

ANNALS
OF THE
NATAL MUSEUM

EDITED BY
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**Descriptions of some South African Marine
Shells.**

By

Edgar A. Smith, I.S.O.

With Plate I.



IN a collection of shells, mostly from Natal, kindly submitted to me for examination by Mr. H. C. Burnup, five species appear to be undescribed, and therefore I have drawn up the following descriptions of them, and at the same time made some remarks on two known forms of the genus *Tivela*.

Mangilia shepstonensis *n. sp.* Pl. I, fig. 1.

Testa parva, turrata, cerea, circa medium anfractus ultimi linea rufa interrupta cincta; anfractus 6; superiores læves (? detriti), convexi, cæteri planiusculi, superne rotunde tabulati, costis circiter duodecim leviter obliquis instructi, liris spiralibus (in anfr. penult. tribus, in ultimo ad tredecim) supra costas subnodulosis cincti, inter liras striis spiralibus et lineis incrementi minute decussati; apertura angusta, spira paulo brevior; labrum extra valde incrassatum, macula rufa ornatum, prope sinum conspicuum superiorem tuberculo parvo munitum; columella rectiuscula, callo tenui induta.

Longit. $4\frac{1}{3}$, diam. 2 mm.

Hab.—Port Shepstone (Burnup).

The apical whorls are large for so small a shell. Two specimens have been examined, and one of them has the spire

rather more produced than the other. The fine decussation of the surface between the costæ and the spiral liræ is only visible under a powerful lens or microscope.

Cerithiopsis (*Seila*) *natalensis* *n. sp.* Pl. I, fig. 2.

Testa subulata, nigro-fusca, ad apicem pallida; anfractus circiter decem, convexi, regulariter acerescentes, sutura obliqua sejuncti, liris spiralibus ad quinque instructi, liris incrementi fortibus oblique arcuatis sculpti, inter liras spiraliter tenuiter striati; ultimus infra concentricè striatus; apertura irregulariter rotundata, intus nigrescens; columella arcuata, callo tenui reflexo induta, ad basim oblique truncata.

Longit. 10 mm., diam. 2.5. Apertura 1.75 longa, 1.25 lata.

Hab.—Tongaat, Natal (Burnup).

Very like *Seila attenuata* *Hedley* from Port Jackson, but with stronger lines of growth and more equal spiral cords, and intermediate thread-like lines. On crossing the spirals these become almost granulated. The nuclear whorls are wanting in the specimen described.

Glyphis levicostata *n. sp.*, Pl. I, figs. 3-5.

Testa oblongo-ovata, antice leviter angustata, mediocriter elata, alba, fusco-olivaceo radiata, circa foramen interdum pallide livida costulis numerosissimis vix elatis et liris incrementi tenuibus confertis undulatis sculpta; foramen magnum, oblongum, intus callo livido postice truncato succinctum; superficies interna albo-pellucida lineis opacis albis radiata, ad marginem lateraliter paulo elatum tenuiter crenulata.

Longit. 35, diam. 23, alt. 14 mm.

Hab.—Tongaat and Port Shepstone, Natal (Burnup).

This species is remarkable for the fineness of its sculpture, and the elongate cap-shaped form. The radiating riblets are very little raised, and separated merely by impressed lines

or striae. The concentric lines of growth are crowded and wavy, and in the grooves between the riblets there is in places a somewhat punctate appearance. Four or five concentric waves or ridges at fairly equal distances from the foramen may indicate periods of arrested growth. The subapical hole is very anterior, oblique in front of the apex, and the front slope beneath it is considerably concave. Considering the lightness of the external costulation, the margin is distinctly denticulate, the grooves between the denticles extending within a little distance from the edge. The denticles are about eighty in number, and those upon the anterior end are often sub-bipartite. *G. tenuistriata* (Sowerby) is rather like the present species as regards form, but the sculpture is not the same. In the largest specimen examined the colour rays are very faint, probably through fading. A smaller and fresher specimen exhibits seven rays—three on each side and one in front; the two behind slope posteriorly, four are inclined towards the front, the seventh ray extending from near the foramen to the margin down the middle of the shell.

Tivela compressa Sowerby. Pl. I, figs. 6–8.

Hab.—Port Shepstone, Tongaat, Scottburgh (Burnup); Isipingo (Miss Lois Trotter); Isezela (Miss Chapman).

T. compressa was originally described from the Cape of Good Hope, and it also occurs at Muizenberg, in False Bay, and at Port Alfred. The specimens from Port Shepstone, etc., differ from the typical form in having the ventral margin less roundly curved, so that the valves have a more triangular appearance, and the height of the shell is less in proportion to the length. The pallial sinus is more acuminate and generally extends beyond the middle of the valves, whereas in the normal form it hardly reaches half-way across. The reddish-brown posterior dorsal area appears to be a constant feature in this species. It sometimes attains a length of 60 mm.

Tivela dunkeri (Römer). Pl. I, figs. 9, 10.

Venus (Cytherea) (*Tivela*) *dunkeri* Römer, Novitat. Conch. Monog. Venus, p. 5, pl. v, fig. 1.

Hab.—Port Shepstone (H. Burnup).

The locality of this species has not been hitherto recorded. It is very donaciform in shape, the anterior end being longer than the posterior. It is described by Römer as pale violet-white, tinged with violet dorsally. His specimen was 25 mm. in length, whilst the valves under examination, evidently young shells, are only 15.

The other S. African *Tivelas* are: *T. natalensis* Dkr. 1864 (= *alucinans* Sow. 1897), *T. transversa* Sow. 1897, and *T. polita* Sow. 1851 (= *dolabella* Sow. 1851).

Tivela rejecta *n. sp.* Pl. I, figs. 11–13.

Testa trigona, fere æquilateralis, sordida lactea rufo maculata, distanter livido zonata, lineis incrementi striata; margines dorsales utrinque recte declives; basalis late curvatus; latus anticum acute rotundatum, posticum magis acuminatum; umbones acuti, purpureo tincti; lunula vix definita, fusco-purpurea tincta; area postica fusco-purpurea; pagina interna fusco-purpurea, ad marginem basalem albida; pallii sinus angustus, trans medium procurrens.

Longit. 15·5, alt. 11·5, crass. fere 7 mm.

Hab.—South Africa.

The shell here described may not be adult, but it differs from the young of all the other South African *Tivelas*. *T. polita* most nearly approaches it, but that species is higher in proportion to its length, flatter, and the pallial sinus is shorter and wider. The dorsal margins within the valves in *T. rejecta* are of a deep purplish-brown with pale rays beneath them, one on each side, which join the white ventral margin. The reddish-brown markings on the outer surface are irregular, but disposed more or less in transverse bands.

There are also one or two livid zones at distant intervals. There are slight differences in the hinge-teeth, which it would be difficult to describe, but which can be observed by comparing the two forms.

T. dunkeri, Römer, differs in form, the posterior end being rounded and not acuminate as in the present species.

Loripes burnupi *n. sp.* Pl. I, figs. 14-16.

Testa irregulariter ovata, mediocriter convexa, subæquilateralis, tenuis, albo-pellucida, periostraco tenui lutescente partim oblecta, lineis incrementi tenuissime striata; lunula parva, profunda; umbones supra lunulam incurvati; dens cardinalis unicus valvæ dextræ crassus, solidus, irregularis, infra umbonem situs; dentes duo valvæ sinistrae, quorum posticus angustus, retrorsum inclinatus, anterior solidus, irregularis, a postico fossa lata sejunctus; ligamentum elongatum, fere internum; pagina interna obsolete radiatim tenuiter striata, in fundo cicatricem angustam obliquam exhibens; cicatrix antica, mediocriter elongata, postica elongato-piriformis.

Long. 19·75, alt. 20, crass. 10 mm.

Hab.—Port Shepstone (Burnup).

Although the ligament is not so completely internal in this shell as is the case in typical forms of *Loripes*, I do not consider this a sufficient difference upon which to found a distinct genus since the position of the ligament is subject to considerable variation.

A much larger shell from the Cape Verd Islands, described by Sowerby¹ as *Cryptodon muchlandi*, externally closely resembles the present species. The hinge-teeth, however, are absent, or may have become obliterated with age. The form of the anterior scar also is somewhat different.

¹ Sowerby, G. B., 'Proc. Malac. Soc.', vol. vii, p. 303, pl. xxv, fig. 13.

EXPLANATION OF PLATE I,

Illustrating Mr. Edgar Smith's paper, "Descriptions of
some South African Marine Shells."

FIG. 1.—*Mangilia shepstonensis* *n. sp.*

FIG. 2.—*Cerithiopsis* (*Seila*) *natalensis* *n. sp.*

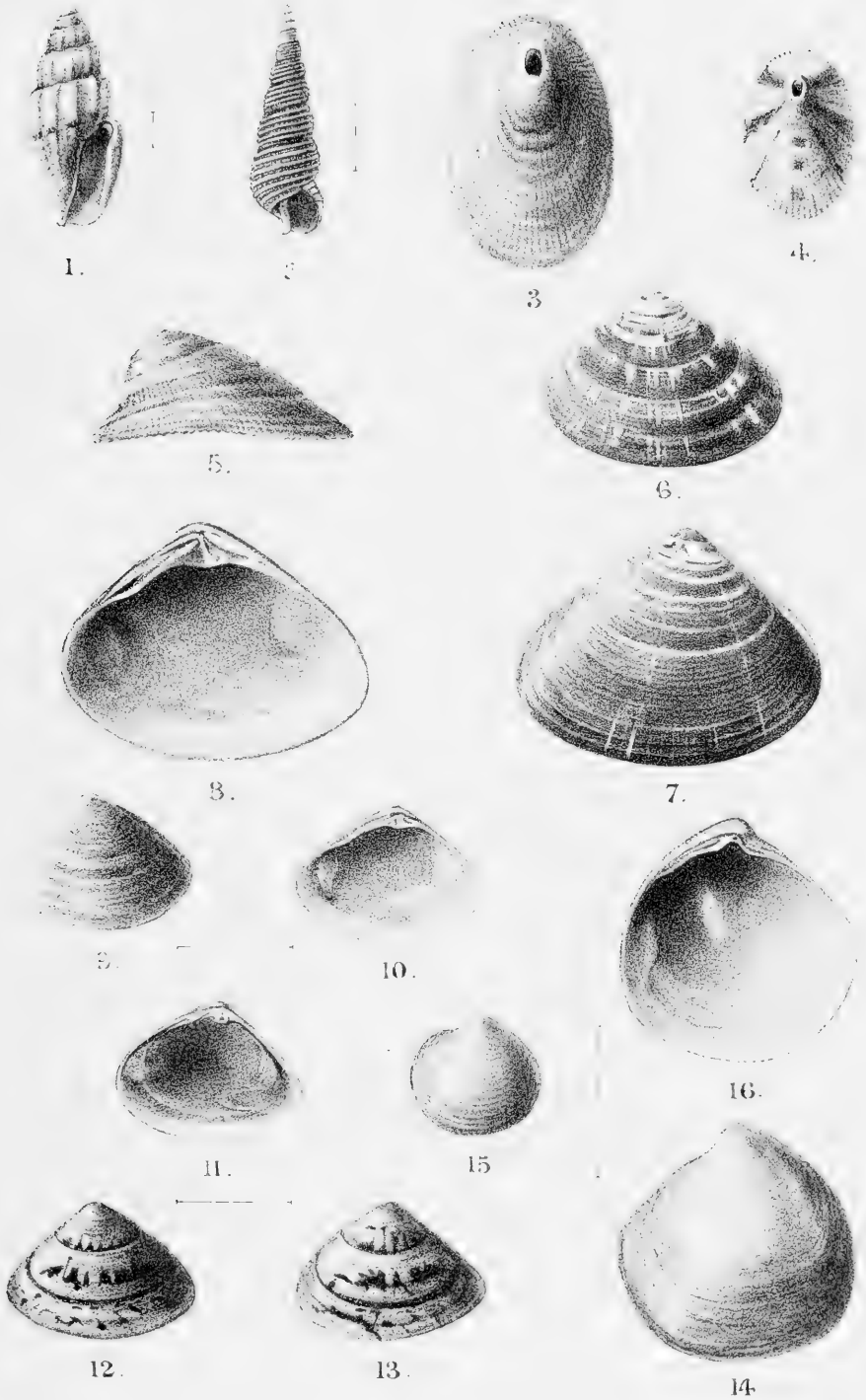
FIGS. 3-5.—*Glyphis levicostata* *n. sp.*

FIGS. 6-8.—*Tivela compressa* *Sowerby.*

FIGS. 9, 10.—*Tivela dunkeri* *Römer.*

FIGS. 11-13.—*Tivela rejecta* *n. sp.*

FIGS. 14-16.—*Loripes burnupi* *n. sp.*



A Case of Hybridism among Cockatoos.

By

Ernest Warren, D.Sc.Lond.

With Plate II.

THERE has recently occurred an interesting example of hybridism among certain tame cockatoos in Pietermaritzburg, and since the character of hybrids gives some insight into the problems of hereditary transmission it appeared to be desirable to publish an account of the matter, and the living birds have been studied as carefully as circumstances would permit.

The cockatoos belong to Lieut.-Colonel A. T. Wales, resident in Pietermaritzburg, who has very kindly allowed me to sketch the birds and have them photographed; my thanks are also due to his daughter, Mrs. Brown, who, having considerable control over the somewhat wild birds, rendered great assistance while they were being photographed. My friend, Dr. Conrad Akerman, was good enough to undertake the photographing, and from the prints of the negatives thus obtained the lithographic plate was prepared. The artist who coloured the plate was provided with a selection of the variously coloured feathers.

The male-bird is the common sulphur-crested cockatoo, *Cacatua galerita* (*Lath.*), and the female is the so-called slender-billed cockatoo, *Licmetis nasica* (*Temm.*). The birds were obtained on different occasions at the coast-town of Durban, and were doubtless at the time of purchase recently imported from Australia.

The birds live in a garden under fairly natural conditions;

they are mostly confined in a capacious wired-in enclosure protected from the rain, but quite frequently they escape into the garden and climb among the trees. At the present time there are five birds in the aviary; namely, two hybrids, the parents of the same, and a second specimen of sulphur-crested cockatoo. By wire-partitions and wire-cages the birds can be separated from one another. This is particularly necessary in the case of the elder of the hybrids, which at times exhibits a violent disposition. The bird has already killed a grey parrot, and has very severely mauled the second specimen of cockatoo, which, nevertheless, is a considerably larger and more powerful-looking bird.

The female-bird was purchased some twelve years ago, and the male-bird about four years afterwards. Thus the birds have been associated together for a period of about eight years. During the first two years the birds were not confined at all; they lived among the trees in a garden in a different portion of the town. Apparently no pairing occurred during this period, and no eggs were laid. Subsequently the owner moved to another residence and the birds were lodged in their present quarters.

It is difficult to say whether the closer association of the two birds arising from the confinement favoured the pairing, but for the following six years (1908-1913) eggs were laid regularly every August. It is possible, however, that the production of eggs by the female cockatoo does not necessarily mean that copulation invariably took place; for in this connection it may be mentioned that a tame owl (*Syrnium woodfordi*) in my possession occasionally produces perfectly formed eggs, although the bird is unpaired; also, a certain unpaired, tame and unidentified parrot belonging to the Misses Blackmore of this town has laid eight or nine eggs annually for several years. In the case of the birds with which we are now concerned, actual pairing has been observed and probably it occurred every season.

The eggs are laid about the middle of August. In 1908 two eggs were produced, and the owner, under the impression

that the cockatoos would not give proper attention to incubation, placed them under a hen, but the egg-shell proved to be too delicate, and the eggs were soon broken. In 1909 another two eggs were laid, and they were placed under a pigeon; but the pigeons were not disposed to take any notice of them, and they were almost immediately smashed. In 1910 two eggs were likewise laid in the middle of August, and the cockatoos were allowed to take charge of them. The male- and female-birds took turns in incubation, and in due time one egg hatched, while the other was addled. Colonel Wales informs me that he did not take special note of the period of incubation, but he believes that it was about twenty-one days. The egg which did not hatch was thrown away without being examined. In 1911 the female-bird dropped two eggs from her perch and they were smashed. In 1912 two eggs were laid and sat upon by the birds, but they were addled. In 1913 three eggs were laid, and after incubation by the cockatoos one egg hatched while the other two were addled.

Thus in three separate years, 1910, 1912, 1913, out of seven eggs laid in all, only two hatched, and the hybrids thus arising form the subject of the present observations. It cannot be said for certain whether the eggs failed to hatch through non-fertilisation, or through the death of the embryos owing to constitutional weakness. It is clear that the proportion of eggs which hatched (two out of seven) was low, and it would appear probable that this was due to the fact that the male- and female-birds were of different species.

The male-bird (Pl. II, A), was a fine specimen of *C. galerita*; and it may be useful to quote here the description of the species given in the British Museum Catalogue.¹

“Adult.—White, crest sulphur-yellow; base of the inner web of quills and tail-feathers pale sulphur-yellow, like the base of the feathers of the head and neck; ear-coverts sometimes tinged with sulphur-yellow; naked skin round the eyes white; iris dark-brown; bill black; feet blackish. Total

¹ ‘Catalogue of the Birds in the British Museum,’ vol. xx, p. 117.

length 20-18 inches, wing 15-13.5, tail 8.5-7.5, bill 2-1.7, tarsus 1.15-1.1.

“Hab.—Australia and Tasmania.”

Count Salvadori further remarks: “I have not been able to examine specimens from Tasmania, which, on account of some little difference in the shape of the bill, have been specifically separated as *C. licetorhyncha* (Bp).”

The present specimen when standing on perch measured 17.5 inches (445 mm.) from the crown of the head to the tip of the tail.

Sulphur-yellow crest well-developed, and with recurved extremity; the longest feather measured 4.5 inches (114 mm.).

Prominent projecting forehead.

The ear-coverts were tinged with sulphur-yellow.

Exposed portion of eye, when eye-lids were open, was somewhat oval in shape, set horizontally, and measured 31 sq. mm. Eye-lids, when wide open, exhibited at their margin a circle of well-developed, symmetrical, squarish granulations. Iris very dark brown.

Naked skin round the eye oval in shape, set horizontally, and measured 144 sq. mm. It was irregularly furrowed, and both it and the eyelids were of a chalky white.

The bases of many of the feathers of the head and throat were sulphur-yellow in colour.

Length of tail 8 inches (203 mm.); base of inner web of tail-feathers resembled that of the quill-feathers in being pale sulphur-yellow.

Bill, black horn-colour, with the appearance of being dusted with white powder. The upper mandible from forehead to tip of hook measured 1.68 inches (42 mm.); depth from forehead to lower inner angle, 1.05 inches (27 mm.). The lower edge of the upper mandible, when bill was in a normal position of rest, was only about 8° from the horizontal, and was nearly parallel to a line passing through the centre of the eye and the middle point of the junction of the forehead and bill. There is considerable variation in this matter in different individuals, as it has been observed that in some

specimens the lower edge slopes upwards towards the inner corner at an angle of 10° – 15° . The hook of the bill was short and perpendicular. There is also much individual variation in the length and curvature of the hook; and from Count Salvadori's remarks, quoted above, it would appear that in Tasmanian specimens the hook tends to be longer and more nearly like that of the genus *Licmetis*.

The upper edge of the lower mandible is slightly concave for its proximal two-thirds, while towards the tip it is deeply concave owing to the curvature of the bill.

Nostrils surrounded by narrow naked cere at the insertion of the bill.

The female-bird (Pl. II, B) was a normal specimen of *Licmetis nasica*, and the description of the species given in the British Museum Catalogue¹ is as follows:

“Adult.—White; lores and a narrow frontal band red; the feathers of the head, neck and breast are scarlet at the base, showing through the white, especially on the breast: the under surface of the wing washed with pale brimstone-yellow, the under surface of the tail also washed with brimstone-yellow, but brighter: iris light brown; bill white; naked skin round the eyes light blue; feet dull olive-grey. Total length 15 inches; wing 11; tail 5; bill 1.95; tarsus 0.95.

“Hab.—Australia, from the Gulf of Carpentaria, through the interior to N. S. Wales and South Australia.”

The present specimen when standing on perch measured $13\frac{1}{2}$ inches (343 mm.) from the crown of the head to the tip of the tail.

The crest is in the form of a ruff consisting of the front white feathers of the crown, which are erected when the bird is annoyed. The feathers which correspond to the long recurved sulphur-yellow feathers of the crest of *C. galerita* are further back on the crown, and are short feathers about 1.5 inches (38 mm.) in length. These have red bases which are not ordinarily visible when the bird is quiescent.

¹ *Ibid.*, p. 134.

Forehead high, but with a receding aspect, and not prominent as in *C. galerita*.

Ear-coverts pale brownish-yellow or buff.

Exposed portion of eye, when eye-lids were wide open, was circular in shape and measured 25 sq. mm. The edges of the eye-lids did not exhibit granulations. Iris, very dark-brown, not light-brown as stated in the description quoted above.

Naked skin around the eye was irregular in shape and extended much further below the eye than above it. The area was large, measuring 343 sq. mm., and grooved and furrowed; both it and the eye-lids were of a whitish-blue colour.

Lores red; a narrow red frontal band was continued from the lores above the insertion of the upper mandible, and a rather paler red coloration extended backwards both above and below the naked area around the eye.

The bases of most of the features of the head, throat, neck and upper chest were bright red in colour.

Length of tail 4.75 inches (120 mm.). Under surface of tail and wing sulphur-yellow.

Bill whitish, the colour of boiled bone, proximally a slightly bluish tinge and distally a yellowish tinge. The upper mandible from forehead to tip of hook measured 1.8 inches (47 mm.); depth from forehead to lower inner angle 0.75 inches (19 mm.). The lower edge of upper mandible, when bill was in a normal position of rest, sloped upwards towards the inner corner at an angle of about 27° with the horizontal. The hook was long and conspicuously curved, and the proximal portion of the hook projected outwards and not perpendicularly as in *C. galerita*. The upper edge of the lower mandible was nearly straight proximally for about one-third of its length, while the distal two-thirds was very deeply concave.

Cere feathered, and nostrils situated further in from the insertion of the bill than in *C. galerita*.

The three years old hybrid (Pl. II, C), when standing on

perch, measured 15 inches (381 mm.) from the crown of the head to the tip of the tail.

A crest was present consisting of short reddish-yellow or orange feathers obviously representing the recurved sulphur-yellow feathers of the crest of *C. galerita*. These feathers were only 2·8 inches (73 mm.) in length, and they were quite straight and exhibited no tendency towards the recurved condition seen in *Cacatua*. Thus, in the condition of the crest, the hybrid stands between the male- and female-parent, but somewhat nearer to the male. The short feathers of the female corresponding to the crest-feathers of the hybrid are red at their bases, and the colour of the crest of the hybrid is clearly a mixture of yellow and red.

The forehead of the hybrid was more prominent than in the female- and less so than in the male-parent.

The ear-coverts were pale yellowish-buff and did not differ appreciably in colour from those of *Licmetis nasica*.

The eye was large, and when the eyelids were wide open the exposed area was 34 sq. mm., thus equalling, or even slightly exceeding, the size of the eye in the male-bird. The edge of the eyelids when open exhibited granulations, but they were smaller and less regular than in *C. galerita*. Iris very dark brown.

The naked skin around the eye was oval in outline, and was more or less intermediate in size (208 sq. mm.) between that of the male and that of the female; but in this character also the hybrid stands somewhat closer to the male- than to the female-parent. The colour of this skin was of the palest bluish-white, which was almost exactly intermediate between the chalky white of the male and the pale blue of the female.

The red colour of the lores of the female was converted into a yellowish orange in the hybrid; while the red colour of the bases of the feathers of the head and neck was replaced by a beautiful gold colour.

Length of tail 7 inches (178 mm.). Under surface of tail and wing sulphur-yellow.

Bill dark horn-colour, but not quite so black as in *C.*

galerita; the difference is more obvious when the bill is wetted. The upper mandible, from forehead to tip, measured 1.7 inches (43 mm.); depth from forehead to lower inner angle 0.93 inch (24 mm.). The lower edge of upper mandible, when bill was in a normal position of rest, sloped upwards towards the inner corner at an angle of about 19° to the horizontal. The hook was larger than in the male-bird and was more or less intermediate in shape between that of the male and female. The upper edge of the lower mandible was, on the whole, somewhat more concave than in the male-, but less so than in the female-bird.

Cere partially feathered so that the nostrils, which were situated just inside the junction of the bill and head, had the back edge feathered and the front edge naked, a condition strikingly intermediate between that seen in the male- and in the female-bird.

The three months old hybrid (Pl. II, D) was not sufficiently mature to render it advisable to compare its measurements with those of the parents. In all general characters it very closely resembled the mature hybrid.

The orange crest was already rather longer than in the older hybrid, but none of the feathers were recurved.

The area of the lores coloured yellowish-orange was relatively less than in the three years old hybrid, and considerably smaller than the red area in *L. nasica*. Naked skin around the eye very pale bluish-white. Iris very dark brown.

Bill very dark, but not quite so black as in *C. galerita*.

The shape of the upper mandible and hook of same was somewhat nearer to that seen in the male than was the case in the older hybrid. Also, the curvature of the upper edge of the lower mandible was somewhat closer to that of the male.

From a Mendelian point of view animal hybrids derived from the crossing of species are as a rule singularly unsatisfactory. They usually exhibit an intimate blending in the majority of the characters of the two parent species, and

they are mostly sterile. The present case is no exception; the characters of *C. galerita* and *L. nasica* have very obviously blended, and the resulting hybrid stands between the two species, but somewhat nearer to *Cacatua* than to *Licmetis*.

A simple Mendelian relation would have been shown if, for example, the sulphur-yellow of the *Cacatua* had been dominant and the red of *Licmetis* recessive, and on subsequent crossing of the hybrid (assuming that it was possible) if 75 per cent. of the offspring had been entirely yellow and 25 per cent. entirely red. But in the present case of hybridism we do not find any definite evidence of the existence of such dominance in any of the characters examined. It is true that the colour of the hybrid is nearer to yellow than to red, and that in this character there is prepotency on the part of the male-bird; but the yellow colour of the hybrid is not the sulphur-yellow of *Cacatua*; the latter colour has become blended with red to form an orange crest, orange lores, and a beautiful gold under-plumage to the head and neck.

Again, it would not serve any useful purpose to regard the possession of a crest as a dominant character. The short, straight, orange crest of the hybrid is obviously a kind of mean between the long recurved sulphur-yellow crest of *Cacatua* and the short, white and red feathers of the crown of *Licmetis*.

A similar blending of characters is seen in the position of the nostrils, the condition of the cere with reference to the feathering, the colour and shape of the upper and lower mandibles, and the shape of the forehead.

The characters which do not readily admit of numerical expression are grouped together in the accompanying table (p. 16).

It will be noticed that under "Hybrid" more of the characters are found in the column "nearer *Cacatua*" than elsewhere, but it must be remembered that in every case the influence of *Licmetis* is very distinctly obvious, and, except perhaps in the character of the possession or non-possession

TABLE I.

Character.	Male (Cacatua).	Hybrid.		Female (Licmetis).
		Nearer Cacatua.	More or less intermediate between ♂ and ♀.	
Colour of crest	Sulphur-yellow	Dull yellowish-orange	—	Red.
Colour of bases of head and neck feathers	Sulphur-yellow or white	Brilliant gold	—	Red.
Colour of naked area around eye	Chalky white	—	Very pale blue	Light blue.
Shape of naked area around eye	Oval, set horizontally	—	Roughly circular	Irregular oblong, set perpendicularly.
Feathering of cere	Naked	—	Partly feathered	Feathered.
Prominence of forehead	Prominent	—	Medium	Receding.
Granulation of eyelid	Well-marked and regular	Less well-marked and regular	—	Scarcely at all developed.
Shape of the upper and lower mandibles and condition of hook	Shape massive; hook short, straight, and set perpendicularly	Shape less massive; hook less straight and somewhat longer, curved	—	Shape comparatively slender; hook long and curved.
Colour of bill	Black horn	Dark coloured, but less black	—	Dirty white.
Possession of coloured lores	Not coloured	—	—	Coloured red.
Addition of columns	10	5	4	10
				Coloured orange and area smaller than in ♀
				1

TABLE II.

Dimension.	<i>Cacatua galerita</i> ♂.	Hybrid.				<i>Licmetis nasien</i> ♀.
		Difference between ♂ and hybrid.	Diff. from ♂ hybrid $\times 100$.	Dimension in hybrid.	Diff. from ♀ hybrid $\times 100$.	
Standing length	445 mm.	64 mm.	17 per cent.	381 mm.	10 per cent.	343 mm.
Length of longest hinder crest feather	114 mm.	41 mm.	56 "	73 mm.	48 "	38 mm.
Area of eye when eyelids open	31 sq. mm.	3 sq. mm.	9 "	34 sq. mm.	26 "	25 sq. mm.
Area of naked skin round eye	144 sq. mm.	64 sq. mm.	31 "	208 sq. mm.	65 "	343 sq. mm.
Length of tail	203 mm.	25 mm.	14 "	178 mm.	32 "	120 mm.
Length of upper mandible from forehead to tip	42 mm.	1 mm.	2 "	43 mm.	9 "	47 mm.
Depth from forehead to inner angle	27 mm.	3 mm.	13 "	24 mm.	21 "	19 mm.
Slope of lower edge of upper mandible with horizontal	8°	11°	58 "	19°	42 "	27°
Mean of percentages			25 "		32 "	

of coloured lores, it is nowhere possible to speak of a character as being dominant. In this case the actual colour of the lores is to be disregarded, and only the fact that some of the feathers of the lores are wholly coloured and not white in their upper portions would have to be taken into consideration. But the coloured area between the eye and the bill is relatively smaller in the hybrids than in *Licmetis*, and this is particularly the case in the younger hybrid. On the whole, therefore, it would appear easier to regard the condition seen in the hybrids as resulting from a blend of the male and female characters with a slight prepotency on the part of the female, than to take the view that the presence of the coloured lores is an example of dominance in the Mendelian sense.

Finally, it may be said that out of these ten characters the hybrid is nearer to *Cacatua* in five, nearer to *Licmetis* in one, and almost exactly intermediate in four.

The characters which lend themselves more readily to numerical expression may be summarised in the accompanying table (p. 17).

In the fifth column the measurements in the hybrid are given, and in the third and seventh columns the differences between these measurements and those of the male (second column) and female (eighth column) respectively are shown. These differences, expressed in percentages of the measurements of the hybrid, are given in the fourth and sixth columns. Thus, for example, with respect to the length of the tail the divergence of the hybrid from the male- and female-parent expressed in percentage of the length of the tail in the hybrid is 14 per cent. and 32 per cent. respectively; and the hybrid in this character is therefore 18 per cent. further removed from the female (*L. nasica*) than from the male (*C. galerita*). The means of these percentage ratio-differences between the hybrid and the parents in the eight characters tabulated are 25 per cent. for the male and 32 per cent. for the female. In other words, on the average, ratio-deviation of the hybrid from the male : ratio-deviation of the hybrid from the female :: 25 : 32.

We see from this that the hybrid in these characters, just as in the case of the incommensurate characters tabulated on p. 16, stands nearer to the male than to the female. Of course, the actual ratio thus arrived at can be regarded only as the very roughest approximation, since we are dealing with a single specimen of the hybrid.

The only examples of hybridism among the Psittacidae that have been traced in the available literature are those quoted by Hans Przibram.¹

“Macaws: *Ara macao* ♂ and *A. militaris* ♀, one young rather similar to *militaris*, died early.

“Parakeets: *Platyercus pallidiceps* ♂ and *Pl. eximius* (Roselle Parakeet) ♀; also, *Platyercus eximius* ♂ and *Pl. pennantii* ♀.”

From the remark under macaws it would appear that the characters of *militaris* tend to be prepotent over those of *macao*. In this case it will be noticed that it was the female which was prepotent, while in the present example of the cockatoos it was the male.

An interesting point in this connection is whether the prepotency of the male-parent in this case was due to the stronger inheritable nature of the *Cacatua* characters than of the *Licmetis* characters, or whether the prepotency was in some way connected with the male sex or with the individual specimen. To test this point it would be of great interest to obtain hybrids with male *Licmetis* and female *Cacatua*.

Przibram,² in his recent work, has compiled a considerable list of cases of hybridism, and has illustrated a good number in a series of sketches. In many examples the hybrid is represented as being very strikingly intermediate between the two parent forms in all the general characters depicted. As far as can be seen, a very thorough blending of characters has mostly occurred, and from a general inspection it is often

¹ Przibram, Hans, ‘Experimental-Zoologie. Phylogenese,’ p. 89, 1910.

