to be almost confined to ponds and lakes.

Of the 41 species of Tardigrada recorded for Scotland, 31 have been found in the lochs: the remaining 10 are as yet only known as moss-dwellers.

The subject is in this paper treated under the various headings—"Tardigrada of the Scottish Lochs"; "Tardigrada of Orkney and Shetland"; "Scottish Alpine Tardigrada"; and "Notes on the Genera and Species."

The Tardigrada of the Scottish Lochs.

In the previous paper on the Tardigrada of the Scottish lochs there were enumerated 21 species. Despite this considerable number of species, it must not be supposed that very many Tardigrada are normal inhabitants of permanent waters. The Tardigrada were obtained among mosses and other plants growing round the margins of the lochs; and though rightly included in the lake fauna, many of them were doubtless only casually present. The Tardigrada are most at home among mosses which are intermittently moist. Some species of *Macrobiotus* are of usual occurrence in ponds, peat bogs, and other permanently moist places. *M. macronyx* has been usually regarded as the only really aquatic species. Some similar species, which are described in this paper, seem also to be peculiar to ponds. The genus *Echiniscus* rarely occurs in ponds or lakes.

Since the previous paper appeared, ten additional species have been found at lake margins, making the total of 31 species for the Scottish lochs.

In the appended list of the 31 species it was necessary to include one or two which, there is reason to believe, were wrongly identified, as they had been recorded in the previous paper. Those doubtful or erroneous records are indicated in the list. *M. macronyx* and *M. islandicus* are not yet certainly known to occur in Britain.

There is a certain doubt whether *E. granulatus*, *E. quadrispinosus*, and *M. tuberculatus* are identical with the species described under those names, but they are certainly very close to them.

Though it is certain that 29 indubitably distinct species have been found in our lochs, a few of the determinations are open to doubt. The following table gives the distribution in the lochs so far as known.

List of Species in Scottish Lochs.

Echiniscus arctomys, Ehr. Morar, Ness, and Earn.
E. mutabilis, Murray. Morar, Ness, Earn, Tay.
E. gladiator, Murray. Morar, Ness.
E. wendti, Richters Morar, Earn, Tay.
E. reticulatus, Murray. Morar, Ness, Earn, Tay.
E. oihonnæ, Richters. Ness, Earn.
E. granulatus, Doy. Morar, Ness, Tay.
E. spitsbergensis, Scourfield. Morar, Earn.
E. quadrispinosus, Richters. Morar, Ness.
Milnesium tardigradum, Doy. Ness.
Macrobiotus hufelandi, C. Sch. Lomond, Earn, Gelly, etc.
M. intermedius, Plate. Morar.
M. echinogenitus, Richters. Morar, Ness.

M. islandicus, Richters. Ness? (record untrustworthy).
M. dispar, Murray. Tay.
M. ambiguus, Murray, Ness (egg).
M. pullari, Murray. Gryfe, Ness.
M. hastatus, Murray. Tay (egg).
M. oberhäuseri, Doy. Ness (other records doubtful).
M. ornatus, Richters. Ness (other records doubtful).
M. tuberculatus, Plate. Morar.
M. sattleri, Richters. Earn.
M. papillifer, Murray. Morar, Ness.
M. macronyx, Duj.? (All records doubtful.)
M. annulatus, Murray. Morar.
Diphascon chilenense, Plate. Ness.
D. spitzbergense, Richters. Ness.
D. angustatum, Murray. Ness.
D. scoticum, Murray. Morar.
D. bullatum, Murray. Leven (Evans).
D. oculatum, Murray. Ness.

Tardigrada of Orkney and Shetland.

The Tardigrada of these remotest northern fragments of Britain were studied during September 1906, while the lochs of these islands were being surveyed.

A large number of collections were made, at the margins of lakes, in ponds, and among moss, from every kind of situation and at all elevations, from sea-level to the tops of the highest hills.

When those collections were examined during the succeeding months, it soon became apparent that they were of the highest interest.

The first general fact of interest was that there were a number of species previously only known in more northern lands, some of them only within the arctic circle. *E. islandicus*, *M. coronifer*, *M. crenulatus*, *M. harmsworthi* are such species. All of these, except *E. islandicus*, were unknown outside the arctic circle till they appeared in Orkney or Shetland.

Another interesting fact was the occurrence of a number of peculiar species previously unknown. Such were *M. zetlandicus* and *M. orcadensis*. Several other species, discovered about the same time in Scotland, were shown, by simultaneous studies of Mr Bruce's collections, to extend into the extreme north.

A curious fact is the abundance of species of the genus *Macrobiotus*, and the extreme scarcity of *Echiniscus*. Thirteen species of *Macrobiotus* were found, and only six of *Echiniscus*. The discrepancy is greater than appears from these figures, as all but 3 or 4 of the species of *Macrobiotus* were frequent and abundant, while of the *Echinisci* only *E. arctomys* was at all frequent, *E. mutabilis* was found several times, *E. gladiator* var. *exarmatus* several times, but only in one locality, and all the others were known from single examples.

The group of species to which belong *M. coronifer*, *M. crenulatus*, and *M. harmsworthi* is only known to occur in northern lands; indeed, till the finding of these three species in Shetland, no member of the group was known outside the arctic circle, within which they have a wide distribution. This group is characterised by a crescent-shaped ridge in front of each pair of claws, the ridge often spiny or wrinkled.

Comparing the two groups of islands, as may be done by referring to the accompany-

ing table, where the records are set out in parallel columns, it appears that Shetland was more productive, giving 18 species against 10 from Orkney. Only 6 species were common to the two groups, leaving 12 peculiar to Shetland and 4 to Orkney.

Six species and one variety are as yet unknown on the Mainland of Scotland: 5 of these were in Shetland only (all from Ronas Hill), 1 in Orkney only, and 1 was common to Orkney and Shetland.

List of Species in Orkney and Shetland.

	Orkney.	Shetland.
Echiniscus arctomys, Ehr.	Rousay.	Ronas.
E. mutabilis, Murray	Hoy	Saxavord.
E. islandicus, Richters	...	Ronas.
E. gladiator, Murray (var.)	...	Ronas.
E. granulatus, Doy.	...	Mainland.
E. quadrispinosus, Richters, var.	...	Ronas.
Milnesium tardigradum, Doy.	Pomona.	Mainland.
Macrobiotus oberhäuseri, Doy.	Pomona.	...
M. zetlandicus, Murray	...	Ronas.
M. tuberculatus, Plate	...	Mainland.
M. sattleri, Richters	Pomona.	...
M. hufelandi, C. Sch.	Hoy	Ronas.
M. orcadensis, Murray	Hoy	...
M. coronifer, Richters	...	Mainland.
M. crenulatus, Richters	Pomona.	Ronas.
M. harmsworthi, Murray	...	Ronas.
M. echinogenitus, Richters	Pomona.	Mainland.
M. dispar, Murray	...	Ronas.
M. ambiguus, Murray	...	Ronas.
M. dubius, Murray	...	Ronas.
Diphascon chilenense, Plate	Pomona.	...
D. angustatum, Murray	...	Mainland.

Scottish Alpine Tardigrada (8).

The term Alpine is here used simply to denote species which have been found at a considerable elevation. It is not intended to have the restricted application which may have a use in botanical studies. The Tardigrada of the hills are separately considered, because there is reason to believe that the more rigorous climate of the mountain tops is favourable to the existence of certain arctic species, and because one or two species have only been found on the hill tops. The data for the study of our mountain Tardigrada are sufficiently meagre,—Ben Lawers has been visited twice, with encouraging results; collections from Ben Ledi, Meall nan Ptarmagan, and some other Perthshire hills have been sent to me by Mr Wm. Evans; and lastly, the highest hills in Orkney and Shetland have been visited.

Those northern peaks, Ward Hill, in Hoy, and Ronas Hill, in Shetland, though

only about 1500 feet in height, might be expected, from their high latitude, to be as alpine or arctic in character as much higher hills on the Mainland of Scotland, but this is discounted by the very mild climate enjoyed by those northern lands.

Ronas Hill was indeed very rich both in arctic and in peculiar species, but this may be attributed rather to geographical position than to climate. Remote though Shetland is from Spitzbergen and Franz Josef Land, there are numerous stepping-stones, —the Faröes, Iceland, Norway, Bear Island, etc.—between them, and the peculiar feature of Ronas Hill is its union of species from so many northern but isolated lands.

