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ZOOGEOGRAPHICAL INVESTIGATION OF GREENLAND
LEADER: CHRISTIAN VIBE

LUMBRICIDAE AND LUMBRICULIDAE OF GREENLAND

BY

PIETRO OMODEO

WITH 5 FIGURES IN THE TEXT

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This paper deals with a collection of Greenland Oligochaeta belonging to the Zoological Museum of the University of Copenhagen. The collection is rather rich and contributes greatly to the knowledge of the earthworm fauna of Greenland.

I am greatly indebted to the Directors of the Zoological Museum of Copenhagen for having placed at my disposal this valuable collection, and I wish to express my gratitude to Mr. Christian Vibe, who collected most of the specimens, for kindly helping and advising me during the progress of this research.

The few, ancient data concerning the Lumbriculidae and Lumbricidae of Greenland were summarized by Elise Wesenberg-Lund (1926) and by Ude (1931). The following species have hitherto been recorded in the literature:

1) *Lumbriculus variegatus* (Müller), by Eisen (1873) and by Levinsen (1883).
2) *Dendrobaena octaedra* (Savigny), by Levinsen (1883) and by Stephenson (1931).
3) *Allolobophora chlorotica* (Sav.), by Levinsen (1883).
4) *Lumbricus terrestris* L. (see p. 21).

The following species have been determined by the present writer, in the collections of Greenland material:

1) *Lumbriculus variegatus* (Müller).
2) *Dendrobaena octaedra* (Sav.).
3) *Dendrobaena rubida* (Sav.).
4) *Lumbricus rubellus* (Hoffmeister).

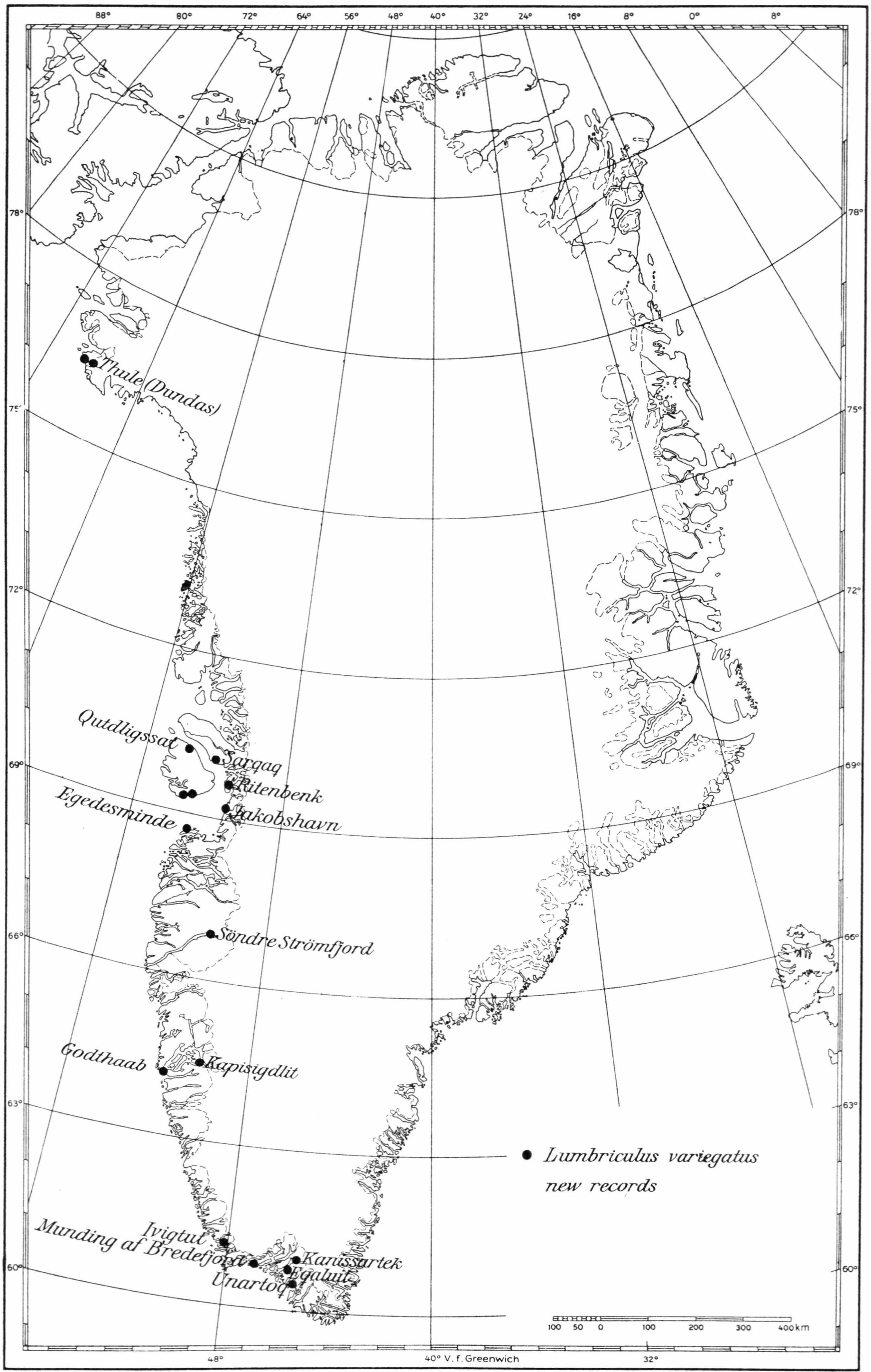

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Fig. 1.

SYSTEMATIC ACCOUNT

Family **Lumbriculidae.**

Genus **Lumbriculus.**

1) *Lumbriculus variegatus* (Müller).

1879 *Lumbriculus variegatus* (Eisen p. 9).
1883 *Lumbriculus variegatus* (Levinsen p. 228).

Greenland records: Godhavn (Eisen 1873), Karajak (= Qarajaq) (Levinsen 1883, cf. Wesenberg-Lund 1926).

Occurrence in Greenland:

	Thule, fjeldsø	Chr. Vibe	leg.	7/7/40	1	specim.
	— Midesø	—	-	28/7/39	1	—
	Mosesø on the Ritenbenk island	Johansen	-	8/10/31	2	—
	Jakobshavn	?	-	1/11/92	1	—
	—	—	-	1892	2	—
	Godhavn. Fresh water pool	Chr. Löfting	-	8/8/31	1	—
	— Deep hole in the outflow from the lake in the Bläsedalen	?	-	27/7/31	10	— (fragm.)
	Egedesminde. Water hole, almost fresh	Chr. Löfting	-	3/8/31	1	—
	— Fresh water pond	Lundager	-	10/9/04	1	—
	—	Sørensen	-	11/10/94	7	—
205	— In the bottom of small pool	Chr. Vibe	-	9/6/49	1	—
	Søndre Strømfjord. Small stream	—	-	25/6/52	2	—
	Godthaab	—	-	7/7/42	1	—
	Kapisigdlit. From fresh water lake		-	20/8/31	1	—
236	Kutdligssat (= Qutdligssat)	Chr. Vibe	-	13/6/49	1	—
435	Sarqaq. Fresh water pool	—	-	9/7/49	2	—
483	— Artemia-lake	—	-	12/7/49	2	-
	Bredefjord mouth, Tobias Sø, thawed N.	"Ruth"	-	15/7/12	1	—
222	Eqaluit. Inland farm	Chr. Vibe	-	15/7/48	2	—
106	Ûnartoq Kloster	—	-	6/7/48	1	—

107	Ûnartoq Kloster. Small fresh water pool, 16°	Chr. Vibe	leg.	5/7/48	2	specim.
	— — Small lake	—	-	/7/48	2	—
5	Kanissartek. Small lake amongst grass	—	-	18/6/48	1	— (fragm.)
	Ivigtut. Rock-pool	—	-	8/7/49?	1	—

Morphological remarks: most of the specimens show marks of regeneration after architomic division; semi-mature specimens were observed in the material from many stations, but only one mature specimen was collected at Sarqaq. In another specimen from Sarqaq the male openings were on the 9th segm. instead of on the 8th segm.