² *Ibid.*, p. 89.

not possible to say that the hybrid as a whole is closer to one parent than to the other.

In the case of hybrid moths, the cross *Smerinthus ocellatus* ♂ × *Sm. populi* ♀ [Westwood] is nearer to the male-parent *ocellatus*, and the cross *Sm. populi* ♂ × *Sm. ocellatus* ♀ [Standfuss] is also nearer to the male-parent which is *populi*.

Similarly in the case of mammals, the cross *Equus burchelli* ♂ × *E. caballus* ♀ [Ewart] is nearer to the zebra in the amount of striping, while the cross *E. caballus* ♂ × *E. burchelli* ♀ [Ewart] is closer to the horse in the comparative absence of stripes in the hybrid.

Also, the mule is perhaps somewhat closer in general character to the male-ass than to the female-horse, and the hinny is stated to be nearer the male-horse than to the female-ass.

In these several examples the male appears to be pre-potent.

Nevertheless, no general rule exists, for among fishes the cross *Acerina cernua* ♂ × *Perca fluviatilis* ♀ [Kammerer] is strikingly close to *A. cernua*, while the cross *Perca fluviatilis* ♂ × *A. cernua* ♀ [Kammerer] is also very near to *cernua*.

In the cross of the moths *Saturnia pavonivæ* ♂ × *S. pyri* ♀ [Standfuss] the hybrid is obviously nearer to *pyri*, the female-parent.

In the case of reciprocal crosses of the moths *Deilephila euphorbiæ* ♂ × *D. vespertilio* ♀ [Berge-Rebel] and of *D. vespertilio* ♂ and *D. euphorbiæ* ♀ [Berge-Rebel], the hybrids appear to be as nearly as possible intermediate between the parent species, and there is very little difference between them.

In the above few examples of the crossing of distinct animal species the resulting hybrids exhibit considerable diversity with respect to their general average character compared with that of the two parent-forms.

We see that (1) the hybrids may be nearer to the male-

parent than to the female; (2) the hybrids may be nearer to the female-parent than to the male; (3) in reciprocal crosses the hybrids in both cases may be nearer to the male-species than to the female-species; (4) also, it is probable that in some reciprocal crosses the hybrids in both cases may be nearer to the female-species than to the male-species; (5) in reciprocal crosses the hybrids may be much alike, and nearly intermediate between the two parents.

There appear to be no examples of the hybrids between distinct animal species being widely different from both parents.

We already know from Karl Pearson's researches that the co-efficient of correlation in man between male-parent and offspring tends to be slightly greater in the inheritance of some characters than between female-parent and offspring. For example, in the case of stature the co-efficient for father and son is .396, and for mother and son .302.

The few examples of hybridism above quoted do perhaps give some slight evidence of the male-parent sometimes exerting a certain general prepotent influence on account of sex; but the influence of sex is doubtless altogether overshadowed by the prepotency of characters which may be regarded as phylogenetic. The very fact that a particular character occurs in a number of species of a genus is evidence that the character has been strongly inherited. In other words, the view is, that in blended inheritance if one parent of a hybrid has the typical character of the genus, and the other parent has a less usual one, then the typical character seen in the majority of the species of the genus would tend to be more strongly inherited in the hybrid than the more peculiar one.

Possibly, if it is legitimate to surmise at all in the matter, the hybrid *Licmetis nasica* ♂ × *Cacatua galerita* ♀ would not differ greatly from the hybrid above described, since the characters appertaining to the large genus *Cacatua*, to which *galerita* belongs, might be expected to conceal any small prepotent influence that the male sex might possess.



From this point of view a glance at Table III may be of interest. In this table the characters of the different species of *Cacatua*, as given in the British Museum Catalogue, are rather imperfectly summarised; but we are able to see the general range of variability in the genus, with a view to obtain some insight into the hereditary tendencies of the male-parent; and also of the female-parent, since the genus *Licmetis* to which the latter belongs is closely related to *Cacatua*.

For example, the general coloration in the different species of *Cacatua* is nearly always white, and we find as the result of the blended inheritance that the amount of coloration in the hybrid is less than half of that of the female-parent.

The recurved condition of the crest is found in less than half of the species of *Cacatua*, and we notice that the recurved feathers of the male-parent are not so strongly impressed on the offspring as to counteract the influence of the female-parent. Yellow or white crests occur in the majority of the species of *Cacatua*, and the amount of red coloration mixed with the yellow of the hybrid is comparatively small.

The feathered and non-feathered conditions of the cere are about equally divided in the different species, and in the hybrid the condition with respect to this matter is almost exactly intermediate between the two parents.

The bill is more often black than light-coloured in the various species, and in the hybrid it is much nearer to black than white.

In nearly all of the species of *Cacatua* the naked skin around the eye is oval or circular, and in the hybrid it is roughly circular. The shade of colour of the naked skin, whether white, blue or grey, varies considerably in the different species of *Cacatua*, and the hybrid in this character is closely intermediate between the two parents, thus indicating that there is no marked preponderating influence in either direction.

The general shape of the upper and lower mandibles is very

similar in all the species of *Cacatua*, while it is rather peculiar in *Licmetis*; in the hybrid the general shape is nearer to that in the former genus than to that in the latter.

Lores separable from the surrounding plumage in colour are seen apparently in only three or four of the fifteen species of *Cacatua*, and to be comparable with the above results the colouring of the lores in the hybrid should be less than half the amount seen in *Licmetis*. The amount of colouring in the hybrid is certainly considerably less than in the female-bird, but it is greater than one-half, and consequently in this character there is some prepotency on the part of the mother.

With reference to the absolute dimensions of general body-length, length of tail and bill, given in the second, third and fourth columns of Table III, it will be seen that there is great variation in the different species, and this is also the case with the relative lengths of the tail and bill. Consequently we perhaps should not expect to find any very strong prepotent action. As a matter of fact, the absolute dimensions in the hybrid are not so very far removed from the means of the dimensions of the male- and female-parent. The means for the parents of the three dimensions are 15.5, 6.4 and 1.74 inches respectively, and the measurements in the hybrid are 15.0, 7.0 and 1.7 inches respectively; the male-parent is prepotent with reference to the length of tail and beak, and the female-parent with respect to body-length. The mean ratio $\frac{\text{length of tail}}{\text{length of body}}$ for all the species is .28, for male *Cacatua* .45, for female *Licmetis* .36, and for hybrid .45. Thus, in this case the prepotency of the male-bird has been strong enough to counteract the more typical proportion of the tail-length seen in the female-bird.

On the whole it perhaps may be said that old-established characters appearing in the majority of the species of a genus may from this very fact be regarded as strongly inheritable characters, which if present in one parent would tend to be impressed on the hybrid to the partial exclusion of any more peculiar characters that happened to be present in the other

parent. Thus, the former parent (*Cacatua* in the present case) would appear to be prepotent over the latter parent (*Licmetis*).

There is exhibited, as a rule, no simple Mendelian relationship in the hybrids between animal species. The characters of the parents tend to blend, and often they blend very thoroughly as in the cockatoos: and although the hybrid may be nearer in certain characters to one parent than to the other, yet *in no character is the direct influence of either parent apparently absent*. No character observed could be described as "dominant" or "recessive," unless these terms are used in a popular sense, and a dominant character is simply a prepotent one. It is true that the Mendelian relationship concerns characters only and not individuals as a whole. Thus, supposing that the hybrid cockatoos were capable of crossing among themselves and that the Mendelian mode of inheritance occurred, then the offspring would not be wholly like *C. galerita* or wholly like *L. nasica*, but some of them would very strongly resemble one or the other of the parent forms in some of their characters. According to the Mendelian conception of hereditary transmission by definite unit-characters, every such character is capable of being replaced by an alternative, and by the discovery of the alternatives (Allelomorphs) the exact nature of the units can alone be determined. A character like stature or other dimension of an animal is obviously a complex one which could not be expected to follow the Mendelian mode of inheritance as a whole, unless groups of characters are supposed to be capable of remaining connected together in some obscure manner and of being transmitted as a single character.

Blended inheritance is the antithesis of exclusive inheritance: and in the case of the latter the Mendelian relationship can be readily understood on the simple and ingenious supposition propounded by Mendel of the segregation of the germinal cells. The extreme Mendelian school tend to deny the existence of real blended inheritance; they attempt to explain

the apparent blending as arising through the character being a compound one which requires analysing into its component parts before the Mendelian relationship can be recognised.

In breeding experiments for testing the occurrence of the Mendelian relationship it is most important, as was pointed out by Prof. Weldon some years ago, that the categories into which the offspring are grouped should be clearly defined. In practice it is sometimes extremely difficult to sort out the offspring into clearly defined groups, and unfortunately it may become a matter of personal judgment as to whether an individual should be placed in one or another category.

Colour, independently of its distribution, may doubtless be regarded sometimes as a simple character, and if the present hybrid were fertile, and the Mendelian relationship occurred, we should have, assuming that the yellow was dominant, 25 per cent. sulphur-yellow offspring (pure dominants), 25 per cent. red offspring (pure recessives), and the remaining 50 per cent. would be yellow impure dominants. But the character of the hybrid of the first generation does not favour the view that such a result would be obtained. Neither colour is dominant, but the yellow and red have blended to form a kind of orange in which there is more yellow than red. I have not attempted to obtain a numerical expression for the amount of the two colours in the orange of the hybrid, although possibly such could be obtained.

Again, the possession or absence of a sulphur-yellow lanceolate recurved feathered crest as seen in *C. galerita* might be conceivably a simple character; but the feathers in the hybrid corresponding to the recurved crest-feathers of the male are not recurved, they are relatively wider and much shorter, and they are in fact more or less intermediate in character between the feathers in the male and female.

Thus in every character examined, with the possible exception of coloured and non-coloured lores, there is a very obvious blending of the male and female characteristics; and although the external appearance of any hybrid is not to be regarded as an absolute guide to its inherent gametic

character, the evidence, as far as it goes, would point to a real blending of the characters of the parents, and the probable absence of so-called gametic purity, or the segregation of characters in their sexual elements.

If characters do not blend, and each hybrid parent, whatever the external appearance may be, produces germ-cells in equal numbers capable of producing either one character or the other, but not a mixture of both, then the relationship found by Mendel and others would naturally follow in the offspring by the law of chance in the fortuitous union of the male and female elements.

The hybrids of Mendel, De Vries, Bateson, and other observers are more generally crosses of varieties of the same species, and the reason why the crosses between different species have not been more often employed is owing to the fact that these hybrids are frequently sterile among themselves; but it might be reasonably expected that the appearance of dominant characters would be more often observable in the first generation of hybrids of distinct species, if any approach to gametic purity actually occurred in their sexual cells.

If differentiation of the sexual cells with regard to alternative characters of the parents really occurs in these hybrids, it is highly remarkable that the parent-hybrid itself should usually be approximately intermediate in all its characters between the two parent-species. The fact indicates that the great majority of the characters are capable of blending. Should the Mendelian relationship possess that universality which some are inclined to attribute to it, the hybrids derived from the crossing of distinct species ought certainly to afford some decisive evidence in its support.

It is becoming increasingly obvious that Mendel's law in its original sense is of quite limited application, since very many apparently simple characters appear to blend intimately, so that there can be no question of gametic purity or segregation.

Into the debatable question that the blending is only apparent, owing to the characters being complex ones which

require analysing into their component parts before the Mendelian relation becomes apparent, I cannot enter here, and can but remark that this view offers a wide field for experimentation.

EXPLANATION OF PLATE II,

Illustrating Dr. E. Warren's paper, "A Case of Hybridism among Cockatoos."

FIG. 1.— $\times \frac{3}{4}$. Side view of head and neck of *Licmetis nasica*, female-parent.

FIG. 2.— $\times \frac{3}{4}$. Similar side view of *Cacatua galerita*, male-parent.

FIG. 3.— $\times \frac{3}{4}$. Hybrid three years old.

FIG. 4.— $\times \frac{3}{4}$. Hybrid three months old.



1.



2.



3.



4.

On South African Enneæ, with Descriptions of New Species and Varieties.

By

Henry Clifden Burnup.

With Plates III, IV, V, and Text-figs.

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INTRODUCTION.

IN the following pages an attempt is made to clear up some of the difficulties that stand in the way of the student seeking an intimate acquaintance with the genus *Ennea*, as represented in South Africa. Special attention is given to the comparison of kindred forms and to the consideration of the value of the differences between one form and another, whether they amount, in the opinion of the writer, to specific or varietal distinction, or are too trivial to warrant separate treatment.

The result of the investigation, as far as it goes, is the recommendation that seven species and two varieties be considered synonyms, and two species be degraded to varietal rank. It has been found necessary to differentiate six varieties of known species, and four species that do not seem to have been described.

The alterations involved are as follows: *Ennea labyrinthea*, *microthauma*, *hypsoma*, *oppugnans*, and *periploca* of *Melv. & Pons.* to become synonyms of *Ennea farquhari* *Melv. & Pons.* f. *typica*; *Ennea callista* *Melv. & Pons.* to become a synonym of *Ennea mariæ* *Melv. & Pons.*; *Ennea parallela* *Melv. & Pons.* to become a synonym of *Ennea montana* *Melv. & Pons.*; *Ennea isipingoënsis* *Stur.* var. *cylindrica* *Stur.* to become a synonym of *Ennea isipingoënsis* f. *typica*; *Ennea isipingoënsis* var. *simillima* *Stur.* to become a synonym of *Ennea isipingoënsis* var. *discrepans* *Stur.*; *Ennea berthæ* *Melv. & Pons.* to become a variety of *Ennea farquhari* *Melv. & Pons.*; and *Ennea vitreola* *Melv. & Pons.* to become a variety of *Ennea columnella* *Melv. & Pons.*

The new varieties introduced are as follows: *Ennea isipingoënsis* *Stur.* var. *sturanyi*; *E. elliptica* *Melv. & Pons.* var. *manca*; *E. elliptica* *Melv. & Pons.* var. *cælata*; *E. farquhari* *Melv. & Pons.* var. *avena*; *E. darglensis* *Melv. & Pons.* var. *illovoensis*; *E. maritzburgensis* *Melv. & Pons.* var. *contracta*. And the species, described as new, are: *Ennea melvilli*, *E. mooiensis*, *E. inhluzaniensis*, *E. ponsonbyi*.

It has also been thought desirable to re-describe and re-figure a few forms whose original descriptions and figures appeared to be erroneous or insufficient in detail, or had been published in works not easy of access to South African readers.

The difficulty presented by the writer's inability to examine the types in the British Museum has largely been overcome by the readiness of friends on the spot to compare them with specimens and drawings sent for the purpose, and to report upon such coincidence or disagreement of character as might be observed. To those ready helpers the writer's most cordial thanks are extended, and their special services are duly acknowledged under the heads of the several species involved. No less are sincere thanks due to those who have supplied material for study, prominent among whom are Messrs. J. H. Ponsonby, J. Farquhar, and A. J. Taynton.

The types of the species and varieties described as new, together with a few of the other shells figured herein, will be deposited in the British Museum. A reference to the explanation of the plates at the end of this paper will show the resting-place of each shell figured.

SYSTEMATIC ACCOUNT.

Ennea isipingoënsis *Sturany*; and its varieties.

Through the kindness of Dr. Rudolf Sturany in lending me his types of this species and its three varieties described at the same time, I have been enabled to acquire a better

knowledge of the group than has hitherto been possible. After a careful examination of the original specimens, and a close comparison of them with about 140 other examples, collected principally by myself in various parts of the province of Natal, and three specimens collected by Mr. Farquhar in the province of the Cape of Good Hope, I am convinced that two of Dr. Sturany's varieties are superfluous, and that another form, hitherto undescribed, requires to be differentiated as a distinct variety, in order to make the group, so far as it is yet known, fully understood. In justice to Dr. Sturany, and in order to show how the mistakes have arisen, it is necessary to explain that the original material was very meagre, and insufficient for forming a just estimate of the value of the apparent differences; for Dr. Penther only found four specimens, which, appearing to show sufficient differences, were described provisionally as the type and three varieties. Moreover, the shells were very dirty, and, possibly through the fear of breaking unique specimens, had never been properly washed, for they reached my hands much obscured and disfigured by sand and leaf-mould. The specimen which was described as the variety *cylindrica* was calcined and had a large hole in the body-whorl, and to wash it would probably have led to its destruction; so I was reluctantly obliged to leave it as it was, except that with a damp brush I carefully removed enough of the mould from its aperture to expose the small basal tooth, which is said in the description to be absent, and to show more clearly the tooth within the outer lip, and the columellar plait, which are said to be respectively weaker and not very broad, to be practically identical with those of the typical form. The type of var. *discrepans* had the apex crushed in, but its general condition was such as to justify washing, though not syringing: the other two specimens were sound.

The fragile condition of the specimen described as var. *cylindrica* has prevented my re-figuring it and checking its dimensions, but new figures of the other specimens are

given, and their dimensions as taken by me will be found in the text. The original figure of the typical form does not require to be replaced, except for the convenience of having all the figures to be compared of one magnification.

The original description adequately differentiates the species, but, for the sake of convenience in comparison, it has been deemed advisable to re-describe it here, where also will be found an amended description of var. *discrepans* *Stur.*, and an original description of a new variety with which I have much pleasure in associating the name of the learned author of the species, who has rendered me such material help in the present study.

Ennea isipingoënsis *Sturany*, f. *typica*. Pl. III,
fig. 1.

Ennea isipingoënsis *Stur.*, Anz. k. Akad. Wissensch. Wien (1898), No. xvi, p. 157 (reprint p. 5); *Sturany*, Südafrik. Moll. (1898), p. 27, pl. i, fig. 19.

Ennea isipingoënsis var. *cylindrica* *Stur.*, *ibid.*, *ibid.*, fig. 22.

Ennea isipingoënsis *Stur.*; (sic) Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 77.

Shell small, cylindric-oval, tapering towards the blunt apex, nearly white, umbilicate; whorls $7\frac{1}{2}$, very convex, separated by very deep, almost channelled sutures, and very strongly transversely ribbed except the embryonal whorls, which are smooth, and immediately behind the peristome where the ribs become finer; the last whorl is thickened at the base, forming a callosity almost encircling the umbilicus, and then becomes constricted before expanding to form the peristome; aperture small roundish and furnished with the following plaits: A strong parietal plait arising higher on the body-whorl than the peristome and passing thence, embracing the parietal wall, to the interior of the shell; a long, strong squarish-pointed, tooth-like plait, almost bifid, arising near the margin and about the middle of the labrum, extending nearly to the

centre of the aperture, and the lower edge of it penetrating furthest inwards; near the base of the columellar lip, a small conspicuous tooth; at the base, and set further back than the two processes last named, an inconspicuous denticle; and a deep-seated, scoop-shaped columellar plait with mamillated point on the inner edge presented forwards; peristome white, broad, expanded and reflexed, the ends connected by a slight callus.

Height 2·83, width 1·47 mm.

HAB.—Isipingo, near Durban (Penther); other localities: Natal: Karkloof and Nottingham Road (Taynton), Lower Umkomaas, Umbogintwini, Ntimbankulu—Mid-Illovo, Maritzburg, Edendale, Dargle and Inhluzani (Burnup).

Cape of Good Hope: The Gorge, Van Staaden's River (Farquhar).

The umbilicus is rather widely open for so small an Ennea, and, as is usual in openly umbilicated shells of the genus, has a branch of the perforation passing into the columellar fold. In the type the callus connecting the ends of the peristome is not very clearly defined, and I can readily understand the author having overlooked its presence before the shell was cleaned. In most examples it is much better developed, sometimes obliterating the sculpture underneath, but in many instances, especially in rather young, though mature shells, allowing the ribs to be seen through it. On the outside of the shell can be seen, not only a large deep cavity corresponding with the strong labral plait, but also smaller, shallower pits marking the positions of the basal denticle and the basi-columellar tooth. The distribution, including a locality so remote as Van Staaden's River in the Cape Province, is worthy of note: the specimens from the last-named locality are quite normal.

Since I have shown the type of the variety *cylindrica* to be identical in its characters with the type of the species except in size and slightly in form, it becomes inadmissible to recognise it as a distinct variety. The dimensions given by the author show the two shells to be identical in the ratio of

width to height, though to me *cylindrica* seems perceptibly narrower. The following table of dimensions of a few shells that I have measured will indicate the futility of any attempt to identify a variety based on size and form alone.

Specimen.	Height.	Width.	Width × 100 Height.
<i>E. isipingoënsis</i> (type). Isipingo	mm. 2·83	mm. 1·47	51·94
var. <i>cylindrica</i> (original measurement). Isipingo	3·00	1·50	50·00
Inhluzani	2·74	1·66	60·58
	3·27	1·69	51·68
	3·18	1·85	58·18
Ntimbankulu	3·64	1·86	51·10
	3·94	1·73	43·91
Edendale	2·99	1·48	49·50
Umbogintwini	2·87	1·42	49·48
Lower Umkomaas	3·80	1·74	45·79
Average	3·23	1·64	51·22

The ratios given in the fourth column show great variability even in specimens from the same locality, e. g. Ntimbankulu.

Var. *discrepans* *Sturany*. Pl. III, figs. 2, 3.

Ennea isipingoënsis *Stur.* var. *discrepans* *Stur.*, Anz. k. Akad. Wissensch. Wien (1898), No. xvi, p. 157 (reprint p. 5); *Sturany*, Südafrik. Moll. (1898), p. 27, pl. i, fig. 20.

Ennea isipingoënsis *Stur.* var. *simillima* *Stur.*, Anz. k. Akad. Wissensch. Wien (1898), No. xvi, p. 157 (reprint p. 5); *Sturany*, Südafrik. Moll. (1898), p. 27, pl. i, fig. 21.

Shell like *E. isipingoënsis*, typical, but with the following differences: The contour is more oval and less cylindrical; the aperture is larger and rather oblique and triangular; the processes of the aperture are similarly placed but differ in the following respects: The labral plait is much enlarged, being both longer and wider, and bears a distinct, though minute, denticle on the upper edge; the minute basal denticle is replaced by an inconspicuous, scarcely raised, minute ridge,



whose presence is more easily detected by the corresponding depression and callosity behind the basal lip than by its appearance within; and the columellar plait is much swollen.

The labral and columellar plaits are so long that they overlap, the former in front of the latter.

Height, without apex, which is crushed into the shell, 2.69, width 1.45 mm.

Hab.—Isipingo, near Durban (Penther). Other localities: Umbogintwini and Equeefa (Burnup).

This variety, including var. *simillima* *Stur.* (fig. 3), which is identical in all essential characters, seems to offer nearly as much variation in size as the typical form, the dimensions of the only five specimens that I have seen being as follows:

Specimen.	Height.	Width.	$\frac{\text{Width} \times 100}{\text{Height.}}$
	mm.	mm.	
Type of var. discrepans from Isipingo	2.69	1.45	53.90
Type of "var. <i>simillima</i> " from Isipingo	2.72	1.48	54.41
Specimen from Umbogintwini	2.78	1.47	52.88
Specimens from Equeefa	3.49	1.77	50.72
	3.56	1.78	50.00
Average	3.05	1.59	52.38

The relative width to height is much more regular in this variety than in the typical form, so far as can be ascertained from so small a series.

Var. *sturanyi* n. Pl. III, figs. 4, 5, 6.

Shell like *E. isipingoënsis*, typical, but differing in the following respects: The labral plait is both longer and wider and is more compact, ending in a blunted or rounded point extending beyond the centre of the aperture; the columellar plate is also larger and extends to the centre of the aperture, thus passing slightly behind the point of the

labral plait; and the basal denticle is replaced by an inconspicuous, scarcely raised, minute ridge like that of var. *discrepans*. It differs from var. *discrepans* in being more cylindrical, in the labral process being less massive and more pointed, and in the total absence of the conspicuous denticle on the upper edge of the labral plait.

Height, 2·95, width, 1·55 mm.

Hab.—Ntimbankulu, Mid-Illovo (Burnup). Other localities: Karkloof (Taynton), Maritzburg, Howick and Dargle (Burnup).

The following dimensions of shells that I have measured will give an indication of the extent of variation in size and proportion that this form is liable to :

Specimen.	Height.	Width.	$\frac{\text{Width} \times 100}{\text{Height.}}$
Type of var. from Ntimbankulu	mm. 2·95	mm. 1·55	52·54
Specimens from Dargle	2·57	1·48	57·59
	2·80	1·52	54·29
	2·86	1·48	51·75
	2·91	1·49	51·20
	3·13	1·52	49·20
	3·03	1·47	48·18
	3·25	1·52	46·77
Average	2·94	1·50	51·44

It will be seen from the above table that, while this variety is less stable in ratio of width to height than the variety *discrepans*, it does not exhibit so much variation in that respect as *isipingoënsis*, typical. It will also be seen that, though some individual specimens of the other forms may be smaller than some examples of this, in striking an average of the shells measured, *sturanyi* is the smallest, and *isipingoënsis*, typical, the largest.

The nature and disposition of the armature of the aperture in the several forms remain remarkably constant, no inter-

mediate forms having been observed in the very large series examined.

Dr. Sturany has kindly perused my MS. and compared my figures with his original shells, and concurs in the elimination of the two varieties, *simillima* and *cylindrica*.

Ennea elliptica *Melv. & Pons.* f. *typica*. Pl. III,
figs. 7, 8, 9, 10, 11, 12.

Ennea elliptica *Melv. & Pons.*, *Ann. and Mag. Nat. Hist.*, vol. ii (1898), p. 126, pl. vii, fig. 2; *Connolly, Ann. S. Af. Mus.*, vol. xi (1912), p. 73.

In the original figure, which fairly well represents the characters of the peristomatal dentition, omitting, however, the internal columellar plait, the aperture is drawn out of all proportion to the rest of the shell. It is shown to occupy about 35 per cent. of the whole height, whereas in normal specimens it does not occupy more than about 28 per cent. This would make it appear either that the type is a malformed shell or that the figure is bad. As the authors had before them, at the time the description was written, four specimens agreeing in detail, it is not likely that the type is abnormal; therefore it is to be inferred that the figure is incorrect. In any case it seems desirable to publish a new figure, which is given on Pl. III, fig. 7. This drawing represents a normal shell from the original locality in the Botanical Gardens,¹ Maritzburg. Fig. 8, drawn from another specimen from the same locality, represents the right side of the shell and shows the striate sculpture on the last half whorl.

This species is very interesting in exhibiting, through large series from different localities, the undoubtedly close relationship between forms which, but for the intermediates, might possibly have been taken to be distinct species.

¹ The Botanical Gardens, Maritzburg, as a faunistic locality, must not be looked upon with suspicion as indicating the probability of molluscs having been introduced with plants from a distance. The spot indicated is a bush-clad hill within the boundaries of the gardens but not disturbed by cultivation.

In the bush skirting the beach near the mouth of the Tongaat River, the only place near the coast where I have met with this species, is found a form, quite typical except that it is rather small and has the peristome rather more thickened, and the processes very strongly developed. Two examples of this form are shown in figs. 9 and 10.

Next comes the typical form from Maritzburg at an elevation of a little over 2000 feet (fig. 7).

At Dargle, at an altitude of about 3700 feet, the shells are barely larger than those at Tongaat, and the lower tooth on the columellar lip has deteriorated into a mere inconspicuous callosity, as seen in figs. 11 and 12.

The next stage is seen in the shells found at Fort Nottingham and Curry's Post (altitude about 4000 feet), in which the height is rather greater, and the lower tooth of the columellar lip is suppressed altogether. I think this form may conveniently be regarded as a new variety, differentiated as follows.

Var. *manca* n. Pl. III, figs. 13, 14.

Shell like *elliptica*, typical, but generally rather larger, comparatively narrower, and without the lower tooth on the columellar lip.

Height 3.76, width 1.74 mm.

Hab.—Fort Nottingham; also Curry's Post, Natal (A. J. Taynton).

In a few specimens from these localities an almost imperceptible callosity may be detected in the position of the lower tooth of the columellar lip of *elliptica*, typical; but in by far the greater number there is no trace of it. There are also to be found in some specimens, especially those from Curry's Post, slight traces of the sculpture distinguishing the variety *cælata*, hereafter described, for the most part only infrasutural, but occasionally extending across the whorls. The Curry's Post specimens are rather wider than those from Fort Nottingham.

Yet another form, varying from the type in respects not

affecting the gradual evolution from the Tongaat form to the variety manca, that I have endeavoured to trace out above, occurs at Eshowe, Zululand. Mr. Ponsonby has placed in my hands for determination three examples of this form, which I propose to distinguish as a separate variety, *cælata*.

Var. *cælata* n. Pl. III, figs. 15, 16, 17.

Shell like *elliptica*, typical, but rather larger, more obese, with peristome rather thinner and less reflexed, covered all over, except the earlier whorls and the body-whorl above the aperture, with most delicate, fine, oblique striæ becoming stronger on the last half-whorl, where, however, they are not so strong as those in a similar position in the typical form.

Height 4·06, width 2·11 mm.

Hab.—Eshowe, Zululand (Ponsonby).

The other two specimens are not so obese as the type of the variety, which was chosen as being the best developed specimen. Thus, while they agree better with *elliptica*, typical, in contour, they are more divergent in their still greater height and yet thinner peristome. In all three the distinctive sculpture is clearly seen by the aid of a strong lens.

The following additional measurements will help to convey an idea of the variation as to size :

Specimens from various localities.	Height.	Width.	Figure on Plate.
	mm.	mm.	
F. <i>typica</i> , Maritzburg	4·05	1·82	fig. 7.
	3·84	1·87	
	3·75	1·85	
	3·60	1·73	
F. <i>typica</i> , Tongaat	3·17	1·63	fig. 9.
	3·14	1·71	fig. 10.
	3·11	1·65	
	3·38	1·64	fig. 11.
F. <i>typica</i> , Dargle	3·17	1·66	fig. 12.
	3·00	1·66	
	4·12	1·79	fig. 14.
Var. <i>manca</i> , Fort Nottingham	4·12	1·79	
Var. <i>manca</i> , Curry's Post	3·93	1·92	
	3·91	1·90	
Var. <i>cælata</i> , Eshowe	4·44	2·06	
	4·09	2·02	

In considering the figures illustrating the various forms of this species, it should be borne in mind that they are not all drawn to the same scale ; therefore it is the more desirable to keep in view the dimensions given above.

Ennea farquhari *Melv. & Pons.* f. *typica*. Pl. IV,
fig. 24.

Ennea farquhari *Melv. & Pons.*, *Ann. and Mag. Nat. Hist.*, vol. xvi (1895), p. 478, pl. xviii, figs. 3-5.

Ennea labyrinthea *Melv. & Pons.*, *ibid.*, p. 479, pl. xviii, figs. 7, 8.

Ennea microthauma *Melv. & Pons.*, *ibid.*, vol. iv (1899), p. 194, pl. iii, fig. 1.

Ennea hypsoma *Melv. & Pons.*, *ibid.*, vol. iv (1909), p. 488, pl. viii, fig. 7.

Ennea oppugnans *Melv. & Pons.*, *ibid.*, p. 488, pl. viii, fig. 8.

Ennea periploca *Melv. & Pons.*, *ibid.*, p. 489, pl. viii, fig. 10.

Ennea farquhari *M. & P.*; *Connolly, Ann. S. Af. Mus.*, vol. xi (1912), p. 74.

Ennea microthauma *M. & P.*; *Connolly, ibid.*, p. 80.

Shell minute, ovate-cylindrical, with rounded apex, rimate and narrowly perforate, thin, vitreous, transparent and shining; whorls $5\frac{1}{3}$, moderately ventricose, the first two smooth, the rest sculptured with regular transverse striae, strong below the suture and evanescent lower on the whorls, except the last, on which the sculpture continues round the base; suture moderately impressed; aperture triangularly auriform with thickened, expanded and reflexed, white, rather vitreous peristome, and furnished with the following processes: a prominent blade-like, in-running, parietal plait, a massive, blunt, lobed, labral tooth, a small internal basal tooth, an inconspicuous, broad, slightly raised tooth on, and parallel to, the columellar lip, and a deep-seated, rounded, flattish, scoop-shaped columellar plait.

Height 2·11, width 1·03 mm.

Hab.—Grahamstown (Farquhar and Langley); also Highlands (19 miles N. of Grahamstown) and Bathurst (Farquhar), all in the Cape Province. The locality, Bosch-

berg Mountain, Somerset East, given in the description of *Ennea periploca*, is erroneous (see p. 61).

The right side of the parietal plait, which is very prominent, arises higher on the body-whorl than the labrum; the upper lobe of the bipartite labral tooth is a little within the plane of the aperture, the lower is more internal; the short, broad tooth on the columellar lip is nearly level with the general plane of the peristome; and the small basal tooth stands well back from the edge. A narrow channel enters the columellar plait from the rimal cavity, and the teeth on the labrum, columellar lip and base, have corresponding excavations behind the peristome.