The accompanying list of hill Tardigrada, numbering 23 species, shows at a glance what a large proportion of arctic species there are on our hills. *E. islandicus*, *E. wendti*, *E. spitsbergensis*, *M. coronifer*, *M. crenulatus*, *M. harmsworthi*—all, except *E. spitsbergensis* (which is frequent on the Mainland of Scotland), only previously known from high northern lands, if not actually within the arctic circle. And the proportion of arctic species is yet higher than appears above, for *M. zetlandicus*, *M. dispar*, and *M. ambiguus*, though only recently discovered in Scotland, are known to extend into Franz Joseph Land or Spitsbergen, and Scotland is, as far as yet known, the southern limit of their range.*

List of Scottish Alpine Species.

Echiniscus arctomys, Ehr. Stuc-a-Chroin (Evans).
E. mutabilis, Murray. Ben Lawers.
E. islandicus, Richters. Ronas Hill, Shetland.
E. gladiator, Murray. Ben Lawers.
var. *exarmatus*, Murray. Ronas Hill, Shetland.
E. wendti, Richters. Ben Lawers.
E. spitsbergensis, Scourfield. Ben Lawers.
E. quadrispinosus, Richters. Ronas Hill, Shetland.
Milnesium tardigradum, Doy. Ward Hill, Hoy.
Macrobiotus oberhäuseri, Doy. Ben Lawers.
M. zetlandicus, Murray. Ronas Hill, Shetland.
M. tuberculatus, Plate. Ronas Hill, Shetland.
M. papillifer, Murray. Ben Ledi (Evans).
M. hufelandi, C. Sch. Ward Hill, Hoy, Ben Lawers.
M. orcadensis, Murray. Ward Hill, Hoy.
M. coronifer, Richters. Ronas Hill, Shetland.
M. crenulatus, Richters. Ronas Hill, Shetland.
M. harmsworthi, Murray. Ronas Hill, Shetland.
M. echinogenitus, Richters. Ben Lawers, Ronas Hill.
var. *areolatus*, Murray. Ben Lawers.
M. dispar, Murray. Ronas Hill, Shetland.
M. ambiguus, Murray. Ronas Hill, Shetland.
M. dubius, Murray. Ronas Hill, Shetland.
Diphascon chilenense, Plate. Ben Lawers.
D. alpinum, Murray. Ben Lawers.

List of all known Scottish Species.

The first list gives the distribution in Scotland, and indicates such subdivision of the genera as is possible in the present state of our knowledge. Some of the groups thus separated are undoubtedly natural; others may not be so. So many are the species now known that the subdivision of the two large genera *Echiniscus* and *Macrobiotus* will doubtless soon be necessary, but in the meantime our knowledge is too fragmentary to permit of this.

The second list gives the world distribution so far as the data at my disposal permit.

* *M. ambiguus* has been recently found in abundance, among *Thamnium lemani* collected by Prof. F. A. Forel, at a depth of 200 feet, in the Lake of Geneva.

In compiling this I am mainly indebted to Richters' "Arktische Tardigraden" (19) and subsequent papers, and to Lance's "Contribution à l'étude" (4). The distribution is given under three heads—Britain; Polar Regions; other Regions. The Tardigrade fauna of the Polar Regions has received as much attention as that of any part of the world, except perhaps Germany. Under the heading "Britain" the Orkneys and Shetlands are treated separately from Scotland, as they form important links with the Arctic Region.

The polar regions are not defined as strictly limited by the polar circles, but include Iceland in the Arctic, and all lands south of the great continents in the Antarctic.

Distribution in Scotland.

Echiniscus.

A. Segment V distinct from VI, paired or single.

1. *E. arctomys*, Ehr. Perth, Inverness, Orkney, Shetland, Edinburgh.
2. *E. mutabilis*, Murray. Perth, Inverness, Edinburgh, Orkney, Shetland, St Kilda.
3. *E. islandicus*, Richters. Ronas Hill, Shetland.

B. Segments V and VI fused into one plate.

4. *E. gladiator*, Murray. Perth, Inverness.
   var. *exarmatus*, var. nov. Ronas Hill, Shetland.
5. *E. wendti*, Richters. Perth, Inverness, Edinburgh.
6. *E. reticulatus*, Murray. Perth, Inverness.
7. *E. oihonnæ*, Richters. Perth, Inverness.
8. *E. granulatus*, Doy.? Perth, Inverness, Shetland, Edinburgh.
9. *E. spitsbergensis*, Scourfield. Perth, Inverness, Edinburgh.
10. *E. quadrispinosus*, Richters?
    var. *cribrosus*, var. nov. Perth, Inverness, Lanark, Shetland.
    var. *fissispinosus*, var. nov. Peebles, Inverness.
11. *E. muscicola*, Plate? Perth.

Milnesium.

12. *M. tardigradum*, Doy. Perth, Inverness, Edinburgh, Orkney, Shetland.

Macrobiotus.

A. Eggs smooth, laid in the cast skin.

13. *M. oberhäuseri*, Doy.? Inverness, Orkney, Perth.
14. *M. ornatus*, Richters. Inverness, Perth.
    var. *verrucosus*, Richters. Inverness.
15. *M. zetlandicus*, sp. n. Inverness, Shetland.
16. *M. macronyx*, Duj.? All Scotch records doubtful.
17. *M. angusti*, sp. n. Inverness.
18. *M. annulatus*, Murray. Inverness.
19. *M. tuberculatus*, Plate. Inverness, Shetland.
20. *M. sattleri*, Richters. Perth, Orkney, Nairn.
21. *M. papillifer*, Murray. Inverness, Perth.

B. Eggs (where known) spiny, crescent in front of claws.

22. *M. coronifer*, Richters. Shetland.
23. *M. crenulatus*, Ritchters. Orkney, Shetland.
24. *M. harmsworthi* (Murray 12). Shetland.

C. Eggs spiny, no hyaline matrix.

25. *M. hufelandi*, C. Sch. Common everywhere, St Kilda.
26. *M. intermedius*, Plate. Inverness, Edinburgh.
27. *M. orcadensis*, sp. n. Orkney.
28. *M. echinogenitus*, Richters. Common everywhere.
    var. *areolatus* (Murray 12). Perth, Shetland.
29. *M. islandicus*, Richters? All Scotch records doubtful.
30. *M. dispar*, Murray. Lanark, Edinburgh, Perth, Nairn, Shetland, Uist.
31. *M. ambiguus*, sp. n. Ronas Hill, Shetland, Inverness.
32. *M. pullari*, sp. n. Renfrew, Inverness, Edinburgh.

D. Eggs spiny, spines imbedded in a hyaline matrix.

33. *M. hastatus*, sp. n. Inverness.

E. Eggs unknown.

34. *M. dubius*, sp. n. Inverness, Shetland.

Diphascon.

A. Pharynx round or shortly oval.

35. *D. chilenense*, Plate. Perth, Inverness, Orkney, Fife.

36. *D. bullatum*, Murray. Loch Leven (Evans).

37. *D. oculatum*, Murray. Forth Valley, Inverness.

38. *D. alpinum*, Murray. Perth.

B. Pharynx narrow, at least $1\frac{1}{2}$ times as long as broad.

39. *D. spitzbergense*, Richters. Inverness.

40. *D. angustatum*, Murray. Inverness, Shetland, Perth, Uist, Fife.

41. *D. scoticum*, Murray. Inverness, Perth, Lanark, Fife, Edinburgh.

General Distribution.