Faunistic remarks: *Lumbriculus variegatus* is a holoarctic species; quite common in Northern Europe, it has been recorded many times from high latitudes: Alaska, Yukon, Herschel I. (70° N.), Novaja Zemlja (73° N.), N. Siberia (as far as 72°17′ N.). No Lumbriculidae have ever been registered from Svalbard and Bear I., the oligochaetological faunae of which have been thoroughly explored (cf. Stephenson 1924, 1926).

L. variegatus has previously been collected in Greenland, where it seems to be quite common in limicolous habitat.

Family **Lumbricidae.**

Genus **Dendrobaena.**

Dendrobaena octaedra (Savigny 1826) 6 ×, parthenogenetica.

1883 *Dendrobaena Boeckii*, Levinsen p. 310.
1900 *Helodrilus (Dendrobaena) octaedrus*, Michaelsen p. 494.
1902 *Helodrilus octaedrus*, Ude p. 25.
1903 *Helodrilus octaedrus*, Michaelsen p. 25.
1926 *Helodrilus octaedrus*, Wesenberg-Lund p. 112.
1931 *Dendrobaena octaedra*, Stephenson p. 89.

Greenland records: Egedesminde (Levinsen 1883, cf. Wesenberg-Lund 1926), Qugssuk near Godthaab (Stephenson 1931).

Occurrence in Greenland:

	Godthaab. Under stones	C. L.	leg.	20/8/31	1	specim.
	—	Chr. Vibe	-	Summer 32	1	—
	—	—	-	12/5/43	9	—
38	—	—	-	24/6/49	2	—
	Korkut (= Qôrqut). Along the beach	—	-	28/5/44	5	—
	— —	—	-	5–15/8/42	1	—
	— —	—	-	7/7/44	27	—
	Kobbefjord	—	-	19/7/42	1	—
111	Kapisigdlit. Among grass roots, under stones	—	-	27/7/50	1	—

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Fig. 2.

175–184	Kapisigdlit	Chr. Vibe leg.		7/8/50	4	specim.
104	Aabets	Bendixen	–	23/6/16	2	—
178	Narssarssuaq (B.W. 1). Among spring moss in small stream from a meadow	Chr. Vibe	–	30/4/49	1	cocoon
15	— — Among moss, newly thawed out	—	–	15/9/49	3	specim.
92	— (350 m.) Among moss, under stones	—	–	25/5/49	4	—
11–13	Kanissartek. Small lake, under stones of the shore	—	–	18/6/48	10	—
63	— Small lake, under stones and roots	—	–	22/6/48	1	—
	Ûnartoq Kloster	—	–	9/7/48	13	—

86	Ûnartoq Kloster	Chr. Vibe	leg.	5/7/48	5	specim.
	— —	—	-	3/7/48	1	—
	Ûnartoq. Hot springs at the upper course of the river	—	-	8/7/48	1	—
157	— Hot spring, in the moss, 17.5 C°	—	-	10/7/48	1	—
227	Eqaluit. Inland farm	—	-	15/7/48	1	—
374–413	Julianehaab	—	-	14/7/48	11	—
417	— Field close Jhb., 400 m.	—	-	14/7/48	3	—
511	Qagssiarssuk	—	-	29/7/48	1 2	— + cocoons
	Nanortalik	—	-	30/6/48	1	specim.
	Frederiksdal	—	-	30/6/48	2	—
104	Augpilagtoq	—	-	29/9/32	15	—
78	Narssaq, Lindenows Fjord. Under stones	R. B.	-	9/9/32	4	—

Specimens of *D. octaedra*, not examined by the present writer, are recorded in the catalogue of the Zoological Museum of Copenhagen, from the following localities:

Tunugdliarfik	Lundbeck	leg.	18/7/89
Tasiussaq	—	-	24/7/89
Frederikshaab	Lassen	-	(5/12/90)
Kassigmut (= Qagssimiut)	—	-	(5/12/90)
Frederikshaab	K. Rosenvinge	-	28/9/88
Godthaab	Neergaard	-	20/8/83
Ujaragssuk (= Ujarasugssuk ?)	S. Hansen	-	(9/9/85)
Kagsiarsuk (= Qagssiarssuk)	Petersen	-	?
Nekamiut	Lundbeck	-	18/7/89 (1/10/89)
Kangerdluarssuánguaq (in fjord near-)	Holm	-	28/6/48

External characters:

Size: 21—58 × 2.5—3.5 mm; average length 33.54 mm. Number of segments 67—105, modal values 87.5 and 99.5, median 99, mean 96.9. All these figures are higher than those obtained by me in samples of this species from the eastern Alps (cf. fig. 4, table I), and are also higher than those recorded by Backlund (1949) for Icelandic material: 59—110 segments with a mean of 88.4 (34 adult specimens).

The frequency distribution curves for the number of segments are bimodal for both alpine and Greenland samples. I suppose the higher modal value is that of individuals developed isolatedly in the cocoons, the lower one that of individuals developed in couples in the same cocoon: therefore in the latter case young worms have a lower number of segments (cf. Omodeo and Magaldi, 1951).

Intersetal ratios are slightly variable; the average intersetal ratios are similar both in samples from the Alps and from Greenland:

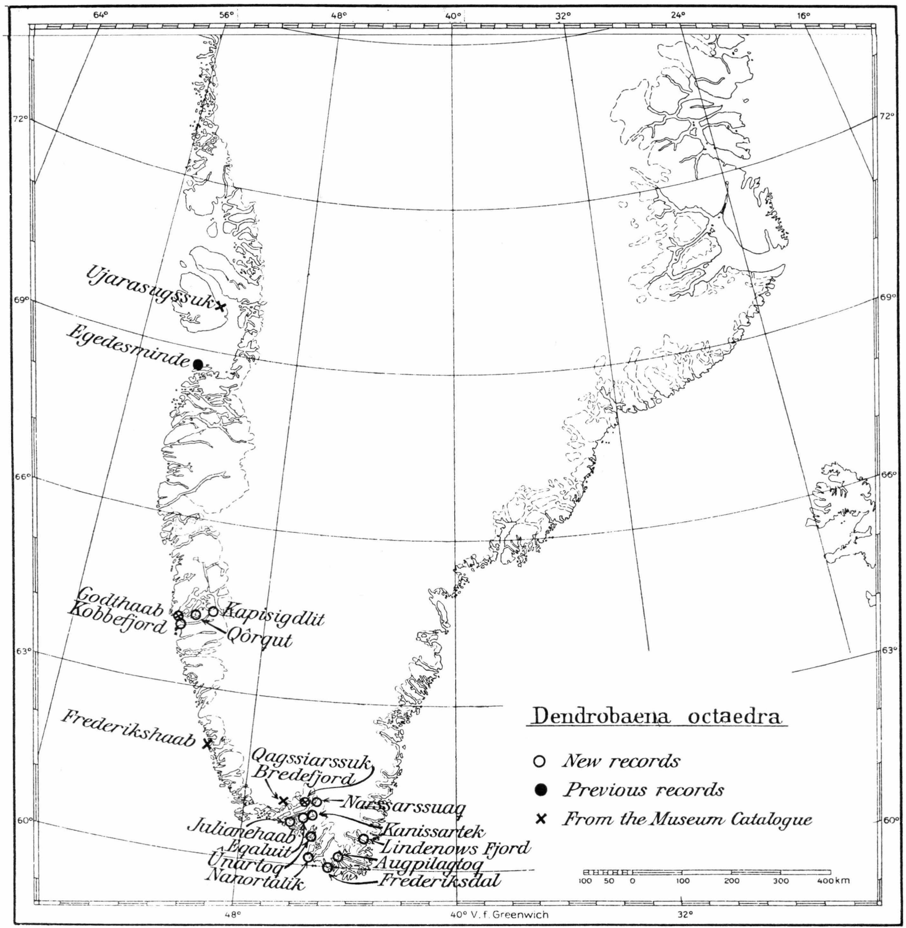

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Fig. 3.

aa	ab	bc	cd	dd	
1.3	1.2	1	1.12	1.25	Kanissartek
1.41	1.17	1.12	1	1.57	Kapisigdlit
1.64	1.29	1.24	1	1.44	Julianehaab
1.5	1.25	1.19	1	1.17	Narssaq, Lindenows Fjord
1.6	1	1.1	1.05	1.3	Korkut (= Qôrqut)
1.76	1.33	1.24	1	1.48	Augpilagtok
1.75	1.22	1.22	1	1.33	
1.53	1.18	1.13	1	1.33	Greenland
1.63	1.29	1.21	1	1.39	Le Vette
1.37	1.29	1.31	1	1.24	
1.83	1.31	1.40	1	1.71	Marmolada
1.36	1.2	1.14	1	1.27	
1.62	1.21	1.21	1	1.52	Passo Pordoi
1.56	1.22	1.21	1	1.43	Dolomitic Alps
1.7	1.43	1.36	1	1.6	Norðfjorður (Iceland)

Table I. *Dendrobaena octaëdra.*

Number of segments

Provenance / No. of segments	Eastern Alps f		Eastern Alps f %	Greenland Godthaab f	Greenland Julianehaab f	Whole of Greenland f	Whole of Greenland f %
62		2	1.54		..		..
63							
64	1						
65	1						
66		1	1.54			2	0.82
67					1		
68	1				1		
69							
70		4	4.12				0.82
71	1						
72							
73	3						
74	2	5	5.15		2	2	1.64
75	2						
76							
77	1						
78	3	4	4.12	1		2	1.64
79	1				1		
80							
81							
82	1	6	6.2	2		3	2.46
83	4			1			
84	1				2		
85							
86		2	2.06		1	6	4.92
87	1			1	3		
88							
89	1				1		
90		14	14.43			5	4.10
91	5						
92	2			3	1		
93	7				1		
94	8	35	36.09	3	1	17	13.93
95	12			1	3		
96	6			1	2		
97	9			1	5		
98	8	19	19.6	7	4	67	54.92
99	8			12	11		
100	2			8	12		
101	1			6	7		
102	3	4	4.12	2	5	18	14.75
103					4		
104	1			1	2		
105				1	3		
106		1	1.03				
107	1						
108							
109							
N = ...	97			49	73	122	
Mean ...	91.48			97.69	96.44	96.94	
Median .	95					99	
Modal values .	83.5 95.5					87.5 99.5	
Variance (on the right arm of the curve)			4.12			2.47	

Body length in mm

Provenance / Body length in mm	Eastern Alps f		Eastern Alps f %	Greenland f		Greenland f %
16	1	1	2	..		..
17						
18		3	6		1	1.89
19						
20	3			1		
21						
22						
23	3	16	32		9	16.98
24	1			1		
25	3			3		
26	6			4		
27	3			1		
28	3	18	36	1	16	30.19
29	1			1		
30	10			6		
31				3		
32	4			5		
33	1	8	16	4	17	32.08
34	3			3		
35	2			6		
36	1			2		
37	1			2		
38		2	4	1	5	9.44
39						
40	1			4		
41						
42	1					
43		2	4	1	2	3.77
44	1					
45						
46				1		
47	1					
48	..		..		2	3.77
49	..		..			
50	..		..			
51	..		..	1		
52	..		..	1		
53	..		..			0.94
54	..		..			
55	..		..			
56	..		..			
57	..		..			
58	..		..	1	1	0.94
N = ...	50			53		
Mean ...	29.48			33.54		
Median .	29.5			33		
Modal values .	28.5			33		
Variance	± 5.77			± 7.05		

The male openings on segm. 15 are situated on somewhat swollen papillae; two specimens from Augpilagtoq had no male openings at all, a very common occurrence in alpine *D. octaedra.* The characteristic papillae situated on the segm. 16, just behind the ♂ openings, are generally but slightly developed; in many cases they are missing.

Internal anatomy:

Sometimes the first pair of seminal vesicles are undeveloped or missing; similarly some of the four testes may be rudimentary or lacking. In a specimen from Julianehaab the first pair of spermathecae were missing.

The lamellae in Morren's glands (= calciferous glands) are 42—48. There are three pairs of esophageal hearts, placed in segments 7—9.

Biological and cytological observations:

Cocoons of *Dendrobaena octaedra* were collected at Narssarssuaq and Qagssiarssuk; they are ellipsoidal in shape and of a pale greenish-yellow colour. They correspond to the ones I observed in alpine materials, but lack the thin short filaments at the two ends.

Specimens from Godthaab, Kanissartek, Julianehaab, Narssarssuaq, Kapisigdlit, and Ûnartoq have been investigated citologically.

The oögonia have 108 mitotic chromosomes in their nuclei; their number has at last been reliably established in the case of the Kapisigdlit and Kanissartek specimens, but in the other specimens the chromosome counts ranged very close to this figure. The animals are hexaploid, the most common basic aploid number in the Lumbricidae being 18 (cf. Omodeo, 1952).

Like most polyploid parthenogenetic earthworms (see Omodeo, l. cit.) the hexaploid *D. octaedra* from Greenland have metaphasic 1st oöcytes with as many chromatinic bodies as the mitotic chromosomes of the gonia[1]); but unlike what I have observed in other parthenogenetic earthworms, the shape of these 1st metaphase bodies is not the shape of typical bivalents. They may be asyndetic chromosomes instead of true bivalents[2]).

Whatever they are bivalents or asyndetic chromosomes, it is indisputable that such oöcytes must undergo a parthenogenetic development according to their set of chromosomes, owing to the fact that in

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[1]) "The last oögonial mitosis is a restitutional one, giving I oöcytes with a double number of chromosomes. A normal meiosis with production of two polar bodies follows, giving unreduced eggs. This type of parthenogenesis, named herein as "parthenogenesis with premeiotic restitution", is probably widespread in the Oligochaeta", Omodeo 1952.