The types of all the so-called species here placed in the synonymy, being in the British Museum, are not available to me for examination, but I have been fortunate in securing, from the collections of Messrs. Ponsonby, Farquhar, and Langley, a very large series comprising co-types of every form, except that which was described as *E. labyrinthea*. These I have submitted to a searching study and careful comparison, and cannot doubt that all belong to one variable species, whose divergence from a common type is not wide enough to justify the retention of any of the later names in a varietal capacity. The form described as *Ennea berthæ Melv. & Pons.*, as represented by my co-type, *ex coll.* McBean, supported by seven other specimens from three localities in Natal, which undoubtedly also belongs to the same species, is specially considered hereafter.

Of the form described as *E. labyrinthea*, alone, I have been unable to obtain any reputed example, and so have only had the original description and figure to guide me in uniting it with *E. farquhari*.

Melvill and Ponsonby not being able to concur in my views, and I being unable personally to consult the types, and hesitating to make such a sweeping consignment to synonymy without reference to them, Mr. Ponsonby most kindly arranged, through Major Connolly, with Messrs. E. A. Smith and G. C. Robson, of the British Museum, that the two last-

named should examine my numerous camera drawings of all the forms under consideration (except, of course, labyrinthea), compare them with the types in the British Museum, and generally consider the case of synonymy that I had made out. Their deliberations have resulted in the following decision, dated at the British Museum (Natural History), Cromwell Road, December 6th, 1912 :

“ We have examined the seven species named below,¹ as requested by Major Connolly, and after careful consideration have come to the conclusion that, making due allowance for variability, the species in question are all indistinguishable from *E. farquhari* save in a few unimportant characters, the general characters of the aperture and dentition remaining the same in all seven.

(Signed) G. C. ROBSON,
E. A. SMITH.”

I am deeply indebted to these gentlemen, for without their co-operation my conclusions must have remained unconvincing through the possibility of the material studied by me being wrongly identified.

Major Connolly has been good enough to supply me with revised measurements of all the types, which in some cases vary considerably from those originally published; but it seems to me more useful to give here a selection of dimensions of specimens from the various localities, than to emend those of the specimens originally described under names which it is sought to show should drop out of use. To this resolve, however, it may be well to make exception in the cases of the original type of *E. farquhari*, and the shell originally described as *E. labyrinthea*—the former because it is the persistent type, and the original dimensions are manifestly wrong, no specimen in the large series examined approaching such an attenuate form as they indicate; and the latter because Major Connolly's measurement, if correct,

¹ “*E. farquhari*, *E. microthauma*, *E. hypsoma*, *E. periploca*, *E. oppugnans*, *E. berthæ*, *E. labyrinthea*.”

removes from the record dimensions that are suspiciously under-estimated.

His measurements are as follows :

E. farquhari *M. & P.* (type), height 2·80, width 1·50 mm.

E. farquhari (type of "labyrinthea"), height 2·05, width 1·20 mm.

Both of these shells were collected at Grahamstown.

The dimensions in the following table are selected from those of over forty specimens that I have measured, from the various localities in which the species in its typical form is known to live :

Locality.	Largest.	Intermediate.	Smallest.
	mm.	mm.	mm.
Grahamstown	2·35 × 1·07	2·20 × 1·04	1·89 × 0·99
Highlands, about 19 miles N. of Grahamstown	2·14 × 1·05	2·06 × 1·04	1·94 × 1·00
Bathurst, about 25 miles S.E. of Grahamstown	3·19 × 1·36	2·63 × 1·27	2·04 × 1·01

As these measurements are taken from the largest, the smallest, and an intermediate specimen from each locality, they indicate very fully the divergence of size and proportion of width to height to which the form is subject, the greatest development being reached at Bathurst.

Var. *berthæ* (*Melv. & Pons.*). Pl. IV, figs. 25, 26, 27.

Ennea berthæ *Melv. & Pons.*, *Ann. & Mag. Nat. Hist.*, vol. viii (1901), p. 315, pl. ii, fig. 1.

Ennea berthæ *Melv. & Pons.*; Connolly, *Ann. S. Af. Mus.*, vol. xi (1912), p. 67.

Shell like *E. farquhari*, typical, but elliptical in contour, with six, less ventricose, whorls and shallower suture; the striae are rather less regular, shorter, and a little further apart; the armature of the aperture is very similar, but the labral tooth is not quite so massive, and is less divided, the internal columellar plait is somewhat broader, and the short,

broad tooth on the columellar lip is even less conspicuous than in the typical form.

Height 2·84, width 1·50 mm.

Hab.—Karkloof (McBean & Taynton); Nottingham Road (Taynton); and Ntimbankulu, Mid-Illovo (Burnup), all in Natal.

The dimensions given above are those of a co-type of "E. berthæ *M. & P.*," from the original lot collected by Mr. McBean at Karkloof, now in my collection at the Natal Museum (Mus. No. 1441), and here figured. Those of the type in the original description are manifestly wrong, for they give a ratio of width to height of 35·71 per cent., while the figure represents a ratio of 50·98 per cent., the latter being well supported by my shell and new figure with a ratio of 52·11 per cent. It will be seen that if Melvill and Ponsoby's height dimension of 3·5 mm. be a misprint for 2·5, and the width measurement of 1·25 mm. be correct, a ratio of 50 per cent. is established, corresponding very satisfactorily with their figure; but in this case their shell is rather smaller than any that I have examined. The suggestion of a misprint, however, is supported by the fact of the dimension line alongside their figure being 2·6 mm. long.

The other known specimens of this variety, excepting the two in McBean's collection, whose dimensions I have not been able to ascertain, measure as follows:

Karkloof: height \times width, 3·11 \times 1·50, 2·85 \times 1·55, 2·79 \times 1·44 mm. Nottingham Road: 3·25 \times 1·52, 2·86 \times 1·50 mm. Ntimbankulu: 3·32 \times 1·59, 3·13 \times 1·57 mm.

Although Messrs. Smith and Robson concur in my view that this form belongs to the species *farquhari* *Melv. & Pons.*, they have expressed no opinion as to its claim to varietal distinction. I think, however, that such a distinction is not only desirable, but inevitable, since it can be distinguished from the typical form by the characters above enumerated, and inhabits a different district, the variety having only been met with in the Province of Natal, and the typical form in the Province of the Cape of Good Hope. In three of the

eight shells examined the distinction is not quite so fully maintained as in the other five, as the shells are longer without material corresponding increase in width, and the form therefore is less elliptical; but the other distinctions remain. The number of whorls increases with the additional height to $6\frac{1}{2}$, my largest specimen of *E. farquhari*, typical, having $5\frac{3}{4}$ whorls.

Var. *avena* n. Pl. IV, figs. 28, 29, 30, 31.

Shell small, cylindrical, with rounded apex, rimate and most narrowly perforate, thin vitreous, whitish, transparent and shining: whorls $6\frac{1}{4}$, only slightly convex, and, excepting for a few irregularly scattered faint transverse scratches, smooth all over, except the last half whorl, which is sculptured with regular distinct transverse rib-striae continued round the base; suture rather shallow; aperture somewhat broadly triangularly auriform, with well thickened slightly expanded and reflexed white porcellanous peristome, and furnished with the following processes: a prominent blade-like, in-running parietal plait, a massive, rounded, undivided labral tooth, a small internal basal tooth, a most inconspicuous, broad, very slightly raised tooth on, and parallel to, the columellar lip, and a deep-seated, rounded, flattish, scoop-shaped columellar plait.

Height 3·21, width 1·30 mm.

Hab.—Maritzburg; also Pinetown and Durban (Burnup), Nottingham Road (Taynton), all in Natal.

The axial perforation rises from a position so deep in the rima that it is difficult to detect, but the branch passing into the deep-seated columellar plait is more easily seen: depressions behind the lips correspond with the labral, basal, and columellar teeth.

This variety differs from *E. farquhari*, typical, in its generally greater size, its more cylindrical form with nearly parallel sides, less ventricose whorls, shallower suture, absence of defined sculpture except on the last half whorl, less expanded yet more thickened peristome, more open aperture

with more superficial, undivided labral process, and columellar tooth less developed so showing more of the deep-seated columellar plait behind it. From the variety *berthæ* it is separable by its more slender, cylindrical form, narrower columellar lip with more open aperture and solid, nearly superficial labral tooth, and generally the absence of striation, or when it is present above the last half-whorl, its extreme shortness.

The twenty-five specimens collected in Durban, one of which is shown in fig. 31, and two of those found in Maritzburg, are sculptured immediately below the suture with more or less regular, rather coarse, typical striation, which, however, soon disappears, leaving the remainder of the whorls almost smooth, except the last half-whorl, which is sculptured all over. With the presence of this infrasutural striation occurs a slight increase in width; otherwise the shells agree in all respects with the smoother shells from Maritzburg and those from Pinetown and Nottingham Road.

There is considerable variation in the height of individuals of this variety, though not much in width unless accompanied by the variation in sculpture; with an increase in height there seems to be invariably also an increase in the number of whorls: thus, the specimens that I have examined vary from 2.74 mm. to 3.51 in height, and the number of whorls from $5\frac{1}{2}$ to 7.

The following dimensions show very fairly the extent to which the variety, so far as is yet known, differs in size and proportion in various individuals:

The smoother form:

Maritzburg: 3.32×1.27 , 3.10×1.28 , 2.77×1.31 mm.

Pinetown: 3.41×1.33 , 2.74×1.33 mm.

Nottingham Road: 2.85×1.32 mm.

The form with infrasutural sculpture:

Durban: 3.51×1.45 , 3.30×1.45 (fig. 31), 3.02×1.45 mm.

Maritzburg: 3.37×1.45 , 3.33×1.47 mm.

These dimensions, which are chosen to include the most divergent forms of the shells examined, well show the re-

markable stability in width of this variety. Among the smooth shells there is a difference in height, between the extremes, of .67 mm.; but in width there is no more than .06 : among those with infrasutural striation there is, in height, a difference of .49 mm., and in width only .02.

Ennea darglensis *Melv. & Pons.* f. *typica*. Pl. IV,
fig. 32.

Ennea darglensis *Melv. & Pons.*, *Ann. and Mag. Nat. Hist.*, vol. i
(1908), p. 130, pl. vii, fig. 1.

Ennea darglensis *Melv. & Pons.*; *Connolly*, *Ann. S. Af. Mus.*, vol.
xi (1912), p. 71.

The original figure not showing clearly the complex character of the columellar plait and representing the labral tooth as rather too solid and the sculpture too sharply defined, the result possibly of over-magnification, a new figure is here offered. The magnification chosen, about $10\frac{2}{3}$ diameters, is the same as that adopted for the figures of the new variety hereunder described, so that a fairer comparison of the variety with the typical form can be made, using the new figure instead of the old.

The sinuous, duplicate columellar plait is a conspicuous characteristic of the species. The upper branch is wholly internal with its point produced forward; and the lower, and larger, is less deep-seated, its base arising near the edge of the columellar lip with its point curving inward. From the rimal cavity an axial perforation passes upwards, and, at a right angle thereto, a deep, narrow passage enters each branch of the columellar fold. The labral and basal processes are also indicated by depressions behind the peristome. The labral tooth is more distinctly bifid than the original figure suggests, the upper branch being longer, and the lower more internal.

To the localities cited by Connolly, in his most useful "Revised Reference List of South African Non-marine Mollusca,"¹ may be added Bulwer, near which village, in

¹ 'Annals of the South African Museum,' vol. xi (1912), pp. 89-306.

the District of Polela, Mr. C. W. Alexander has collected a single specimen while these notes were being written. It is a good deal smaller than any of the specimens from the other localities, but in form is exactly proportionate to the shell here figured, and is identical in all detail.

The locality Gowie's Kloof, Grahamstown, cited in the same place, is erroneous, and should be expunged. The shell on which the locality was cited is not *darglensis*, but is *Ennea ponsonbyi n. sp.*, described hereafter, p. 78.

The following are the dimensions of such shells as I have measured, besides the type :

From Inhluzani: height \times width, 2.69×1.25 , 2.62×1.18 , 2.54×1.18 , 2.53×1.19 (fig. 32), 2.46×1.12 . From Bulwer: 2.23×1.07 mm.

The first and second on the list are picked, as appearing to be the largest, from a series of about seventy specimens.

Var. *illovoensis n.* Pl. IV, figs. 33, 34, 35.

Shell small, rimate and narrowly perforate, elongate ovate-cylindrical, thin, glossy, transparent, whorls $6\frac{1}{4}$, rather convex, almost smooth except the last half-whorl and the base which are regularly rib-striate; suture rather shallow; aperture rather quadrate and somewhat oblique, with white, thickened and reflexed peristome armed with the following plaits and teeth: A broad blade-like, squarish parietal plait, a deeply cleft labral tooth, a small, sharp in-running basal tooth-like plait, and a complicated two-pointed columellar plait with detail as in *darglensis*, typical.

Height 2.92, width 1.37 mm.

Hab.—Ntimbankulu, Mid-Illovo (Burnup).

In form and arrangement of the armature of the aperture, this variety almost coincides with the type. The upper branch of the labral tooth in the variety is squarish at the end instead of pointed, and the complex columellar process is situate a little lower; but, though these features seem constant in the specimens examined, they are but trifling divergencies such as might be looked for in individuals of the same form.

There are, therefore, only the superior size and the smooth polished surface to distinguish the variety from the typical form; but these are sufficiently marked to warrant, in my opinion, the assigning of a varietal name to the form from Mid-Illovo, even if intermediates be eventually found.

I have examined a great number of each form and find them very constant. The dimensions of other specimens from the same locality, that I have measured, are as follows: height \times width, 3.07×1.40 , 2.87×1.35 , 2.83×1.34 , 2.80×1.34 , 2.72×1.38 mm.

In most specimens there is the appearance of a "margined suture": but I look upon this as an optical illusion rather than a shell character, not only in this species, but in most South African *Enneæ* where it occurs. The lower sutural line cannot be felt with the point of a fine needle, and is, without doubt, merely the base of the previous whorl seen through the transparent shell. As the shell becomes calcined the illusory line vanishes.

Ennea consobrina *Ancey*. Pl. IV, fig. 36.

Ennea consobrina *Ancey*, Brit. Nat. (1892), p. 125; Melv. & Pons., Ann. and Mag. Nat. Hist., vol. i (1898), p. 24, pl. viii, fig. 9.

Through the courtesy of Mr. J. R. le B. Tomlin, in entrusting to me for examination the type-specimen from his collection, I have been enabled to identify further examples of this little-known species, collected by Mr. Farquhar at Martindale, Bathurst, a division of the Province of the Cape of Good Hope, adjoining that of Albany, in which the type was found. I have also taken the opportunity of having the type temporarily in my possession to re-figure the shell, it not having been figured in the first instance, and the figure published by Melvill and Ponsonby in 1898, though bearing some general likeness to the shell, not showing enough detail for purposes of comparison. *Ancey* rightly compares his species with *E. thelodonta* *M. & P.*, but, while stating that the denticles in both species are similar, though somewhat

different, does not specify in what respects they differ. Melvill and Ponsonby's figure of *Ennea thelodonta*¹ is confusing, showing at the same time, to a great extent, a side view of the spire, and a front view of the aperture; besides, the detail is faulty. I therefore present a new figure of their species (fig. 37), for comparison with that of *consobrina*. It will be seen from these that the likeness between the two species, though striking, is only superficial, the detail of the labral tooth and columellar plait in each being of quite a distinct character. In *consobrina* the large labral process bears on the inner edge two distinct, little in-running plaits: in *thelodonta* a somewhat similar, but smaller, process is merely slightly divided into two lobes. In *consobrina* the deep-seated columellar plait is strengthened by a transverse rib; in *thelodonta* it is merely drawn forward at the lower, inner corner, into a rounded point. In neither case does it seem likely that the difference between these processes is the result of the direct evolution of one form from the other, for they seem to be constructed on different plans; therefore I consider the two species quite distinct. In addition, there is, as pointed out by Ancey, the difference in size and number of whorls, which is very considerable, though probably not quite so great as would appear from a comparison of the descriptions; for, while Ancey describes his shell as 8 mm. high and 4 mm. wide, or, as he says, twice as large as *thelodonta*, which is described as 4 mm. high and 2 mm. wide, my measurement of Ancey's type makes it 8 mm. high and 3.7 mm. wide, while my two specimens of *thelodonta* measure as follows:

Height \times width, 4.87 \times 2.26, 4.25 \times 2.15 mm. (fig. 37).

These specimens were collected at Port Elizabeth by Mr. J. Farquhar.

Other specimens of *E. consobrina* examined by me measure as hereunder:

In my collection at the Natal Museum, 7.75 \times 4.0; in collection of J. H. Ponsonby, 7.75 \times 3.67, 7.75 \times 3.67 mm.

¹ 'Ann. and Mag. Nat. Hist.,' vol. ix (1892), pl. vi, fig. 4.

The dimensions of the remaining specimen in Mr. Ponsonby's collection were not taken, as, the lip at the base being chipped, they would be misleading.

As regards the difference in the number of whorls, while Ancey describes his type as having 8 whorls, I can but count $7\frac{3}{4}$; and while Melvill and Ponsonby assign 6 as the number of whorls in their type, their figure seems to indicate about $6\frac{1}{2}$ or $6\frac{3}{4}$, and my specimens have $6\frac{3}{4}$ and 7 whorls respectively.

Ennea munita *Melv. & Pons.* Pl. IV, fig. 38.

Ennea munita *Melv. & Pons.*, Ann. and Mag. Nat. Hist., vol. ix (1892), p. 86, pl. vi, fig. 5.

Shell small, rimate, ovate-cylindrical, whitish, transparent, shining, rounded towards the blunt apex; whorls about 7, only slightly ventricose, rather strongly sculptured with regular transverse striæ, except the first two, which are smooth, and the area immediately above the aperture, which is nearly smooth and brightly polished; suture rather shallow; aperture rather long and ear-shaped, with thickened, much expanded, and slightly reflexed, white porcellanous peristome furnished with the following teeth and plates: a comparatively small, blade-like, in-running parietal plait, a massive, rounded tooth on the labrum bearing a denticle on the upper edge, a small, deep-seated basal tooth, a rather broad, short, expressed tooth, tapering below and ending abruptly above, on the columellar lip, and a very deep-seated, rounded mammillate columellar plait.

Height 3.58, width 1.86 mm.

Hab.—Griqualand East; also Kowie (Ponsonby and Langley).

The original description being rather deficient and the original figure indistinct and misleading, I have described and figured a specimen in my collection given to me by Mr. Ponsonby. Major Connolly, who has kindly compared for me the figure with the type in the British Museum, writes that the only differences he could find between the type and

my figure are that the columellar lip of the former is of more uniform breadth than that of the figure, and the prominence on the deep-set columellar plait is not situate quite so high.

There is a certain resemblance between this species and *Ennea crassidens* Pfr., but the greater size, the ovoid form and conical apex, and the shortness and squareness of the labral tooth of the latter are enough to distinguish it at a glance. It also seems to bear some resemblance to *Ennea tharfieldensis*, M. & P., a species unknown to me except from description and figure. Connolly has kindly compared the two types in the British Museum, and considers the latter sufficiently distinct through the presence of a denticle at the junction of the columella and the paries, should this feature prove to be constant. The colour attributed to the type in the original description probably arises through the remains of the animal being seen through the transparent shell. The upper whorls of my shell have an ochraceous tint from the same cause.

From the rima a deep narrow channel passes into the deep-seated columellar plait, but no axial perforation can be distinguished. The processes on the outer and the columellar lips and at the base have corresponding depressions on the outside of the shell.

Besides the shell figured I have been privileged to examine two specimens in Mr. Ponsonby's collection and three in Mr. Langley's, all from Kowie. They are all much larger than the specimens from Griqualand East, but exhibit no important variation. A slight difference in the development of the peristome and its processes may be observed, but not to any material extent.

The dimensions of the specimens from Kowie are as follows:

Height \times width, 4.94 \times 2.18, 4.94 \times 2.13, 4.84 \times 2.29, 4.40 \times 2.15, 4.34 \times 2.14 mm.

Ennea sylvia *Melv. & Pons.* Pl. III, figs. 18, 19, 20.

Ennea sylvia *Melv. & Pons.*, Ann. and Mag. Nat. Hist., vol. xii (1903), p. 599, pl. xxxi, fig. 4; Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 86.

Another species, hereafter described as *E. melvilli*, from Natal, having been mistaken for, and distributed as, *E. sylvia* *M. & P.*, it has become necessary to examine critically the characters, description, and figure of the older shell before describing the new, and to re-figure the former with a magnification corresponding to that chosen for the figures of the latter, in order to make comparison easier. For this purpose I have been able to examine the four co-types in Mr. Ponsonby's collection and three shells from the original lot, presented to me by Mr. Farquhar; and from the latter I have chosen my type for the new figure, the co-types being unsuited to the purpose in that one has a broken peristome, one is holed, one is abnormally large, and the fourth has a slight extraneous obstruction within the aperture which I failed to remove. Though unsuitable for figuring, their characters are quite sufficiently revealed to leave no room for doubt that my other three specimens belong to the same species.

In the original description a contradiction occurs in that the teeth and plaits are said to be *four*, while the details of *five* are given. Five is the correct number, of which the deep-seated internal columellar plait is more than mammæ-form, having a strong rib across it, obliquely from left to right and downwards. The small basal "tooth" is a small in-running plait, and that on the columellar lip appears like a triangular swelling, but is well excavated from behind. From the rima a very narrow perforation rises up the axis with a wider branch into the deep-seated columellar plait. Besides the processes of the aperture detailed in the original description there is a very inconspicuous thickening of the shell on the base forming a slightly raised ridge, hardly amounting to a plait, parallel to the basal lip and behind the basal and labral processes. A slight corrugation indicates its position

externally, and the outer wall bears a double pit corresponding to the bifid labral plait.

If the dimensions of the type as given in the original description, viz. height 1·75, width 0·75 mm., are correct, they cannot be considered normal in view of the measurements of the remaining available specimens, which are as follows:

Co-types in collection of J. H. Ponsonby: height \times width, 2·58 \times 1·06, 2·26 \times 1·01. Specimens in my collection: 2·25 \times 1·06, 2·25 \times 1·01, 2·06 \times 0·96 mm. (figs. 18–20).

I regard the first of these as being abnormally high.

Ennea melvilli n. sp. Pl. III, figs. 21, 22, 23.

Shell minute, elongate-oval, rimate, thin, whitish, glossy, transparent, apex rounded; whorls 6, rather ventricose, very closely, finely sculptured with delicate transverse rib-striae, except the first two, which are smooth; suture moderately deep; aperture very small, rather roundly triangular, with white peristome slightly thickened and reflexed and joined by a narrow callus, and furnished with the following plaits and teeth; a broad blade-like parietal plait, a squarish, bifid tooth on the outer lip, a small basal in-running plait, a broad, slightly raised, rounded tooth on the columellar lip, a deep-seated, rounded, scoop-shaped plait on the columella, and a slightly raised ridge within, and nearly parallel to, the basal lip.

Height 2·12, width 0·91 mm.

Hab. — Nottingham Road (Taynton); also Karkloof (McBean), Curry's Post and Fort Nottingham (Taynton), Dargle and Edendale (Burnup).

The parietal plait is very prominent, the right edge standing well forward from the general plane of the peristome before entering the aperture; its left edge is shorter and more internal. The bifid labral tooth arises very near the edge of the peristome, the lower half being rather more internal. The

small basal tooth-like plait arises but little within the edge of the peristome at the base of the columellar lip and curves inwards and upwards slightly to the left. The process on the columellar lip, which I have above called "a broad, slightly raised, rounded tooth," consists of an inward bend of the lip covered by its outward expansion, and is quite superficial. The deep-seated columellar fold, which is wholly internal, is rounded in outline, scoop-shaped, and presents its right, lower edge furthest forward. The ridge across the base is very inconspicuous, and might easily be overlooked; its position, however, can be traced on the outside by a slight corrugation. The positions of the other processes, except the parietal, are also indicated externally by corresponding depressions. The peristome, which is comparatively but little thickened, is exceedingly sinuous on the labrum (fig. 22). From the rima there is a deep opening passing into the columellar fold, but none can be detected into the axial perforation.

Besides those of the type the following dimensions of normal specimens have been taken: Dargle: height \times width, 2.12×0.88 , 2.10×0.88 , 2.05×0.89 . Nottingham Road: 2.04×0.89 , 2.07×0.89 , 2.00×0.91 , 1.94×0.89 mm., and the following are the dimensions of the largest and smallest examples in my collection, both manifestly abnormalities: Nottingham Road, 2.60×0.91 ; Dargle, 1.83×0.93 mm.

This shell has been confused with *E. sylvia* *M. & P.*, but though the armature of the aperture is arranged much on the same plan, only one plait differing very materially, this fact, I think, must be taken as an indication of parallel development rather than close affinity, for in all other important respects the two species vary widely. The form of this species is elongate-oval or fusiform; that of *sylvia* cylindrical, with almost parallel sides. In *sylvia* there is an umbilical opening from the rima, fairly wide for so small a shell; in *melvilli* it seems to be closed. *Melvilli* has rather more than half a whorl in excess of *sylvia*, the whorls of the former being more ventricose and separated by deeper sutures: with the exception of the embryonal whorls, they

are most finely, delicately, closely and regularly rib-striate; while *sylvia* is nearly smooth, except for a few irregularly dispersed striæ, all over except on the last half-whorl, where the striæ become more regular and more clearly defined. The aperture is smaller, and the peristome much less thickened and expanded in *melvilli* than in *sylvia*, and the parietal plait is larger and more prominent, the labral tooth smaller and less distinctly divided, the "tooth" or swelling on the columellar lip is less angular, and the internal columellar fold is of quite a different nature, being simple instead of crossed by an oblique strengthening rib as in *sylvia*. The profile of the outer lip, too, is much more sinuous in *melvilli*.

The specimen with the abnormal height of 2.6 mm. is no wider than the type, has fully 7 whorls and has the peristome scarcely thickened, leaving the swelling of the columellar lip undeveloped; the internal columellar fold is small.

Ennea columnella *M. & P.* (Pl. V, fig. 47), is found in company with this species at Karkloof, Dargle, and Edendale, and, both being much of the same size, a critical comparison may here be convenient.

The form of *columnella* is rather wider and less fusiform; the surface is almost smooth, except immediately below the suture, where irregular microscopic striation may be detected in a few places, and on the last half-whorl where somewhat regular striation appears; the parietal plait is narrower, the labral tooth more widely bifurcate, the basal tooth smaller and more central, the slight ridge across the base of *melvilli* is absent, and the columellar plait is of quite different construction (see *postea*, p. 58). With the assistance of a moderately powerful hand-lens their separation is quite easy.

I have pleasure in dedicating the species to Dr. J. Cosmo Melvill, who has done so much towards the elucidation of the South African non-marine molluscan fauna.

This is the form referred to by Connolly¹ as examples from Natal, distinct from *E. sylvia*, whose habitat is Maeström Forest, Bedford, Cape of Good Hope.

¹ *Ibid.*, p. 86.

Ennea columnella Melv. & Pons., f. *typica*. Pl. V,
fig. 47.

Ennea columnella Melv. & Pons., Ann. and Mag. Nat. Hist., vol. viii
(1901), p. 316, pl. ii, fig. 2; Connolly, Ann. S. Af. Mus., vol. xi
(1912), p. 69.

In the original figure the parietal plait appears to be wholly internal, which is quite wrong, as its right side arises above, and in front of, the aperture. Hence a new figure has become necessary in order that comparison with kindred forms may be facilitated. In the original description the true nature of the very distinctive columellar plait is not very clearly set forth. It is not, as is usual in the South African *Enneæ*, wholly internal; but, from the lower inner edge of a flattish, somewhat scoop-shaped internal surface, a strengthening rib curves outwards almost to the outer edge of the labium. By this feature the species can be readily distinguished from other species of similar size and superficial likeness.

I have not found the peristomatal processes of the many examples that I have examined exhibit among themselves considerable variation, as Melvill and Ponsonby did in the original lot; but, as one of my "co-types" belongs to a different species, described in this paper as *Ennea melvilli*, the divergence from the type that they observed seems easily explained.

The figure here presented is drawn from a co-type in my collection from the original lot found by McBean in the Kar-kloof Bush. The shell measures as follows: Height 2.15 mm., width 1.00 mm., and is the largest that I have examined.

The following measurements of shells collected by me at Dargle have also been taken:

Height \times width: 2.08 \times 0.89, 2.06 \times 0.93, 1.99 \times 0.92,
1.99 \times 0.90, 1.98 \times 0.90, 1.97 \times 0.94, 1.87 \times 0.92 mm.

The original width dimension of .75 mm. is probably wrong, as the original figure, taking the height as 2 mm., represents the width to be 1 mm., and Connolly's measurement of the type as communicated *in lit.*, gives height 2, width 0.9 mm.

Since the above was written, my attention has fallen upon two shells collected by me in the year 1900 in the Beach Bush at Lower Umkomaas, which could not be identified at the time but undoubtedly belong to this species. Their dimensions are as follows :

Height \times width: 1.94×0.79 , 1.82×0.83 mm.

Though among the smallest measured, their ratio of width to height corresponds with the typical form rather than with the more obese variety *vitreola*, considered below. In fact, the higher of the two is the most attenuate of all.

This newly cited locality is interesting, as but few species, at least in typical form, are found both on the coast and in the higher altitudes of the midlands.

Var. *vitreola* (*Melv. & Pons*).

Ennea vitreola *Melv. & Pons.*, Ann. and Mag. Nat. Hist., vol. i (1908), p. 130, pl. vii, fig. 3; Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 87.

I cannot separate this form from the preceding, except on the grounds of its more ovoid contour with shallower sutures, and the slightly weaker development of the peristome and peristomatal processes. The general appearance of the shells in other respects, their sculpture, and the arrangement of the peristomatal processes, are almost identical. The type having been reported lost, I sent the better of the co-types to take its place; and this, I believe, is the specimen now in the British Museum. The remaining co-type is in my collection at the Natal Museum.¹

Although the exact locality at Hilton Road has been diligently searched several times since the original shells were discovered, no further examples of the variety, and no specimen of the typical form at all, have been found until the present time (November, 1913), when, a final effort being made, one specimen was obtained confirming the varietal

¹ Connolly's statement, in loc. cit., that the type is in Maritzburg, is incorrect.

features to a marked extent, it being even shorter than any of the others, with a greater relative width.

In my co-type of this variety and in the newly found specimen the two parts of the labral tooth are more distant than the original figure shows to have been the case in the type, so bringing them slightly nearer to the typical form of *E. columnella*. The strengthening rib connecting the columellar plait with the columellar lip is rather more tortuous than in the type (of *vitreaola*), but I do not consider that an important feature.

The following are the dimensions of the only four specimens known :

	Height.	Width.
Type of <i>E. vitreaola</i> (lost) . . .	1·87	0·94 mm.
Co-type in British Museum . . .	1·82	0·92 „
„ „ Natal Museum . . .	1·81	0·93 „
Specimen collected 10th Nov., 1913	1·76	0·92 „

The ratio of width to height in above varies from 50·27 to 52·27 per cent., while that of the measured specimens of *columnella*, typical, from Dargle, varies from 42·31 to 49·20 per cent., and that of the higher shell from Lower Umkomaas is 40·72 per cent.

I am indebted to Messrs. E. A. Smith, Connolly, and Preston for their views on the relationship of these two forms, *E. columnella*, typical, and var. *vitreaola*, arrived at during a discussion over the type of the former and co-type of the latter in the British Museum. It is at their suggestion, in which I now fully concur, that I have retained the distinction of the Hilton Road form under the name *vitreaola* used in a varietal sense.

Although it will be seen that one of the Lower Umkomaas specimens of *E. columnella* is even shorter than the type of *vitreaola*, it agrees in every respect except size with *columnella*, typical, its relative proportions being about equal to an average example of the Dargle specimens. The most stunted example from Dargle approaches the proportions of the variety *vitreaola*, but can readily be distinguished

by its more cylindrical, less ovoid, form, and its deeper suture.

Ennea mariæ *Melv. & Pons.* Pl. V, fig. 48.

Ennea mariæ *Melv. & Pons.*, Ann. and Mag. Nat. Hist., vol. ix (1892), p. 92, pl. vi, fig. 12.

Ennea callista *Melv. & Pons.*, *ibid.*, vol. iv (1909), p. 486, pl. viii, fig. 1.

