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Regeneration of Appendages in Some New Zealand Wetas (Insecta: Orthoptera)

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Abstract

FIVE examples of naturally occurring limb regeneration are recorded from three species of New Zealand weta, *Turbottoplectron* sp., *Hemideina thoracica* (White), and *Deinacrida rugosa* Buller. Five cases in *D. rugosa* nymphs of regeneration induced under laboratory conditions either through the aggressiveness of nymphs or by deliberate removal of limb parts, are also described. The growth coefficient of regenerating appendages was found to be initially higher than that of the corresponding normal limb of the opposite side. An example of the related abnormal phenomenon known as reduplication is also recorded.

REGENERATION of appendages is a widespread phenomenon in blattids, mantids and phasmids but is relatively rare in the Orthoptera (sensu stricto) (Chopard, 1938). Griffini (1911) described regeneration occurring in any of the three limbs of fifteen different gryllacridoid and tettigonioid species and sub-species, and Megusar (1910), mentioned regeneration in *Gryllus campestris* Linn., the acridid *Chorthippus biguttulus* (Linn.) and in the hind leg of the rhapidophorid *Troglophilus neglectus* Krauss, but considered the phenomenon to be rare if not absent from the great majority of saltatorial Orthoptera (see Chopard, 1938 and Griffini, 1911). There are apparently no previous records of regeneration occurring in the family Henicidae.

Limb regeneration in New Zealand wetas was found to be rare under natural conditions, only five examples being encountered in the field during observations extending over more than two years and involving several hundred specimens. This is rather surprising in view of the fact that some weta species at least, probably live for two years or longer. The lengths of regenerated limbs in the five examples are shown in Table I, together with the lengths of the normal corresponding limbs of the opposite side for comparison.

The first example is an adult male rhaphidophorid (probably a new species of *Turbottoplectron* Salmon) from a pine plantation at Riverhead, Auckland, in which a fully formed tibia and tarsus of the left middle leg have been regenerated. These differ from normal only in their smaller size and reduced number

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Table I.—Comparison of Lengths of Regenerated and Normal Appendages of New Zealand Wetas.
(All measurements are in millimetres.)

	Femur		Tibia		Tarsus		Cercus	
	Norm.	Reg.	Norm.	Reg.	Norm.	Reg.	Norm.	Reg.
Turbottoplectron sp. adult ♂ (middle leg)	11	11	12	6	8	4		
Hemideina thoracica penultimate ♂ (hind leg)	16	15.25	17	14	7.25	2		
Hemideina thoracica adult ♀ (hind leg)	16.75	16	20	12	8.5	4.5		
Hemideina thoracica adult ♀ (hind leg)	19	18	20	17	8	7.25	4	2
Deinacrida rugosa adult ♀ (fore leg)	15	12	14	5.25	8.5	3		

of spines. The second example is a penultimate male henicid, *Hemideina thoracica* (White), from the Tararua mountain range, Wellington, in which part of the right hind tibia and the whole tarsus have been lost. A short conical tarsus comprising three segments and rudimentary claws has been regenerated on the shortened tibia. The next two are adult female henicids of the same species from Wellington, in both of which a complete hind tibia and tarsus have been regenerated on the left side. The regenerated tibiae are relatively slender and a little distorted in both specimens. Distal spurs are present on each, but superior spines are lacking. On one tibia a few inferior retro-lateral spines are present. In the fourth specimen the left cercus, probably almost completely lost at an earlier stage has regenerated and formed a short blunt projection. The fifth example is also a henicid, *Deinacrida rugosa* Buller, from Stephen's Island, in which the entire tibia and tarsus of the left fore leg have been lost, probably during the sixth or seventh instar, so that by the adult stage a miniature tibia and three-segmented tarsus without claws have been regenerated on a slightly smaller than normal sized femur (Fig. 4).

With *Deinacrida rugosa* under laboratory conditions examples of regeneration were more frequent, limbs, portions of limbs and antennae often being lost as a result of the aggressive character of nymphs kept together. Data from these are summarised in Tables II and III.