[2]) Further researches allow me to state that they are asyndetic chromosomes (cf. Omodeo, 1955).

all specimens the spermatogenesis is abortive, and spermathecae as seminal vesicles are empty and reduced in size[1]).

Zoogeographical remarks:

D. octaedra is a widespread holoarctic species and the northernmost extant (as far as 73°30′ N. in Novaja Zemlja). In N. America it is found southward as far as Mexico (about 19° N.); in Europe southward as far as Madeira, the Balearic Isles, Corsica, the Alps, Macedonia, and Transcaucasia. The species is not found in Sardinia, in the Italian peninsula, in Greece, and in the eastern Mediterranean countries. The eastern boundary of the distribution of *D. octaedra* is not known exactly; it should be somewhere in western or central Siberia.

Probably there are many citological races of *D. octaedra* whose distribution ranges are not known:

A specimen from Northern Iceland (Norðfjörður) had the same set of chromosomes as the Greenland specimens, *i. e.* 108 chromosomes in the oögonia and 108 bivalents (or asyndetic chromosomes) in 1st oöcytes; but in contrast to the Greenland specimens this one had normal spermotogenesis, and spermathecae filled with ripe normal sperms. It is possible that the Icelandic strain of *D. octaedra* may be pseudogamic (gynogenetic) and therefore biologically different from the parthenogenetic strain from Greenland.

The alpine specimens of *D. octaedra* have a greater number of chromosomes than the boreal specimens (about 120), and they are probably heptaploid (7 × 18 = 126) or hyper-hexaploid; they are also almost totally male sterile and never copulate (Omodeo, 1952a)[2]).

From morphological analysis and from the cytological characteristics, as far as they are known, the Greenland population of *D. octaedra* seems to be somewhat different from the other known European populations.

D. octaedra has previously been recorded from Greenland and is undoubtedly the most common earthworm there, as it has been found in 16 out of 19 places where Lumbricidae were collected. It is also the most abundant species, as 131 *D. octaedra*, out of a total of 185 earthworms (i. e. 70.8 %), were collected.

The northernmost station where I have studied specimens is Qôrqut (Godthaab) at 64°25′ N., the northernmost station mentioned in the literature being Egedesminde at about 68°40′ N. It is interesting to note that in Disko I. (Kuanit and Engelskmandens Havn) twenty *Dendrobaena rubida* were collected, but no *D. octaedra*.

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[1]) A specimen from Qôrqut (Godthaab) had a spermatophore sealed dorsally and laterally on intersegm. 8/9.

[2]) Further researches allow me to state that some alpine specimens are true hexaploids (n = 108; cf. Omodeo 1955).

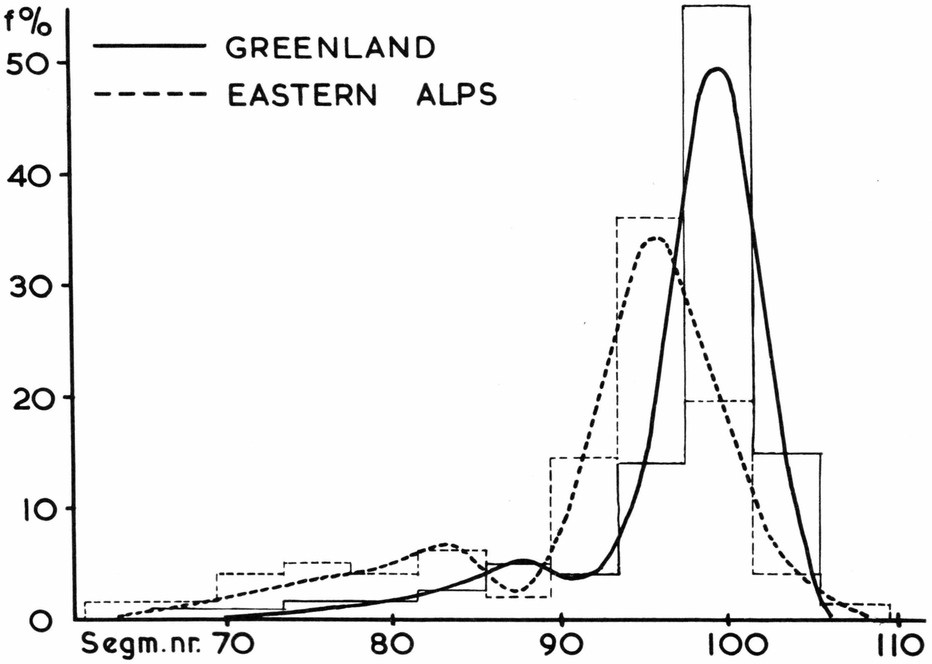

Fig. 4 a.

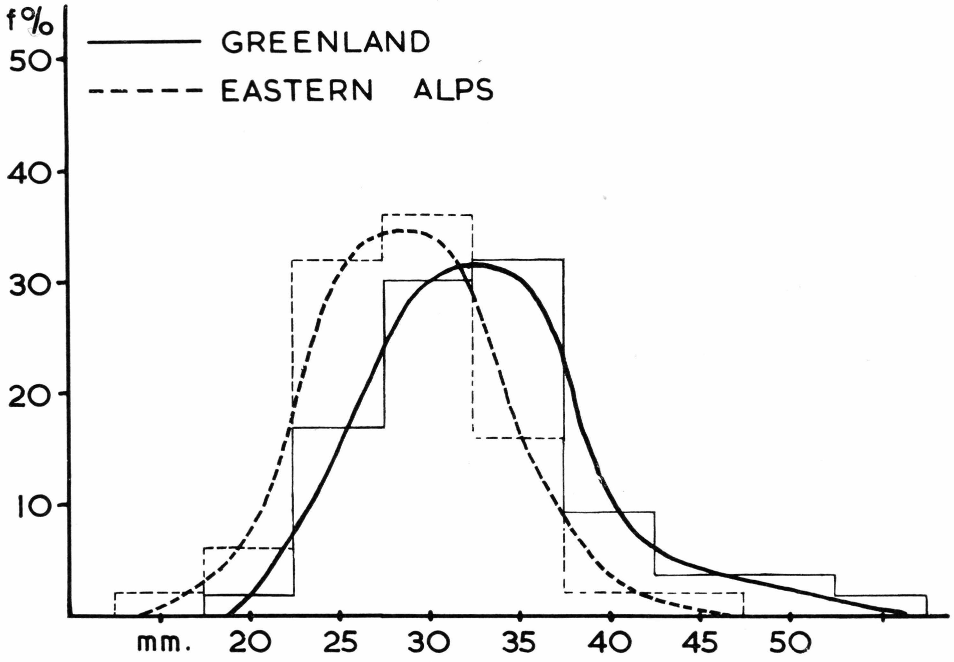

Fig. 4 b.

Fig. 4. Frequence distribution curves for segment numbers and body length (in mm.) of *Dendrobaena octaedra* from Greenland ——— and from oriental Alps - - - - -.

Dendrobaena rubida (Sav. 1826) f. *typica* ad *norvegica* (Eisen 1874) 6 ×, amphigonica.