As neither the original figure of *E. mariæ* nor that published with the description of "*E. callista*" is drawn in true proportion, or expresses clearly the characters of the species, I take this opportunity of publishing a new figure. For this purpose I have been fortunate enough to secure the loan from Mr. Ponsonby of one of the original specimens collected by Miss M. Bowker at Somerset East. I have also examined one specimen, collected by the late Mr. Crawford, in Mr. Ponsonby's collection, three specimens (co-types of "*E. callista*") in Mr. Ponsonby's collection, and three specimens collected by Mr. Farquhar at the same time as the type of "*E. callista*," two of which are in his collection and one in mine. All these specimens were found at Somerset East, the locality, "Dassy Krantz, Grahamstown," given in the description of "*E. callista*," being an error arising through the interchange of the contents of two boxes. Thus Somerset East remains the only known locality for *E. mariæ*. The other shells affected by the interchange were those described as "*E. periploca*"; so Somerset East cannot be accepted as a locality for *E. farquhari*, of which "*periploca*" is a synonym, on our present knowledge of its distribution.

The tooth on the columellar lip is not connected with the internal columellar plait, as stated in the original description of *E. mariæ*, but is quite distinct as defined in the description of "*E. callista*." A narrow axial perforation rises from the umbilical slit, a branch entering the columellar fold; and the three peristomatal processes have corresponding depressions behind the lips.



The dimensions of the various specimens examined are as follows :

	Height. mm.	Width. mm.
Type of new figure (fig. 48), Miss M. Bowker	3.03	1.19
Mr. Crawford's specimen (in coll. Ponsonby)	2.78	1.18
Co-types of "callista" (in coll. Ponsonby)	2.79	1.17
	2.71	1.17
	2.71	1.17
Original specimens of "callista" (in coll. Farquhar).	2.70	1.24
	2.70	1.13
Original specimen of "callista" (in Natal Museum).	2.55	1.09

My examination of these well-authenticated examples leaves no room for doubt that they belong to one species; indeed, there is little individual variation among them. "E. callista" must, therefore, become a synonym of E. mariæ. I am indebted to Major M. Connolly, who has kindly examined the types in the British Museum for me, for the following confirmation of my views: "In E. mariæ the trace of a cusp on the upper part of the labral tooth is slightly more prominent than in E. callista. The rest of the dentition, together with the form and sculpture, is similar in both types, and the shells are undoubtedly conspecific."

He also furnishes me with the following revised dimensions of the types as taken by him :

"Type of E. mariæ, height 3.00, width 1.35 mm.

„ „ E. callista, height 2.80, width 1.30 mm."

Ennea mooiensis n. sp. Pl. V, figs. 49, 50, 51.

Shell minute, elongate-elliptical, deeply rimate, thin, glossy, transparent, apex blunt; whorls $5\frac{1}{2}$, rather ventricose, almost smooth except immediately behind the peristome where a few transverse striæ appear; suture not deeply impressed; aperture roundly triangular, with white peristome thickened and reflexed, the ends joined by a thin, narrow callus, and furnished with the following processes: a broad blade-like,

in-running parietal plait, a sub-central moderately large labral tooth slightly bifid, a small pointed tooth near the base of the columellar lip, a flattish scoop-shaped internal columellar plait whose lower right edge advances forward almost as a mammillate point, and a slightly raised ridge within the basal lip extending from behind the labral tooth downwards and forwards towards the base of the columellar lip.

Height 2.55, width 1.24 mm.

Hab.—Game Pass, Upper Mooi River, Natal (Burnup).

The details of the several processes as set forth under the description of *E. melvilli*, herein, would apply almost equally well to those of this species, but the following differences exist: the tooth near the base of the columellar lip is smaller, less erect, and less plait-like in form in this species; the broad, slightly raised, rounded tooth higher on the columellar lip of *melvilli* is here absent; and the ridge on the basal wall is less parallel with the peristome. Although so much of the description of the one species applies to the other, the greater dimensions, especially in width, the less fusiform contour, the larger aperture and the smoothness of the surface of this species distinguish it very readily from *melvilli*. The labral tooth and that near the base of the columellar lip have corresponding depressions on the outside, but the ridge on the basal wall does not seem to be excavated, though its position within can be traced on the outside by a white scar. The opening from the rima to the columellar plait is exceedingly narrow, while that to the axial perforation is even narrower, only being discerned by the aid of a very strong lens.

This species may also be compared with *E. columnella* *M. & P.*, whose peculiar columellar plait, however, will always readily distinguish it; besides, the latter is smaller, has traces of minute striæ below the suture, and much more numerous and stronger striæ on the last half-whorl, has the labral tooth much more widely bifid, and the basal tooth, or tooth-like plait, much more central and in-running.

The figures of *E. sylvia* *M. & P.* (Pl. III, figs. 18, 19, 20) and the comparison between that species and *E. melvilli* (p. 56) may here be referred to, for there is also some general likeness between the former species and *E. mooiensis*, which I think an examination of the figures and a perusal of the text, above indicated, will show to be only superficial.

The greater height and narrower, more cylindrical form of *E. mariæ* *Melv. & Pons.*, and the prominent tooth situate subcentrally on its columellar lip, prevent the possibility of it being confused with this species.

The following are the dimensions of a few specimens of *E. mooiensis* which, in addition to the type, I have measured: height \times width, 2.65 \times 1.25, 2.65 \times 1.16, 2.55 \times 1.21, 2.43 \times 1.19, 2.33 \times 1.18, 2.25 \times 1.12, 2.21 \times 1.19, 2.18 \times 1.18 mm.

This species is plentiful in its locality, almost to the exclusion of other species of the genus, but has not yet been found elsewhere. Whilst visiting the district twice, during the Christmas holidays 1910–1911 and 1911–1912, I collected 224 specimens of *Ennea*, 220 of which belong to this species and 4, all distinct inter se, to different, larger species not yet identified.

Ennea maritzburgensis *Melv. & Pons* f. *typica*. Pl. IV, figs. 39, 40, 41, 45, 46.

Ennea maritzburgensis *Melv. & Pons.*, *Ann. and Mag. Nat. Hist.*, vol. xii (1893), p. 107, pl. iii, fig. 11.

The original description seeming to require some slight revision, and the type being unavailable to me, I have chosen a normal specimen from the original locality as my type of the following emended description and accompanying new figures (Pl. IV, figs. 39, 40, 41).

Shell small, rimate and narrowly perforate, thin, whitish, subdiaphanous, shining; whorls 7, slightly convex, of which the first 2, constituting the protoconch, are smooth all over, the next 4½ are delicately, transversely striate immediately

below the suture, and smooth beyond, except for a few irregular striæ occasionally extending lower, or even passing from suture to suture, and the last half-whorl is regularly, similarly striate all over; aperture ovate; peristome white and shining, expanded and reflexed, and furnished with four processes, as follows: a moderately large, squarish, blade-like, in-running parietal plait, a large labral tooth widely bifurcate, the lower branch being much the larger, a small tooth near the base of the columellar lip, and a columellar plait, wholly internal and bearing a conspicuous, strengthening transverse rib.

Height 4.46, width 2.07 mm.

Hab.—Maritzburg, Natal, typical; and, aberrant, Nottingham Road (Taynton) and Rosetta (Hickey, per Ponsonby).

The axial perforation is very narrow and is easily overlooked; from it a branch passes at right angles into the strengthening rib of the columellar plait. The process within the labrum, originally described as two simple teeth, is, I think, better considered as one bifurcate tooth, as the two points spring from a common base, which is indicated on the outside by a single depression. The bifurcations, being solid, appear in this cavity as two white porcellaneous spots. The basiocolumellar tooth is barely excavated, and also appears as a white porcellaneous spot behind the peristome.

The dimensions given in the original description seeming to indicate a shell of smaller size and much narrower form than this species usually assumes, and not agreeing with the proportions of the original figure, Mr. Robson has kindly re-measured the type very carefully for me, and finds that its dimensions are, height 3.9, width 1.8 mm., almost exactly of the same relative proportions as the type of the new figure, but considerably smaller. On finding the emended dimensions so much smaller than those of any of my shells collected within recent years, I looked up my earliest examples, found about the same time as the type, and have picked out two nearly as small, measuring respectively 4.05×1.83 and 3.94×1.95 mm. This difference in size between the old and the new specimens might suggest that recent seasons have

been more favourable for the growth of the shells, but it seems to me more likely to arise through the position in which they were collected. Since I have found the species plentifully under boxes of plants in the Alexandra Park, watered daily in dry weather, I have ceased to look for them in natural surroundings, where they are much less plentiful and their supply of moisture is restricted to the rain and dew.

It is noticeable that, as far as is known, the typical form has not been found beyond the precincts of the borough of Maritzburg.

The aberrant forms figured on Pl. IV, figs. 45, 46, will be more conveniently discussed after the introduction of the following variety.

Var. *contracta* n. Pl. IV, figs. 42, 43, 44.

Shell like *E. maritzburgensis*, typical, with the following differences: Shell much smaller, less fusiform and more ovate; whorls $6\frac{1}{2}$, more finely and more obscurely sculptured; aperture rounder, proportionately much smaller, and rather less obstructed, with peristome much less expanded, and labral tooth smaller and less widely bifurcate.

Height 3.32, width 1.58 mm.

Hab.—Nottingham Road (A. J. Taynton), very plentiful; also Karkloof and Curry's Post (Taynton), all in Natal.

The pinched appearance of the relatively small aperture, taken in conjunction with the much reduced size of the shell, would, without further consideration, readily induce one to suppose that this form is quite distinct from *E. maritzburgensis* *Melv. & Pons.*; but a close study shows both forms to be built upon exactly the same plan, such differences in detail as exist being merely a matter of degree. The sculpture is of the same nature, and the disposition of the apertural processes is identical, with the one exception of the labral tooth in *contracta* being less widely cleft. In view of such important coincidence, I should have felt disposed, even if no further evidence were forthcoming, to consider the new form a variety of the older; but with the support of the

aberrant forms from Karkloof and Rosetta, the close relationship seems manifest. I think the Nottingham Road form, which is also found at Karkloof and Curry's Post, showing the extreme divergence from the type and being well established in numbers, may conveniently be distinguished by a varietal name, *contracta* being chosen in reference to the pinched appearance of its aperture, while the aberrant forms remain undistinguished in name, simply as forms intermediate between *maritzburgensis*, typical, and its variety. These intermediates have not so far been found plentifully; from Karkloof I have four specimens corresponding with fig. 45, taken with twenty-seven specimens of var. *contracta*; and from Rosetta I have two specimens only, corresponding with fig. 46, without representatives of *contracta*. These, however, are from a small parcel, of whose numbers I have no record, given to Mr. Ponsonby by Miss Hickey; but it is justly presumable that they are a fair sample of the lot, and that var. *contracta* was not collected by Miss Hickey.

The shell represented by fig. 45 is but little removed from *maritzburgensis*, typical, the peristome being only slightly less expanded, but the labral tooth is much smaller and its bifurcation much less distinct. The Rosetta form, fig. 46, on the other hand, is much nearer var. *contracta*, the shell being almost equally small and the peristome much narrowed; but the aperture is relatively large, so avoiding the pinched appearance of the named variety.

The dimensions of other specimens are as follow:

Intermediate form from Karkloof: height \times width, $4\cdot47 \times 1\cdot89$, $4\cdot31 \times 1\cdot95$, $4\cdot09 \times 1\cdot97$ (fig. 45), $4\cdot03 \times 1\cdot94$ mm.

Intermediate form from Rosetta: $3\cdot68 \times 1\cdot76$, $3\cdot46 \times 1\cdot76$ mm. (fig. 46).

Var. *contracta* from Nottingham Road: $3\cdot73 \times 1\cdot73$, $3\cdot51 \times 1\cdot76$, $3\cdot38 \times 1\cdot66$, $3\cdot13 \times 1\cdot63$ mm.

Var. *contracta* from Karkloof: $3\cdot60 \times 1\cdot66$, $3\cdot46 \times 1\cdot66$, $3\cdot43 \times 1\cdot68$ mm.

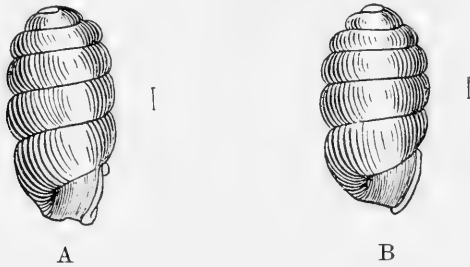
Var. *contracta* from Curry's Post: $3\cdot51 \times 1\cdot62$, $3\cdot40 \times 1\cdot62$ mm.

In general appearance, without regard to detail, var. *contracta* is much like a diminutive *E. obovata* Pfr., but the arrangement of the apertural armature is quite distinct.

Ennea arnoldi Sturany. Text-figs.

Ennea arnoldi Sturany. Anz. k. Akad. Wissensch. Wien (1898), No. xvi, p. 158 (reprint p. 6); Sturany, Südafrik. Moll. (1898), p. 28, pl. ii, figs. 26-30; Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 67.

From Miss Phyllis Radford I have received two shells,



A. Specimen from Tongaat. B. Specimen from East London.

collected by her at East London, which at first appeared new to me, but a closer examination, and comparison with the shells in the Natal Museum, have convinced me that they can but belong to this species; and the differences between them and typical shells do not seem to be of sufficient importance to warrant a varietal name. The new locality, East London, then, may be added to the localities cited by Connolly in his Revised Reference List.

The chief differences are the less cylindrical form of Miss Radford's shells, with sharper apex, the more oblique aperture, and the absence of the intense constriction behind the peristome at the base. The species varies considerably in size and in relative width, two of the specimens of which Sturany gives the dimensions being even shorter, and one of them

relatively wider, than the East London shells; therefore, the *average* smaller size and greater obesity of the East London shells cannot be considered of importance, since they might not be maintained in a series.

The obliquity of the aperture which inclines from the right, above, to the left, below, is conspicuous, and is not equalled in any of Sturany's figures, nor in any Natal example that I have examined. The absence of the deep constriction behind the labrum is probably the most important feature, but is not so easily detected. The accompanying figures are designed to illustrate this divergence from the type.

The dimensions of the East London shells are as follows: height \times width, 2.69×1.36 , 2.64×1.37 mm.

It will be seen that while the width of these shells exceeds that of even Sturany's largest measured example, the ratio of width to height is greater in the specimen of which he gives the dimensions as 2.5 mm. high and 1.3 mm. wide.

Ennea connollyi Melv. & Pons. Pl. V, fig. 52.

Ennea connollyi Melv. & Pons., Ann. and Mag. Nat. Hist., vol. iv (1909), p. 486, pl. viii, fig. 2; Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 69.

As Connolly indicates, *loc. cit.*, the original figure does not adequately represent the shell. Not only is it too wide, but the sutures are too shallow, and certain apertural processes are not shown. Therefore this opportunity is taken to publish a new figure.

The dimensions set forth in the description, given in "round numbers," probably give almost as erroneous an idea of the true proportions of the shell as the figure does, for in my series, kindly supplied by the discoverer, I have no example nearly so attenuate as the recorded dimensions of the type would indicate it to be.

The following table of dimensions and ratios will indicate the amount of variation in those respects which may be

looked for in this species, and also the extent of the discrepancy between the authors' original dimensions and those indicated by their figure. To ascertain the dimensions represented by the figure, the height is taken from the artist's dimension line, and the width is calculated therefrom, proportionately to the height and width of the figure.

Specimens from various localities.	Height.	Width.	$\frac{\text{Width} \times 100}{\text{Height}}$
Type as per authors' dimensions .	mm. 3·00	mm. 1·00	33·33
Type as per original fig.	3·25	1·56	48·00
Type of new figure from Amajuba .	3·02	1·29	42·71
Other specimens from Amajuba	3·19	1·27	39·81
	3·16	1·31	41·46
	3·06	1·32	43·14
Specimens from Hennop's River	3·28	1·28	39·02
	3·28	1·22	37·20
	3·09	1·22	39·48
	2·97	1·24	41·75

Although my examples from Hennop's River tend towards a more attenuate form than those from Amajuba, some of the narrowest of the latter are, either actually or relatively, narrower than the widest of the former; so a larger series than I have been able to examine would be necessary before it could be seen if the narrower average would be maintained. Coincident with the more attenuate form, a deeper, more oblique suture is observable; but no increase in the number of convolutions, beyond, perhaps, a quarter of a whorl, can be traced; therefore it would appear that the increase in height is mainly attained by a looser coiling of the whorls.

In the Hennop's River shells the aperture is less erect than in those from Amajuba, sloping, in varying degree, from right, above, to left, below; and the upper tooth of the columellar lip is uniformly situate higher, being close up to the junction of that lip with the wall of the body-whorl.

Melvill and Ponsonby draw attention to the alliance of this

species with *E. arnoldi* *Stur.*, to which it bears a strong resemblance; but the former is easily distinguished by its wider, less obstructed aperture, and the two teeth on the columellar lip which are absent in *Sturany's* species.

Ennea inhluzaniensis n. sp. Pl. V, figs. 53, 54, 55.

Shell small, cylindro-elliptical, deeply rimate, thin, shining, semi-transparent, apex rounded; whorls $6\frac{1}{2}$, slightly convex, the first $2\frac{1}{2}$ smooth, the next $3\frac{1}{2}$ delicately transversely striate immediately below the suture, with occasional striæ passing partly or wholly across the whorl, and the last $\frac{1}{2}$ -whorl more strongly, regularly striate across its breadth, round the base, and into the rimal depression; suture moderately impressed; aperture erect, oblong, with white peristome slightly thickened and moderately expanded, the ends joined by a distinct white callus, and furnished with the following processes: A rather narrow, sharp, in-running parietal plait arising a little above the suture and in front of the plane of the peristome, a rather long, narrow, simple, sub-central labral tooth, and a small, rounded, internal columellar plait. There is also a slight, sub-central swelling on the columellar lip.

Height 3.60, width 1.47 mm.

Hab.—Inhluzani Hill, Dargle, Natal (Burnup).

Among the forty-five specimens collected, scarcely any deviation from the type, except in size, is observable. The "columellar plait" of the description is merely the rounded termination of the axial column without contortion or thickening. The labral tooth is more solid than is usual, the excavation behind the lip being very shallow; but the position of the tooth is there very clearly shown by a conspicuous white spot. The swelling on the columellar lip is scarcely thickened, the corresponding excavation being very deep.

In the study of this shell I feared, from Melvill and Ponsonby's description and figure of *Ennea juxtidentis*, and from two very poor specimens, immature, calcined, and

holed, in my collection, that the new form might possibly be inseparable from their species. Mr. E. A. Smith, therefore, most kindly undertook the comparison of my type with the type of *juxtidentis* in the British Museum, and has furnished me with the following detailed report:

“*Ennea juxtidentis*, type, is a larger shell than yours, the sculpture is hardly apparent, or at all events much less visible than in your shells: the peristome is stronger, especially on the columellar side, where, and at the base, it is rather more expanded than in *inhluzaniensis*. The parietal lamella, beyond being stronger, offers no difference of any importance—it arises higher on the body-whorl than the suture, just the same as in your shells. The columellar fold is quite the same as in *inhluzaniensis*. The tooth on the labrum is of the same character. In *juxtidentis* there is a feeble denticle low down on the columellar side, but not quite basal; it is well within the edge of the peristome. The swelling about the middle of the columellar lip in your shells is higher up than the faint tooth in *juxtidentis*. This is the most distinguishing feature in M. & P.’s species in comparison with yours.

“On the whole I think it would be safer to regard *inhluzaniensis* as a distinct species rather than as a variety of *juxtidentis*.”

Since seeking Mr. Smith’s opinion, Mr. J. H. Ponsonby has generously given me a mature co-type of *E. juxtidentis* in excellent condition, from his own collection. Thus I am enabled to present new figures of that species (Pl. V, figs. 57, 58, 59) for comparison with those of *inhluzaniensis*. The dimensions are—height 4·53, width 2·05 mm. In considering the difference in size, it should be borne in mind that the figures of *inhluzaniensis* are magnified by 9·2 diameters, and those of *juxtidentis* by 7·45.

Mr. Farquhar has suggested a relationship between *inhluzaniensis* and *elliptica* *Melv. & Pons.*, and though I think the differences are too many and too great to admit of close affinity, the size and general form of the

shells, together with the unusual freedom from obstruction in the aperture, warrant a comparison.

The flatter whorls, shallower suture, much smoother and more highly polished surface, rounder aperture, with more widely expanded peristome, shorter parietal plait, and the two teeth on the columellar lip (or one in var. manca) should always readily distinguish *elliptica* from the present species. *Elliptica*, too, shows a conspicuous opening from the rima to the axial perforation, while none is visible in *inhluzaniensis*. The swelling on the columellar lip of *inhluzaniensis* cannot be looked upon as representing one or other of the teeth on the columellar lip of *elliptica*, for its position does not correspond with that of either.

The dimensions of such specimens of *inhluzaniensis* as I have measured in addition to the type, are as follows: height \times width, 3.59×1.52 , 3.41×1.49 , 3.35×1.49 , 3.17×1.42 , 2.84×1.42 mm.

From the dimensions of the two specimens figured it would appear that *juxtidentis*, besides being larger than *inhluzaniensis*, is also proportionately a wider shell, the ratio of width to height of these specimens being respectively 45.25 and 40.84 per cent.; and Melvill and Ponsonby's dimensions of their type uphold the suggestion. The appearance of my calcined co-types of *juxtidentis*, which are too brittle to admit of actual measurement, also seems to support it; but a larger series would be required before the fact could be established, for my smallest example of *inhluzaniensis*, manifestly a dwarfed shell, is, with a ratio of 50 per cent., proportionately much wider than the figured *juxtidentis*.

Ennea premnodes, *Sturany*. Pl. V, fig. 56.

Ennea premnodes *Stur.*, Ann. Hofmus. Wien, xvi (1901), pub. 1902, p. 69, fig. 5; Connolly, Ann. S. Af. Mus., vol. xi (1912), p. 84. "1901" (*sic*).

Through the kindness of Dr. Sturany in giving me one of his co-types, I am enabled to offer a description and figure of

this little-known species, which will be easier of access to South African readers than the original.

Shell small, elongate, cylindrical, narrowly umbilicate, thick, white, opaque, apex rounded; whorls $7\frac{1}{2}$, slightly ventricose, the first 3 smooth, the next 4 nearly smooth, except immediately below the suture, where they are clearly, rather coarsely transversely rib-striate, and the last half whorl similarly rib-striate all over, except immediately behind the lip, where it again becomes smooth; suture moderately deep; aperture rather large, rounded, with peristome much thickened, expanded and reflexed, with well-developed callus connecting the extremities, and furnished with the following processes: a strong blade-like in-running parietal plait, a large prominent, bluntly pointed labral tooth with corresponding pit outside, a small tooth near the base of the columellar lip, and a medium-sized deep-seated columellar plait, flattish and drawn to a small mammillated point at the lower right corner. In addition to these regular processes there is a very minute denticle on the outer, upper edge of the labrum, close to the suture, not shown in the fig.

Height, 5.89; width (including expanded labrum), 2.21 mm.

Hab.—Albany District, Cape of Good Hope (Penther).

The width of the shell gradually increases with each successive whorl after the rapid increase of the apex, so giving the spire a somewhat bluntly elongate-conical form. To what extent the opaqueness of the shell may be considered characteristic of the species, or to what extent it may be due to incipient erosion, could only be decided were more examples available for examination; but its solidity suggests that in maturity it would always be opaque: my shell, though in good condition, does not appear to have been collected alive, so slight erosion in it is probable, though it is not conspicuous. The minute denticle on the outer, upper edge of the labrum, which is very inconspicuous, may not be characteristic, and is scarcely worthy of note except as regards a comparison of this shell with one of the forms of *Ennea montana* *Melv. & Pons.* (Pl. V, fig. 60), hereafter discussed.

Ennea montana *Melv. & Pons.* Pl. V, figs. 60, 61, 62, 63, 64, 65, 66.

Ennea montana *Melv. & Pons.*, Ann. and Mag. Nat. Hist., vol. xii (1903), p. 599, pl. xxxi, fig. 15.

Ennea parallela *Melv. & Pons.*, *ibid.*, vol. iv (1909), p. 489, pl. viii, fig. 9.

On first studying this species the material at my command was small, and showed so much variation, especially between my own two shells, *ex coll.* Farquhar, reputed to represent respectively *montana* and *parallela* (figs. 61, 62, 63, and fig. 60), but also between these two shells and two of the co-types of *parallela* lent to me by Mr. Ponsonby (figs. 65 and 66), and between those two co-types *inter se*, that I was not only prepared to admit the validity of the two species, but was endeavouring to define the limitations of intermediate forms. As, however, neither of my shells and none of Mr. Ponsonby's co-types of *parallela* seemed to agree accurately with Melvill and Ponsonby's descriptions and figures, a comparison with the types in the British Museum became essential. Mr. Edgar A. Smith most kindly undertook the investigation, and, being supplied by me with certain shells and drawings, has furnished the following report :

" Fig. 65 represents the true *parallela*. Of the shells, that figured as 65 and the one unfigured agree with M. & P.'s type. I do not regard the third example (fig. 66) as a distinct species. In my opinion it is an older shell with more developed teeth and a slightly modified labrum. The shell figured as 60 I also consider as *parallela* with well-developed lip and teeth ; the labral tooth is strong, and does not show the tendency to be double, as in other specimens.

" I have compared the types of *parallela* and *montana*, and cannot regard them as distinct. The latter is an old shell with lip and teeth more thickened. Your figure (re-drawn as fig. 61) shows a minute columellar tooth which does not exist in the type."

Mr. Smith does not comment upon the presence, in the shell

drawn as fig. 60, of the minute tooth on the *outer* edge of the labrum, close under the suture, so I infer that he attaches no significance to it, and it is probably an accidental development. It is interesting, however, to note the presence of an equivalent tooth in my specimen of *Ennea premnodes Stur.* (fig. 56), a somewhat similar but much larger and heavier-built shell. The position of this tooth in *premnodes* is a little further forward, and so it is lost in perspective and shade in the figure. As Sturany does not mention this tooth in his description of *premnodes*, it is to be inferred that it is absent from the type, and its presence in my specimen is also accidental.

The minute columellar tooth shown in fig. 61, and, *vide* Smith, non-existent in the type of *montana*, is, curiously enough, shown in the original figure, though not very prominently, but is not referred to in the original description. In no specimen that I have examined is it so conspicuous as in that shown in figs. 61, 62, 63. In some it is but slightly raised (e. g. fig. 60); in others it is merely represented by a slight swelling (e. g. fig. 66), but in the greater number it is entirely absent.

Since submitting the matter to Mr. Smith, Mr. Farquhar has kindly sent me his whole series for examination, consisting of four specimens of *montana* collected at and near Mountain Drive, Grahamstown, one of them being from the original lot, five specimens collected with the original lot of *parallela* near the Asylum, Grahamstown, and ten specimens, unnamed, collected at Gowie's Kloof, near the same city. I have also been favoured by an opportunity to examine the only specimen in the Alexander McGregor Museum, Kimberley, also from Gowie's Kloof. This large series amply confirms Mr. Smith's views that *parallela* is inseparable from *montana*. It seems to be a species very constant in its elongate cylindrical form, in its sculpture confined (except on the apical whorls, which are smooth, and the last half-whorl, in which the sculpture crosses the whole width) to the area immediately below the suture, and in the position of the important apertural processes, but most variable in the

development of those processes and in the extent to which the peristome is thickened and expanded.

The divergencies from a conceivable normal type being apparently more a matter of degree in development than a modification of plan, and no series of specimens exactly supporting any definite line of departure from such a normal type, it would not seem desirable to attempt to define named varieties, and the species must remain one difficult to determine. It is hoped that the series of figures chosen to illustrate the species may serve as a guide to the amount of variation to be looked for.

From these a summarised definition of the species may be drawn up as follows:

Shell small, elongate-cylindrical, rounded above and below, deeply rimate and narrowly perforate, semi-transparent, polished; whorls about 7, moderately convex and impressed at the suture, sculptured immediately below the suture with transverse rib-striae of varying strength, except the first $2\frac{1}{2}$ whorls, which are smooth, and the last half-whorl, in which the striae are continued across the width of the whorl and around the base; aperture somewhat roundly trigonal, broader than high, with more or less thickened and expanded peristome reflexed on the columellar and basal lips, furnished with at least four processes varying much in development, viz. a moderate, sometimes heavy, in-running parietal plait, a moderate or large, simple or more or less divided labral tooth, a small tooth about the base of the columella, and a wholly internal columellar plait, large or small, more or less thickened below, rounded or produced to a mammillate point at the lower right margin, the columellar lip sometimes bearing a minute subcentral tooth or swelling.

Height 3.03, width 1.19 mm. (average of 22 specimens measured).

Hab.—Environs of Grahamstown, Cape of Good Hope.

The following are the dimensions of the figured specimens and a few others:

	Height mm.	Width mm.
In my collection (figs. 61, 62, 63)	3.23	1.27
Ditto (fig. 60)	3.08	1.19
In collection of J. H. Ponsonby (co-type of parallela) (fig. 65)	2.93	1.17
Ditto, ditto (fig. 66)	3.06	1.27
In collection of J. Farquhar (part of original lot of parallela)	3.19	1.24
Ditto, ditto.	3.10	1.13
In collection of J. Farquhar (part of his series of montana)	3.05	1.21
Ditto, ditto.	3.02	1.19
In collection of J. Farquhar, from Gowie's Kloof	3.08	1.13
Ditto, ditto	2.67	1.15
In collection of Alexander McGregor Museum, Kimberley	2.94	1.12
In collection of J. H. Ponsonby, from Hamilton Reservoir, Grahamstown (fig. 64)	3.03	1.24

Ennea ponsonbyi n. sp. Pl. V, figs. 67, 68, 69.

Shell small, ovate-cylindrical, with blunt apex, vitreous, semi-transparent, whitish, deeply rimate and narrowly but distinctly perforate; whorls 6, rather convex, the first 2 smooth, the rest regularly, distinctly, rather strongly, sculptured with transverse rib-striae, except a small area on the body-whorl, the whole width of the whorl, immediately above the columellar lip, which is smooth; suture rather deeply impressed; aperture rather erect, roundly quadrate with whitish peristome much thickened, widely expanded and strongly reflexed, the ends connected by an indistinct callus, and the apertural processes being as follows: A strong, in-running, blade-like parietal plait, a large, strong, bi-lobed labral tooth, a small in-running basal tooth, a large, flattish,

deep-seated columellar plait, but little thickened on the lower edge and slightly drawn forward on the right, and a swelling on the columellar lip.

Height 2·91, width 1·33 mm.

Hab.—Gowie's Kloof, Grahamstown, Cape of Good Hope (Farquhar).

All the specimens that I have seen, namely five in my own collection, received from Mr. Farquhar, nine in Mr. Ponsonby's collection, and a large series in the Alexander McGregor Museum, Kimberley, come from the same locality, and are most constant in detail, varying slightly only in size, relative width, and in the number of whorls ($5\frac{1}{2}$ to $6\frac{1}{4}$).

The following are the dimensions of such examples as I have measured, in addition to the type, and fairly represent the extent of variation observed: Height \times width, $3\cdot20 \times 1\cdot37$, $2\cdot94 \times 1\cdot37$, $2\cdot88 \times 1\cdot31$, $2\cdot72 \times 1\cdot30$, $2\cdot66 \times 1\cdot33$ mm.

A curious feature in this species is the position of the smooth area on the body-whorl. In many, if not most, striate Enneæ, there is such an area distinct from the callus, more or less smooth, immediately above the aperture, in which position it is easily conceived to be formed by the constant passage of the mantle over the spot while the mollusc is active. In by far the greater number of the specimens of this species examined, the centre of the smooth area is considerably to the left of the aperture, though in a few its position is normal. It is difficult to understand why it should generally be so far misplaced, unless the animal possess some peculiar development of the mantle.

This species has been tentatively identified as *Enneæ darglensis* *M. & P.*, and distributed as such; but the differences are so many and so great that the two species cannot be considered as closely akin; a mere glance at the figures of the two species should be enough to bring conviction as to their wide distinction.

The general arrangement of the processes of the aperture is somewhat similar to that of *E. montana* *M. & P.*, but the shorter, stouter form with fewer whorls, the continuous

sculpture, and the much more thickened and reflexed peristome, readily distinguish the present species.

I have much pleasure in associating with this shell the name of Mr. J. H. Ponsonby, from whose collection the type is chosen, and from whom I have received so much help in the form of advice, specimens for study, and the obtaining and transmitting of reports upon the types in the British Museum, without which much of this paper must have remained unwritten.

EXPLANATION OF PLATES III-V,

Illustrating Mr. Henry C. Burnup's paper "On South African *Enneæ*, with Descriptions of New Species and Varieties."

PLATE III.