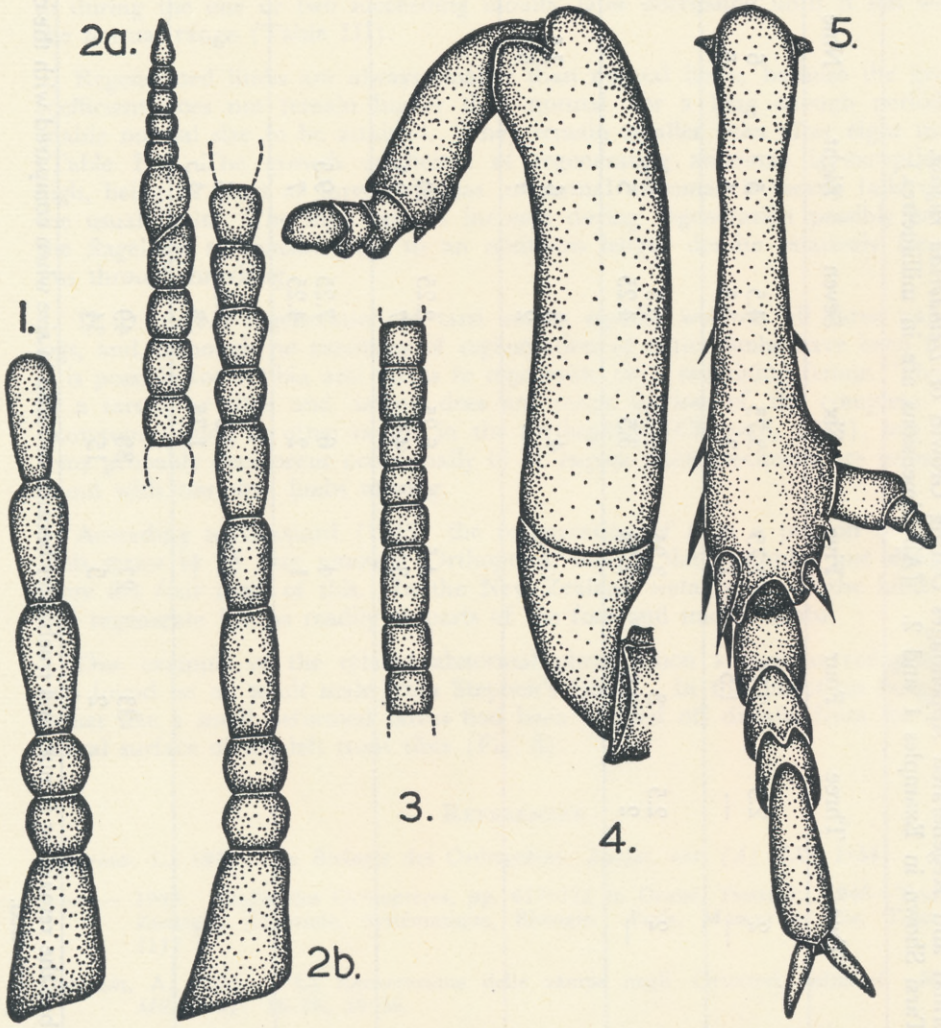
In the first two examples the tarsus was deliberately amputated during the first instar, one specimen requiring two and the other three moults before a regenerated element became visible. The new tarsus did not become as large as the corresponding normal one of the opposite side, even after seven or eight moults. In the third example a tarsus lost during the sixth instar commenced regenerating at the next moult but was smaller than normal at the adult stage. A complete tibia and tarsus lost during the third instar in the fourth example, commenced regenerating after the fourth moult when the femur also was found to be smaller than normal.

Regenerating antennae show relatively enormous increases in length at each moult. In the final example an antenna was lost as far back as the scape, probably during the second or third instar. The figures quoted for the normal antenna of the opposite side are not quite comparable, because portions of the flagellum were broken off—a frequent occurrence in captivity. By the fifth instar five elongate antennal segments had been regenerated (Fig. 1) and at the sixth instar, twenty-eight, including five much smaller terminal segments which may have resulted from apical growth of the flagellum (Figs. 2a and 2b). At the seventh instar seventy segments, including three much smaller terminal ones, had developed.

TABLE II.—Length of Normal and Regenerated Appendages During Growth of *Deinacrida rugosa*. Deliberately Removed Tarsi Shown in Examples 1 and 2. (All dimensions are in millimetres.)