Dendrobaena rubida auctores.
Bimastus tenuis auctores.
Bimastus norvegicus auctores.

No previous Greenland records.

Occurrence in Greenland:

No.	Station	Habitat	Legit	Datum	No. of specim.
11–13	Kanissartek.	Small lake; under the stones of the shore..	Chr. Vibe	18/6/48	7
	Ûnartoq Kloster		—	9/7/48	10
86	— —	....	—	5/7/48	5
150	Ûnartoq.	Hot spring above the lower course of the stream............	—	10/7/48	1
157	—	Hot spring, in the moss, 17,5 C°...........	—	—	2
158–159	—	Hot spring, in the moss of the shore........	—	—	2
396	Julianehaab		—	14/7/48	1
	Ilua		Fru Lundholm	10/5/89	2
	Qôrqut		Chr. Vibe	5/6/45	1
	Engelskmandens Havn (Disko I.)		—	12/7/48	3
	Kuanit (Disko I.)....................		D. Danske arkt. stat.	/7/08	17
	Greenland (Kassigmut?)		Lassen	(5/12/90)	1

External characters:

Size 27—34 × 2.5—3.5 mm; average length 37.8 mm. Number of segments 78—112; modal values 80 and 103; median 101; mean 99.17 (cf. table II, fig. 5)[1]). Dorsal pigment reddish, moderately deep at the two ends. Prostomium 2/3—3/4 epilobic, occasionally tanylobic. First dorsal pore in the intersegm. 5/6. Male pores on segm. 15, with moderately swollen atria; the characteristic papillae on segm. 16, behind male pores, are lacking or slightly developed. Occasionally the *ab* setae on segm. 20 are implanted on small glandular papillae.

Clitellum saddle shaped 1/n 25—1/n 32, more often 26—31. The clitellar bands (tubercula pubertatis) are rather variable, also in animals from the same locality: in one third of the specimens, 29—30; in another

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[1] The bimodality of the frequency distribution curves for the segment number is probably connected with the number of larvae developing in the same cocoon (cf. p. 8); Evans and Mc Guild (1948) state that from 33 $^0/_0$ of the viable cocoons of this species two worms emerge, and from 64 $^0/_0$ a single worm. I can state that in the case of diploid *D. rubida* from Naples 21.7 $^0/_0$ of viable cocoons disclose two worms, and that from 75 $^0/_0$ only a single worm emerges.

Table II. Number of segments of *Dendrobaena rubida.*

Ploidy / Provenance / No. of segments	Diploid Italy (Naples & Bologna) f		f %	Hexaploid Italy (Eastern Alps) f		f %	Di- and Hexaploid Iceland f		f %	Hexaploid Greenland: Godhavn f	Julianehaab f	Other localities f	Whole of Greenland f	f %
70.....	1	4	4.4		3	8.57	..		..				..	..
	2			3										
	1													
				1										
75.....		3	3.3		1	2.86	..		..				..	..
	3													
				2			1				1			
80.....	1	1	1.1		3	8.57		3	7.5				2	4.26
											1			
				1			2							
	1			1										
	1			2			1				1			
85.....	2	8	8.8	1	6	17.14		2	5				1	2.13
	3			2			1							
	1													
	1											1		
90.....		6	6.6	1	2	5.71	1	1	2.5				4	8.51
	1			1							2			
	4										1			
				1						2				
							2			1				
95.....	3	9	9.9	3	8	22.86	2	7	17.5	2			8	17.02
	3						1				2			
	3			4			2				1			
	6			2			3							
	7			1						1	1			
100.....	5	33	36.2	1	6	17.14	3	13	32.5	2	2		16	36.04
	6						2			3	2			
	9			2			5			2	3			
	6			1			1				4	1		
	3			1			3			1	1			
105.....	3	21	23		3	8.57	1	10	25	2	1		14	29.79
	4						4				2			
	5			1			1				2			
	5			2			3				1			
	1			1										
110.....		6	6.6		3	8.57		4	10				2	4.26
							1			1				
N = ...		91			35			40		17	28	2	47	
Mean ...		97.22			89.39			99.07		100.11	98.85		99.17	
Median .		99			95			101					101	
Modal values .		85 100.7			85 97			80 101.5					80 102.7	
Variance (on the right arm of the curve)			4.23		6.9			4.41					3.71	

third of the specimens, 28—30; in the rest of the cases 28—29, 29—1/2 31, 28—1/2 30, or they are quite absent. The setae are widely paired, the intersetal ratios are somewhat variable, and the average intersetal ratio slightly different from those of alpine and Icelandic samples:

aa	ab	bc	cd	dd	
2.19	1	1.88	1.25	4.37	Julianehaab
2	1	1.85	1.33	5	
2.23	1	1.54	1.06	4	Ûnartoq
1.88	1	1.5	1.28	4.33	Kanissartek
1.8	1	1.63	1.23	4.28	
1.68	1	1.82	1.20	4.50	Godhavn
2	1	1.52	1.30	4.94	Engelskmandens Havn
1.97	1	1.68	1.24	4.47	Greenland
1.79	1	1.72	1.20	4.12	Reykjavìk (2 ×)
2.07	1	1.68	1.28	4.43	
2.18	1	1.88	1.18	3.72	Grindavìk (2 ×)
2.46	1	1.66	1.21	4.42	Laugarvatn (2 ×)
1.67	1	1.87	1.13	3.33	Akureyri (6 ×)
1.9	1	1.7	1.15	3.7	
2	1	1.84	1.31	3.72	Trollahals Hraunsfjörður
1.78	1	1.62	1.03	3.5	Hornafjörður
3.08	1	1.71	1.03	4.34	Valhöll Þingvellir
2.1	1	1.75	1.15	3.92	Iceland
2.24	1	2	1.12	4.27	Dolomitic Alps (6 ×)
2.54	1	2.2	1.45	4.75	
1.96	1	1.65	1.0	4.07	
2	1	1.9	1.04	3.47	
2	1	1.87	1.25	4	
2.15	1	1.82	1.18	4.11	Dolomitic Alps

Internal anatomy:

Usually two pairs of spermathecae with duct openings in intersegm. 9/10 and 10/11; in one specimen from Ûnartoq and in all specimens from Ilua the spermathecae were missing; in a specimen from Kanissartek one spermatheca of the anterior pair was lacking.

Seminal vesicles: usually two pairs in segm. 11 and 12 (*Bimastus* disposition), in specimens from Kuanit (Godhavn), however, the animals had a third pair of vesicles in segm. 9 (*Dendrobaena* disposition).

The lamellae in the Morren's glands are 41—47, and less numerous in the fore part.

Biological and cytological observations:

Most of the animals examined had their seminal vesicles heavily parasytized by Gregarines. The Gregarines which in Italy and Anatolia very often parasytize the spermathecae of diploid specimens, were not found; nor were the Nematodes which live in the blood vessels of Icelandic and Italian *D. rubida.*

Specimens from Ilua, Julianehaab, Kuanit, and Engelskmandens Havn were studied cytologically. They have 102 mitotic chromosomes in the gonia, and 51 bivalents in the 1st oöcytes. Spermatogenesis is quite normal; normal sperms are collected on seminiferous funnels, and the sperms or their remnants are stored in the spermathecae.