FIG. 1.—*Ennea isipingoënsis* *Stur.*, from the type in Naturh. Hofmus., Vienna.

FIG. 2.—*Ennea isipingoënsis* *Stur.* var. *discrepans* *Stur.*, from the type of the variety *discrepans* in Naturh. Hofmus., Vienna.

FIG. 3.—*Ennea isipingoënsis* *Stur.* var. *discrepans* *Stur.*, from the type of the variety *simillima* *Stur.*, in Naturh. Hofmus., Vienna.

FIGS. 4, 5, 6.—*Ennea isipingoënsis* *Stur.* var. *sturanyi* *n.* Type of var., from Ntimbankulu, to be placed in the British Museum.

FIGS. 7, 8.—*Ennea elliptica* *Melv. & Pons.*, typical, from specimens from the original locality, Maritzburg, in the Natal Museum.

FIGS. 9, 10.—*Ennea elliptica* *Melv. & Pons.*, from specimens from Tongaat Beach Bush, in the Natal Museum.

FIGS. 11, 12.—*Ennea elliptica* *Melv. & Pons.*, from specimens of aberrant forms from Dargle, to be placed in the British Museum.

FIG. 13.—*Ennea elliptica* *Melv. & Pons.* var. *manca* *n.* Type of var., from Fort Nottingham, to be placed in the British Museum.

FIG. 14.—*Ennea elliptica* *Melv. & Pons.* var. *manca* *n.*; from a specimen from Fort Nottingham, in the Natal Museum.

FIGS. 15, 16, 17.—*Ennea elliptica* *Melv. & Pons.* var. *cælata* *n.* Type of var., from Eshowe, to be placed in the British Museum.

FIGS. 18, 19, 20.—*Ennea sylvia* *Melv. & Pons.*, from a specimen from the original locality, Maestroom Forest (Farquhar), in the Natal Museum.

FIGS. 21, 22, 23.—*Ennea melvilli* *n. sp.* Type, from Nottingham Road, to be placed in the British Museum.

PLATE IV.

FIG. 24.—*Ennea farquhari* *Melv. & Pons.*, from a co-type from Grahamstown, in coll. J. H. Ponsonby, to be placed in the British Museum.

FIGS. 25, 26, 27.—*Ennea farquhari* *Melv. & Pons.* var. *berthæ* (*Melv. & Pons.*), from a co-type of *Ennea berthæ* *Melv. & Pons.*, from Karkloof, in the Natal Museum.

FIGS. 28, 29, 30.—*Ennea farquhari* *Melv. & Pons.* var. *avena* *n.* Type of var., from Maritzburg, to be placed in the British Museum.

FIG. 31.—*Ennea farquhari* *Melv. & Pons.* var. *avena* *n.*, from a specimen from Durban, to be placed in the British Museum.

FIG. 32.—*Ennea darglensis* *Melv. & Pons.*, from a specimen from Inhluzani Hill, Dargle, in the Natal Museum.

FIGS. 33, 34, 35.—*Ennea darglensis* *Melv. & Pons.* var. *illovoensis* *n.* Type of var., from Ntimbankulu, Mid-Illovo, to be placed in the British Museum.

FIG. 36.—*Ennea consobrina* *Ancey*, from the type, from Albany, in coll. J. R. le B. Tomlin.

FIG. 37.—*Ennea thelodonta* *Melv. & Pons.*, from a specimen from Port Elizabeth (Farquhar), in the Natal Museum.

FIG. 38.—*Ennea munita* *Melv. & Pons.*, from a specimen from " ? near McLear " (Ponsonby), in the Natal Museum.

FIGS. 39, 40, 41.—*Ennea maritzburgensis* *Melv. & Pons.*, typical, from a specimen from Maritzburg, to be placed in the British Museum.

FIGS. 42, 43, 44.—*Ennea maritzburgensis* *Melv. & Pons.* var. *contracta* *n.* Type of var., from Nottingham Road (Taynton), to be placed in the British Museum.

FIG. 45.—*Ennea maritzburgensis* *Melv. & Pons.*, from a specimen of an aberrant form near *maritzburgensis*, typical, from Karkloof (Taynton), to be placed in the British Museum.

FIG. 46.—*Ennea maritzburgensis* *Melv. & Pons.*, from a specimen of an aberrant form near var. *contracta*, from near Rosetta (Hickey, per Ponsonby), to be placed in the British Museum.

PLATE V.

FIG. 47.—*Ennea columnella* *Melv. & Pons.*, from a co-type from Karkloof (McBean), in the Natal Museum.

FIG. 48.—*Ennea mariæ* *Melv. & Pons.*, from a co-type from Somerset East (Miss M. Bowker), in coll. J. H. Ponsonby.

FIGS. 49, 50, 51.—*Ennea mooiensis* *n. sp.* Type, from Game Pass, Upper Mooi River, Natal, to be placed in the British Museum.

FIG. 52.—*Ennea connollyi* *Melv. & Pons.*, from a specimen from the original lot from Amajuba (Connolly), in the Natal Museum.

FIGS. 53, 54, 55.—*Ennea inhluzaniensis* *n. sp.* Type, from Inhluzani Hill, Dargle, to be placed in the British Museum.

FIG. 56.—*Ennea premnodes* *Stur.*, from a co-type from Albany District (Penther, per Sturany), in the Natal Museum.

FIGS. 57, 58, 59.—*Ennea juxtidentis*, *Melv. & Pons.*, from a co-type from Van Reenan (*ex coll.* J. H. Ponsonby), in the Natal Museum.

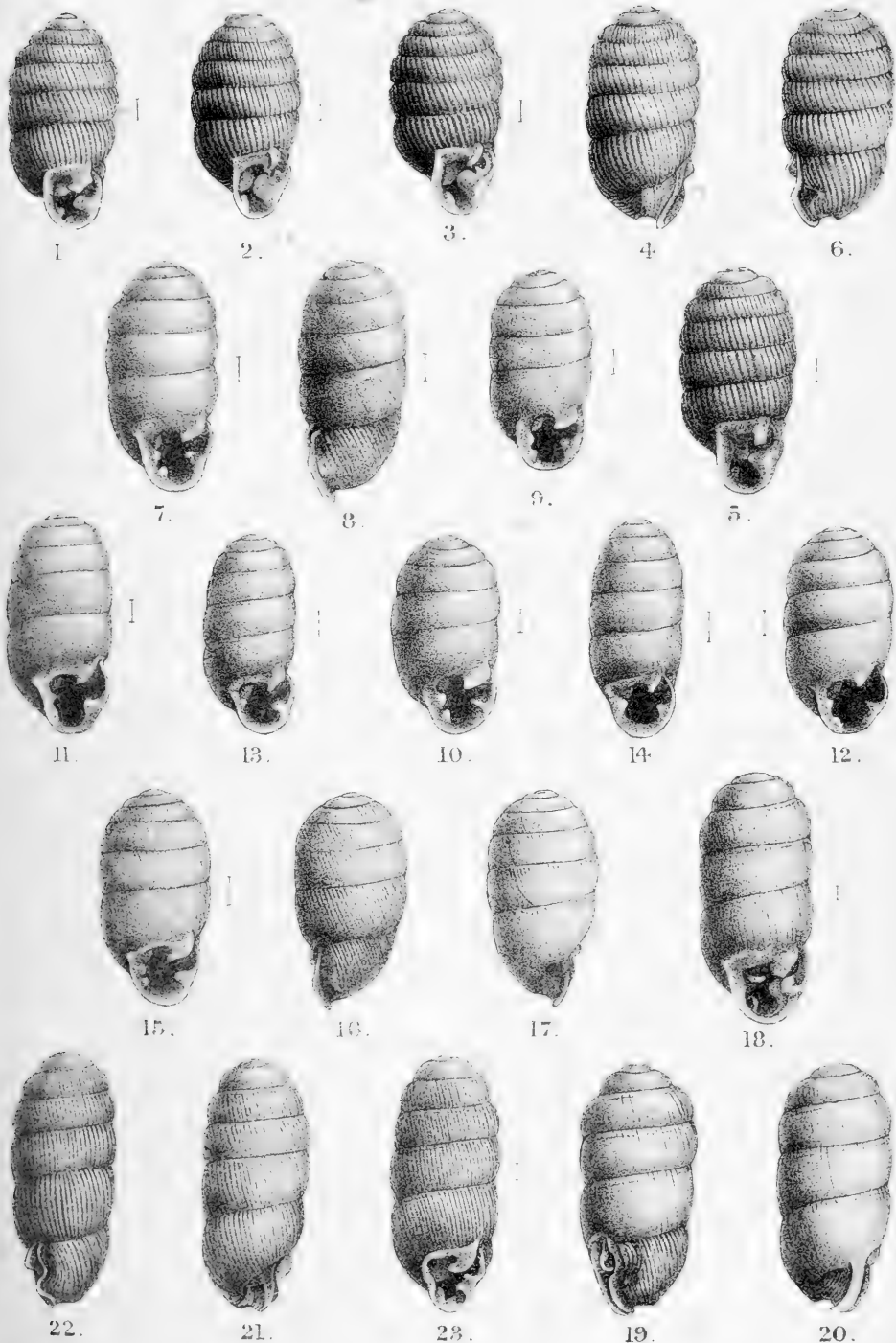
FIG. 60.—*Ennea montana* *Melv. & Pons.*, from a specimen of the original lot of *Ennea parallela*, collected near the Asylum, Grahamstown (Farquhar), in the Natal Museum.

FIGS. 61, 62, 63.—*Ennea montana* *Melv. & Pons.*, from a specimen from Mountain Drive, Grahamstown (Farquhar), in the Natal Museum.

FIG. 64.—*Ennea montana* *Melv. & Pons.*, from a specimen from near Hamilton Reservoir, Grahamstown (Farquhar), in coll. J. H. Ponsonby.

FIGS. 65, 66.—*Ennea montana* *Melv. & Pons.*, from co-types of *Ennea parallela* *Melv. & Pons.*, from Grahamstown, in coll. J. H. Ponsonby.

FIGS. 67, 68, 69.—*Ennea ponsonbyi* *n. sp.* Type, from Gowie's Kloof, Grahamstown (Farquhar), *ex coll.* J. H. Ponsonby, to be placed in the British Museum.



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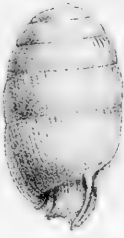
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SOUTH AFRICAN ENNEÆ.





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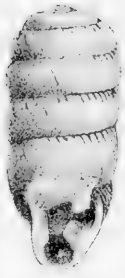
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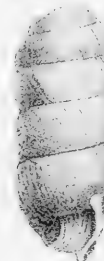
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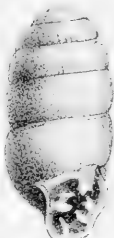
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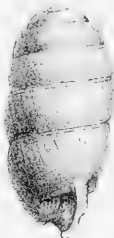
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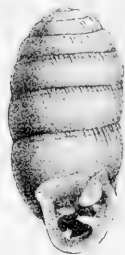
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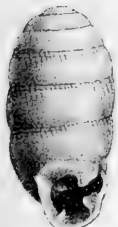
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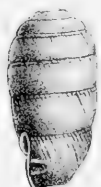
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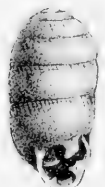
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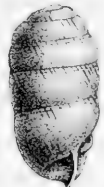
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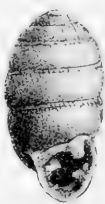
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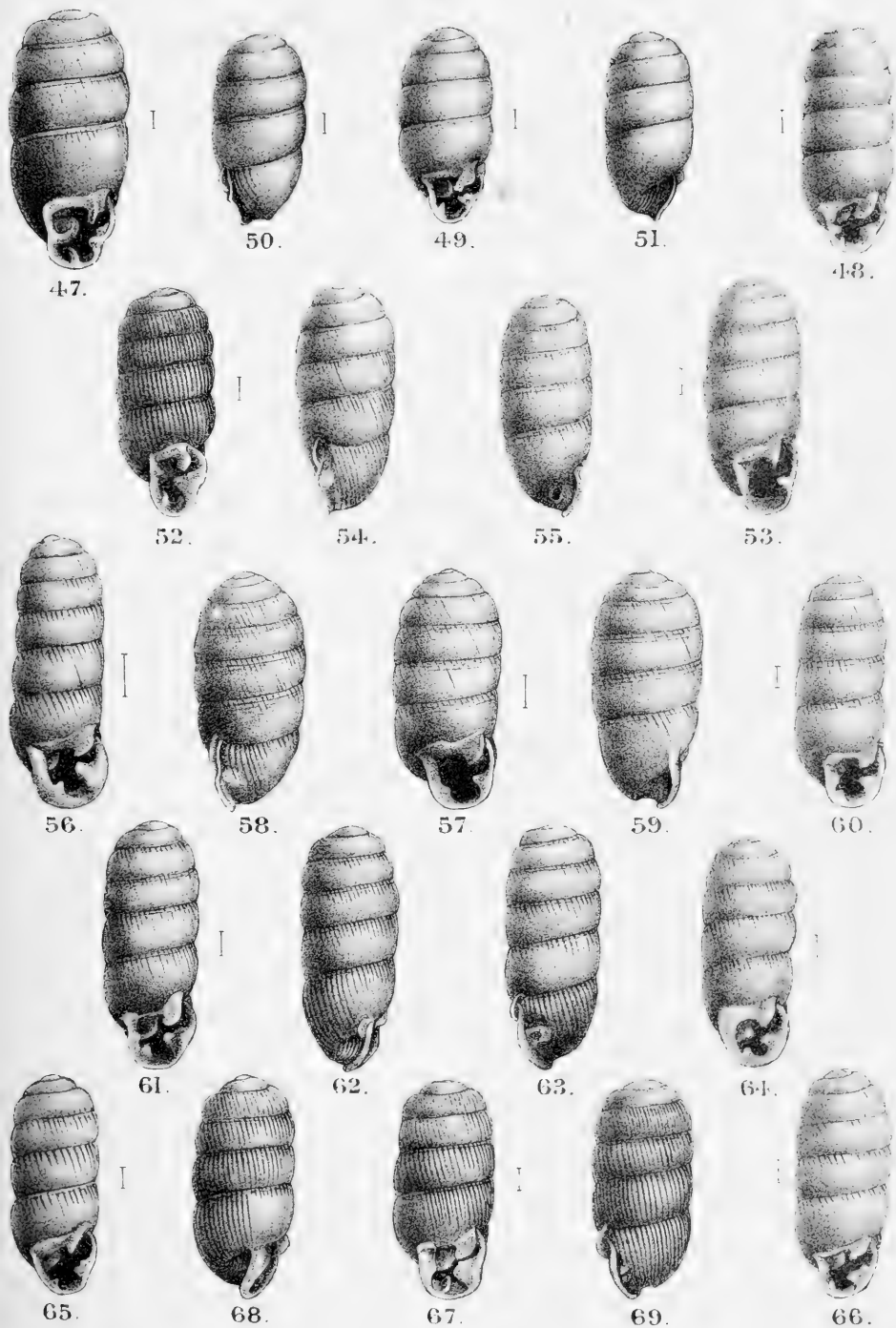
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SOUTH AFRICAN ENNEÆ.





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SOUTH AFRICAN ENNEÆ.

On the Development of the Planula in a Certain Species of Plumularian Hydroid.

By

Ernest Warren, D.Sc.(Lond.).

With Plate VI and 4 Text-figs.

I.

THE development of the planula in this hydroid is noteworthy in that the egg never becomes charged with yolk. The ovum remains small and segments in the midst of a feeding or placental tissue. Ultimately the embryo grows into a well-developed planula with dimensions very greatly exceeding those of the original egg.

Some brief notes on the subject were communicated to the South African Association for the Advancement of Science at the annual meeting held in Lourenço Marques, July, 1913. In the present paper the necessary details with drawings are given, and the species of hydroid is described.

The hydroid was found in January, 1911, in a rock-pool on the north side of the mouth of the St. John's River, Pondoland. Only two clusters were gathered, and they both occurred on the shells of living oysters much incrustated with the calcareous tubes of *Serpula*. The upright pinnate stems were about $\frac{1}{2}$ in. in height.

TROPHOSOME.—*Hydrorhiza* consists of an irregularly branched stolon, which in the present specimens was creeping among the tubes of *Serpula* covering oyster-shells (text-

TEXT-FIG. 1.

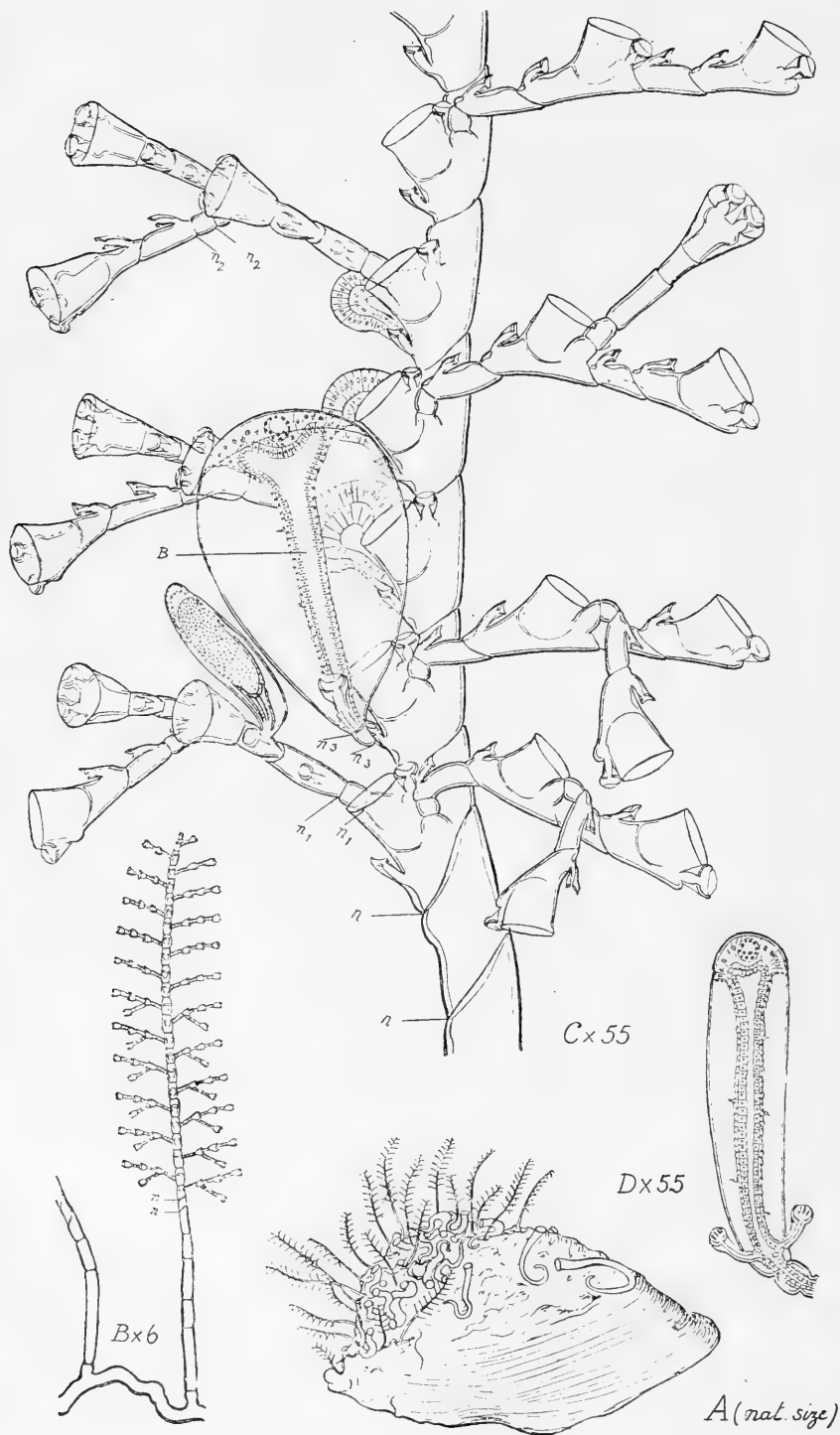


fig 1, A). The perisarc is not so distinctly divided into an outer diffuse layer and an inner compact layer as in some species of *Plumularia*.

Diameter of hydrorhiza about 0.19 mm.; thickness of perisarc 22.7 μ .

Hydrocaulus.—Monosiphonic, the hydrorhiza carries upright pinnate stems of various heights.

The proximal portion of the main-stem, not bearing pinnae, is about half the length of the distal portion carrying them, and it is somewhat irregularly divided into internodes by transverse nodes (text-fig. 1, B). The distal portion of the stem is regularly divided by oblique nodes. Between the two portions of the main-stem there are two very oblique joints (text-fig. 1, B; C, *n.*, *n.*).

All the internodes of the main-stem in the distal pinnate portion carry a hydrotheca with a mesial sub-calycine nematophore and a pair of supra-calycine ones.

The pinnae alternate, and on an ordinary stem there are nine to eleven on each side. They usually carry only two hydrothecae, but sometimes there may be three (text-fig. 1, B). The pinnae are borne on a short process springing from the main-stem at the back of the hydrotheca (text-fig. 1, C). The proximal internode is very short, bears no structures, and the upper and lower nodes are transverse (*n.*₁, *n.*₁); the rest of the pinna generally consists of only two alternating non-thecate and thecate internodes separated by oblique nodes. These non-thecate internodes carry a median nematophore.

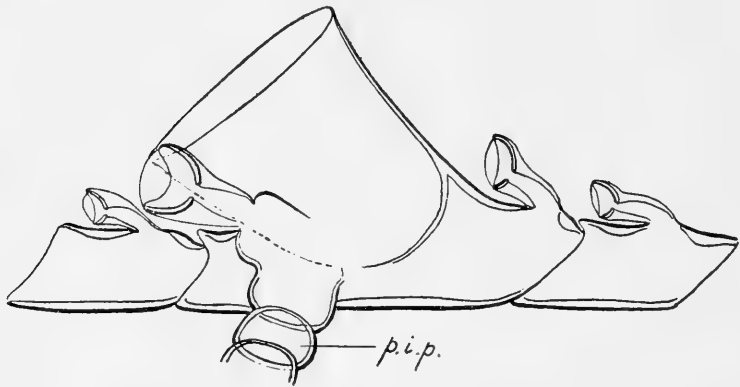
Frequently the pinnae, especially the proximal ones, bear a pinnule which is carried on a short process springing from the level of the proximal hydrotheca. It consists of a basal internode (text-fig. 2, *p.i.p.*) with transverse nodes (text-fig. 1, C, *n.*₂, *n.*₂), followed by a non-thecate and thecate internode.

TEXT-FIG. 1.—*A* (nat. size). Colony on oyster shell. *B* $\times 6$. Hydrorhiza bearing pinnate stem with pinnae carrying three hydrothecae. *C* $\times 55$. Piece of pinnate stem with male and female gonangia. *D* $\times 55$. Side view of female gonangium carrying nematophores at the base.

It appears that the pinnules invariably spring from the lower side of the pinnae. They are set at an angle of about 30° to the pinna, and project downwards and outwards. These short pinnules are characteristic of the species.

Length of the pinnate-stem with 11 pairs of pinnae about 12 mm., proximal non-pinnate portion 4 mm., pinnate part 8 mm. Diameter of main-stem in non-pinnate region 0.16 mm., thickness of perisarc 21.58 μ . Length of thecate internode about 0.30 mm., width 0.14 mm. The average length of

TEXT-FIG. 2.

Internodes of pinna and base of pinnule, $\times 200$.

pinna with two hydrothecae is about 0.91 mm., and the average length of pinnule is about 0.51 mm. The cœnosarc of the internodes exhibits an ectoderm channel on the posterior surface (text-fig. 3, A, *p.e.c.*).

Hydrotheca.—Cup-shaped, rather deep, expanding, margin somewhat everted, adcauline surface not adnate for whole length, but free above for about one-half of its length. Plane of mouth of hydrotheca is set at an angle of about 35° to main-stem or pinna. The hydrothecae are placed on the front or anterior surface of the pinnae (text-fig. 1, C).

Height of hydrotheca about 0.16 mm., width at mouth about the same.

Nematophores all free and have the typical plumularian structure; there is a median sub-calycine nematophore, and a pair of larger supra-calycine ones which scarcely project beyond the level of the mouth of the hydrotheca (text-fig. 2). The sarcothecæ are bithalamic, canaliculate, and tend to be narrow at the base.

Hydranth.—About twenty tentacles in a single verticil. Polyp constricted below the whorl of tentacles, dividing the coelenteron into an upper and lower division; the upper part is lined by narrow columnar cells, the lower portion by vacuolated digestive endoderm (text-fig. 3, A).

Nematocysts in the ectoderm of the tentacles are small; they measure about 3.2μ in length and 1.06μ in breadth. In the nematophores the nematocysts are of considerable size, having a length of 14.8μ and a breadth of 3.2μ .

GONOSOME.—The male gonangia are borne on the more proximally placed pinnae. The female gonangia occur on the proximal portion of the pinnate region of the main-stem; they arise just below the hydrotheca and on one side of the sub-calycine nematophore. The nutritive substances are naturally more abundant in the main-stem than in the lateral pinnae, and from analogy with other hydroids we should expect to find the female gonangia in the former rather than in the latter position. This is in accordance with the view that the development of the female sex is partly induced by a rich nutritive supply.

Male Gonangium.—The gonotheca when fully grown is cylindrical, and is about 0.36 mm. in length and 0.12 mm. in width (text-fig. 1, C). The perisarc is quite thin, and there is no distinct operculum. At the base where it springs from the pinna there is no jointed stalk, and there are no nematophores arising from it.

In the developing male gonangium the spermatic cells, which will subsequently form the generative mass of the single reduced gonophore, may be seen embedded in the endoderm of the hydrocaulus (text-fig. 3, A, *sp.c.*). In the figure the spermatic cells are entering the blastostyle (*b.G.*) of

the growing gonangium. Subsequently the genital cells will separate themselves from the endoderm on one side of the blastostyle, and this may be regarded as representing the formation of a gonophore (fig. B, t), which is covered by a thin layer of ectoderm cells continuous with the ectoderm of the blastostyle. At the apical region the ectoderm (*c.p.*) of the blastostyle consists of elongated cells constituting the "Deckenplatte" of Weismann.

Female Gonangium.—The gonotheca when mature is ovoid and flattened. The plane of flattening is at right angles to the antero-posterior plane passing through the main-axis.

The female gonotheca arises on the main-stem just below the hydrotheca and on one side of the sub-calycine nematophore. It possesses a short stalk-segment with transverse nodes (text-fig. 1, C, n_3 , n_3). The stalk and the basal portion of the gonotheca are so curved that the main-axis of the structure is set at an angle of about 30° to the main-stem (text-fig. 1, C and D). The oldest gonangium is the most proximal one, and the gonangia are successively younger on passing distally. The perisarc is not very thick, but there is a well-defined large operculum, and there the perisarc is stouter. At the base of the gonotheca itself and on the flattened surface there is a nematophore on each side (text-fig. 1, D).

Length about 0.81 mm., greatest lateral width 0.51 mm., thickness at right angles to plane of flattening 0.12 mm.

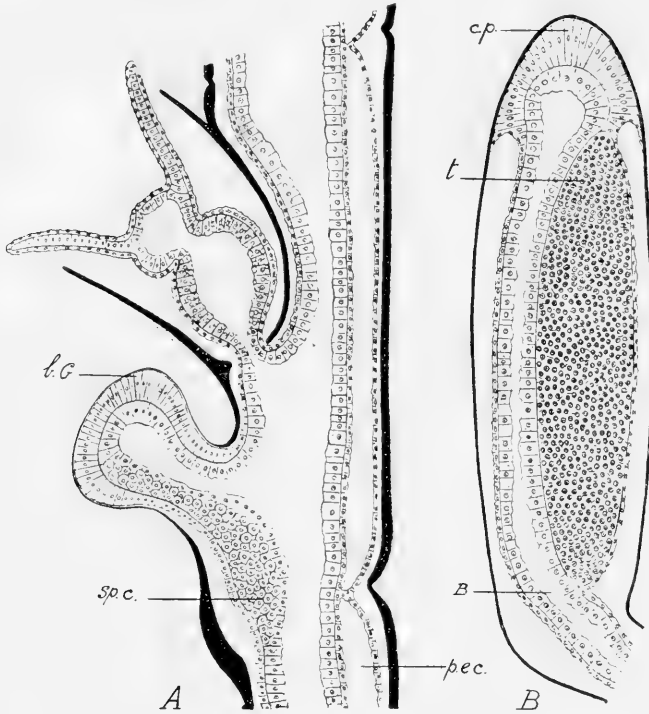
The female gonangium bears in an obscure manner a single gonophore which becomes provided with a single ovum. Before the ovum commences segmentation the gonotheca is very hollow, and the blastostyle occurs as a thin tubular structure running through the mid-axis.

SYSTEMATIC POSITION.—The hydroid possesses the typical characters of the genus *Plumularia* with the exception of the presence of the downwardly directed offshoots from the pinnae, and the somewhat unusual occurrence of the main-stem bearing hydrothecae. These pinnules are similar in every way to the pinnae, and they originate from

the pinnae just as the latter do from the main-stem; they bear a short basal internode with transverse nodes and no nematophore.

Bale¹ describes both *Plumularia campanula* *Busk* and

TEXT-FIG. 3.



Longitudinal sections of male gonangium. $\times 250$.

Plumularia buskii *Bale* as bearing hydrothecae on the main-stem; and Allman² figures a similar condition in *Plumularia armata* *Allman*.

¹ Bale, W. M., 'Catalogue of the Australian Hydroid Zoophytes,' 1884, pp. 124-5.

² Allman, G. J., "'Challenger' Reports,' vol. vii, 1883, pl. iv, fig. 4.

In the species *Plumularia aglaophenoides* *Bale*, *Bale*¹ describes the occurrence of pinnules in the following terms :

“*Hydrocaulus* polysiphonic, flexuous, pinnæ alternate, distant, given off from each flexure of the stem, with two distinct oblique joints near the base, and obscurely jointed for the rest of their length, bearing hydrothecæ as well as pinnules ; pinnules alternate, approximate, one on each internode of the primary pinnæ, both series borne towards the front and supporting a hydrotheca on each internode.”

According to the definition of the genus *Plumularia* as given by *Nutting*,² the pinnæ are without accessory branches of any kind ; and the only other genera to which the present species could be referred are *Polyplumularia* *G. O. Sars* (modified by *Nutting*) and *Schizotricha* *Allman* (modified by *Nutting*). *Nutting* defines *Polyplumularia* as possessing pinnæ furnished with a hydrothecate ramulus or pinnule which springs from the first internode, and is more slender than the pinna from which it grows ; while in *Schizotricha* the pinnæ bifurcate beyond the first internode at least in the mature colony.

In the present species the ramulus or pinnule springs not from the first internode, but from the first hydrothecate internode. The pinnule arises from the pinna by a short internode bearing no structures and with transverse nodes, just as the pinna itself arises from the main-stem. This condition is shown in *Allman*'s³ figure of *Schizotricha unifurcata* *Allman*. Consequently, the lower of the two branches is to be regarded as the pinnule, and the upper as the distal portion of the pinna, as in the case of the species being described.

It is not very clear that this production of pinnules forms a very satisfactory basis for founding a genus. The present species is transitional in this respect between *Plumularia*

¹ *Bale*, *W. M.*, loc. cit., p. 126.

² *Nutting*, *C. C.*, ‘*American Hydroids. Part I: The Plumulariæ.*’ 1900, pp. 54, 78, 83.

³ *Allman*, *G. J.*, loc. cit., pl. vii, fig. 2.

with no pinnules according to definition, and *Schizotricha* with many. In the present species the formation of the pinnules tends to be limited to the more proximally placed pinnæ, while in *Schizotricha* it would appear that practically all the pinnæ bear them. As a provisional designation, however, the name *Schizotricha simplex* is proposed.

II.

The Development of the Planula.

The material was fixed in a warm alcoholic solution of corrosive sublimate and acetic acid. Several pinnate stems with female gonangia were sectioned in different planes, and the sections were stained with Delafield's hæmatoxylin followed by orange.

Each stem bore gonangia of varying ages, and consequently all the different stages of development would appear to have been observed. Although such was the case, yet the youngest ovum that could be definitely identified as such was already in the endoderm situated at a short distance below the level of the mesial sub-calyxine nematophore.

Presumably, according to August Weismann and from analogy with observations on other hydroids, the ova first arose in the ectoderm, and then migrated into the endoderm; but in the present case the young ova were not definitely located in the ectoderm.

The youngest ovum seen was small, measuring about 14μ in diameter, and surrounded by ordinary endoderm cells. The presence of the ovum causes a slight swelling to project into the lumen of the internode (Pl. VI, fig. 1, *O.*).