	Britain.	Polar Regions.	Other Regions.
1. *Echiniscus arctomys*, Ehr.	Scotland, Orkney, Shetland,	Arctic, Antarctic.	Europe, Asia, Africa.
2. *E. mutabilis*, Murray	Scotland, Orkney, Shetland.	Arctic (Spitsbergen).	Asia (India).
3. *E. islandicus*, Richters	Shetland.	Arctic (Iceland).	...
4. *E. gladiator*, Murray	Scotland.	...	Europe (Faröes).
var. *exarmatus*, Murray	Shetland.	...	...
5. *E. wendti*, Richters	Scotland.	Arctic.	...
6. *E. reticulatus*, Murray	Scotland.	...	Asia (India).
7. *E. oihonnæ*, Richters	Scotland.	Arctic.	Europe (Germany).
8. *E. granulatus*, Doy.	Scotland?	...	Europe (France).
9. *E. spitsbergensis*, Scourfield	Scotland.	Arctic.	...
10. *E. quadrispinosus*, Richters	Scotland, Shetland.	...	Europe, S. America.
11. *E. muscicola*, Plate	Scotland?	...	Europe.
12. *Milnesium tardigradum*, Doy.	Scotland, Orkney, Shetland.	...	Europe, S. America, Asia, S. Africa.
13. *Macrobiotus oberhäuseri*, Doy.	Scotland.	Arctic, Antarctic.	Asia, Europe.
14. *M. ornatus*, Richters	Scotland.	Arctic.	Europe (Germany).
15. *M. zetlandicus*, Murray	Scotland, Shetland.	Arctic (Spitzbergen).	...
16. *M. macronyx*, Duj.	Scotland?	Arctic.	Europe, America.
17. *M. angusti*, Murray	Scotland.	Arctic?	...
18. *M. annulatus*, Murray	Scotland.	Arctic.	...
19. *M. tuberculatus*, Plate	Scotland, Shetland.	Arctic.	Europe (Germany).
20. *M. sattleri*, Richters	Scotland, Orkney.	Antarctic.	Europe, Asia.
21. *M. papillifer*, Murray	Scotland.	...	...
22. *M. coronifer*, Richters	Shetland.	Arctic.	...
23. *M. crenulatus*, Richters	Scotland, Orkney, Shetland.	Arctic.	...
24. *M. harmsworthi*, Murray	Shetland.	Arctic.	...
25. *M. hufelandi*, C. Sch.	Scotland, Orkney, Shetland.	Arctic, Antarctic.	Europe, Asia, Africa, America.
26. *M. intermedius*, Plate	Scotland.	Arctic, Antarctic.	Europe, Asia, America.
27. *M. orcadensis*, Murray	Orkney.	...	...
28. *M. echinogenitus*, Richters	Scotland, Orkney, Shetland.	Arctic, Antarctic.	Europe, Asia, Africa, America.
29. *M. islandicus*, Richters	Scotland?	Arctic.	...
30. *M. dispar*, Murray	Scotland, England, Shetland.	Arctic.	Asia.

General Distribution—*continued.*

	Britain.	Polar Regions.	Other Regions.
31. *M. ambiguus*, Murray	Shetland.	Arctic.	Europe (Geneva).
32. *M. pullari*, Murray	Scotland.	...	...
33. *M. hastatus*, Murray	Scotland.	...	Europe(Switzerland).
34. *M. dubius*, Murray	Scotland, Shetland.	...	...
35. *Diphascon chilenense*, Plate	Scotland.	Arctic, Antarctic.	Europe, Asia, America.
36. *D. bullatum*, Murray	Scotland.	...	...
37. *D. oculatum*, Murray	Scotland.	...	...
38. *D. alpinum*, Murray	Scotland.	Antarctic.	...
39. *D. spitzbergense*, Richters	Scotland.	Arctic.	...
40. *D. angustatum*, Murray	Scotland.	Arctic.	Europe (Germany).
41. *D. scoticum*, Murray	Scotland.	Arctic.	...

Notes on the Genera and Species, with Descriptions of New Species.

Genus Echiniscus.

Structure.—In this genus the structures which serve for specific distinction are the number of plates, their arrangement, texture, setæ, spines, or other processes; the fringe on the last legs; the barbs on the inner or outer claws. Two characters, the eggs and the pharynx, of the greatest value in the genus *Macrobiotus*, are of little service here, being invariable.

Eggs.—In all known species they are smooth, round or oval, and they are always laid in the skin at the moult.

Pharynx.—In the majority of known species there are none of the rods so characteristic for each species of *Macrobiotus*. Professor Richters has found such rods in *E. islandicus*, and I have seen them in a species not yet identified.

Legs.—The spine on the first leg, which is given as a specific character of *E. creplini* and some other species, is not distinctive. It is present in most species. Its size may be characteristic, as in *E. reticulatus*, in which it is of exceptional length. An undescribed species has similar spines on all the legs. The *fringe* on the fourth legs, found in the great majority of species, changes with age, but is believed to be of characteristic form when fully grown. The *barbs* of the inner claws, also present in most species, appear to be invariable. They are often larger in the larva. *E. arctomys* and *E. borealis* (Murray 12) are without them. *Straight spines* near the base of the outer claws are known only in a few species (*E. blumi*, *E. merokensis*, *E. oihonnæ*, and *E. granulatus*?). They are not invariably present in the same species. They appear to be absent in the young and to develop with age, and in one species they increase in number with age till there are three on each outer claw of the last leg (*E. granulatus*).

Plates.—Professor Richters distinguishes six segments (see Plate I. fig. 4*a*, I to VI), of which I, II, III, IV, and V correspond to the brain and the four ventral ganglia.

Segment VI is regarded as all that remains of the abdominal segments of other Arthropods. Originally Professor Richters considered as segment VI the middle lobe of what I have called the *lumbar* plate, but the discovery of many species having three pairs of plates has led him to modify his views. He now regards this type of structure as more primitive than the commoner type. *E. islandicus* (fig. 4*a*) is a good example of it. Segments III, IV, and V each bear pairs of dorsal plates; segment VI is three-lobed. In the commoner type of structure (Plate I. fig. 5) only III and IV bear paired plates. After IV comes a single large three-lobed plate, like segment VI of *E. islandicus*, which is regarded as being composed of V and VI, so fused together that their limits are indistinguishable. The species conforming to the more primitive type, with V and VI distinct, are *E. arctomys*, *E. mutabilis*, *E. conifer*, *E. islandicus*, and a number of other species still undescribed.

All species are easily referable to one or other of these types of structure. Minor differences consist in the subdivision of certain plates, or the intercalation of smaller plates among the larger ones. The first and second median plates are often divided transversely into two more or less distinct plates. Plates II and VI are in some species divided by both longitudinal and transverse plain bands, but the "panels" thus formed can hardly be regarded as separate plates.

Texture of Plates.—Nearly all the known species have some kind of surface markings. In many species these are granules, and it has been usual to refer to any markings as granules. There is no doubt that in many cases they are not granules, though their true nature is difficult to make out. If *Echiniscus spitsbergensis* is turned about into various positions, so that the markings may be seen in profile, it becomes evident that they do not project.

In many species the markings look like perforations, and in descriptions I refer to them as such, using the terms *cribrose* or *pitted*; but in these cases I am dealing with appearances, and am not yet satisfied as to the nature of the dots. They may be of different texture from the rest of the skin, and only become perforations when the skin is cast, yet many have this appearance during life.

A few species are reticulate on the dorsal plates.

In *E. reticulatus* the pattern is very regular, the lines separating the hexagons being merely the very slightly raised margins, the spaces themselves being depressed. The reticulation of *E. islandicus* is of another nature. The spaces are of unequal sizes, generally irregular polygons, and they are bounded by pearly dots, of unknown nature, sometimes in double or treble rows between the spaces. In both species the reticulation dies out towards the margins of the plates.

Processes.—In framing diagnoses of species, much reliance has been placed on the various dorsal and lateral spines and setæ. As superficial processes are often the most variable of characters, it may be thought that too much weight had been given to such peculiarities; and it is true that, if the processes vary in number, there is little or no other distinction between most of the earlier-described species. The distinction of

species by the spines is mechanically easy, and has been accepted as sufficient by most authorities. Professor RICHTERS requires the animal described to be mature, unless there are some striking peculiarities.

There is no doubt that the processes are remarkably constant in some species, even among those of complex and unusual armature, such as *E. oihonnæ* and *E. islandicus*. It is also known that some species, while still in the two-clawed larval stage, possess all the processes which characterise the adult.

Nevertheless there is reason to believe that the processes vary in number; and if this can be demonstrated, it will be necessary to broaden the diagnoses in accordance with the facts. If this caution is disregarded, species may be *made* almost *ad lib.*, with a repetition of the disastrous fate which has overtaken some other groups of animals, or rather the students of them.

The difficulty is greatest in dealing with the central group of species of simplest structure, all built on the same plan, with two pairs of plates, two median plates (or three, the third being rather uncertain), and V and VI joined into a single 3-lobed plate. The distinctions among species of this group rest on the variations of lateral processes (maximum number 4, excluding the head) and two dorsal processes, on the paired plates,—all of these processes, in their greatest development, being long whip-like setæ. If we suppose the suppression of one or more pairs of processes (a common accident of development), and some of the others shortened in various degrees, a great number of changes can be rung on this simple arrangement. Distinctions of texture, which might help matters, have been overlooked, and, moreover, many species of this group have never been seen mature.