Example Number	INSTAR	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Adult
1	Front Tarsus (Male)										
	Normal	1.5	2	2.5	2.75	2.75	3.75	4.5	5	6	
	Regenerated	—	—	—	1.5	2	3	3.5	4	5	
2	Middle Tarsus (Female)										
	Normal	1.5	2	2.5	3	3.25	4.25	5.5	6.5		
	Regenerated	—	—	2	2.5	2.75	3.5	4.25	5		
3	Hind Tarsus (Male)										
	Normal						4	5	6	7.5	9
	Regenerated						—	2	4	5.5	7
4a	* Middle Limb Femur and Trochanter (Male)										
	Normal					4.5	6.25	8.25	10		
	Regenerated					3	4.5	7	9.5		
4b	Middle Limb Tibia (Male)										
	Normal					4	6	7.25	9.5		
	Regenerated					1	2	4.25	7		
4c	Middle Limb Tarsus (Male)										
	Normal					2.75	3.5	4.5	6		
	Regenerated					—	1.75	3	4.5		
5	Antenna (Female)										
	Normal				33	27	38	49			
	Regenerated				2	5	15	34			

* In this example only the tibia and tarsus were lost, but the remaining femur and trochanter became reduced in size when compared with the corresponding segments of the opposite side as the regeneration proceeded.



Regenerated and abnormal appendages of *Deinacrida rugosa*. Fig. 1—Regenerated antenna, fifth instar. Fig. 2—Regenerated antenna, sixth instar; a, distal portion; b, proximal portion. Fig. 3—Portion of normal flagellum, sixth instar. Fig. 4—Left front leg with regenerated tibia and tarsus, adult female. Fig. 5—Tibia and tarsus of front leg showing abnormal reduplicated tarsus on the tibia, adult male.

Each segment or annulus of the flagellum was considerably longer and more rounded than those of the normal flagellum on the other side (Fig. 3). Regenerating antennae are often bent and distorted, possibly as a result of there being insufficient space within the old flagellum to accommodate the greatly increased length of the new, during the early stages of ecdysis.

In general the growth coefficient of limbs of *D. rugosa* falls within the range calculated elsewhere for head width, pronotum width, and pronotum length—viz., 1.14–1.29 (Ramsay, 1964) although exceptions occur. Regenerating limbs usually appear at the second or third moult after the loss of the appendage, especially in young nymphs. The initial growth coefficient is then usually higher than that of the corresponding appendage on the opposite side, and may remain

TABLE III.—Growth Coefficient of Regenerating Appendages Between Successive Instars of *Deinacrida rugosa*.

Example Number	Moult Number	One	Two	Three	Four	Five	Six	Seven	Eight	Nine
1	Front Tarsus (Male)									
	Normal	1.33	1.25	1.10	1.00	1.36	1.20	1.11	1.20	
	Regenerated	0.00	0.00	0.00	1.33	1.50	1.17	1.14	1.25	
2	Middle Tarsus (Female)									
	Normal	1.33	1.25	1.20	1.08	1.30	1.29	1.18		
	Regenerated	0.00	0.00	1.25	1.10	1.27	1.21	1.18		
3	Hind Tarsus (Male)									
	Normal						1.25	1.20	1.25	1.20
	Regenerated						0.00	2.00	1.38	1.27
4b	Middle Tibia (Male)									
	Normal					1.50	1.21	1.31		
	Regenerated					2.00	2.13	1.65		
4c	Middle Tarsus (Male)									
	Normal					1.27	1.29	1.33		
	Regenerated					0.00	1.71	1.50		
5	Antenna (Female)									
	Normal				0.82*	1.41	1.29			
	Regenerated				2.50	3.00	2.27			

* Part of flagellum broken off and lost.

so during the one or two succeeding moults, later decreasing until it lies within the normal range (Table III).

Regenerated limbs are always smaller than normal limbs, because the growth coefficient does not remain higher than normal for a long enough period to enable normal size to be attained. They remain smaller even after eight moults (Table II). The growth coefficient of regenerating antennae is exceptionally high, being as great as three, whereas in normal antennae it mostly falls within the usual limits. The high rate of increase during regeneration possibly enables the flagellum to remain close to an optimum length despite relatively frequent loss through breaking.

In *D. rugosa* regeneration of tarsi occurs equally well on all three pairs of legs, and, although no examples of regeneration of entire limbs have been found it is possible for a tibia and tarsus to regenerate on a remaining femur. The loss of a tarsus, or tibia and tarsus, does not result in loss of the complete limb (autotomy) such as often occurs in the Orthoptera (Chopard, 1938), but autotomy probably does occur occasionally in *D. rugosa* since specimens are sometimes found with complete limbs missing.

According to Chopard (1949) the regeneration of even a portion of a hind limb seems to be rare amongst Orthoptera, but in the examples just described there are four cases of this. In the New Zealand wetas parts of the hind limb will regenerate just as readily as parts of the fore and middle limbs.

One example of the related abnormal phenomenon known as reduplication was found on an adult male from Stephen's Island. In this insect an outgrowth rather like a small deformed tarsus had been budded off distally from the retrolateral surface of the left front tibia (Fig. 5).

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