The ectoderm immediately above the area where the ovum is imbedded in the endoderm early becomes slightly modified in that the cells are more columnar and regular than ordinary ectoderm cells (fig. 1, *b. G.*). This is the first beginning of the future gonangium.

The perisarc situated just above (*d. p.*) has become markedly

thinner, apparently through some dissolving action of the subjacent ectoderm cells.

In the next stage the plate of ectoderm has grown out into an ovoid swelling which is covered by a very delicate layer of perisarc continuous with the general perisarc. The endoderm follows the ectoderm, and the portion of endoderm (fig. 2, *end.*) carrying the ovum (*O.*) passes into the gonangium, and becomes located on one side of the blastostyle. The diameter of the ovum has increased to 17 μ .

It may be mentioned here that all the figures in the plate are drawn from sections cut in the plane of flattening of the gonangium, with the exception of the following: figs. 7 and 18 represent sections at right angles to the plane of flattening, and fig. 3 is a transverse section.

At this time the mesogloea between the ectoderm and the area of endoderm in which the ovum occurs becomes thin and evanescent. The ovum gradually separates from the endoderm, and the ectoderm above becomes modified, divides into smaller cells and forms a kind of cap over it. This cap and the layer of endoderm (fig. 2, *end.*, and fig. 4, *g. e.*) immediately below the ovum may be regarded as representing a rudimentary gonophore.

The distal portion of the ectoderm of the young gonangium consists of tall columnar cells with short pear-shaped granular cells wedged between. This is the beginning of the covering plate or "Deckenplatte" (fig. 2, *c. p.*). The coelenteron (*C.*) expands distally and becomes somewhat T-shaped.

The ovum now enters the ectoderm (fig. 3, *O.*), and the covering cap becomes divisible into an inner columnar layer (fig. 4, *i. l.*) in immediate contact with the ovum, and an outer layer (*o. l.*) of flat cells. The slight crack-like space (fig. 3, *c. U.*) between the two layers is the equivalent of the umbrella-cavity of a medusa, or more complete gonophore, which arises as a split in a distally placed thickening of ectoderm. The ectoderm at the sides of the gonangium gradually contracts away from the perisarc of the gonotheca (fig. 4, *sp.*₁, *sp.*₂), and outside the flat ectodermal layer (*o. l.*) of the gonophore there

is a narrow space (figs. 3 and 4, *sp.*). The long diameter of the ovum has now increased to about 20 μ .

The gonangium continues to expand, and the ovum grows slightly and reaches a diameter of about 23 μ , but there is no obvious yolk passed into it. The covering cap of ectoderm of two layers also grows, the outer layer (fig. 5, *o. l.*) becomes thinner, and the inner (*i. l.*) thicker. A delicate mesogloea is formed between the ectodermal cap and the endoderm. The endoderm cells on which the ovum is seated are granular and in an active physiological condition; they stain more readily than the rest of the endoderm.

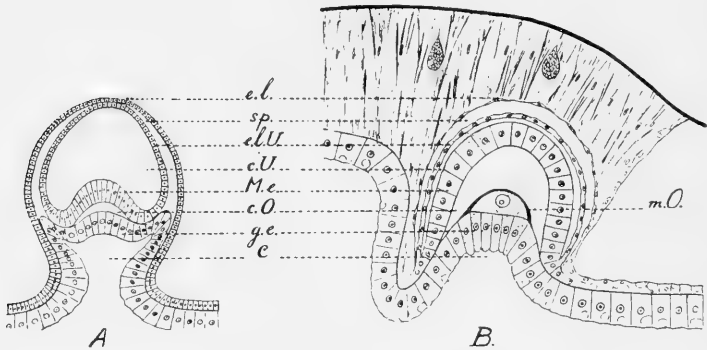
The gonangium expands further, and the distal plate of tall columnar ectoderm cells (fig. 5, *c. p.*) begins to secrete a thicker layer of perisarc; this is the beginning of the operculum. The blastostyle, except in the region of the operculum, has become quite separated from the chitinous gonotheca, and lies in the mid-axis. The ectoderm lining the umbrella-cavity of the gonophore, consisting of the two layers, becomes separated from the ovum, so that a very definite cavity occurs above the egg (fig. 6, *c. O.*). This cavity may be regarded as a space in the mesogloea of the gonophore. The umbrella-cavity (*c. U.*) of the gonophore is very narrow and almost obliterated.

The ovum is probably fertilised just before this stage, and, presumably after such fertilisation, it appears to secrete a kind of vitelline membrane (figs. 6, 7, 8, *v. m.*) which is thicker on the outer than on the inner side. It is possible, however, that this membrane is really of the nature of mesogloea, and is not actually formed by the egg. The endoderm below the ovum becomes slightly pushed outwards into a blunt process (fig. 8, *d. C.*) consisting of narrow granular cells, and the egg is seated on this out-pushing, which may be regarded as the spadix of the reduced gonophore. The ovum now attains its maximum diameter of about 34 μ .

In text-fig. 4 a comparison is made between a typical gonophore (A) and the highly modified gonophore (B) carried by the blastostyle of the present species.

In B the diverticulum of the cœlenteron (*C.*) is directly comparable with the endodermal cavity of an ordinary gonophore, the granular layer (*g. e.*) being equivalent to the manubrial endoderm. Radial endodermal canals are not represented. The cavity (*c. O.*) around the outer surface of the egg is the space between the manubrial endoderm and ectoderm; the manubrial ectoderm (*M. e.*) in the modified gonophore consists of a hemispherical layer of cubical cells. The umbrella-cavity (*c. U.*) is a narrow slit-like space. The outer ectoderm-lining (*e. l. U.*) to the umbrella-

TEXT-FIG. 4.



Comparison of a typical gonophore (A) and the modified gonophore (B).

cavity consists of a layer of flat cells. Outside this ectodermal lining of the umbrella there is a space (*sp.*) equivalent to the space between the umbrella-ectoderm and the outer ectoderm layer of the gonophore. The outermost ectoderm (*e. l.*) of a gonophore is indicated by a few flattened cells adherent to the tall attenuated cells lining the upper portion of the gonotheca.

In fig. 7 of the Plate the gonangium is shown in vertical section at right angles to the plane of flattening. The terminal portion of the cœlenteron of the blastostyle is seen at *C.* and the out-pushing to form the spadix occurs at *d. C.*

The gonangium now grows to its full size, and the cells of

the covering-plate and of the distal endoderm of the blastostyle become very attenuated and full of vacuoles, and will subsequently disappear. The space (fig. 8, *c. O.*) between the egg and the ectoderm of the gonophore increases in size, and the membrane around the ovum (*v. m.*) is very pronounced. The operculum consists of thicker perisarc than that of the rest of the gonotheca, and its lower edge is sharply marked off from the thinner perisarc below. The gonotheca has now assumed its definite form, and it does not further increase in size; its greatest width is about 0.51 mm. and length 0.85 mm.

At a somewhat later stage the outermost gonophore-layer of flat ectoderm cells disappears and the inner layer of cubical or columnar cells breaks up to form an irregular cluster around the ovum (fig. 9, *e. G.*). The covering plate of ectoderm cells below the operculum and the endoderm layer of the terminal portion of the blastostyle are still faintly visible, but they are on the point of disappearing. The out-pushing of endoderm (*d. C.*) or spadix of the gonophore consists of cells which remain in an actively living condition.

The ovum does not grow, the protoplasm is finely granular, and there is a large nucleus with nucleolus (fig. 9). There is still a pronounced membrane around the egg; but it is much less developed on the inner side against the granular cells of the endoderm than on the outer side.

In the next stage it will be seen that considerable changes have occurred in that the whole of the covering plate of ectoderm and the distal horizontal portion of the endoderm of the blastostyle have entirely disappeared. The out-pushing of endoderm (fig. 10, *d. C.*) or spadix of the gonophore has grown upwards, and has pushed the egg, together with the surrounding cells derived from the breaking-up of the columnar ectoderm cells of the gonophore, into a more or less central position in close contact with the operculum. The vitelline membrane or mesogloea-layer round the ovum becomes less distinct. The cells around the ovum arrange

themselves in such a manner that they extend as columnar cells from the perisarc to the endoderm on which the ovum is still seated.

Subsequently the ovum becomes quite central at the apex of the gonangium, and is closely surrounded by the tissue derived from the ectoderm of the rudimentary gonophore. The endoderm is now in the form of two symmetrically placed lateral lobes, one being the terminal portion of the endoderm of the blastostyle (fig. 11, *t. p.*), and the other is the endodermal spadix of the gonophore (*d. C.*). The egg is seated symmetrically between the two lobes.

The ovum segments and a rounded cluster of about sixteen loosely attached blastomeres is formed (fig. 11, *M.*). The cells of the endoderm immediately under the young embryo (fig. 12, *end.*), become taller and more granular than those of the rest of the endoderm. It is considered probable that the nutritive substances for the growth of the embryo are passed by this endoderm into the ectodermal tissue in which the embryo is imbedded.

The blastomeres increase in number and become smaller. A segmentation-cavity soon appears (fig. 13, *Sg. C.*), and this is not central, but is nearer to the apex of the gonangium. Accordingly the embryo is two or three cells in thickness below, while above it is mostly only one cell thick. The cells of the placental tissue (*pl. t.*) increase in size and height; the tissue is continuous with the thin layer of ectoderm which covers the sides of the blastostyle (*e. B.*).

The embryo is very obviously supplied with nourishment by the cells in which it is imbedded. The diameter of the embryo is two and a half times that of the original ovum, which never had any appreciable quantity of yolk.

The embryo continues to expand and the constituent cells increase in number and diminish in size. The segmentation-cavity becomes larger (fig. 14, *Bl.*). A differentiation in the cells of the embryo can be seen on the lower side where an inner layer of flattened cells now becomes evident (*end.*₁). It may be noticed that this inner layer of endoderm lines the

segmentation-cavity only on the lower half of the embryo. In the earliest stages of development the inner layer would appear to arise rather by differentiation than by delamination. The outer cells or ectoderm (*ect.*₁) form a layer one cell thick above and several cells thick below. The cells of the placental tissue in the space between the cup of the endoderm and the lower two-thirds of the embryo also show differentiation. Some of the cells are rounded or somewhat stellate; they are further distinguishable by staining much more readily, and they appear to consist of protoplasm denser than that of the other cells. It is possible that these cells are the more active agents in transferring nutriment to the growing embryo.

The embryo continues to grow, and the cells of which it is composed increase greatly in number, but their size remains the same as before. The embryo becomes pear-shaped (fig. 15). The inner layer of flat endoderm cells (*end.*₁) is beginning to creep upwards, but the upper half of the embryo is still only one cell thick and consists of the outer ectoderm layer. The embryo as a whole is sinking downwards, and the endodermal cup formed from blastostyle and gonophore is becoming deeply flask-shaped. The effective placental tissue (*pl. t.*) now lies only between the embryo and the endoderm-cup. The outer portion of this tissue (*e. E.*), is extending downwards and consists of extremely elongated cells. At the mouth of the flask the ectoderm layer has separated slightly from the perisarc and forms a definite epithelium adhering to the endoderm, and leaves a slight crack-like space (*d. S.*), extending from the perisarc to the pointed apex of the embryo.

In the next stage the embryo has sunk still further towards the centre of the gonangium (fig. 16). The ectoderm of the embryo has become more than one cell thick all round, and the endoderm also is several cells thick below and has completely surrounded the blastocœl (*Bl.*). The placental tissue (*pl. t.*) is well-developed, while the outer portion (*e. E.*) retains its transparent, attenuated condition. The flask-shaped endoderm layer (*g. e.*) derived from the blastostyle

and gonophore is more granular than the rest of the endoderm. The outer surface of the ectoderm of the embryo (fig. 17, *ect.*₁), is not sharply marked off from the placental tissue (*pl. t.*), and there appears to be the most intimate contact. Both rounded and stellate cells of dense protoplasm are seen in this placental tissue. Between the endoderm (*end.*₁) and the ectoderm (*ect.*₁) of the embryo a faint line of division can be seen, and this is the beginning of the mesogloea.

Such is the appearance of the embryo in a section cut in the plane of flattening of the gonangium. In a vertical section at right angles to this plane the planula bears a different aspect. The sides of the embryo are squeezed flat against the perisarc of the gonotheca with no gonangial ectoderm between (fig. 18). Laterally the embryo is very thin-walled, and both the ectoderm and endoderm layers are one cell thick, while on the other hand these layers are two or more cells thick at the distal and proximal ends. The blastocœl (*Bl.*) is roughly rectangular in section.

Thus the embryo at this stage is of a curious shape. It is thick-walled everywhere (fig. 19), except laterally (fig. 18), over the flattened sides of the gonotheca, where the walls are very thin.

The material has not permitted an examination of a later stage, but it is probable that the planula in the above condition is nearly ready to burst out of the gonotheca, for the gonotheca which was immediately below, and therefore slightly older, was empty, and the operculum absent, doubtless through the bursting out of the planula.

Summary.—Here we have an interesting case of the nourishing of the developing embryo. In the great majority of Invertebrata the ovum becomes charged with sufficient food or yolk-material to enable development to proceed far enough for the young creature to be able to provide itself with food. In the present hydroid the egg remains quite small and is never provided with a perceptible quantity of yolk, but it segments, and development takes place, in a kind of maternal placental tissue which supplies the embryo with food during

the whole development. This placental tissue arises as a modification of a specialised portion of the ectoderm of the blastostyle. This portion, as we have seen, forms a kind of cap over the young ovum, and doubtless may be regarded as representing the manubrial ectoderm of a rudimentary gonophore which bears one egg.

EXPLANATION OF PLATE VI,

Illustrating Dr. Ernest Warren's paper, "On the Development of the Planula in a certain Species of Plumularian Hydroid."

EXPLANATORY REFERENCES FOR PLATE AND TEXT-FIGURES.

B. Blastostyle. *Bl.* Blastocœl. *b. G.* Beginning of gonangium. *C.* Cœlenteron. *c. p.* Covering plate ("Deckenplatte") of ectoderm of gonangium. *e. O.* Cavity above ovum, which may be regarded as a cavity between the manubrial ectoderm and endoderm of gonophore. *e. U.* Cavity of umbrella. *d. C.* Diverticulum of cœlenteron representing the endoderm of gonophore. *d. p.* Dissolved perisarc. *e. B.* Ectoderm of blastostyle. *e. G.* Scattered ectoderm cells of gonophore. *e. E.* Outer enveloping ectoderm derived from the scattered ectoderm cells of gonophore. *e. l.* External ectoderm layer of typical gonophore. *e. l. U.* Ectoderm layer of umbrella. *ect.₁* Ectoderm of planula. *end.* Endoderm of blastostyle and of gonophore. *end₁* Endoderm of planula. *g. e.* Granular endoderm. *i. l.* Inner or manubrial ectoderm layer of gonophore. *M.* Morula. *M. e.* Manubrial ectoderm. *n., n.* Oblique nodes at base of pinnate portion of main-stem. *n.₁ n.₁* Transverse nodes at base of pinna. *n.₂, n.₂* Transverse nodes at the base of pinnule. *O.* Ovum, *o. l.* Outer layer of gonophore, equivalent to the layer of ectoderm lining the umbrella-cavity. *op.* Operculum. *p. e. c.* Posterior ectodermal space of hydrocaulus. *p. i. p.* Proximal internode of pinnule. *pl. t.* Placental tissue. *Sg. C.* Segmentation-cavity. *s. p.* Space between the external ectoderm layer of gonophore and the ectoderm of the umbrella-cavity. *sp.₁, sp.₂* Spaces between perisarc of gonotheca and blastostyle. *sp. c.* Spermatic cells in endoderm of hydrocaulus. *t.* Spermatic cells (testis) of male gonangium. *t. p.* Terminal portion of the cœlenteron of blastostyle. *v. m.* Membrane around ovum.

FIG. 1.—× 220. Longitudinal section through the main-stem immediately below a hydrotheca showing the beginning of the gonangium

(*b. G.*), the superimposed attenuated perisarc (*d. p.*), and the youngest observed ovum (*O.*) embedded in the endoderm.

FIG. 2.— $\times 220$. Longitudinal section through a young gonangium showing the ovum (*O.*) being thrust out into a special thickening of the ectoderm, which early becomes differentiated into an outer (*o. l.*) and an inner layer (*i. l.*) and represents the ectodermal portion of a reduced gonophore. The slight space between the two layers is equivalent to the umbrella-cavity of a medusa.

FIG. 3.— $\times 260$. Transverse section through a young gonangium, showing the ovum surrounded by the ectoderm of the gonophore. *sp.* is the space which arises between the outer ectoderm of the gonophore and the ectoderm of the reduced umbrella-cavity.

FIG. 4.— $\times 220$. Longitudinal section through a slightly older gonangium. The gonophore, consisting entirely of ectoderm, is more developed. The outer layer (*o. l.*) is now well-defined, while the inner layer (*i. l.*) closely surrounds the ovum (*O.*). The ectoderm of the gonangium at the distal surface has thickened considerably and forms the "covering cap" (*c. p.*). The space (*sp.*) is clearly seen. Spaces (*sp.*₁, *sp.*₂) are appearing between the perisarc of the gonotheca and the general ectoderm. The endoderm immediately under the gonophore ectoderm is more granular than the remainder of that layer.

FIG. 5.— $\times 220$. Longitudinal section through an older gonangium. The outer layer of ectoderm (*o. l.*) has become more flattened through pressure exerted by the expanding inner layer (*i. l.*). Beneath the gonophore the endoderm is beginning to grow and to form a diverticulum of the coelenteron which represents the coelenteron cavity of the reduced gonophore.

FIG. 6.— $\times 220$. In this older stage the longitudinal section shows a well-defined space (*c. O.*) between the ovum and the ectoderm (*i. l.*) of the gonophore. The ovum is surrounded by a membrane which is more marked externally than on the inner surface, which is in contact with the endoderm.

FIG. 7.— $\times 220$. Longitudinal section of gonangium at right angles to the plane of flattening. Here the cavity (*c. O.*) of the gonophore has expanded, and the membrane around the ovum (*c. m.*) is thickened.

FIG. 8.— $\times 220$. Longitudinal section of gonangium in the plane of flattening. This is in the same stage of growth as in fig. 7.

FIG. 9.— $\times 220$. Longitudinal section at a later stage. The ectoderm layer of the gonophore has broken down (*c. G.*), and forms an irregular mass of tissue around the ovum. The endoderm below is granular and in an active condition of growth. The cells of the distally placed

endoderm and those of the "covering cap" have become very elongated and attenuated.

FIG. 10.— $\times 220$. Longitudinal section at the next stage. The distal endoderm and the "covering cap" have completely disappeared and the ovum is surrounded by cells which have arisen from the scattered ectoderm of the broken-down gonophore. The ovum is being pushed into a central position by the growth of the diverticulum of the cœlenteron (*d. C.*) which is the endodermal spadix of the gonophore.

FIG. 11.— $\times 220$. Longitudinal section showing embryo (*M.*) derived from the segmentation of the ovum. It consists of about sixteen cells, and is central in position immediately below the middle point of the distal surface of the perisarc of the gonotheca. The embryo is surrounded by the placental tissue. The diverticulum of the cœlenteron (*d. C.*) or gonophore spadix has become equal in size to the terminal portion (*t. p.*) of the cœlenteron of the gonangium.

FIG. 12.— $\times 480$. Enlarged view of morula imbedded in placental tissue (*pl. t.*).

FIG. 13.— $\times 220$. Later stage. The embryo, the placental tissue, and the cœlenteron pouches have grown. The embryo has developed a segmentation space (*sg. C.*).

FIG. 14.— $\times 220$. In the next stage, a differentiation of the cells of the embryo into an outer ectoderm and an inner endoderm is seen. Distally there is only ectoderm (*ect.₁*) which is very thin; proximally the ectoderm is thicker and is more than one cell thick.

FIG. 15.— $\times 220$. The embryo becomes pear-shaped, and the endoderm is not continued distally. The maternal ectoderm (*e. E.*), derived originally from the placental tissue, is continued around the outside of the cœlenteron pouches, and the cells become very elongated and reach the lateral perisarc of the gonotheca.

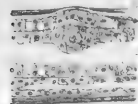
FIG. 16.— $\times 220$. A later stage where the embryo has grown considerably and has extended inwards towards the centre of the gonangium. The cœlenteron pouches, consisting, on one side, of the spadix of the gonophore, and on the other, of the terminal portion of the cœlenteron of the blastostyle, form a deep cup containing the embryo and the true placental tissue (*pl. t.*). The enveloping ectoderm (*e. E.*) has also greatly extended. *Bl.* is blastocœl. The endoderm (*g. e.*) of the gonangium at the base of the embryo is more granular than elsewhere. The endoderm of the embryo now forms a continuous layer. It is mostly more than one cell thick, as also is the outer ectoderm.

FIG. 17.— $\times 440$. Enlarged view of a piece of embryo, the surrounding placental tissue and the endoderm of gonangium. The ectoderm

(*ect.*₁) of the embryo is in intimate contact with the placental tissue (*pl. t.*).

FIG. 18.— $\times 220$. Longitudinal section of gonangium at right angles to the plane of flattening. The planula is seen wedged between the perisarc of the gonotheca. The wall of the planula is very thin laterally, but much thicker proximally and distally.

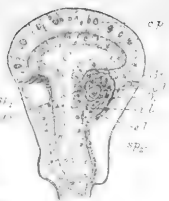
FIG. 19.— $\times 220$. The planula in section in the plane of flattening of the gonotheca. The wall of the planula is of considerable thickness all round. Both the endoderm (*end.*₁) and ectoderm (*ect.*₁) are several cells in thickness.



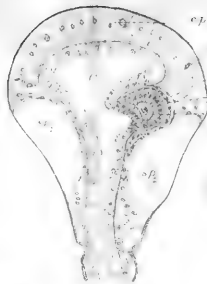
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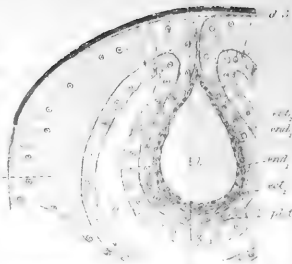
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3 x 220.



4 x 220.



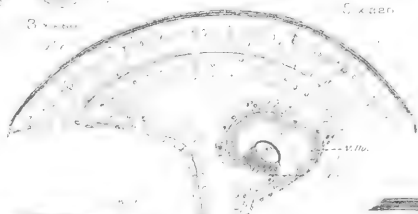
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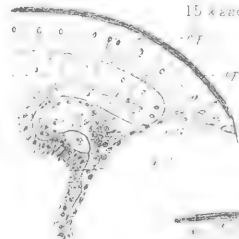
6 x 220.



7 x 220.



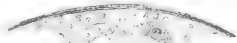
8 x 220.



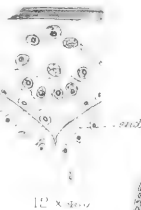
9 x 220.



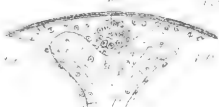
10 x 220.



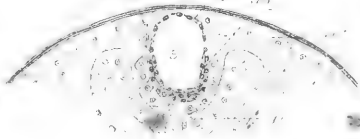
11 x 220.



12 x 220.



13 x 220.



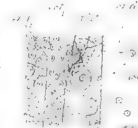
14 x 220.



15 x 220.



16 x 220.



17 x 440.



**Note on the Occurrence in South Africa of a
Termitophilous Beetle of the Genus Corotoca.**

By

Ernest Warren, D.Sc.Lond.

AMONG the most remarkable and interesting of the termitophilous insects are the beetles of the genera *Spirachtha* and *Corotoca*, belonging to the family Staphylinidæ. They have a much swollen abdomen, with the greater portion of it permanently turned forwards over the dorsal surface of the thorax. It extends as far as the middle of the pronotum. These beetles were first described and figured by J. C. Schiödte in 1854 from specimens obtained from termite nests in Brazil.

In 1905, Dr. Ivar Trägårdh, of the Upsala University, visited South Africa on a collecting trip, and he discovered in the nest of a species of *Eutermes*, in a limited area in Zululand, a great number of specimens of a new Staphylinid, which he has called *Termitomimus*. This genus is characterised by the second and third segments of the abdomen being very greatly swollen, and the remainder of the abdomen, which is somewhat less swollen, is turned forward over the thorax.

Dr. Trägårdh examined many nests of termites in Natal, but no other physogastric Staphylinids were discovered.

Recently, numerous nests of the common termite *Eutermes trinervius* (*Rambur*) have been examined in another connection by Dr. Conrad Akerman and myself in the neighbourhood of Pietermaritzburg, and in March, 1913, Dr. Akerman found in one of the nests a single specimen of a physogastric Staphylinid. Subsequent examination proved that it un-

doubtedly belongs to the genus *Corotoeca*, and is closely allied to, although specifically distinct from, *Corotoeca melantho* Schiödte of Brazil.

Since this discovery, about 120 nests in different localities have been examined with a view to obtaining more material and ascertaining the life-history of the species, but only three other specimens have been found.

In certain nests a beetle-larva with some resemblance to the larva figured by Schiödte as being that of *Corotoeca melantho* has been found in fair numbers, but all attempts to rear it have proved fruitless. The termite *Eutermes trinervius* does not live for any length of time under artificial conditions, and the beetle-larva is even more delicate. The antennæ and mouth-parts are quite like those of the larva of *C. melantho*; the abdominal segments also bear lateral processes, but in the present species they carry bristles. On the whole it seems probable that the larva is that of the *Corotoeca*, but it is remarkable that it is comparatively common, while the beetle appears to be excessively rare, and this rarity explains the circumstance that apparently it has not been previously found. A possible explanation is that the termites interfere injuriously with the beetle when in the pupal condition, so that only a very few ever arrive at the perfect state.

It is hoped that when further material has been collected, a comparison of the anatomy of this genus may be made with that of *Termitomimus entendvniensis* Träg., which was carefully described and figured by Dr. Trägårdh¹ in 1907.

The occurrence of this highly specialised termitophilous genus *Corotoeca* both in Brazil and South Africa is interesting in indicating its antiquity, and in connection with the fact that the similarly modified termitophilous dipteran, *Termitoxenia*, is found both in South Africa and India.

¹ Trägårdh, Ivar, 'Description of *Termitomimus*, a New Genus of termitophilous physogastric Aleocharini, with Notes on its Anatomy,' Upsala, 1907.

J. S. Schiödte¹ has given a careful definition of the genus *Corotoea*, and also concise diagnoses of two species, *C. melantho* and *C. phylo*, both from Brazil.

These diagnoses are quoted below in order that they may be compared with the brief description of the new species which is now given, pending a detailed account of the anatomy of the insect, which it is proposed to publish later.

I have pleasure in associating this interesting species with its discoverer, Dr. Conrad Akerman.

“1. *Corotoea melantho* *Schiödte*.

“Fusca, fronte foveolata, pronoto multifoveolato, disco bituberculato: tibiis posterioribus fusiformibus, fuscis: scutis ventralibus segmenti quarti quintique transversis.—Mas, Fem.

“Long. a fronte ad apicem segmenti secundi abdominis, 2½–3 millim.

“2. *Corotoea phylo* *Schiödte*.

“Fusca, vertice foveolato, pronoto multifoveolata, disco trituberculato: tibiis posterioribus linearibus, nigrofuscis: scutis ventralibus segmenti quarti quintique subquadratis.—Fem.

“Long. a fronte ad apicem segmenti secundi abdominis, 2½–3½ millim.”

3. *Corotoea akermani* *sp. n.*

Brown, forehead or vertex not pitted, occiput flat or slightly concave, not tuberculated; pronotum smooth, except for a very shallow and rather wide and inconspicuous median groove extending along the posterior three-quarters of its length; posterior tibiæ rather slender, straight or slightly curved, not fusiform, but rod-shaped; sternites of the third, fourth, fifth, sixth and seventh abdominal segments appear as five isolated, uniform, narrow, transverse, brown strips of chitin

¹ Schiödte, J. C., ‘*Corotoea* og *Spirachtha*,’ Kjøbenhavn, 1854, pp. 8–9.

on the upper surface, all of which are widely separated from one another by intersegmental membranes caused by the swelling of the abdomen; the morphologically dorsal surface of the abdomen rather deeply concave, fitting over the thoracic region, which is not flattened or otherwise much modified.

Length from forehead to hinder end of upturned abdomen, 3.2-3.6 mm.

Loc.—Environs of Pietermaritzburg: Durban Road (Dr. Akerman, March, 1913); Botanical Gardens (W. Cullingworth, July, 1913); Sweetwaters Road (July, 1913); Bisley Road (December, 1913).

Studies on
The Carnivorous Slugs of South Africa,

INCLUDING

A Monograph on the Genus *Apera*, and a Discussion on
the Phylogeny of the *Aperidæ*, *Testacellidæ*, and
other Agnathous Pulmonata.

By

Hugh Watson, M.A.

With Plates VII-XXIV, and 7 text-figures.

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INTRODUCTION.

MANY snails and slugs of great interest inhabit South Africa, but very little is known about their anatomy. I have therefore been asked to describe some of these animals, beginning with those in which the shell is degenerate or absent. The present article deals with the slugs belonging to the carnivorous group, and principally with those contained in the genus *Apera*; and as this genus is a very remarkable one and seems to be confined to South Africa, I am endeavouring to describe it in some detail. Unfortunately, however, the material at my disposal has been limited to a small number of preserved specimens, some of which have proved to be immature. More than half of these specimens were collected and sent to me by Mr. H. C. Burnup, of Pietermaritzburg, to whom I am very deeply indebted. I am also glad to have this opportunity of expressing my thanks to the Rev. Prof. H. M. Gwatkin, to Dr. Doncaster of Cambridge, Dr. Péringuey of Cape Town, Dr. Pilsbry of Philadelphia, Dr. Simroth of Leipzig, and Dr. Warren of Pietermaritzburg, to Major M. Connolly, and to Messrs. Keppel H. Barnard, Walter E. Collinge, John Farquhar, John H. Ponsonby, G. C. Robson, Edgar A. Smith, and William Tams.

THE HISTORY OF THE GENUS *APER*A.

Nearly forty years ago, when Mr. J. S. Gibbons was visiting Natal, he found a strange slug under a stone in a wood. This animal puzzled him greatly; it seemed more like a *Testacella* than anything else he knew; yet clearly it was not a *Testacella*, for where the shell should have been there was merely a little hole—the respiratory orifice.¹ Gibbons therefore sent the slug to Mr. W. G. Binney, with a description of its appearance when alive. Binney examined its radula, and found that its teeth were like those of *Glandina*. He also discovered that it had no jaw, but that it possessed an internal shell, which was broken when he found it, but which he wrongly assumed to be hexagonal when perfect. And Binney² established a new genus for this peculiar animal, and published a description of it in 1879, together with Gibbons's account of its appearance when alive, a rough drawing of the animal, and a figure of its radula. And he named the slug *Chlamydephorus gibbonsi*.

In 1884 Binney³ repeated his description of the radula of this slug and reproduced his figure. In the same year Tryon⁴ reproduced the rough drawing of the animal, and gave a brief description of the genus, which he placed in the *Testacellidæ*; and he also amended the spelling of the generic name, changing it to *Chlamydephorus*. In the following year, however, he reverted to the original spelling, when he described the genus and species in the 'Manual of Conchology,'⁵ and again reproduced the rough drawing of the animal.

Now Binney named the genus *Chlamydephorus* because he said that the mantle covered the whole back. But in this Binney was wrong, as Heynemann⁶ was the first to point out,

¹ *Vide* Collinge, W. E., 'Ann. Natal Mus.,' 1910, vol. ii, p. 164.

² 'Bull. Mus. Comp. Zool. Harvard,' vol. v, p. 331, pl. ii, figs. a, b.

³ "Notes on the Jaw and Lingual Dentition of Pulmonate Mollusks," 'Ann. N. Y. Acad. Sci.,' vol. iii, p. 81, pl. xvii, fig. A.

⁴ 'Struct. and Syst. Conch.,' vol. iii, p. 13, pl. ci, fig. 47.

⁵ Vol. i (2nd ser.), pp. 7, 17, pl. ii, fig. 95.

⁶ 'Jahrb. d. Deutsch. Mal. Ges.,' vol. xii, p. 17, pl. ii, figs. 5-7.

when, in 1885, he published a description and three figures of the external characters of a specimen in the British Museum, labelled "Cape Colony." He thought that the animal was nearly related to *Testacella*; and as he showed that it had no mantle on its back, he suggested that the generic name should be changed to *Apera*.