Variation in the number of spines has been noticed in several species. When a pair of spines is suppressed it is difficult to prove variability, but when in a plentiful collection of animals, alike in general build and texture, sometimes one spine of a pair and sometimes both are absent, the presumption is that all belong to one species, and that the spines vary in number. *E. spitsbergensis* has a very distinct characteristic texture of the plates (though the nature of the markings, which are not papillæ, is not known). Many examples have the second dorsal process (a broad triangle as figured by SCOURFIELD) more or less elongate, and a series may be formed showing all gradations to a long seta, like the first dorsal process. Some examples are found which lack seta *b*, without other difference.

It is in a form which I here unite doubtfully with RICHTERS' *E. quadrispinosus*, as var. *cribrosus*, that the widest series of variations have been traced. This also has a characteristic texture, of unequal dots, which look like perforations, but may be of another nature, and plates II and V + VI are further crossed by plain bands, both transverse and longitudinal. This has typically all four lateral processes, after the head, as long setæ, and the dorsal processes as short curved spines. One variation shows all the lateral processes reduced to short curved spines, the second dorsal process to a broad triangle; another lacks seta *b* at one side or both; a third lacks seta *b* and

all the dorsal processes, and is the most reduced condition yet seen. Another series of variations of the same species has as its principal peculiarity the forking of seta *d*. This may be forked from the base or from some distance above it (fig. 3); the branches may be equal, or one may be a short, thick spine and the other a long seta; the seta *d* of one side may be forked and the other undivided; and lastly, as in the other series, all the processes may be reduced to spines, the second dorsal to a triangle, and the seta *b* as well as all dorsal processes may be lacking. Truly a remarkable range of variation if all really belong to one species; and if not, we have, following the old rule, a considerable number of species, all built on the same lines, and differing only by the processes. I prefer to regard the processes as somewhat variable in number.

The five commonest lateral processes, which Professor Richters distinguishes by the letters *a* to *e*, are indicated by the letters in the figure of *E. islandicus* (Plate I. fig. 4*a*). Many species possess all five processes, either as setæ, spines, or knobs, and many lack all of them except the first. This first seta, *a*, between the first and second segments, is present in every known species of *Echiniscus*. The other lateral processes are also intermediate between the other segments, except *e*, which springs from the slit separating the lobes of segment VI.

Larvæ.—It is highly probable that all species of *Echiniscus* have only two claws in their earliest stage. In all species of which the larva is known this is the case. When a species is found in abundance and can be well studied, there is usually little difficulty in finding some larvæ. It is therefore curious that the two-clawed larvæ of *E. reticulatus* have never been seen, though the species is very abundant in some lochs, and individuals of various sizes have been found, some very small ones laying eggs.

Two-clawed larvæ of the undernoted species are known :—*E. arctomys*, *E. mutabilis*, *E. gladiator*, *E. islandicus*, *E. testudo*, *E. granulatus*, *E. quadrispinosus*, *E. oihonnæ*, *E. blumi*, *E. merokensis*, *E. duboisi*, *E. wendti*, as also of several species not yet described.

E. arctomys, Ehr. (3).

Segment V is distinct from VI, and forms a half-ring. In *E. mutabilis*, and most of the other species which have V separate, it has a pair of plates.

The two-clawed larva has been found in Loch Morar.

E. mutabilis, Murray (6).

Two-clawed larva, Loch Morar.

E. islandicus, Richters (18). (Plate I. figs. 4*a* to 4*c*.)

Description.—Very large; 12 main plates, 3 pairs and 3 median; V paired, first and second median each divided into two parts; VI deeply 3-lobed. Lateral processes 5; *a* and *e* very long setæ; *b*, *c*, and *d* short curved spines. Dorsal processes; short, tooth-like spines on posterior border of II, III, and IV; a pair of large broad spines on V, near the middle line. Two small spines on the lateral lobes of VI. Fringe of sharp

spines on fourth leg. Small barbs on the inner claws. Central parts of all plates with pattern of pearly dots, forming irregular reticulation (fig. 4*c*). Colour red.

Sizes,—length up to 500μ, claws 32μ, reticulations 6μ to 10μ. There is a small spine on the first leg.

Top of Ronas Hill, Shetland, September 1906.

The above diagnosis is made from the Scotch example, and agrees with Professor Richters' description, except in some minor details. The small dorsal spines appear to be variable in number. Our examples had four on segment II, 8 on III, and 6 on IV. All of these, except 2 on IV, are on the margins bordering on the median plates.

The reticulation is quite different from that of *E. reticulatus*, both in the nature of the bounding lines and in their irregularity of size and form.

It is by far the largest member of the genus yet found in Scotland.

E. gladiator, Murray (6).

The eggs, unknown when the description was published, have been found in Loch Morar. An example 166μ in length (far from the largest size) had two eggs measuring 70μ by 58μ. A two-clawed larva 120μ long was also got in Loch Morar. An example from Ben Lawers, 200μ long, had claws 14μ long.

Hitherto only known in Scotland. I have the pleasure of reporting that Herr Sellnick of Königsberg has recently discovered it in the Faröes.

Var. *exarmatus*, var. nov. (Plate I. figs. 5*a*, 5*b*.)

Exactly like the type, except in two characters—there is no median spine, and the barbs of the inner claws are smaller. Length 166μ.

Top of Ronas Hill, Shetland, September 1906. Though *E. gladiator* (type) was not found in Shetland, the variety was found several times. Both the variety and the type have segments III and IV with paired plates, though this is not indicated in the original figure of *E. gladiator*. The pairing is indicated mainly by the cessation of the dots. The dotting, unlike that of *E. mutabilis*, is not continued on the connecting membrane between the plates. All the median plates are small; the first and second are divided in two transversely; and all show slight appearance of being paired, most marked in the anterior part of the second median.

E. wendti, Richters (16), (19).

Loch Lochy, length 260μ; the two-clawed larva Ben Lawers.

E. oihonnæ, Richters (16). (Plate I. fig. 7.)

Scottish examples usually have straight barbs on the outer claws of the last legs.

In Loch Earn examples the four little lateral spinules, as in *E. spinulosus*, were seen.

E. spitsbergensis, Scourfield (21).

The Scottish animal supposed to belong to this species never grows so large as I have found it in Spitzbergen moss. A variety found in Loch Earn and elsewhere differs in having both dorsal processes long spines. It approaches a variety from Franz Josef Land.

E. quadrispinosus, Richters (15).

The type of this species has not been found in Scotland, but several closely related animals occur, which I think it best, in our present ignorance as to the amount of variability in the genus, to unite with *E. quadrispinosus* as varieties. The type has 5 long lateral setæ, *a*, *b*, *c*, *d*, and *e*; 4 dorsal spines, on the paired plates; the surface markings, which look like perforations, are interrupted by a plain band connecting the two slits of the lumbar plate, and also by median bands on the shoulder and lumbar plates, and some transverse bands on the shoulder plate. In addition to the 10 normal plates, it has 3 additional small plates on each side—2 between II and III, and 1 between III and IV.

Var. *cribrosus*, var. nov. (Plate I. fig. 1*a* to 1*c*.)

Exactly resembling the type in all other respects, but the three additional small plates on each side were not seen. Only the 10 normal plates (3 median). There are small barbs on all inner claws. Three eggs seen. Among tree moss, Broughton, Peeblesshire, July 1906. A modification of this variety, having all the lateral processes shorter and the second dorsal spine a short triangle, was found in Loch Morar, 1903.

Var. *fissispinosus* var. nov. Exactly like the form of var. *cribrosus* found in Loch Morar, but the lateral spine *d* is double. Also in Loch Morar, July 1906 (Plate I. fig. 2): var. *fissispinosus*, forma,—lateral process *b* lacking, *c* large, strong, and curved, *d* furcate from the base or some distance above the base; all dorsal processes lacking. This would be counted a good species but for the existence of the variety *fissispinosus*, intermediate between the form and type. In tree moss, Broughton, with the variety *cribrosus* (fig. 3): var. *cribrosus*, forma—like the form (fig. 3): but spine *c* is smaller and spine *d* is not forked. There are no dorsal processes. Top of Ronas Hill, Shetland, September 1906.

The differences between *E. quadrispinosus*, type, and the form with furcate *d* and the Shetland form, seem sufficiently great. Yet all have the same surface texture, interrupted by the same plain bands, and with the var. *cribrosus* we have such a connected series of gradations that it would seem to me impossible to separate any of the varieties as distinct species. The paired lateral processes are a principal specific character of *E. aculeatus*, Plate, but in that species it is *c*, not *d*, which is double.

Length up to 280μ.