These specimens obviously belong to a hexaploid amphigonic mutation ($17 \times 6 = 102$), the diploid specimens of *D. rubida* having a set of 34 mitotic chromosomes in their gonia.

Faunistic remarks:

Up to now, only sporadic data concerning the caryology of *D.rubida* are available; they are arranged below in table III.

Table III. *D. rubida* (sensu lato).

Locality	Chromosome sets				
	Form	Ploidy	Reproduction	2 n	Author
Italy (Naples and Bologna)......	*subrubicunda*	2×	amphigonic	34	Omodeo 1952
Anatolia........	—	—	—	—	— 1955
South and western Iceland.......	*typica* ad *subrub.*	—	—	—	— 1955
England........	*tenuis*	3×-3	parthenogen.	48	Muldal 1952
England........	*typica*	4×	amphigonic	68	— —
England........	*subrubicunda*	—	—	68	— —
Eastern Alps....	*constricta*	—	—	68	Omodeo, 1952 a
Eastern Alps....	*tenuis*	6×	—	102	— —
Greenland.......	*typ.* ad *norvegica*	—	—	102	— this paper
Northern Iceland.	*typ.* ad *tenuis*	—	—	102	— — —
Italy (Latium) ..	*constricta*	8×-20?	—	115–120	— (unpubl.)

From these figures it would seem logical to suppose that hexaploid Greenland specimens and hexaploid alpine specimens are related to each other, but the data available do not corroborate that supposition.

The anatomy of the sexual organs is similar in the two populations, but the reduction of the spermathecae and seminal vesicles is more marked in the alpine specimens. Statistics for body size and segment number are quite different for alpine samples and Greenland ones: in particular, both the modal values for the segment number are smaller in the southern specimens (fig. 5, table II). Some cytometric data recorded in table IV also show conspicuous cytological differences.

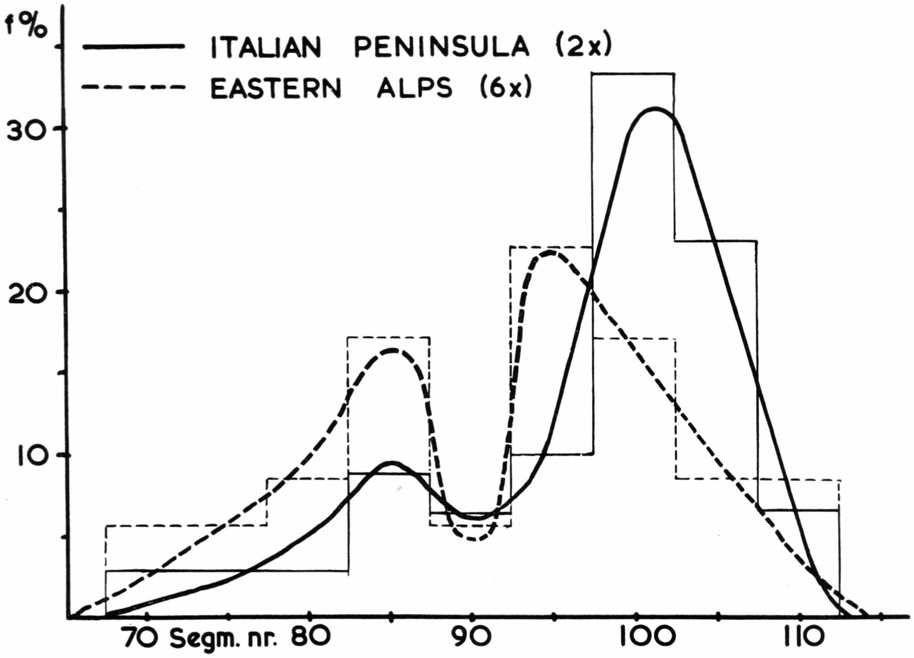

Fig. 5 a.

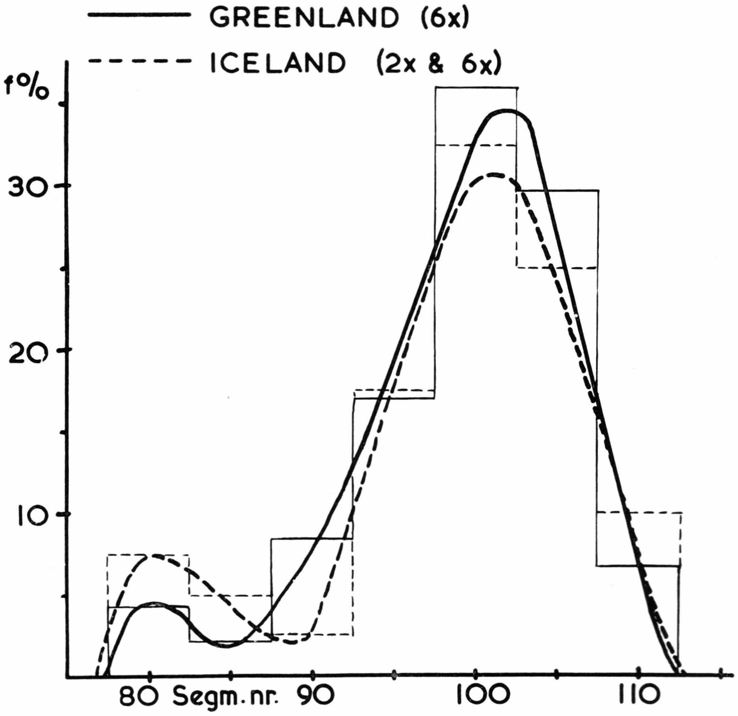

Fig. 5 b.

Fig. 5. Frequence distribution curves for segment numbers of diploid and hexaploid *Dendrobaena rubida* from Greenland, Iceland and Italy.

Because of these differences and the large geographical gap existing between the two populations, I think it is correct to state that no direct relationship exists between the populations from Greenland and those from the Eastern Alps.

The relationship between the Greenland and the Icelandic specimens is difficult to establish. The whole of the Icelandic material is morphologically homogeneous and very similar to that from Greenland: statistics of number of segments (mean, modal values, variance) are practically identical (fig. 5, table II). The anatomy of the sexual organs and the morphology of the clitellar organs are nearly the same; some slight difference exists only in the setal ratio (see above, page 16).

But, if the material from Iceland appears homogeneous from the morphological standpoint, it is not so from a cytological standpoint: specimens from the northern sector (Akureyri and Husavìk) are amphigonic hexaploids, and the specimens from the southern and western

Table IV. *Dendrobaena rubida*, some cytometric data.