In 1890 Prof. T. D. A. Cockerell¹ published a short description with measurements of what appears to be the same specimen, and he said that Heynemann's name would probably have to be used, as *Chlamydephorus* (differing from Binney's name only by one letter) had been employed by Harlan for a genus of Mammalia in 1825.

In 1892 Mr. E. A. Smith² described the external characters of a new species of *Apera*, very different from *A. gibbonsi*, which Mr. H. C. Burnup had found in Natal, and he named it *Apera burnupi*. He also thought that *Apera* was the best name to use, as *Chlamydephorus* had been employed in the Mammalia, but he attributed the latter name to Agassiz ('Nomenclator Zoologicus, Mammals,' 1842, p. 8), instead of to Harlan. Prof. Cockerell³ then discovered that *Apera* was preoccupied in botany, and therefore thought that it might be better to use Binney's name with the original spelling. He placed the genus in the *Testacellidæ*. On the other hand, Dr. Simroth,⁴ after studying Heynemann's article, suggested that the genus might be allied to the *Janellidæ*, its carnivorous characters having arisen independently of those of *Testacella*. He thought that the fragmentary condition of the shell, as found by Binney, might be natural; but had difficulty in explaining how it was that *Apera* had two pairs of tentacles and *Janella* only one. In 1895 *Apera* and *Chlamydephorus* were treated as though they were separate genera by Dr. A. H. Cooke.⁵

¹ 'Ann. Mag. Nat. Hist.' (6th ser.), vol. vi, p. 390.

² 'Ann. Mag. Nat. Hist.' (6th ser.), vol. x, p. 466.

³ 'Conchologist,' 1893, vol. ii, p. 206.

⁴ 'Nacktschnecken, Deutsch-Ost-Afrika,' 1895, ex. vol. iv, p. 20.

⁵ 'The Cambridge Natural History,' vol. iii. 'Molluscs and Brachiopods,' pp. 333, 334, 440.

Two years later Mr. W. E. Collinge¹ described and figured the alimentary canal, pedal gland, and reproductive organs of a specimen of *Apera* which he had received from Mr. E. A. Smith. Unfortunately this specimen was not in good condition for dissection, and Collinge's description is inaccurate in several respects, and his figures bear but little resemblance to the natural condition of the organs that they are intended to portray. Moreover the specimen was named *Apera burnupi*, whereas it really belonged to a quite distinct species. Collinge stated that he considered that *Apera* had affinities with the Testacellidæ, but he thought that there was a wide gap between it and either *Testacella* or *Daudebardia*, and a still wider gap between *Apera* and *Schizoglossa*. In the following year Dr. Pilsbry published a short review of Collinge's article in the 'Nautilus.'²

In 1899 Paul and Fritz Sarasin³ brought forward the theory that *Apera* was ancestral to *Atopus*. Now *Atopus* has a large mantle covering the whole body, and the brothers Sarasin therefore rejected Heynemann's interpretation of the morphology of *Apera*, and advocated the use of Binney's name *Chlamydephorus*.

In 1900 Collinge⁴ received through Mr. J. H. Ponsonby an example of *Apera burnupi* Smith, found by the Rev. J. R. Ward at Richmond, Natal, and belonging to the South African Museum, Cape Town. He at once saw that this specimen differed from the species which he regarded as *Apera burnupi*, and accordingly he named it *Apera natalensis* n. sp. He made a superficial dissection of some of the internal organs, but the specimen does not appear to have been in a much better condition than that of the other species which he had previously dissected, and his figures of its anatomy are in consequence equally faulty. In the same

¹ 'Ann. Mag. Nat. Hist.' (6th ser.), 1897, vol. xx, pp. 221-225, pl. v. figs. 1-6.

² Vol. xii, p. 12.

³ 'Die Land-Mollusken von Celebes,' p. 112.

⁴ 'Ann. S. Afr. Mus.,' vol. ii, pp. 3-5, pl. i, figs. 3, 4, pl. ii, figs. 14, 15.



paper Collinge published two coloured figures of both species by Mr. F. J. Partridge.

In the following year Collinge¹ had an opportunity of examining a better specimen of the species which he supposed to be *Apera burnupi*, and he discovered how misleading were his former figures of its anatomy. He therefore published a more accurate figure and description of the reproductive organs of that species. At the same time he criticised the theory of P. and F. Sarasin, and said that *Apera* was probably closely allied to the Testacellidæ, while *Atopus* on the other hand seemed to be far removed from that family.

In December, 1901, Collinge² described the external features of a new species of *Apera* found by Mr. R. M. Lightfoot on the slopes of Table Mountain, Cape Town, and published coloured figures of it by Partridge. This species he named *Apera purcelli*.

Dr. Simroth,³ in the same month, published a copy of Collinge's figure of *Apera natalensis* (= *A. burnupi Smith*), in his interesting article on carnivorous snails and slugs. In this paper he unfortunately stated that *Apera* was without a shell, and again suggested that the genus might have been derived from the Janellidæ, or possibly from some other ancient family of herbivorous slugs found in the Southern Hemisphere, although he admitted that too little was known of the genus to give any value to his hypothesis.

In 1902 Collinge⁴ reproduced on a larger scale his second figure of the reproductive organs of the species which he erroneously supposed to be *Apera burnupi*. In the following year Dr. von Moellendorff⁵ removed the genus from the Testacellidæ, and placed it in a family by itself, which he

¹ 'Journ. of Malac.' vol. viii, pp. 71, 72.

² 'Ann. S. Afr. Mus.' vol. ii, p. 230, pl. xiv, figs. 1, 2.

³ 'Naturwiss. Wochenschrift,' vol. xvii, p. 111, fig. 7.

⁴ 'Journ. of Malac.' vol. ix, pl. vi, fig. 66.

⁵ 'Conch.-Cabinet (Agnatha),' p. 5.

named the *Aperidæ*. In 1906 Heynemann¹ devoted a paragraph to the genus in his article on the geographical distribution of slugs. In 1907 Dr. Pilsbry² followed Moellendorff's example and placed the genus in the family *Aperidæ*, which he included in his super-family *Agnathomorpha*; and he suggested that it might prove to be more nearly related to the *Rhytididæ* than to the other carnivorous families.

In 1909 and 1912 Simroth³ included in Bronn's 'Tier-Reich' some of the information given in Collinge's articles, and published copies of four of the figures which had illustrated his first paper in the 'Annals of the South African Museum.'

In 1910 Collinge⁴ gave a short account of the external features of the three species of *Apera* then known to inhabit Natal, together with a definition of the genus, and some remarks on its habits, distribution, affinities, and history. This paper contains valuable quotations from letters of Gibbons and Burnup, but the error about *Apera burnupi* is repeated. In treating of the affinities of the genus, Collinge again stated that he considered that P. and F. Sarasin were wrong in regarding *Apera* as in any way related to *Atopus*; but he now expressed the opinion that it was not related to *Testacella* either, and thought that it should probably stand by itself as a remnant of some very ancient stock of carnivorous Pulmonates. Accordingly he placed it in a separate family, which he termed the *Aperaidæ fam. nov.*, being apparently ignorant of the classification of both Moellendorff and Pilsbry.

Lastly, in 1912, Major Connolly⁵ included *Apera* in his valuable "Reference List of South African Non-marine Mollusca," following Collinge's nomenclature of the species.

Such is the story of the treatment that *Apera* has received,

¹ 'Abhandl. Her. v. d. Senkenb. Naturf. Gesell. (Frankfurt),' vol. xxx, p. 23.

² 'Manual of Conchology' (2nd ser.), vol. xix. pp. ix, xi.

³ 'Klassen und Ordnungen des Tier-Reichs III, Gastropoda Pulmonata,' pp. 143, 611, 612, fig. 42c, pl. iv, figs. 9-11.

⁴ 'Ann. Natal Mus.,' vol. ii, pp. 163-170.

⁵ 'Ann. S. Afr. Mus.,' vol. xi, pp. 62, 63.

and it is largely a story of mistakes. It will have been seen that four species have been described, three from Natal and one from the Cape, but that very little is known about the anatomy of any of these, as only two reliable figures have hitherto been published of their internal features, namely, Binney's figure of the radula of *Apera gibbonsi*, and Collinge's second figure of the reproductive organs of the species which he supposed to be *A. burnupi*. Nevertheless this ignorance does not seem to have prevented malacologists from speculating about the affinities of the genus; for, as we have seen, it has been suggested in turn that it may be related to the *Testacellidæ*, to the *Janellidæ*, to *Atopus*, or to the *Rhytididæ*, forms which differ immensely from one another. It is hoped that the information contained in the present article may give greater value to such speculations in the future.

In the following pages I am attempting to describe this remarkable genus in as great detail as the limited number of specimens at my disposal will permit, giving numerous figures of its anatomy. Secondly, I am giving a concise description of the distinctive characters—both external and internal—of each species; that is to say, of *Apera gibbonsi*, *A. purcelli*, *A. burnupi*, the species that Collinge erroneously supposed to be *A. burnupi*, which I am naming *A. sexangula*, and two new species—*A. dimidia* from Natal, and *A. parva* from Grahamstown. And at the same time I am pointing out that there are some very distinct races of *A. gibbonsi*, which may also prove to be separate species, but which I am provisionally regarding as sub-species until more material is obtainable. After dealing with the relation of these forms to one another, I am describing briefly the species of *Testacella* that occurs at the Cape, and am then discussing at some length the probable relations of *Apera* and *Testacella* to each other and to the remaining genera of carnivorous snails and slugs.

A DESCRIPTION OF THE GENUS *APER*A.

EXTERNAL CHARACTERS.

GENERAL SHAPE.—The slugs contained in the genus *Apera* are subcylindrical, tapering gradually towards the head and more abruptly at the hind end, the broadest region being usually behind the middle of the animal. The height is equal to the breadth or sometimes slightly less, while the width of the foot varies from three-fifths to scarcely one-half of the greatest breadth of the body. Most of the species are rather slender, especially *A. parva* and some forms of *A. gibbonsi*; and it is interesting to notice that the latter do not contract when about to rest, after the usual manner, but merely bend their bodies at various angles, in which state, Mr. Burnup informs me, they much resemble the rhizomes of ferns.

SIZE.—So few specimens of *Apera* have been examined that the mean dimensions attained by each species cannot be stated with accuracy. It seems probable, however, that the average length of each of the three larger species—*A. gibbonsi*, *A. burnupi* and *A. sexangula*—lies between 60 and 65 mm., in the case of specimens preserved in alcohol, although occasional examples may reach a length of nearly 80 mm. On the other hand adult specimens of *A. dimidia* preserved in spirit are only about 33 mm. long, and *A. parva* and *A. purcelli* seem to be still smaller species.

TENTACLES.—As usual in the *Stylommatophora*, there are two pairs of tentacles, the upper pair being retractile and bearing the eyes.¹ The lower tentacles are small, and beneath them there is another pair of short processes of a paler colour, which doubtless correspond to the labial feelers found in most of the carnivorous genera.

GENITAL OPENING.—The common opening of the reproductive organs is on the right side of the head, two or three millimetres behind the right lower tentacle, and about half that distance from the margin of the foot.

¹ See pp. 153, 154 for structural details.

RESPIRATORY OPENING.—The aperture of the mantle-cavity or “respiratory orifice” is situated towards the hind end of the back, just to the right of the mid-dorsal line. Its posterior position, about four times as far from the head as from the hind end of the slug, is due to the lengthening of the anterior part of the body and the retrogression of the pallial organs, as in *Selenochlamys* and *Testacella*. The dorsal position of the opening is explained by the absence of any external mantle or shield in *Apera*.¹

The orifice is always a little nearer the right side than the left, a fact which previous writers seem to have overlooked, although it is of considerable morphological importance, as may be seen from Pl. X, fig. 33 (a transverse section through the respiratory opening of *Apera gibbonsi rubella*). This illustration also shows that the opening is surrounded by two lips, one within the other. In *Apera gibbonsi* and *A. parva* the outer lip projects over the inner lip so as almost to conceal it; but in the other four species the outer lip is much narrower, and leaves a wide circular opening, within which the light-coloured inner lip is exposed to view (Pl. VII, fig. 12; Pl. VIII, figs. 24, 25, 26). The right anterior edge of the inner lip is cleft by an oblique slit, running forwards and outwards from the central aperture.

KEELS.—In most of the species of *Apera* the back is rounded, but *A. burnupi* and *A. sexangula* both have four longitudinal keels, two on each side of the body, which may possibly serve to increase the rigidity of the skin. The upper keels of *A. sexangula* are nearly parallel throughout the greater part of their length, the distance between them measuring about three-fifths of the breadth of the body. When followed backwards, however, they diverge very slightly just in front of the respiratory opening, and then gradually approach each other behind it, until they unite to form a single median keel, 3 or 4 mm. in length, at the hind end of the animal. In *A. burnupi* the upper keels are further apart, and become very prominent towards the hind end, diverging considerably and

¹ See pp. 130, 131.

then curving round to meet in a very obtuse angle just above the posterior extremity of the foot.

The lower keels of *Apera sexangula* extend on each side along the whole length of the animal, about half-way between the upper keels and the edges of the foot. The slug is thus roughly hexagonal in transverse section, but when it contracts the surfaces between the keels become concave. In *A. burnupi* the lower keels are much nearer the foot than in *A. sexangula*, and become obsolete towards the hind end of the slug.

The other species of *Apera* are without any traces of either median or lateral keels. They are bluntly pointed at the posterior end.

There is no caudal mucous pore in *Apera*.

DERMAL GROOVES.—In all the species of *Apera* the back and sides of the animal are covered with a network of grooves, dividing the skin into numerous polygonal rugæ. These grooves are specially deep in *A. burnupi*. The centres of the rugæ are often raised in well-preserved specimens, and the skin has therefore a granular appearance.

Certain of the grooves are larger than the others, and run in more definite directions, forming as it were the main channels from which branch the smaller grooves that form the network. First there are the two dorsal grooves which run along the middle of the back from the respiratory opening to the head. These are most strongly developed in *Apera burnupi*, and least conspicuous in *A. dimidia*, in which species the main grooves are scarcely more distinct than the other grooves of the network. The distance separating the dorsal grooves varies from about one-seventh of the breadth of the body in *A. dimidia* to less than half that proportion in some forms of *A. gibbonsi* (Pl. VII, fig. 4). In *A. burnupi*, *A. sexangula*, and *A. purcelli* these grooves are separate throughout their entire length, but in *A. gibbonsi*, *A. parva*, and *A. dimidia* they are united posteriorly, and arise from the respiratory opening as a single groove which divides between 3 and

5 mm. in front of the opening (Pl. VII, figs. 1, 4; Pl. VIII, figs. 22, 24).

A single median posterior groove runs backwards from the orifice. It is usually deep and conspicuous in front, but breaks up into finer irregular grooves before reaching the hind end of the slug.

Well-marked radial grooves diverge laterally from the region of the respiratory opening. About four of these on each side arise from the opening itself, and two or three others branch from the median posterior groove behind the opening. In *Apera purcelli*, the most anterior grooves, instead of arising from the respiratory opening, branch from the dorsal grooves in front of it (Pl. VIII, fig. 25). As a rule the radial grooves extend down the sides of the body, but in *A. gibbonsi* some of them usually bifurcate before reaching the edge of the foot. The most anterior grooves of *A. gibbonsi*, *A. parva*, and *A. dimidia* always divide within a short distance of the respiratory opening, the lower branch sloping downwards towards the foot, while the other continues forward. The latter branch soon divides again in a similar manner, and this process is repeated several times, so that an irregular lateral groove is formed, which runs forward parallel to the dorsal groove and gives off oblique sub-lateral grooves parallel to one another. The lateral grooves are seldom well developed in *A. gibbonsi* and *A. dimidia*, but the oblique sub-lateral grooves are rather conspicuous in the former species (Pl. VII, figs. 2, 3, 5, 6). On the other hand, in *A. parva*, *A. burnupi*, and *A. sexangula* the lateral grooves are more definite and better developed than the sub-lateral grooves, of which there are only a small number (Pl. VIII, fig. 23; Pl. VII, figs. 11, 13). The lateral grooves of the two latter forms are lower down than those of the other species, and branch from the most anterior pair of radial grooves at a greater distance from the respiratory opening. They run along between the upper and lower keels as far as the head, the right lateral groove ending in the genital opening as in *Testacella* and other forms. It is probable that the greater

development and lower position of the lateral grooves in these two species is due to the presence of the keels. There are no definite lateral grooves in *A. purcelli*.

The foot-fringe is bounded above by a peripodial groove, which is usually rather deep (Pl. XI, fig. 35). In *Apera burnupi* and *A. sexangula* there is a second groove, parallel to the peripodial groove, but separated from it by a narrow row of rugæ, and the radial grooves do not extend below this upper groove, but terminate in it. As a rule the other species have only the single peripodial groove with which the radial grooves unite, but in *A. dimidia* the upper limits of the lowest row of rugæ are sometimes arranged so as to form an irregular groove parallel to the peripodial groove on each side.

The foot-fringe itself is narrow and is crossed by a number of small vertical grooves, which are often continued across the edges of the foot-sole. In contracted specimens many of these transverse grooves extend right across the sole, although they are never so numerous in the middle as at the edges. A conspicuous but irregular longitudinal groove often runs along the centre of the foot-sole, but this also is probably due to the contraction of the specimens. In some examples two grooves diverge from a point at the hind end of the foot-sole and extend forward nearly parallel to the edges of the foot, thus dividing the hinder part of the sole into median and lateral areas. Occasionally these grooves may be traced forward for about two-thirds of the length of the animal, but they are more usually confined to the hind end, as shown in Pl. VII, fig. 9, and in many specimens they are entirely absent. In *Natalina* I have sometimes found similar grooves towards the hind end of the foot; but none of the grooves on the foot-sole seem to have so much systematic value as those on the back and sides of the slug, for they may be present or absent in different individuals of the same species.

COLOUR.—The skin of *Apera* is coloured, and the colour is almost entirely due to pigment. It is true that specimens of the more darkly coloured species when preserved in spirit

sometimes have a slightly bluish or bluish-green tinge, and that this is probably due not to pigment, but to minute particles in the outer layer of the skin which intercept the blue rays. It is doubtful, however, whether this interference effect would be as noticeable in living specimens.

Apera possesses two chief kinds of pigment: the first is dark and relatively stable, the second is lighter, very unstable, and superposed upon the first.

The dark pigment is usually brownish-grey, varying from dull brown in typical examples of *Apera gibbonsi* to dark grey in *A. purcelli*. It does not spread uniformly over the back and sides of the animal, but is more concentrated in some parts than in others. In the first place the dark pigment tends to be aggregated into small irregular patches, which give the slug a mottled appearance. This tendency is least apparent in *Apera purcelli*, and most marked in *A. dimidia*, *A. burnupi*, and some varieties of *A. gibbonsi*. In these animals the patches of colour are well defined, so that the skin is conspicuously mottled. When the dark patches are examined through a strong lens they are seen to contain minute lighter specks, which are probably caused by the dermal mucous glands.

Secondly, the dark pigment generally shows a tendency to become concentrated along the sides of the dermal grooves. Thus in *A. gibbonsi* the oblique sub-lateral grooves are usually rendered more conspicuous by the way in which the patches of pigment tend to coalesce along their courses.

Thirdly, the dark pigment is more abundant on some regions of the body than on others. In *Apera gibbonsi* it is concentrated dorsally, although a lighter band is generally left along the very centre of the back (Pl. VIII, figs. 14-19). On the sides of the animal the mottling becomes sparser, and it dies out before reaching the foot-fringe. In the keeled species, as well as in *A. dimidia* and *A. purcelli*, the dark pigment tends to be concentrated laterally, so as to form an irregular longitudinal band on each side of the body. Between the bands there is a lighter

dorsal area, palest at the edges, but a little darker in the middle; below them the colour shades off gradually towards the foot. This arrangement of the pigment is best developed in *Apera dimidia* (Pl. VIII, figs. 20 and 21), but it is also fairly conspicuous in *A. burnupi*, where the dark mottling is concentrated to form a band on each side below the upper keels. In *A. sexangula* and *A. purcelli* the bands, though present, are less noticeable and the colour is more evenly distributed, although the edges of the keels of *A. sexangula* are almost free from pigment.

It will be seen that in these four species the pigment tends to form a pattern similar to that found in the genus *Arion*. On the other hand in *Apera gibbonsi* the scheme of coloration is different, and the narrow lighter band which this slug usually has along the centre of the back recalls the similar band possessed by many species of *Veronicella*. It should be noticed that this difference in the position of the greatest concentration of the pigment is not correlated with the difference in the position of the lateral grooves; for in *A. dimidia* the grooves are situated as in *A. gibbonsi*, while the dark bands are lower down and occupy a similar position to those of the keeled species.

Apera dimidia is singular in having small patches of the dark pigment on the foot-sole (Pl. VII, fig. 9). But in some specimens of *A. sexangula* and in at least one example of *A. gibbonsi* minute reddish-brown specks are scattered over the body, and in the former species these extend on to the foot.

The lighter pigment is usually of some shade of orange, but varies from pale orange-yellow to dull red. It is generally diffused over the whole surface of the body, including the foot-sole, but is often darker above than below, the backs of *Apera burnupi* and *A. gibbonsi rubella* being especially deeply coloured. But this pigment is very unstable, and specimens which have been preserved in spirit seldom show more than very slight traces of it. In the case of an example of *A. gibbonsi rubella*, which was

drowned by Mr. Burnup, the red pigment came out of the skin when the animal was dead, and coloured the water in which the slug was immersed. Notwithstanding the dark grey mottling of this form, the living animal is of a reddish colour, changing to orange below, as the unstable colouring matter is sufficiently abundant to mask the darker pigment underneath.

The coloration of a typical specimen of *Apera gibbonsi* increases its resemblance to the rhizome of a fern, and the chestnut-brown colour of *A. burnupi* may help to render the slug inconspicuous among dead leaves. Even the reddish colour of *A. gibbonsi rubella* may serve to conceal the animal, although the bright pigment of the red variety of *Arion ater* is supposed to act as a warning colour. Mr. Burnup found a specimen of this *Apera* in the bush at Durban, and he noticed that a few of the dead leaves¹ under which the slug was found were of a dark brownish-red colour, strongly veined, and curled up into rolls, and these were so very like the slug that it might easily have been mistaken for one of them.

On the other hand, it seems possible that the unstable red and orange pigments found in *Apera* and other slugs which are often carnivorous, as well as the similar bright colours so characteristic of most of the snails belonging to the *Strep-taxidæ*, may be partly due to their animal food. It is known that this is the case with the red pigment found in the flamingos, the scarlet ibis, and the roseate spoonbill; for the colour tends to disappear when the birds are deprived of their natural food, which consists chiefly of mollusks and other invertebrates. M. F. Woodward² has described the rich orange colour of the edge of the mantle in specimens of *Natalina caffra* which were fed on snails and beefsteak, and Miss Davies³ mentions the brilliant orange-red colour of

¹ Dr. J. Medley Wood, Director of the Natal Herbarium, has kindly examined one of these leaves, and thinks that it probably belongs to *Combretum kraussii*.

² 'Proc. Mal. Soc.,' 1895, vol. i, p. 271.

³ 'Proc. Roy. Soc. Victoria,' 1913, vol. xxi, p. 222.

the mantle-border and foot in *Paryphanta atramentaria* (*Shuttl.*), another carnivorous snail.

Again, the climate has a marked influence on the colour of slugs, moisture being favourable to the development of dark colours, while heat increases the production of red pigments. Now in *Apera gibbonsi rubella* both the dark and the red pigments are specially well developed, and this form is at present only known from the coastal region of Natal, which is both moist and warm; whereas the typical form of *A. gibbonsi*, as well as the other species inhabiting the Province, extend further inland.

Dr. Simroth¹ has maintained that in *Testacella* the skin probably plays a more important part in respiration than the lung, and it is suggested that in such slugs as these the chief function of the pigment is to assist in the taking up of oxygen. But it does not seem likely that this is the case in *Apera*. For in this genus the respiratory tissue of the lung is well developed; while, on the other hand, the structure of the integument and the arrangement of the blood-vessels which it contains do not suggest that the skin plays an important part in respiration.

On the whole it seems probable that the pigments of these slugs, like those of many other animals, may be looked upon as by-products of metabolism, which are deposited in the skin usually in such a way as to help to render the animal inconspicuous or to protect it from harmful rays of light, the development of the pigments depending partly on the food, but being also influenced by the climate and surroundings. Yet it must not be forgotten that the coloration of any slug is due not simply to the climate, the food, and the colour of the surroundings, but to the power of reacting to these influences which the animal possesses through inheritance.

¹ ·Nova Acta Acad. Caesar Leop.-Carol. Germ. Nat. Cur.,' 1891, vol. lvi, p. 245.

THE STRUCTURE OF THE SKIN.

EPIDERMIS.—The outermost layer of the skin on the back and sides of the animal consists of a well-marked cubical epithelium, which in *Apera dimidia* attains a thickness of rather less than $\cdot 01$ mm. (Pl. XII, fig. 37). The cells composing this epithelium are approximately square in section; they stain rather deeply, and each contains a large rounded nucleus. The outer walls of these cells are thickened to form a cuticle, while the remaining walls are much thinner. In this respect, therefore, the epidermis of *Apera* seems to resemble that of *Testacella* rather than that of *Daudebardia*, in which all the walls of the epidermal cells are thickened,¹ or of *Paryphanta*, in which a cuticle is said to be absent.²

The epidermis does not change its character on the dorsal side of the foot-fringe, as in such forms as *Daudebardia*³ and *Cystopelta*,⁴ but on the sole of the foot it becomes quite different. Here the epithelium is columnar rather than cubical, and the inner ends of the cells taper and interdigitate with the underlying connective tissue, so that the limits of the epithelium are very ill-defined (Pl. XII, fig. 38⁵). Excepting towards the edges of the foot-sole, the outer end of each cell is produced into a number of delicate cilia, which in *A. dimidia* measure about $\cdot 0035$ mm. in length.

INNER LAYERS OF THE SKIN.—In the outer part of the connective tissue, which everywhere underlies the epidermis, are embedded the dermal mucous glands and the pigment-granules. The mucous glands (Pl. XII, fig. 37) are oval or pear-shaped, and reach a considerable size, although each is formed from a single cell. The protoplasm of the cell is

¹ Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, p. 529.

² Beutler, B., 'Zool. Jahrb.,' 1901, vol. xiv, p. 374.

³ Plate, *op. cit.*, p. 527.

⁴ Davies, Miss O. B., 'Proc. Roy. Soc. Victoria,' 1912, vol. xxiv, p. 332.

⁵ I am indebted to Mr. W. Tams for kindly taking this photomicrograph.

chiefly confined to a thin layer lining the base of the gland and containing the rather large nucleus; the rest of the interior is filled with mucous secretion, which can be extruded through a narrow pore between the cells of the epidermis. Dr. Plate has separated the unicellular mucous glands of *Testacella*¹ and *Daudebardia*² into two classes, according to the nature of this secretion. A similar classification seems applicable to the dermal glands of *Apera*, for in sections some of the glands are seen to be entirely filled with a vacuolated colourless secretion, while in others the mucus has become concentrated into a compact, deeply stained mass in the centre of the gland. No dermal glands of either kind occur in the foot-sole. In this respect *Apera* resembles *Paryphanta*,³ and contrasts strongly with *Testacella*⁴ and other forms. Possibly the great development of the pedal gland may have rendered the unicellular glands unnecessary, although in *Paryphanta* the pedal gland is not much more highly developed than it is in *Testacella*.

The minute granules of dark pigment occur in the connective tissue between the mucous glands, being chiefly aggregated just beneath the epidermis. Some of the granules are contained in pigment-cells, others appear to be irregularly scattered about, but possibly these may occur inside delicate branches of the pigment-cells.

Beneath this glandular zone the connective tissue contains blood-vessels, nerves, and numerous muscle-fibres, longitudinal, radial, oblique, and circular, the last-mentioned being especially abundant near the inner surface of the skin.⁵ In *Apera dimidia* there are more muscle-fibres in the foot than in the connective tissue of the back and sides. This

¹ *Op. cit.*, p. 530.

² *Op. cit.*, pp. 527, 528.

³ Beutler, *op. cit.*, p. 375.

⁴ Lacaze-Duthiers, H. de, 'Arch. Zool. Expér.' (2nd ser.), 1887, vol. v. p. 526.

⁵ I use the term "skin" in a wide sense to include the whole body-wall, for no sharp line can be drawn separating the subcutaneous tissue with its muscle-fibres from the dermis or cutis vera.



zone of connective tissue is extremely thick, especially towards the hind end of the animal; indeed, the most remarkable thing about the skin of *Apera* is its great thickness and strength. Only in the region of the head, where flexibility is essential, is the skin moderately thin. Its thickness further back in *A. gibbonsi* is well shown in Pl. X, fig. 32. On the other hand, *A. dimidia* has a somewhat thinner skin than most of the other species, though even in this form its thickness is not inconsiderable, as will be seen from Pl. XI, figs. 34 and 35. This unusual thickness of the skin can easily be explained. In *Apera* the shell is so degenerate that it can no longer fulfil its proper functions. Yet the slug still needs protection from other animals seeking to prey upon it, and from the pressure of the soil if it burrows in the ground like *Testacella*, and also from excessive evaporation. And it still needs a firm attachment for its powerful retractor muscles. Therefore the skin has taken over the functions of the shell, and has become adapted to fulfil these functions adequately. The Rev. Dr. Cooke¹ has recently called attention to a case among the *Polyplacophora* in which the protection once afforded by the shell has been transferred to the integument. But in that case the mantle has taken the place of the shell, while in the present instance it is the skin itself which has been strengthened.

The blood-vessels contained in the skin are irregularly disposed, though most of them run in a longitudinal direction. They communicate with the body-cavity or hæmocœle by minute pores, which can be seen puncturing the inner surface of the skin (Pl. X, fig. 32). In all parts of the skin these vessels are provided at rather frequent intervals with powerful sphincters composed of circular muscles (Pl. XIII, fig. 40). Similar sphincters have been described by Dr. Simroth and P. and F. Sarasin² in *Veronicella* (a genus in no way allied to *Apera*); and it has been suggested that they serve to prevent the reflux of the blood when the animal moves.

¹ 'Proc. Mal. Soc.,' 1913, vol. x, pp. 321, 322.

² 'Die Land-Mollusken von Celebes,' 1899, p. 90, pl. xiii, figs. 122, 123.

Perhaps in *Apera* they also assist the circulation of the blood in a similar manner. But it seems possible that their chief function may be to enable the animal to increase the turgidity of some or all of the dermal vessels when it contracts, and thus to give greater rigidity to the skin either as a whole or in part. For if the slug by closing the sphincters could thus increase the pressure in the dermal blood-vessels, the skin would become much more rigid in consequence, just as the strength of the stem of an herbaceous plant is largely due to the turgidity of its cells.

THE SHELL, THE MANTLE-CAVITY, AND THE MANTLE.

THE SHELL.—The small shell of *Apera* lies deep in a little pocket in the skin just behind and to the left of the respiratory opening. As a rule its length is only about one-fourteenth of that of the animal (in alcohol). When viewed from above the somewhat oval contour of the shell is seen to be interrupted by a broad sinus which extends backwards from the front end more than half way along the right side. The posterior part of the shell is thus broader than the anterior half, which projects forward on the left side of the respiratory opening. The sinus is deepest in *Apera gibbonsi*, and shallowest in *A. purcelli* and *A. dimidia*. It will be seen from Pl. XIII, figs. 42, 45, 48, and 51, that the shell of *Apera* is often much less flattened than is usually the case with the internal shells of slugs. In *A. burnupi* and *A. sexangula* it is very convex, and culminates in a conical apex, which overhangs the posterior margin of the shell. In *A. purcelli* the apex projects still further, but it is rounded instead of conical, as is also the case in *A. dimidia*, in which the apex is less prominent. Lastly, in *A. gibbonsi* and *A. parva* the shell is more depressed, and the apex is in front of the posterior margin.

The shell is extremely thin and translucent in *Apera purcelli* and *A. dimidia*. In the other species it is thicker

and more calcareous, especially in full-grown specimens, though it is usually very brittle. Indeed in some examples of *A. gibbonsi* its thickness is sufficient to suggest that the chief function of the shell in this species and its allies may be to enable the animal to get rid of any excess of calcium carbonate in its blood. It is difficult to see what other function it could fulfil; and if it were to be regarded as a purely vestigial structure with no function at all, one would have expected it to have become much smaller as well as flatter in this species than in the more primitive forms such as *A. purcelli*. Yet, while the shape has degenerated, the relative size has remained the same and the thickness has greatly increased.