E. muscicola, Plate? (13). (Plate I. fig. 6*a*, 6*b*.)

Description.—Small, red; plates 10, arrangement normal, 3 median; granules coarse, regular. Lateral processes 4 on each side, all setæ (*a*, *c*, *d*, *e*). Dorsal processes, one strong spine on each plate of first pair. Fringe on fourth legs. Strong barbs on claws.

Length 185μ (excluding the legs). Eggs large, (58μ), nearly round, red.

Monument Hill, Comrie, Perthshire, June 1905.

The number of processes corresponds with that of *E. testude* and *E. muscicola*, but their position differs from both. As the dorsal spine is over seta *c*, the correspondence is closest with E. *muscicola*, Plate, but the lateral setæ of that species are *a*, *b*, *c*, *d*.

Genus Macrobiotus.

It has been thought that most of the organs which might have been used in discriminating species were too variable to permit of their use in this way, the claws alone being regarded as trustworthy characters. In consequence of this supposition most of the earlier species are insufficiently described, and are hardly recognisable; they can only be firmly established by subsequent more detailed diagnoses.

With increasing experience, faith is being established in the practical constancy of most of the structures, or at any rate it is now supposed that their variability is confined within narrow limits. If further work confirms this belief, it will have to be conceded that species are much more numerous than has hitherto been supposed.

An amount of caution in describing new species is laudable, yet too much of it may hinder the progress of knowledge.

The most different animals have been regarded by various observers as *M. hufelandi*, partly because they allowed too much for variation, and partly because they supposed there were only a few species in the genus, whereas there may be probably from 12 to 20 or upwards of common species in any district.

Lance (4) naïvely (p. 206) discusses the improbability of the existence of *M. tuberculatus*, Plate, merely because he hadn't found it.

The three most useful characters in framing diagnoses are, the pharynx, the claws, and the egg. Of secondary but still great importance are the teeth and the texture of the skin.

The pharynx.—The chitinous rods in the pharynx are found in three principal types. There appears to be nearly always a short, thick process attached to the end of the gullet. The differences of the three types are found in the succeeding thickenings.

The *hufelandi* type of pharnyx has in each row of thickenings two unequal rods, the first, nearest the gullet, longer, and apparently formed by the junction of two shorter rods; the second usually about half the length of the first. The second type, which

may be called the *echinogenitus* type, has three nearly equal rods, the third slightly the largest. The third type may be called the *oberhäuseri* type. In this the process attached to the gullet is very large, and there are only two other rods, which are almost exactly equal, and usually short, often as broad as long.

With each type there may be an addititional more obscure process of the end of each row. This Richters aptly calls the "komma." It appears to be a reliable character, but there is some little doubt about this.

Variability of the pharnyx.—The only variation noted is in the number of rods, and appears to be a matter of age. The pharnyx is, I believe, very constant in adults, but the young have sometimes one rod less in each row. In most species the well-developed young in the egg have all the essential characters like the adult, but the young of *M. angusti* and *M. annulatus* have one long rod in place of the two rods nearest the gullet. These two rods are simply joined in the young, and become free in the adult. In the *hufelandi* type of pharnyx they are usually permanently united.

Structure of pharynx.—The true relation of the various parts of the pharynx and their mode of working was first made intelligible by Albert Basse's beautiful sections, figured in his instructive "Beiträge zur Kenntnis der Baues der Tardigraden" (22).

The claws.—There are four well-marked types of claws. The *hufelandi* type has the two claws of each pair united in their lower parts, say from one-third to two-thirds of the length of the larger claw. A variety, of which *M. coronifer* is an example, has a crescent-shaped ridge, sometimes bearing a series of spines, in front of each pair of claws. The *echinogenitus* type has the claws of each pair united at the base only, or for a short distance above it; the pairs are similar, but one claw of each pair is somewhat longer. The *macronyx* type has the claws of each pair very unequal, the pairs similar, the disparity less between those of the last legs. The *oberhäuseri* type, which might also be called the *Diphascon* type, as it prevails throughout that genus, has one pair of claws slightly unequal, and joined at the base, the other pair consisting of one short claw and one very long slender claw, apparently springing from the middle of the back of the shorter claw, but movable upon it.

There is usually no difficulty in assigning a species to one of these types, but puzzling intermediate forms sometimes occur. The *oberhäuseri* and *echinogenitus* types are joined by a series of gradations.

The supplementary points near the tips of the larger claws appear to be very often two in number in the *hufelandi* type, and sometimes in the *echinogenitus* type.

The eggs.—There are also four distinct types of eggs, but they fall into two great groups—those which are normally laid in the cast skin of the animal itself, and those which are laid free from the skin. The eggs laid in the skin, which may be called the *macronyx* type, are always smooth, usually oval or elliptical, but sometimes nearly round. There are three varieties of eggs laid free,—first, the *hufelandi* type, which is round, with the surface covered with processes, generally uniform and evenly spaced over the surface (the egg may be oval [*coronifer*], and the processes may be irregular

[*islandicus*]); second, the *hastatus* type, which is round or oval, with the surface studded with rods, which are imbedded in a clear matrix, a form of egg-covering similar to that of many winter eggs of Rotifers and other animals; third, the *antarcticus* type, which is oval, without spines, viscous, and is laid free.

The eggs of *M. hastatus*, the only British species of the group which has the spines imbedded in a hyaline matrix, though it lays its eggs free from the moulted skin, yet has been found to deposit them three together in the cast skins of certain Cladocera so constantly that this seems to be a normal provision for their safety. Another species, *M. annulatus*, which lays smooth eggs in the skin, carries this skin about with it, like a sack on its back, till the eggs are hatched. Living young have been seen in the body of one species, *M. zetlandicus*; but as this species constantly lays eggs in the skin, we must suppose the living young to be the result of some mischance in development, such as inability to deposit the eggs, which would then hatch in the body.

Moulting.—Eggs of the *macronyx* type are usually all laid before the parent begins to emerge from the skin, though of course the old skin has been completely loosened before the eggs are laid. The animal in its new skin has room to move freely inside the old, and can easily turn end for end. It has been seen in many species to finally quit the old skin by simply walking out, the skin having split in the front part of the ventral side.

Eyes.—It is recognised that the presence or absence of the eye-spots is too uncertain to allow of their use as specific characters. While agreeing with this, I am inclined to think that the eye-spots are as stable as in other groups of the lower Invertebrata. In a species possessed of eyes, blind individuals may occur—it is a case of defective development merely,—but I do not expect to find the converse, viz. species normally blind, to have occasionally individuals with eyes.

Blood.—The watery fluid filling the body cavity contains numerous large nucleated corpuscles, now called fat-cells. These, commonly hyaline and colourless, may become yellow, grey, or black, doubtless in relation to the activity of their functions. In some species they are of a characteristic colour—golden brown in *M. coronifer*, paler yellow in *M. islandicus*, reddish in an Indian species, etc.

Stomach.—The stomach walls often present distinctive characters. They may be composed of very few large cells, only 6 or 8 visible in one view, or of very numerous smaller cells (*M. coronifer*). These cells often have contents of a characteristic colour—sienna-brown in *M. annulatus*, umber in *M. coronifer*, and so on. Animals are often found with the stomach of a deep blue or sometimes green colour. This colour is within the cell, and independent of the stomach contents, though perhaps chemically resulting from the nature of the food. It is not known whether it is an invariable characteristic of certain species, but there are reasons to doubt this. *M. papillifer* only occasionally has the blue granules in the stomach cells. Richters found the blue stomach in *M. islandicus*, but whether constantly I do not know. In littoral collections from Loch Ness examples with blue stomach are always abundant and belong to several species.

One of these appears to be more constantly blue than the others. This was erroneously recorded as *M. islandicus* (6), trusting to the blue colour and the pharynx. It is now known to lay smooth eggs in the skin, and is therefore quite distinct from *M. islandicus*. The blue colour is found in large granules, of nearly uniform size, densely filling the cells. The colour is sometimes modified by a distinct green tint in the most anterior and posterior cells.