	Length of sperm heads	N	Size of the nuclei of the oögonia	Volume of the nuclei of the oögonia	N	Notes
2×						
Naples........	11,7	80	7.88 × 6.41	189	90	Specim. preserved in Bouin's fluid
Bologna	11.7	40	8.38 × 6.25	201	40	Id.
Italy	11.7	120	8.13 × 6.36	193	130	
Anatolia	—	—	9.51 × 5.3	139	60	Specim. preserved in alcohol.
Reykjavìk	11.1	70	8.73 × 6.04	167	40	Id.
Grindavìk	10.6	50	8.15 × 5.88	154	60	Id.
Iceland.......	10.9	120	8.44 × 5.96	161	100	
6×						
Husavìk	16.3	40	12.46 × 8.82	508	50	Id.
Akureyri......	—	—	11.98 × 9.2	622	50	Id.
Iceland	16.3	40	12.22 × 9.01	565	100	
Ilua	17.1	70	12.3 × 6.97	313	40	Id.
Kuanit	16.5	20	12.1 × 6.49	267	40	Id.
Julianehaab ...	16.9	40	— —	—	—	Id.
Greenland.....	17.0	130	12.2 × 6.73	290	80	Id.
The Dolomites.	12.0	60	11.73 × 7.23	325	70	Id.

sectors (Reykjavìk, Grindavìk, Laugarvatn) are amphigonic diploids. I did not investigate the cytology of worms from other localities in Iceland, yet I can state that in the case of the material mentioned above some cytometric values for hexaploid *D. rubida* from Iceland and from Greenland differ; moreover, these values for diploid *D. rubida* from southern and western Iceland, on the one hand, and for those from peninsular Italy, on the other, are similar. (Cf. Omodeo 1955).

The cariogram is the same for Italian and Icelandic diploid races. Yet while Mediterranean diploids always belong to the form *subrubicunda*, Icelandic diploids often belong either to the form *typica* or to the form *subrubicunda.*

Summing up all these considerations, I am inclined to conclude that both Greenland and Icelandic hexaploid mutations are derived from the very similar diploid Icelandic race of *D. rubida*, and are not related to hexaploid mutants known from the alpine regions. These, in their turn, have probably derived from the Italian diploid race, which is cytologically similar to, but morphologically rather different from the Icelandic one.

D. rubida is common in the whole of the Holoarctic and the Indian regions; in the southern hemisphere it has probably been introduced by man, both in the continents and in the islands. All forms of this species are almost cosmopolitan, except the f. *norvegica*, which till now has been recorded only from northern Norway.

D. rubida has never previously been recorded from Greenland, up to now it has been recorded from Iceland, the Faroes, Newfoundland, and many other boreal countries.

Genus **Allolobophora.**

Allolobophora chlorotica (Sav. 1826).

1883 *Lumbricus riparius*, Levinsen p. 310.
1900 *Helodrilus (Allolobophora) chloroticus*, Michaelsen p. 486.
1903 *Helodrilus chloroticus*, Michaelsen p. 25.
1926 *Helodrilus chloroticus*, Wesenberg-Lund p. 112.
1931 *Allolobophora chlorotica*, Ude p. 52.

Greenland records: Egedesminde. (Cf. Wesenberg-Lund 1926).

In the collections of the Zoological Museum of Copenhagen there is a tube containing a dried specimen and labelled "Helodrilus chloroticus, Jacobshavn, Pfaff leg.". Miss Wesenberg-Lund kindly informs me that this specimen was probably determined by Levinsen. Levinsen was an excellent specialist in Lumbricidae, and thus there is no reason at all for doubting the exactitude of his identification, especially considering that this species is most easily recognizable, having very characteristic tubercula pubertatis.

This specimen is about 40 mm long and has strictly paired setae.

A. chlorotica is a very common Euro-American species; in Asia it has been recorded only from Syria. It has previously been recorded by Levinsen (1883) for Iceland and Greenland; no particular localities are indicated in Levinsen's paper, but Wesenberg-Lund (1926) gives Egedesminde as the location in Greenland. Ude (1931) also indicates Egedesminde as a location of *A. chlorotica*.

Genus **Lumbricus.**

Lumbricus rubellus, Hoffmeister 1848.

No previous Greenland records.

Occurrence in Greenland: Godthaab, Landsfoged Eske Brun's garden 23/8/1942, Vibe (Johan Brun).

The only specimen undoubtedly belongs to *L. rubellus*; it is the biggest specimen of that common species I have ever seen. Its size is 175 × 7 mm; its number of segments is 110. External characters are quite typical, internal anatomy has not been investigated.

L. rubellus is very common in the Holoarctic region except in the far East. It has never been recorded from Greenland; it has been found in Iceland, in the Faroes, in Northern Europe, and Siberia, in Newfoundland, etc.

Lumbricus terrestris L.

1780 *Lumbricus terrestris*, Fabricius p. 276.

This species has been recorded by Wesenberg-Lund (1926) and Ude (1931), from Greenland, teste Fabricio.

Fabricius' description (p. 276) is as follows: "Lumbrici groenlandici, inter minores numerandi, sunt magis fusci quam rubri; coeterum conveniunt descriptioni, quam exactam habemus Mull. Verm. l. cit.

Habitat in terra, et praesertim ad littora aquarum.

Saepius vidi hunc vermem sub tactu in duos evadere, minorem nempe de maiore prehenso cadere. Hoc sciunt Groenlandi id me docentes, qui putant maiorem pullum parere; quod etiam non abnuerem: erant enim ambo integri."

This description does not apply to *L. terrestris* or to any other earthworm species; perhaps it deals with specimens of *Lumbriculus variegatus*, which autotomize most easily when stimulated.

As a matter of fact, *L. terrestris* has been described by Fabricius (l. cit., p. 277) very exhaustively, but the author states that these observations are made "in Lumbrico (non Groenlandico sed) norvegico" (l. cit. p. 277).

Thus the record of *L. terrestris* from Greenland must be considered erroneous.

Discussions and conclusions.

Oligochaeta have been found in Greenland as far as the highest latitudes where zoological samples have been collected: about 76°20′ N. At these high latitudes only Enchytraeidae and Lumbriculidae are represented.

It is well known that some Enchytraeidae can withstand the hardest climates and can live even on ice and snow, without contact with the soil; they have been found, previously, in high latitudes on Svalbard I. (Stephenson, 1924, '26), so it is not surprising that they are present as far North as Thule, and it is also possible that they live in the most northerly part of Greenland. However, the finding of a *Lumbriculus* species in such a northerly locality is new; they are not found on Svalbard I., or on Bear I., although they reach 73° N. in Novaja Zemlja.

In Greenland the Lumbricidae have not been found farther North than Disko I., at about 70° N., they do not live either on Svalbard I. or Bear I., but they are reported at 73°20′ N. in Novaja Zemlja (*D. octaedra*, cf. Eisen 1819, Smith 1921) and at about 75° N. on Cotelnoi I. (Lumbricidarum sp., cf. Čejka, 1914). The northern boundary of the Lumbricidae has an average July temperature of + 7.5 C° and an average January temperature of — 17 C° in Greenland, an average July temperature of + 5 C° and an average January temperature of — 20 C° in Novaja Zemlja, and a similar July temperature and a much lower January one on Cotelnoi I.

It is my opinion that Lumbricidae can withstand any climate which allows herbs and moss to grow, and that the northern boundaries are not imposed by actual conditions, but were determined by conditions in the past, *viz.* the Ice Age.

Up to now, four earthworm species are known from Greenland; three species (*Dendrobaena rubida*, *D. octaedra*, *Lumbricus rubellus*) have been determined by the present writer, in the Copenhagen collections, while a fourth species, represented in these collections by one poorly preserved specimen, is almost certainly the *Allolobophora chlorotica*, already recorded by Levinsen (1883) from Greenland. *Lumbricus terrestris* has been erroneously recorded for Greenland.

Two species appear to be exceedingly rare (*L. rubellus* and *A. chlorotica*), but this is possibly due to the way the collecting was carried out: these species, actually, dwell at some depth in the soil, and the collectors have generally been looking for earthworms in superficial layers, under stones and among the moss.