Simplex forms.—No explanation has yet been offered of these curiously reduced forms. Richters, without attempting to account for them, regards them as parallel forms, comparable with the various castes of bees and other sociable insects. This implies that they are permanent, and that the peculiarity continues throughout life, and this view is supported by the fact that in some species Richters has seen the simplex form emerge from an egg slightly different from the typical egg of the species. In this view of their permanence I cannot concur, basing the opposite opinion on the fact that the simplification may go so far as the total disappearance of the alimentary canal in front of the stomach, with all its accessory organs. Large well-nourished animals, with stomachs full of food, and no mouth or gullet, obviously cannot have been long in that condition. I have suggested (6) that this change is correlated with moulting, and I still think that this is the general fact, though it cannot apply to the simplex forms in the egg. In view of the investigations into the encystment of *Macrobiotus* now going on in various quarters, the connection of simplex forms with moulting may have a possible meaning. The simplification which happens during encystment is carried much further than in the ordinary simplex forms, involving the loss of claws and stomach as well as pharynx. There is at least a very striking parallel between the two phenomena, and it may prove to be more. If the encystment is demonstrated to be, as among lower forms, really a kind of rejuvenescence, and if this requires the absorption of all the organs and their re-creation anew, then the simplex forms might be individuals in which the absorption had been stimulated prematurely before the moulting, which usually precedes it, or, conversely, that the moulting had been retarded.

Encystment.

It has recently been discovered that certain species of *Macrobiotus* encyst themselves. Professor Lauterborn published the first note on the subject (5). The animal forms within the skin, which is loosened as for an ordinary moult, an elliptical yellow cyst, within which, in one species at any rate, it undergoes a curious metamorphosis, losing all its conspicuous organs. The process is not fully understood, and has never been completely traced. What happens next, after the reduction above referred to, is unknown. The escape of animals from cysts has been seen by Professor Richters and myself, but in no case could we tell whether these animals had ever undergone reduction. I am inclined to think that these escapes have been premature, and due to stimulation by the unnatural heat of a room. In one species, *M. dispar*, recently

described in the *Zoologist* (11), the process is very complex, and an outer and an inner case are formed (see figs. 11*f*, 11 *g*). Cysts of various species are now known. *M. echinogenitus*, *M. oberhäuseri*, and a species of *Diphascon* have been found with cysts like the inner elliptical cyst of *M. dispar*. In those cases the peculiar outer case is not formed.

Professor Richters, in a recent letter, suggests that *Macrobiotus* cysts were known to Spallanzani. His figures are copied by Schultze (20).

Classification.—So numerous are the species of *Macrobiotus* now known and so varied in structure that, as a matter of convenience, it is already necessary to attempt to subdivide the genus into natural groups, eventually into distinct genera.

Any of the distinct types of pharynx, claws, or egg described in a previous paragraph might serve as a basis for subdivision. It is at present quite uncertain whether any of these types are characteristic of natural groups. A given type of one organ does not appear to be ever invariably associated with a certain type of another organ, although there are long series where two organs correspond in type. There are always some exceptions, and indeed most species could be recognisably defined merely by the combinations of the types of pharynx, claws, and egg.

We may then inquire whether it is possible to found a natural classification on the various types of one organ. There seems no reason for supposing that the various forms of claws distinguish more natural groups than the various forms of pharynx. The difference between the smooth and spiny eggs seems to point to a more profound separation of the groups producing them, since there is not only the widely different eggs, but their future is provided for in a totally different manner,—the spiny eggs being deposited and left to their fate, while the smooth eggs are enclosed in a sack formed of the cast skin of the parent.

M. oberhäuseri, Doy. ? (2). (Plate IV. figs. 27*a* to 27*d*.)

Though recorded in the Tardigrada of the Scottish Lochs (6), that record cannot be trusted, as I did not then sufficiently understand the species. Having been favoured by Professor Richters with living examples and slides of the animal, a brief diagnosis can now be given. *Claws* of the type common in the genus *Diphascon*, one pair nearly equal and joined at the base, the other having one very long slender claw, movably attached to the middle of the back of the shorter claw. *Pharynx* with 3 nuts in each row—a small one attached to the gullet, and 2 larger free nuts.

The brown pigment is a very warm colour, inclining to madder; it is variable, and may be absent.

Animals with claws and pharynx as described above are frequent; one pigmented example in moss from the pier, Fort-Augustus.

An animal having the claws and pharynx of *M. oberhäuseri* was seen to hatch out of an egg found in Loch Ness, December 1906.

This egg was of the *hastatus* type. The egg is round, the hyaline layer thinner

than in *hastatus*, the processes very short round-topped rods. The egg might sufficiently fit Doyère's description of "mulberry-form" but for the exceeding minuteness of those rods. Looked at from above, they look like pellucid dots (see figs. 27*a*, 27*d*).

M. sp. ? (6).

The *Macrobiotus* erroneously recorded as *M. islandicus* (6) appears to be related to *M. oberhäuseri*. It has claws of the same type, and pharynx with the same number of thickenings, but two of these are rods instead of nuts. The eggs are smooth, and four have been seen laid in the skin. The stomach cells are usually filled with dark blue granules, but these may be absent.

It appears to be distinct from any described species, but further study is needed. Common at lake margins.

M. zetlandicus, sp. n. (Plate IV. figs. 24*a* to 24*d*.)

Specific characters. — Large, brown. Teeth straight, very stout, furca of large lobes; pharynx of the *oberhäuseri* type, with all the three thickenings in each row short and broad, the second and third deeply two-lobed on outer side; claws also of *oberhäuseri* type, all large and strong, the longest with two supplementary points; eggs elliptical, laid in the skin. Eyes dark.

Length up to 580μ, claws 30μ, egg 94μ by 75μ.

Living young have been seen in the body of the parent, but as eggs are usually laid I do not think we have in this species any exception to the rule throughout the order. I rather suppose that some malformation has prevented the deposition of the eggs, which were retained till hatched.

The deeply-lobed rods distinguish it from all known species. Bog pool, Fort-Augustus, 1905; Shetland, abundant, 1906; Spitsbergen (W. S. Bruce), 1906.

M. macronyx, Duj. ?

All the various Scotch records for this species are open to doubt. It has been found that the animal so identified has spiny eggs (see *M. dispar*, below), and cannot therefore be *M. macronyx*. In the Forth area (10) a skin was found containing 15 eggs, and with claws like those of *M. macronyx*, but the pharynx was not seen, so the identification is not complete.

M. tuberculatus, Plate (13). (Plate IV. figs. 24*a* to 24*c*.)

Plate's description is very meagre and unsatisfactory. More than one form with similar tubercles is known. Plate says there are 2 rods in the pharynx, and figures 3. A Spitsbergen form has a nut and 3 short rods, without "comma." The Shetland form has only 2 short rods and a comma. I have no doubt these are distinct species.

The example from Loch Morar was a simplex form. The claws are very divergent.

M. sattleri, Richters (15). (Plate IV. figs. 26*a* to 26*c*.)

Description of the Scottish form.—Very small. Tubercles in 8 or 9 rows on the posterior half of the body, about 4 tubercles in each transverse row, some small sharp spines like those of *M. papillifer*. Back reticulate, in polygons of various sizes, arrangement somewhat symmetrical, largest polygons central. Only simplex forms seen. Claws equal, widely divergent.

The pharynx of a precisely similar Indian form had a fixed nut and three free nuts, just as in Spitsbergen form of *M. tuberculatus*.

M. papillifer, Murray (6).

Eggs up to 6 in a skin. Stomach sometimes with blue granules.

M. annulatus, Murray (6).

When the skinful of eggs is carried, it is fixed to the centre of the top of the head, where a little cluster of globules may represent a kind of cement gland. The original figure (6) is in this respect inaccurate. Eggs sometimes 4, rarely 5.

M. angusti, sp. n. (Plate IV. figs. 25*a* to 25*d*.)

Specific characters.—Large, hyaline, with brownish stomach. Claws of echinogenitus type, united near base, one claw of each pair longer. Teeth curved, with bearers. Pharynx shortly oval, with 4 thickenings in each row—1st, a nut, joined to gullet; 2nd, 3rd, and 4th, slender rods, the middle one rather shorter. No eyes. Eggs oval, laid in the skin, 4 to 6 or more.

Length 757μ, pharynx 75μ, claws 22μ, egg 115μ by 92μ.

This large species has no very close relatives.

Bog pool near Fort-Augustus, 1904, abundant.

M. coronifer, Richters. (Plate III. figs. 22*a* to 22*c*.)

(16.) Very large: fat-cells golden-yellow. Crescent in front of claws, bearing a series of curved spines. Pharynx shortly oval, thickenings three in each row,—1st, a round nut attached to gullet; 2nd and 3rd, short rods, little longer than broad. Egg very large, golden-yellow, elliptical, closely set with weak straight-pointed spines.

The largest known Tardigrade, attaining 1 mm. in length. It was the first of that interesting group having the crescent in front of the claws, discovered by Professor Richters. As it has not yet been figured in any work in English, a short description and figure are given here. Shetland, near top of Ronas Hill; also on West Coast, few examples, size 862μ.

M. crenulatus, Richters (19).

Specific characters.—Large, hyaline or brown; teeth stout, curved; pharynx of *hufelandi* type, with long double rod, short rod, and comma in each row; claws of

hufelandi type, united more than half-way, crescent in front of claws, plain in the young, wrinkled in the adult. Supplementary points two.

Length 400μ (Spitsbergen examples up to 750μ). Scotch examples have a papillose process on each leg, not mentioned by Richters. The last leg is sometimes papillose. The crescent is most distinct on the fourth legs, and, except in very large examples, only those are wrinkled. Abnormal additional claws are frequent.

Orkney (Pomona), August 1906; Shetland, Spitsbergen (Bruce), 1906; Franz Joseph Land (Bruce), 1897.

M. harmsworthi, Murray (12).

Specific characters.—Size moderate, pharynx shortly oval, thickenings 4 in each row, all nearly equal, short, $1\frac{1}{2}$ times as long as broad, the first attached to the gullet, an obscure narrow "comma." Claws like those of *hufelandi*, united about half-way, supplementary points two, a crescent-shaped ridge in front of each pair. Dark eyes. Egg spiny, the spines acuminate, their bases touching, papillose.

Length, of adult 470μ, of pharynx 45μ, of young 284μ, pharynx of young 30μ.

Shetland. Spitsbergen, Franz Josef Land (Bruce).

The egg is somewhat like that of *M. ambiguus*, but is smaller (105μ over spines) and has fewer spines.

M. hufelandi, C. Sch. (20).

Variety.—The egg figured in Scot. Alp. Tard. (8), fig. 6, is very like the type, with the spines shortened till the discoid part seems to lie on the top of a hemisphere. In Shetland many of these eggs were found with well-grown young. The pharynx is sufficiently like the type, but the second (single) rod is nearly equal to the first double rod. The end of the gullet (in the pharynx) is very much thickened. The gullet is narrower than in the type. There is a faint crescent in front of the claws of the last legs. Only one supplementary point seen on each larger claw. No eye seen.

M. intermedius, Plate (13). (Plate II. figs. 13*a*, 13*b*.)

The characteristic egg, with processes enlarged upwards like little funnels, has been several times found in Loch Morar.

M. orcadensis, sp. n. (Plate II. figs. 10*a* to 10*e*.)

Specific characters.—Pharynx of the *echinogenitus* type, having a nut, 3 short rods, and a comma in each row; teeth curved, with bearers. Claws of *hufelandi* type, united half-way. Eyes dark. Egg small, spiny, the spines like those of *M. furcatus*, Murray (9), but the divided points less regularly dichotomous, having 2, 3, or many slight branches; egg shell between spines dotted.

Only known from the egg and the newly hatched young. Length of young 230μ, pharynx 26μ, claws 9μ. Egg 77μ over spines.

Nearest to *M. furcatus*, it is distinguished by the smaller egg, weaker spines, without the basal circlet, weaker teeth, etc.

Orkney, Ward Hill, Hoy, September 1906.

M. echinogenitus, Richters (16). (Plate III. figs. 14*a*, 14*b*.)

Cysts of this species, Blantyre Moor. There is no outer case as in *M. dispar*; the cyst is yellow and of elliptical form, like the inner case of that species.

Var. *areolatus* (Arctic Tardigrada, 12).

An egg found in Loch Morar and on Ben Lawers appears to belong to this variety, which is very widely distributed, from Spitsbergen to India. There are areolations, round or hexagonal, between the spines of the egg; the pharynx lacks the "comma," and the claws are united for a greater distance above the base.

M. dispar, Murray (11). (Plate II. figs. 11*a* to 11*g*.)

Specific characters.—Large, hyaline or brown; claws of *macronyx* type, very unequal; pharynx large, shortly oval, rods of *hufelandi* type, viz. nut, long double rod, shorter single rod; furca of tooth very large; dark eyes; egg spiny; spines short, sharp cones, standing a little apart.

Length up to 600μ, pharynx 80μ, egg 90μ over the spines.

There are usually two dorsal conical processes between the third and fourth legs (fig. 11*a*), but these are very variable in size and may be obsolete. The egg is not distinguishable from that of *M. pullari*, described in this paper, though that species has quite different claws and pharynx.

M. dispar lives in ponds and lakes. It undergoes a curious metamorphosis, first casting its skin, then forming an *outer case* (fig. 11*g*) and an *inner case* (fig. 11*f*), within which it undergoes further changes which have not yet been completely traced.

Localities.—Nerston Quarry, near Glasgow, 1904; Loch Tay, 1905; ponds near Edinburgh (Evans); pond at Nairn; North Uist; Ronas Hill in Shetland; Askomb Bog, near York; Spitsbergen, and Franz Josef Land.

It is seen to be widely distributed in Britain and to range far north. Of its southern range we have no knowledge. It is supposed to strongly resemble *M. macronyx*, which has, however, a quite different egg, and it is possible that some of the records of *M. macronyx* may refer to this species. It is closely related to *M. ambiguus*, described in this paper, which has also a spiny egg, but of different form.

A *Diphascon-form* of this species, with elongate gullet, was found near Edinburgh (Evans).

M. ambiguus, sp. n. (Plate II. figs. 9*a* to 9*d*.)

Specific characters.—Large, hyaline; claws of *macronyx* type, very unequal, those of last legs less so; pharynx large, shortly oval, of *hufelandi* type—a nut, a long

double rod, and a single shorter rod in each row of thickenings. Egg spiny, spines pretty large, close together, acuminate. Teeth curved, with very large furca.

Length, of adult 430μ, claws of young just hatched 24μ, of pharynx of young 35μ, diameter of egg over spines 130μ.

The adult is hardly distinguishable from *M. dispar*, but the egg is quite different, and more resembles that of *M. echinogenitus*, while it is chiefly distinguishable by its larger size from that of *M. harmsworthi*, recently discovered in Franz Josef Land, and now known to be in Shetland.

Ronas Hill, Shetland, September 1906. Spitsbergen (Bruce), 1906.

M. pullari, sp. n. (Plate II. figs. 8*a* to 8*c*.)

Specific characters.—Large, brown; claws of *echinogenitus* type, joined at base only, supplementary points strong; teeth stout, curved; pharynx of *hufelandi* type, viz. with nut, long double rod, and shorter single rod in each row, and no "comma." Eggs spiny, round; spines short, sharp cones standing a little apart, smooth.

Length up to 570μ, pharynx 48μ long. The dark colour is arranged in longitudinal and transverse bands as in *M. oberhäuseri*, but the colour is different. The eggs are very often laid all at one time, and are found adhering in clusters. A whole "clutch" of them is sometimes accidentally included in the cast skin, and oval eggs are not rare. The round egg is not distinguishable from that of *M. dispar*, and measures 75μ over the spines, the oval egg measuring 90μ long diameter over spines.

Localities.—Gryfe Reservoir, near Greenock; Loch Ness; Forth area (Evans).

Similar eggs are known from various countries, but the identity of form of those of *M. pullari* and *M. dispar* makes it impossible to identify from eggs alone.

The species is named in memory and honour of Frederick Pullar, who with Sir John Murray began the systematic survey of the Scottish Lochs.

M. islandicus, Richters (18).

The records under this name (6) proving to be erroneous, it is doubtful if the species exists in Britain. Eggs with the peg-like processes have been found, but never with sufficiently developed young.

M. hastatus, sp. n. (Plate III. figs. 18*a* to 18*d*.)

Specific characters.—Small; claws of *echinogenitus* type, or a little inclined towards the *oberhäuseri* type, claws joined near the bases, one of each pair longer, and one long claw larger than the other, pharynx of *oberhäuseri* type, with nut joined to the gullet, and two equal rods, twice as broad as long, in each row. Egg spiny, each spine in optical section like a fleur-de-lis, the spines imbedded in hyaline matter, from which only the central spike of the fleur-de-lis projects.

Diameter of egg over spines 70μ. The eggs are round or oval, and were found in large numbers, always three together, in the cast shells of *Alonella nana*. This

happened so constantly that I suppose such shelter is deliberately sought for the eggs, though the selection of the shells of *Alonella nana* is probably only due to their great abundance.

Bog pool at Fort-Augustus, 1904. Loch Tay. Also collected in Switzerland by Dr Chas. Linder.