Two species are rather common; *Dendrobaena octaedra* is more common than *D. rubida*; they are represented by 131 and 52 specimens respectively, *viz.* 71.6 $^0/_0$ and 28.4 $^0/_0$. It is of some interest to notice that the numerical ratio between the two *Dendrobaena* species is very near to the one observed in the Eastern Alps: 74.5 $^0/_0$ and 25.5 $^0/_0$ respectively; this ratio may be the result of the balance established within two species which share the same substrate.

Perhaps other species will be found in Greenland, but it is very unlikely that the common earthworm species which have similar ecological requirements as *D. octaedra* and *D. rubida*, namely *Eiseniella tetraedra* and *Eisenia foetida*, will ever be found.

D. rubida and *D. octaedra* were investigated cytologically; the former proved to be an amphigonic hexaploid, and the latter a parthenogenetic, perhaps apomeiotic, hexaploid.

D. octaedra has hitherto been known only as a non-sexual high polyploid; a hexaploid mutation, maybe pseudogamic, somewhat different from the Greenland one, lives in N. Iceland; a heptaploid (or hyperhexaploid?) mutation lives in the alpine region.

Many polyploid mutants of *D. rubida*, generally amphigonic, are known apart from the diploid strain; the diploid and the polyploid mutants have never been found living together. The hexaploid mutants living in N. Iceland are almost identical with the Greenland strain in morphological characters, though not quite similar in cytological peculiarities. It is a plausible hypothesis that polyploid *D. rubida*, more able to endure the coldest climates than the diploid strains are, were able to survive, in some circumscribed spots, the rigours of the climate of the Ice Age (whilst the less resistant diploid strain became extinct) and then spread again to repopulate the formerly ice-covered territories.

At all events, the diploid *D. rubida*, very common in central and southern Italy, is not found in alpine localities that have been severely glaciated, but has been replaced by tetra- and hexaploid mutants.

To understand the problem of the origin of the earthworm fauna of Greenland it will be expedient to discuss briefly the earthworm fauna of North America.

The great bulk of Oligochaeta terricola in the Nearctic region is represented by some 27 holoarctic earthworm species. No more than 11 species of Lumbricidae, 5 species of *Diplocardia* (Acanthodrilidae), and 1 species of *Sparganophilus* (Sparganophilinae) are endemic in this region, and all of them (*Sparganophilus* excepted) are rare and restricted to a small area in eastern and central USA.

This peculiar distribution justifies the supposition that most of the N. American earthworm fauna is of European origin and that it has reached N. America via a North Atlantic bridge; unless one is prepared to state—as some American authors do (cf. Gates, 1954)—that European earthworms have been imported into N. America during the last few centuries by man. This thesis is difficult to maintain for many reasons, the most important, in my opinion, being the following:

1) The commonest and most abundant earthworms in N. America belong to the Euro-American species; if these species are not taken into account, there remain only a small number of cosmopolitan species and 17 endemic species, which cover only the smallest part of the vast Nearctic region. This would appear an exceedingly scanty fauna for a continent, compared with those of Europe (about 250 species), South America (similar figures), or Africa (about 1000 species, most of which are endemic), etc.

2) The majority of endemic American species of Lumbricidae are very definitely related to European ones.

3) All Euro-American species (except perhaps *Allolobophora limicola*) live in the north-western part of Europe, and some of them (*Octolasium cyaneum*, *Lumbricus festivus*, *All. limicola*, etc.) are restricted to the north-eastern States of America.

4) A characteristic N. American subfamily, the Sparganophilinae, is represented by two similar species in England and France, on one side of the Atlantic, and all over N. America, on the other side.

In my opinion, it is evident that the Euro-American distribution is not a random one as would be the case if the American continent had been populated during recent decades by the greater part of Lumbricidae. It is thus correct to state that a large exchange of earthworms took place in past ages via a North Atlantic bridge.

It must now be considered whether the four Greenland species are the remnants of some preglacial period, whether they were accidentally introduced by some unknown agent, or whether they were imported by man.

It is the opinion of Chr. Vibe, who collected most of the material considered here, that the theory of the importation by man of Greenland earthworms should be ruled out because most of the collecting stations are far away from the most present settlements and the districts inhabited by the Norsemen about ten centuries ago. Some doubt may exist only about *Lumbricus rubellus* collected in a garden at Godthaab.

The idea of the accidental introduction of earthworms into Greenland by floating logs, or by birds, or by similar agencies, is at best unlikely. Actually none of the four species of Greenland earthworms can withstand more than a few minutes' soaking in sea water, nor will their embryos or larvae enclosed in the cocoons withstand such treatment.

The hypothetical transportation by birds would expose the earthworms or their cocoons to a rapid dehydration and to speedy death: at 10° and in still, dry air they lose, in 25—30 minutes, about 40 % of their water, and they invariably die. By the way it must be observed that birds do eat earthworms, and that the globular and smooth cocoons are laid at some depth in the soil, thus making it almost impossible for them to stick to the feet of birds.

In any case, even granting the possibility of accidental introduction of earthworms, it is inadmissible that during the 8,000 or 9,000 years which have elapsed since the last glacial phase, some hundreds of stations of earthworms should have been colonized by means of so many separate accidental introductions, or that the species, introduced in a few places, should have spread by themselves across the vast territory where they live, as the geographical structure of E. Greenland—divided as it is by islands and by fjords, barred by glaciers—does not permit of any, either quick or slow, migration of earthworms.

Ruling out importation by man as well as the accidental introduction by some foreign agent, the hypothesis that the four species recorded are endemic in Greenland remains to be considered. This hypothesis is supported by the fact that all the Greenland Lumbricidae live in N. America, on the one side, and in Iceland, the Faroes, and the British Isles, on the other side, and also by the fact that the most common species in Greenland, *D. octaedra*, has no obvious relationship to the representatives of the same species living in N. Iceland.

This hypothesis implies that the earthworms actually living in Greenland have survived at least the fourth glacial period, since even geologists who agree to the idea of a North Atlantic bridge, do not believe it could have existed later than the last interglacial period.

This survival of a terrestial fauna in Greenland may seem an unorthodox hypothesis to some readers. I am neither prepared nor entitled to discuss the geological basis on which the well-known Ice-Age maps have been worked out. I will only point out that biogeographers in many recent faunistic and floristic papers are inclined to minimize the devastating effects on the boreal and alpine fauna and flora which are usually attributed to the Ice periods. Of the many opinions expressed against the theory of the complete extermination of the boreal fauna during the Ice-Age, I will quote only Vibe's, regarding Greenland (1953):

"That a fauna including mammals, birds, and invertebrates, has been able to exist in Greenland during the glacial period and after, is principally due to the island nature of the country. Even if the present land area were covered with land ice, an ice-free shoreline must have existed below the surface of the present sea . . ."

"Altogether, the question of the zoogeography of Greenland is a question more of survival than of immigration."

As far as the Oligochaeta are concerned, I agree entirely with Mr. Vibe's statement; and I conclude that the oligochaetological fauna of Greenland has characteristics entitling it to be considered the remnants of a fauna which once migrated through a North Atlantic bridge from Europe to America, or vice versa, and that it did survive *in situ* after the disappearance of this land-bridge, through the last Ice period at least.

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