M. dubius, sp. n. (Plate III. figs. 17*a* to 17*c*.)

Specific characters.—Size moderate. Pharynx elliptical, somewhat narrow, of the *hufelandi* type; long rod apparently formed by the junction of two rods, of which the second is much shorter. Claws of *echinogenitus* type, one of each pair longer. Hyaline.

Size 312μ, no eyes. Egg unknown. Saxavord Hill, Unst, Shetland, September 1906; bog pool at Fort-Augustus, November 1906.

Macrobiotus, sp.? (Plate II. figs. 12*a*, 12*b*.)

The egg erroneously recorded as that of *M. coronifer* (8) has not yet been identified, but is undoubtedly distinct from any species yet named. It agrees with *M. coronifer* in the oval form and small weak spines, but has, as Richters points out, nothing else in common with it.

Diphascon.

The genus *Diphascon* now rests upon a very slight foundation. The elongated flexible gullet, on which the genus was founded by Plate, is a character shared by various species of *Macrobiotus*. In *Macrobiotus* this character is abnormal or exceptional; in *Diphascon* it is believed to be normal and permanent. I thought to distinguish a peculiar *Diphascon* type of claw (9), and it is true that all the species known have claws of one type, but it is the type found in *Macrobiotus oberhäuseri*.

The genus can therefore only be defined as having claws of the *oberhäuseri* type, and normally possessing a more or less elongated and flexible gullet. So far as known, the eggs are smooth and are laid in the skin. Eyes are present in one species only. In many species the pharynx is narrow and elongate, which is never the case with *Macrobiotus*, which has the pharynx in all known species shortly oval or roundish. The elongate pharynx cannot be made a generic character, as one or two species have it nearly round. Simplex forms occur.

Professor Richters also expresses little faith in this genus, one species of which, *D. spitzbergense*, he has described. Admitting the slight stability of the genus, and turning to the consideration of the described species, those appear to be all sufficiently distinct forms, even if we admit that the elongate gullet may be an abnormal development.

One feature alone sufficiently distinguishes the species of *Diphascon* from the great

majority of the species of *Macrobiotus*, viz. the claws of the *oberhäuseri* type. Though there is reason to believe that the genus *Macrobiotus* contains many forms having this type of claw, few such species have yet been described.

The species of *Diphascon* need, therefore, only be compared with *M. oberhäuseri*, and species (if any) closely related to it. Those having the narrow pharynx are far removed from any known *Macrobiotus*, and of the other species only one (*D. oculatum*) has the pharynx of the *oberhäuseri* type. That species is sufficiently distinguished from *M. oberhäuseri* by several characters—the lack of the brown pigment, the teeth of quite different form, etc.; the other species are quite distinct in the various details of the pharynx, always associated with *oberhäuseri* claws, even if the distinction of *Macrobiotus* and *Diphascon* breaks down.

For convenience, an artificial subdivision of the genus may be made into—A, pharynx narrow, and B, pharynx round or very shortly oval.

D. scoticum, Murray (7). (Plate III. fig. 19.)

The pharynx has the same number of rods as Richters' *D. spitzbergense* (16), but according to his figure in the "Fauna Arctica" the arrangement is different. He shows the middle narrow rod as the longest, whereas our species has the last narrow rod longest. A more important distinction is the narrow gullet of *D. scoticum*.

D. alpinum, Murray (8). (Plate III. fig. 15.)

The pharynx is intermediate between the round and elongate types, but may be classed with the latter, as it is $1\frac{1}{2}$ times as long as broad, or slightly longer than that.

D. bullatum, Murray (7). (Plate III. fig. 21.)

The blunt tubercles recall *M. tuberculatus*, Plate, but there is no other resemblance.

D. oculatum, Murray (10). (Plate III. fig. 16.)

Only known as a moss-dweller till recently discovered in Loch Ness.

D. angustatum, Murray (6).

A simplex form has been found near Edinburgh and at Killin.

Milnesium.

Within this genus no variation from the typical structure has been observed of specific value, and I agree with Professor Richters in uniting the two described species. The only variation which I have noticed is in the number of points to the shorter claws. In some districts there appear to be constantly three points to these claws. In Scotland they are variable, and we may find from one to three points, not only in different individuals from one district, but in one individual we may find all three conditions. The

long claws have very fine supplementary points, which are sometimes difficult to distinguish. The eggs are laid in the skin, and are smooth. I have seen 2 and 3 eggs. Professor RICHTERS has seen as many as 15.

M. tardigradum, DOY. Length 430μ, pharynx 60μ, eggs 120μ by 85μ.

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EXPLANATION OF PLATES.

It is desirable that all the figures of the complete animals should be drawn to the same scale, so that the relative sizes can be easily seen, and this has been done in most cases, but so diverse in size are various species that the largest species had to be drawn to a smaller scale in order to include them in the same plates with the smaller ones.

In Plate III. *M. coronifer* is drawn to a much smaller scale than the others, and so in Plate IV. *M. angusti* is only magnified about half as much as the small species in the corners.

The details are not drawn to any uniform scale.

Plate I.

1*a*. *Echiniscus quadrispinosus*, Richters, var. *cribrosus*, var. nov.
1*b*. ,, ,, outer and inner claws.
1*c*. ,, ,, portion of surface of plate.
2. ,, ,, var. *fissispinosus*, var. nov.
3. ,, ,, ,, ,, reduced form.
4*a*. *E. islandicus*, Richters, showing segments I to VI, and lateral processes *a* to *e*.
4*b*. *E. islandicus*, Richters, inner claw.
4*c*. ,, portion of reticulation of plates.
5*a*. *E. gladiator*, Murray, var. *exarmatus*, var. nov.
5*b*. ,, inner claw.
6*a*. *E. muscicola*, Plate ?
6*b*. ,, inner claw
7. *E. oihonnæ*, Richters, outer and inner claws.

Plate II.

8*a*. *Macrobiotus pullari*, sp. n., young emerging from egg.
8*b*. ,, ,, pharynx.
8*c*. ,, ,, claws.
9*a*. *M. ambiguus*, sp. n. Egg.
9*b*. ,, pharynx.
9*c*. ,, claws of last legs.
9*d*. ,, claws of other legs.
10*a*. *M. orcadensis*, sp. n., pharynx.
10*b*. ,, egg.
10*c*. ,, three processes of the egg.
10*d*. ,, furca of tooth.
10*e*. ,, claws.
11*a*. *M. dispar*, Murray.
11*b*. ,, claws of last legs.
11*c*. ,, claws of other legs.
11*d*. ,, egg.
11*e*. ,, furca of tooth.
11*f*. ,, outer and inner cases of cyst.
11*g*. ,, outer case, showing stumps of limbs.
12*a*. *Macrobiotus*, egg of unknown species.
12*b*. ,, process of the egg.
13*a*. *M. intermedius*, Plate. Egg.
13*b*. ,, process of the egg.

Plate III.

14*a*. *Macrobiotus echinogenitus*, Richters. Pharynx.
14*b*. ,, ,, claws.
15. *Diphascon alpinum*, Murray. Pharynx.
16. *D. oculatum*, Murray. Pharynx.
17*a*. *M. dubius*, sp. n.
17*b*. ,, pharynx.
17*c*. ,, claws.
18*a*. *M. hastatus*, sp. n. Three eggs in *Alonella* skin.
18*b*. *M. hastatus*, pharynx.
18*c*. ,, claws.
18*d*. ,, some processes of the egg.
19. *Diphascon scoticum*, Murray. Pharynx.
20. *M. hufelandi*, C. Sch. Pharynx.
21. *Diphascon bullatum*, Murray.
22*a*. *M. coronifer*, Richters.
22*b*. ,, pharynx.
22*c*. ,, claws.

PLATE IV.

23*a*. *Macrobiotus tuberculatus*, Plate.
23*b*. ,, ,, claws.
23*c*. ,, ,, pharynx.
24*a*. *M. zetlandicus*, sp. n., pharynx.
24*b*. ,, claws.
24*c*. ,, furca of tooth.
24*d*. ,, egg.
25*a*. *M. angusti*, sp. n.
25*b*. ,, egg.
25*c*. ,, pharynx of young in the egg.
25*d*. *M. angusti*, claws.
26*a*. *M. sattleri*, Richters.
26*b*. ,, pharynx.
26*c*. ,, claws.
27*a*. *Macrobiotus*, sp.? near *M. oberhäuseri*, Doy. Young emerging from egg.
27*b*. ,, pharynx.
27*c*. ,, claws.
27*d*. ,, portion of egg, showing the processes.