THE SHELL-SAC.—The pocket in which the shell lies has no communication with the exterior, but is close to the inner surface of the skin (Pl. X, fig. 33). In those species in which the shell has a prominent apex, the floor of the sac is raised towards the hind end to form a papilla fitting into the hollow of the shell. Where the margin of the shell rests upon the floor of the pocket, there is a fold, which separates the central part of the floor underlying the interior of the shell from a narrow rim beyond it.

The shell-sac is lined by a well-defined epithelium. On the roof of the cavity this epithelium is very thin, being formed in *Apera dimidia* of a compact layer of small cells which are slightly broader than they are high. Underneath the shell the epithelium is thicker in the same species, and composed of larger cells, whose height exceeds their breadth. These larger cells are continued over the edge of the fold mentioned above, the transition from the thicker to the thinner epithelium taking place on the outer side of the fold.

THE MANTLE-CAVITY OR LUNG.—The mantle-cavity occupies the region below the shell and the respiratory opening, and also extends a short distance further forward. It is, nevertheless, mainly behind instead of above the body-cavity or hæmocœle, from which it is separated by a muscular diaphragm sloping obliquely downwards and backwards. There is, however, a

funnel-shaped prolongation of the body-cavity which extends backwards for a variable distance beneath the mantle-cavity, and raises its floor along the middle. This feature is well shown in Pl. XI, figs. 34, 35, and Pl. XII, fig. 36, for the prolongation is unusually large in *Apera dimidia* and *A. purcelli*.

In horizontal section the mantle-cavity or lung is roughly triangular, with the large pericardium occupying the centre of the broad anterior part, which is thus divided into a right and a left wing (Pl. IX, figs. 27-31). The right division opens widely behind into the posterior part of the mantle-cavity, but the left division is cut off by the kidney, which extends obliquely backwards from the pericardium and fuses with the left wall and the roof of the cavity. Thus the left anterior division only communicates with the rest of the mantle-cavity by a narrow space round the top and front of the pericardium and kidney. It is, therefore, not surprising that the walls of this part of the cavity are without respiratory tissue. But the right anterior division, which communicates more freely with the air, and the greater part of the posterior half of the cavity have their walls richly supplied with pulmonary veins. These vessels branch repeatedly, and in the larger species the fine branches form a complicated network which divides the surface into numerous alveoli. The thinness of the epithelium which separates the blood in these vessels from the air in the mantle-cavity will be seen from Pl. XII, fig. 39. The only portion of the posterior half of the cavity that is devoid of respiratory tissue is a part of the roof¹ and the immediate neighbourhood of the respiratory opening and the anus just below it.

At the hind end the cavity tapers to a point. In *Apera gibbonsi* this point is below the extreme hind end of the shell-sac; but in species such as *A. sexangula* and *A. dimidia* it is within the papilla which is formed by the floor of the shell-sac projecting into the hollow apex of the shell. Hence in these species the hind end of the mantle-cavity is inside the shell itself.

¹ See p. 187.

I have only been able to examine the minute structure of the epithelium lining the mantle-cavity in one species, namely *A. dimidia*. In this species (and probably also in the others), that part of the posterior half of the cavity where there is no respiratory tissue is lined by moderately large cells, slightly higher than they are broad, and strongly ciliate near the respiratory opening. These cells are continuous through the aperture with those of the epidermis. The whole of the remainder of the cavity, including both of the anterior divisions, is lined by a pavement-epithelium of cells so thin that the nucleus of each usually forms a knob-like projection in the centre of its surface.

THE MANTLE.—*Apera* has no external mantle—a remarkable fact that was first pointed out by Heynemann.¹ Yet it cannot be entirely without a mantle, for, as we have just seen, it possesses both a mantle-cavity and a shell; and all Gastropods that have a shell also possess a mantle, as the shell is always secreted by the mantle. I therefore regard that part of the integument which forms the roof of the mantle-cavity beneath and around the shell as being undoubtedly homologous with the mantle. Moreover I believe that the mantle is not entirely concealed from view in all the species of *Apera*, for it seems probable that it forms the inner lip of the respiratory opening, and that the upper surface of this lip may be regarded as part of the upper surface of the mantle (Pl. X, fig. 33). This theory is confirmed by the occurrence of an oblique cleft in the inner lip of the opening in a similar position to the cleft which runs from the opening to the edge of the mantle in an ordinary slug.

We may suppose that *Apera* has been evolved from a snail, having on its back a mantle covered by a shell. It might well be an advantage to such an animal to get rid of this projection, especially if it burrowed in the ground in search of worms. Accordingly both mantle and shell seem to have sunk into the back and to have become covered by folds of the surrounding skin which have grown over it on each side.

¹ 'Jahrb. d. Deutsch. Mal. Ges.,' 1885, vol. xii, p. 19.

The upward growth of the skin on the right side would tend to cover the respiratory opening, which would be in its usual position in the right margin of the mantle. To obviate this, the mantle edge, with the opening, would have to move up towards the middle line, and the growth of the right side of the shell would be retarded in consequence. And at the same time the fold of the skin would be likely to grow more slowly immediately opposite the opening than before and behind it, thus forming a notch in the edge of the fold. Eventually this fold of the skin would unite with the other in the middle line excepting at the notch, which would be converted into an opening above the original respiratory opening in the mantle-edge.

This hypothesis may not be correct, but it has at least the merit of explaining not only the absence of an external mantle in *Apera*, but also the dorsal and slightly asymmetrical position of the respiratory opening, the fact that the opening has an inner and an outer lip, the former with an oblique cleft, and the peculiar sinus in the right side of the shell. So far as I am aware the morphology of the mantle and shell of *Apera* differs from that of all other Pulmonates.

THE PEDAL GLAND.

The pedal or supra-pedal gland attains a greater development in *Apera* than in any other genus of snails or slugs known to science. It consists essentially of a long duct with glandular walls, which opens in front between the mouth and the anterior end of the foot, and ends behind in a small vesicle.

THE POSITION AND LENGTH OF THE GLAND.—In the herbivorous genera of snails and slugs the pedal gland is usually more or less embedded in the muscular tissue of the foot, and this is also the case in *Daudebardia*,¹ *Plutonia*,² and the *Trigonochlaminae*³; but in *Apera* it lies freely in the lower

¹ Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, p. 525.

² Simroth, H., 'Nova Acta Acad. Caesar Leop.-Carol. Germ. Nat. Cur.,' 1891, vol. lvi, p. 229.

³ Simroth, H., 'Festschrift Leuckarts,' 1892, pp. 53, 55; etc.

part of the body-cavity, as in *Natalina*, *Rhytida*, *Paryphanta*, *Schizoglossa*, *Testacella*, *Streptaxis*, *Atopus*, and a few other carnivorous genera, and is only held in position by the pedal artery which supplies it with blood. This artery confines the gland to the anterior part of the body-cavity, for it runs back above the gland, giving off branches to it as it goes, and, after becoming attached to the posterior vesicle for a short space, it dips down and unites with the upper surface of the foot about the middle of its length. The pedal gland, however, is many times longer than this free portion of the pedal artery and is consequently thrown into numerous folds and loops. In *Apera sexangula* the gland pursues a comparatively regular zig-zag course, bending alternately to the right and the left about half a dozen times (Pl. XIII, fig. 57). But in *A. burnupi* and *A. purcelli*, and in the posterior part of the gland in the remaining species, the loops are deeper and more complicated, twisting about in all directions (figs. 52-56). The gland attains its greatest length in *A. burnupi*, in which its folds not only extend up the sides of the body-cavity, but even curve over on to the top of some of the other organs (Pl. IX, fig. 30).

THE GLANDULAR TISSUE.—The pedal gland of *Apera* is not only unusually long, it is also often exceptionally broad, as, for example, in *A. burnupi* and in the anterior half of its length in *A. dimidia* (Pl. XIII, figs. 56, 54). In *A. gibbonsi* and *A. parva* it is more slender (figs. 52, 53), possibly because the great size of the odontophore in these species leaves little room for the growth of any other bulky organ in the anterior half of the body-cavity.

The breadth of the gland is due to an enormous development of glandular tissue on the floor and sides of its duct. In *Apera purcelli*, *A. burnupi*, and *A. sexangula* this glandular tissue extends along the whole length of the duct as far as the terminal vesicle; but it is less abundant towards the posterior end and the gland becomes rather narrower behind in consequence. In *A. gibbonsi* *rubella* the

glandular tissue becomes still scarcer towards the hind end, and disappears entirely just before the vesicle is reached, while in the other races of *A. gibbonsi* and in *A. parva* the last few millimetres of the duct are quite destitute of gland-cells. Finally, in *A. dimidia* the glandular tissue only extends along half the length of the duct, the posterior half being entirely without it, and therefore much narrower than the anterior half (Pl. XIII, figs. 54, 59, and 60).

Pl. XIV, fig. 63 shows the structure of the glandular tissue near the front end of the pedal gland in *A. gibbonsi rubella*. It will be seen that among the large oval gland-cells, which taper towards the duct, there are scattered connective-tissue cells with conspicuous rounded nuclei, and there can be little doubt that it is from these cells that the glands are formed. Similar cells occur near the front end of the pedal gland in *A. dimidia*, but further back, near the hind end of the anterior half of the gland, no such cells occur, and a transverse section has the appearance shown in Pl. XIII, fig. 59. Possibly the absence of connective-tissue cells from this region may be correlated with the absence of gland-cells still further back. The posterior part of the gland will probably be the first to be formed in development, and if all its cells, apart from those which form the duct itself, are converted into glands, there will be nothing left to replace these when they die and are discharged into the duct; for according to André¹ the gland-cells perish after a certain time and need to be replaced.

Mr. Collinge² has stated that the pedal gland of *Apera sexangula* contains "a large series of microscopic chitinous (?) dart-like bodies," but his figures leave little doubt that these are merely the solidified contents of the glands. In specimens preserved in alcohol this congealed secretion appears through a simple lens as numerous white specks, which often give a glistening appearance to the pedal gland.

¹ 'Revue Suisse de Zoologie,' 1894, vol. ii, pp. 310, 311.

² 'Ann. Mag. Nat. Hist.' (6th ser.), 1897, vol. xx, p. 223, pl. v, figs. 4, 5.

THE DUCT.—The duct of the pedal gland is semi-transparent, and can be seen running along the centre of its upper surface. Near the opening of the gland the duct usually lies more deeply (Pl. XIV, fig. 63), but elsewhere the glandular tissue is restricted to its sides and lower surface, as shown in Pl. XIII, fig. 59. Where the glandular tissue is less abundant the exposed surface of the duct often shows a tendency to have alternate swellings and constrictions. In *Apera gibbonsi* this culminates in a close convolution of the posterior part of the duct (Pl. XIII, fig. 58), which reminds one of the somewhat similar convolution of part of the duct in *Testacella*.¹ On the upper surface of the anterior half of the gland in *A. dimidia*, two brownish lines can often be seen running along, one on each side of the duct, at its junction with the glandular tissue.

In section the duct is approximately circular, without any folds on its floor (Pl. XIII, figs. 59, 60, Pl. XIV, fig. 63). In this respect it resembles that of *Testacella*, and differs from that of *Daudebardia*, for in the latter genus, as in most herbivorous snails and slugs, the floor of the duct has two longitudinal folds enclosing a median groove, and the gland-cells only open into this groove, instead of all round the duct.² In *Paryphanta hochstetteri* (*Pfr.*) traces of the folds and median groove seem to occur, but only towards the anterior end of the duct.³ The duct is lined by an epithelium composed of small cubical cells, and this is surrounded by two thin muscular layers, the fibres of the inner layer running round the duct, while those of the outer layer are longitudinal. Both layers of muscles occur inside the glandular tissue.

THE TERMINAL VESICLE.—After becoming gradually narrower the gland widens again at the hind end to form an oval or pod-shaped vesicle (Pl. XIII, figs. 52-57). In length this vesicle

¹ See de Lacaze-Duthiers, 'Arch. Zool. Expér.' (2nd ser.), 1887, vol. v, pl. xl, fig. 95.

² Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, p. 525, pl. xxxii, fig. 16.

³ Beutler, B., 'Zool. Jahrb.,' 1901, vol. xiv, p. 376, pl. xxvi, fig. 9.

varies from about 1 mm. in the smaller species to more than 5 mm. in a large specimen of *Apera burnupi*, and its breadth is usually about one-third of its length. The walls of the vesicle are thin and semi-translucent like those of the duct, with which they are continuous. A few gland-cells occur along the ventral¹ surface in *A. burnupi*, *A. sexangula*, and *A. purcelli*, but none at all in the other species. The structure of the walls of the vesicle is similar to that of the walls of the duct, excepting that the cells of the epithelium become somewhat higher on the dorsal side, and among the ordinary epithelial cells there are scattered a few rather small vacuolated cells.

From the dorsal wall of the vesicle there projects into its cavity a remarkable fold, resembling a typhlosole, which fills up a large portion of the interior, so that the cavity is crescentic or horse-shoe-shaped in section (Pl. XIII, fig. 62). If the wall of the vesicle in *Apera sexangula* be cut open, it will be seen that the fold has a spongy and somewhat laminated appearance. Serial sections through the vesicle of *A. dimidia* show that in this species the fold is rounded excepting at the ends, where it becomes wrinkled and divided by furrows (cf. Pl. XIII, figs. 61, 62, Pl. XIV, fig. 66). Fig. 66 shows the structure of the fold in *A. dimidia*. It will be seen that it is entirely composed of vacuolated tissue, which is not bounded by a distinct epithelium. The pedal artery, which always becomes intimately connected with the dorsal surface of the vesicle, gives off a branch into the middle of the fold (Pl. XIII, fig. 62). In *A. gibbonsi* the structure of the fold is different, for in this species it is divided into a complicated series of narrow lamellæ. Fig. 58 shows the appearance of these as dimly seen through the wall of the vesicle, while Pl. XIV, fig. 65, shows them in section. Each

¹ I use the terms "dorsal" and "ventral" in a morphological sense, the dorsal side being that to which the artery is attached. Generally, however, the vesicle lies on its side, owing to the twisting of the duct, and the attachment of the artery to the floor of the body-cavity beyond the vesicle.

lamella seems to be composed of a double layer of peculiar rounded or polygonal cells with thick walls.

The hind end of the pedal gland is also enlarged to form a vesicle in *Rhytida*,¹ *Paryphanta*,² and *Schizoglossa*,³ and indeed this is probably the case in all the genera of the *Rhytididæ*, for I have found such a vesicle in *Natalina* as well. Moreover, Beutler⁴ has shown that in *Paryphanta* it contains a large fold similar to that in *Apera*, but apparently less highly specialised in structure. In *Testacella* there is also a dorsal fold⁵ projecting into the duct at the hind end of the pedal gland, but the structure of the fold appears to be very different from that of *Apera*, and there is no terminal enlargement of the gland to form a vesicle.

Various possibilities suggest themselves with regard to the function of the terminal vesicle of the pedal gland, and the fold which it contains; but so little is known about the physiology of the gland in the carnivorous genera that such speculations can have little value. It is better, therefore, simply to state that the function of these structures is at present unknown.

THE NERVOUS SYSTEM.

The central nervous system of *Apera* consists of three compact ganglionic masses joined by connectives. The first of these is formed of the cerebral ganglia, the second of the buccal ganglia, and the third of the pedal, pleural, and visceral ganglia.

THE CEREBRAL GANGLIA AND COMMISSURES.—As in nearly all carnivorous snails and slugs, excepting *Daudebardia*⁶ and

¹ Collinge, W. E., 'Ann. Mag. Nat. Hist.' (7th ser.), 1901, vol. vii, pp. 67, 68, pl. i, figs. 12, 13.

² Collinge, op. cit., p. 70, pl. ii, figs. 21, 24; Murdoch, 'Trans. N.Z. Inst.', 1904, vol. xxxvi, p. 158, pl. vi, fig. 7.

³ Murdoch, R., 'Proc. Mal. Soc.', 1901, vol. iv, p. 170, pl. xvii, fig. 10.

⁴ 'Zool. Jahrb.', 1901, vol. xiv, p. 376, pl. xxvi, fig. 7.

⁵ Plate, L. H., 'Zool. Jahrb.', 1891, vol. iv, p. 525, pl. xxxii, figs. 17, 18.

⁶ Plate, op. cit., pp. 589, 593.

the *Trigonochlaminae*,¹ the cerebral ganglia are situated very near together on the dorsal side of the buccal mass. Indeed, in *Apera gibbonsi* they are so closely bound to each other by connective tissue that they appear as one (Pl. XIII, fig. 52); and it is only in the smaller species, such as *A. parva* (fig. 53) and *A. purcelli* (fig. 55), that they can be clearly seen to be separate ganglia without the help of any reagents. When freed from their surrounding tissue, the ganglia are seen to be oval structures, nearly twice as long as they are broad, and rather nearer together behind than in front (Pl. XV, figs. 70-72). Their average length in *Apera* is about $\frac{3}{4}$ mm. Towards the outer side of the front end of each ganglion there is a slight eminence formed by the accessory lobe. This is best seen in *A. dimidia*. In this species the apex of each lobe is prolonged into a filament, which is very like a slender nerve (fig. 71), but is probably the remains of the embryonic cerebral tube which originally connected the accessory lobe with the exterior. Similar accessory lobes have been figured by de Lacaze-Duthiers² in *Testacella*, by Wiegmann³ in *Ennea* (*Edentulina*), and by Beutler⁴ in *Paryphanta*, and the last author has described them at some length.

The cerebral ganglia are joined by two commissures, namely, the cerebral commissure above the buccal mass, and the sub-cerebral commissure below it. The cerebral commissure is very short and broad, and is situated somewhat towards the posterior ends of the ganglia (Pl. XV, fig. 71). The sub-cerebral commissure, on the other hand, is very long and extremely slender. It arises from about the middle of the outer sides of the ganglia, and encircles the buccal mass just in front of the cerebro-pedal connectives and the pedal ganglia, being closely bound to these by connective tissue

¹ Simroth, H., 'Festschrift Leuckarts,' 1892, pp. 53, 55.

² 'Arch. Zool. Expér.' (2nd ser.), 1887, vol. v, pl. xxxviii, figs. 70, 71.

³ 'Mitt. Zool. Samml. Mus. Nat. Berlin,' 1898, vol. i, pl. iii, fig. 7.

⁴ 'Zool. Jahrb.,' 1901, vol. xiv, pl. xxix, figs. 58, 61, and pp. 400-402; see also Pelseener, 'Mém. Acad. Roy. Belg.,' 1901, ex. vol. liv, pp. 31-37.

(figs. 73 and 74). It thus forms the most anterior element of the nerve-collar. Amaudrut¹ has described a similar sub-cerebral commissure in *Achatina panthera* (Fér.), *Bulimus funki* (Nyst.), *Nanina cambodjiensis* (Reeve), and *Helix aspersa* Müll.; but hitherto this slender commissure has been noticed in only a very few Pulmonates and in none of the carnivorous forms. I have found it, however, in *Natalina quekettiana* (M. & P.), the only member of the Rhytididæ whose ganglia I have examined microscopically; and I believe that if malacologists would examine the central nervous system of snails with greater care they would find it in many other pulmonate genera. For among the marine Euthyneura a sub-cerebral commissure has been observed not only in the Pleurobranchidæ and in numerous Nudi-branchs,² but also in so primitive a form as *Actæon*.³ Moreover, I am inclined to regard the sub-cerebral commissure as homologous with the important labial commissure found in the Aspidobranchia, and in *Vivipara* and *Ampullaria* among the Pectinibranchia, as well as in the Amphineura, Scaphopoda, and Cephalopoda.⁴ In most of these forms the cerebro-buccal connectives arise from the labial commissure instead of from the cerebral ganglia themselves, and in *Apera* the cerebro-buccal connectives arise from the ganglia very close to the ends of the sub-cerebral commissure.

A little further back arise the thick cerebro-pedal connectives; and behind this again, nearly at the posterior end of the ganglia, the almost equally broad cerebro-pleural connectives arise. In the specimen of *Apera dimidia* that I

¹ 'Bull. Soc. Philom. Paris' (7th ser.), 1885-86, vol. x, pp. 107-117; 'Ann. Nat. Sci., Zool.,' 1898, vol. vii, p. 127.

² Pelseneer, P., 'Mém. Couronné Acad. Roy. Belg.,' 1893, ex. vol. liii. p. 69.

³ Bouvier, E. L., 'Bull. Soc. Philom. Paris' (8th ser.), 1893, vol. v, p. 67.

⁴ Pelseneer has shown that the so-called "labial commissure" which Pleurobranchæa and a few other forms possess in addition to the sub-cerebral commissure, is merely an anastomosis of two of the nerves to the lips (op. cit., p. 33).

examined, these two connectives were joined on the right side by a short transverse filament not far from their origin (Pl. XV, fig. 71).

THE NERVES OF THE CEREBRAL GANGLIA.—From each cerebral ganglion arise two large nerves which are as thick as the cerebro-pedal and cerebro-pleural connectives. These are the olfactory nerve to the upper tentacle, and the nerve to the lower tentacle. The olfactory nerve springs from the upper surface of the anterior end of the ganglion, towards the inner side (Pl. XV, figs. 70–72). Near its origin there also arise three slender nerves, namely, the two peritentacular nerves, and the optic nerve, which is distinct from the olfactory nerve even from the ganglion. The nerve to the lower tentacle arises nearer the outer edge of the ganglion than the four nerves just described, and external to the accessory lobe. Near it arise the two labial nerves, which are very much narrower than the nerve to the lower tentacle, but not quite so slender as the optic and peritentacular nerves. As in most genera the nerve to the penis also springs from this region in the right cerebral ganglion; it is of about the same thickness as the labial nerves. Beutler¹ states that in *Paryphanta hochstetteri* (*Pfr.*) the penial nerve does not arise separately from the cerebral ganglion, but seems to branch from one of the other nerves. On the other hand, in the *Streptaxidæ*² the nerve to the penis arises directly from the pedal ganglion, instead of its fibres first traversing the right cerebral ganglion, as is usually the case.

Near the origin of the sub-cerebral commissure a very slender nerve arises on each side, and runs down with it in the connective tissue on the anterior side of the cerebro-pedal connective. Above this connective, on the dorsal surface of each ganglion, there arises another very slender nerve, which at first goes obliquely backwards, but quickly curves outwards, and runs down to the ventral group of ganglia between the two connectives. This is almost certainly the nervus

¹ *Op. cit.*, p. 400.

² Wiegmann, *F.*, *op. cit.*, p. 62.

otocysticus, although I was unable to find the otocysts themselves even in sections of the pedal ganglia. Lastly, a slender nerve arises from each ganglion between the two connectives, usually nearer to the cerebro-pleural connective than to the other. In *Apera dimidia*, *A. purcelli*, *A. burnupi*, and *A. sexangula* these nerves run back to the anterior end of the buccal retractor, which they innervate. Each gives off two branches close to the cerebral ganglia; one of these anastomoses with the cerebro-buccal connective not far from its origin; the other runs down between the cerebro-pedal and cerebro-pleural connectives, and divides into two about half way to the ventral group of ganglia. One of the divisions of this branch leaves the nerve collar and innervates the retractor of the lower tentacle.¹ The other division continues down to the ventral ganglia; but whether it fuses with the pleural ganglion, as one might expect from Amaudrut's observations,² or whether it merely crosses the dorsal surface of the ventral group of ganglia and leaves it again in the wall of the buccal artery, I was unable to discover with the limited amount of material at my disposal. The examination of these slender nerves, deeply embedded amongst the connective tissue and blood-vessels which surround the larger nerve-cords and ganglia, is a matter of considerable difficulty; but it does not even require a compound microscope to see that the anterior end of the buccal retractor in *A. dimidia*, *A. sexangula*, and their allies is innervated by nerves arising from the sides of the cerebral ganglia. This is one of the very few respects in which *Apera* resembles *Daudebardia* more than any other carnivorous genus with which I am acquainted.³ In *A. gibbonsi* the buccal mass with the odontophore is much

¹ In *Natalina quekettiana* (*M. & P.*) and *Rhytida capillacea* (*Fér.*) the retractors of the lower tentacles are also innervated by very slender nerves issuing from the nerve-collar about half-way down each side, and this is probably the case in several other forms as well.

² 'Ann. Nat. Sci., Zool.,' 1898, vol. vii, pp. 123-126.

³ See Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, p. 591.

larger, and the buccal retractors are more highly developed, and it might therefore have been expected that these nerves would have been larger and more conspicuous than in the other species of *Apera*. The opposite is the case. In this form the corresponding nerves are extremely slender. They are joined for some distance with the cerebro-buccal connectives (Pl. XIII, fig. 52), and then leave these and unite with the sheath of the odontophore at the anterior end of that organ. A possible explanation of this apparent anomaly will be found in my account of the morphology of the buccal retractors.¹

THE BUCCAL GANGLIA.—The buccal or stomato-gastric ganglia are situated close together on the dorsal surface of the odontophore, just behind and beneath the front end of the œsophagus. In *Apera burnupi* and *A. sexangula* they are usually in front of the cerebral ganglia, the cerebro-buccal connectives curving forwards (Pl. XIII, figs. 56 and 57). In *A. dimidia* and *A. purcelli* they are normally situated a short distance behind the cerebral ganglia, when the odontophore is not protruded (figs. 54, 55). Lastly, in *A. gibbonsi* and *A. parva* the buccal ganglia are generally very far behind the cerebral ganglia, and the cerebro-buccal connectives are unusually long in consequence, often attaining a length of 5 or 6 mm. in the former species (Pl. XIII, figs. 52, 53, and Pl. XV, fig. 70). This posterior position of the buccal ganglia and the consequent lengthening of the cerebro-buccal connectives is not uncommon among carnivorous snails and slugs, and is entirely due to the increase in size of the buccal mass corresponding to the growth of the radula. As the buccal mass becomes larger and longer, the opening of the œsophagus, with the buccal ganglia behind it, is pushed back until it comes to lie posterior to the cerebral ganglia, and should this process be continued still further, the cerebro-buccal connectives must be correspondingly lengthened if the cerebral ganglia are to remain in their original position near the sense-organs. Moreover, the

¹ See pp. 173, 174.

longer the cerebro-buccal connectives, the more freely can the odontophore be protruded; for it is evident that when the buccal ganglia normally lie behind the cerebral ganglia, the odontophore bearing the buccal ganglia can be brought forward a distance equal to twice the length of the connectives without moving the cerebral ganglia at all.

The buccal ganglia are rounded or oval, and joined to each other by a short buccal commissure. As might have been expected, they are proportionately larger and closer together in those forms in which the odontophore is very large than in such species as *A. burnupi*, in which the odontophore is much smaller. In *A. gibbonsi* the ganglia, when freed from the connective tissue which surrounds them, are seen to be almost as near to each other as are the cerebral ganglia (Pl. XV, fig. 70).

THE NERVES OF THE BUCCAL GANGLIA.—Three slender nerves arise from the anterior part of each buccal ganglion (figs. 70-72). One of these becomes attached to the salivary duct of the same side, and passes backwards to the salivary glands. The other two go to the œsophagus, one bifurcating soon after it leaves the ganglion. Two more pairs of nerves arise laterally from the ganglia and innervate the sides of the buccal mass and odontophore, one pair going forwards and the other backwards. These nerves are especially large in *Apera gibbonsi*, in which the parts they innervate are so greatly developed. The anterior lateral nerve passes forwards to the side of the buccal mass in front of the œsophagus, and in this species it is generally united at its origin for a very short distance with the cerebro-buccal connective on the same side. In *A. sexangula*, on the other hand, this nerve appears to be united near the ganglion with the posterior lateral nerve, a fact which is probably connected with the anterior position of the buccal ganglia in this species. The posterior lateral nerve on each side passes to the sheath of the odontophore, and bifurcates as it does so. The outer and more slender branch, after passing through the external longitudinal muscles, runs down the sides of the

odontophore in the circular muscles of the sheath, which it doubtless innervates. The inner and larger branch goes more deeply. It runs down in the suspensor muscles of the odontophoral support and then divides, one division running forwards and the other backwards in the angle of the groove between the lower ends of the suspensor muscles and the origin of the lateral retractors of the radula.¹

The nerves which innervate the central part of the odontophore are widely separated from the other buccal nerves in their origin. They arise from the inner sides of the buccal ganglia, or even from the buccal commissure, and consist of two rather large nerves and usually one or two others which are very much smaller. These nerves pass through the sheath of the odontophore, and run back with the median dorsal muscle until it dips down between the lateral retractors of the radula. They then curve forwards again at a lower level, and are distributed where the retractors are inserted on the radula-sac. But the most remarkable feature about these nerves is their asymmetrical origin. The left of the two main nerves always arises nearer the middle line than the right; indeed, it might be said that while the right nerve arises from the inner side of the right ganglion, the left nerve arises from the commissure, though towards its left end (see especially Pl. XV, fig. 71). This asymmetry seems to be a constant feature of the genus *Apera*, for I have examined microscopically the buccal ganglia of five specimens, belonging to three different species, and they all show it. Yet it is very surprising, for the odontophore is one of the few organs which is generally supposed to have escaped the effects of the torsion which has played such havoc with the symmetry of Gastropods. And, in fact, the odontophoral muscles of *Apera* do seem to be quite symmetrically arranged, and the odontophore occupies an approximately symmetrical position, and even the extrinsic buccal retractors show no traces of asymmetry excepting towards the hind end of the animal. Since the cause of this asymmetry cannot be

¹ See pp. 166, 167.

found in *Apera* itself, we must inquire whether it can be discovered in the snails from which the genus may have sprung.

There are certain muscles in the odontophore of *Apera* and *Natalina*—the flexor muscles of the odontophoral support—which, when they are contracted, tend to curve up its front end. When this happens the odontophore is likely to turn on to its right side, for there is not room for it to become curved in a vertical plane above the pedal gland, and the reproductive organs will prevent it turning on to its left side and curving outwards to the right. And in the only specimen of *Apera* that I have seen in which these muscles were contracted, the odontophore was on its right side, curving outwards to the left. Now in carnivorous snails with a dextral heliciform or depressed shell, an odontophore which curves outwards to the left will fit into the body-whorl of the shell much better than one that is straight, when the animal retires into its shell; and the oblique pull of the retractor muscles arising from the columella of the shell will tend to maintain this curvature. Thus one might expect to find that in such snails the anterior part of the odontophore would be normally lying on its right side, with the opening of the œsophagus lateral instead of dorsal; and this is exactly what has been found to be the case in *Paryphanta hochstetteri* (*Pfr.*)¹ and *Natalina trimeni* (*M. & P.*)². The nerve-collar would not be rotated to any extent, as both the cerebral and ventral ganglia would be held in position by the nerves which radiate from them to the skin, tentacles, etc., on each side; but owing to the odontophore curving outwards to the left, the cerebro-pedal and cerebro-pleural connectives would become much more lengthened on the left side than on the right (see Beutler's fig. 60). The buccal ganglia, however, would obviously be involved in the rotation. But owing to the fact that the cerebral ganglia are broader than the buccal ganglia,

¹ Beutler; B., 'Zool. Jahrb.,' 1901, vol. xiv, p. 377, pl. xxix, fig. 60.

² Pace, S., 'Proc. Mal. Soc.,' 1895, vol. i, p. 233.

the left cerebro-buccal connective would become stretched, and would consequently retard the rotation of the buccal ganglia to some extent, so that they would come to lie slightly to the left of the opening of the œsophagus and the median line of the odontophore.¹ The result of this would be that the nerves from the buccal ganglia would slope obliquely to

TEXT-FIG. 1.

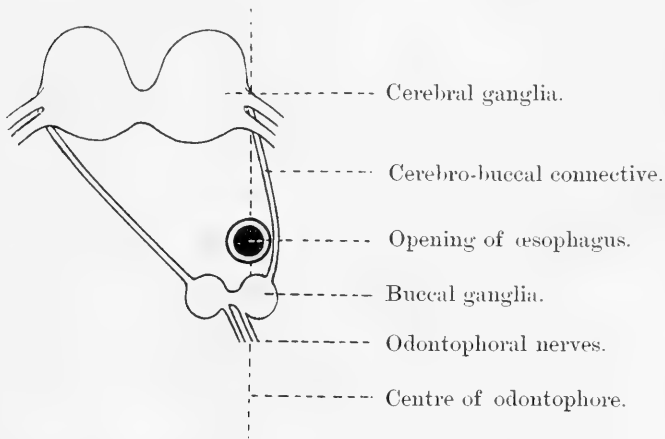


Diagram illustrating the possible origin of the asymmetry of the odontophoral nerves of *Apera*.

the right, as shown in the accompanying diagram, and this would tend to shift their origin to the right. When the shell became degenerate and the animal assumed a symmetrical form, the odontophore would tend to return to its original condition and to lie in a straight line between the mouth and the buccal retractor²; but it might be a long time before the buccal nerves moved back again to their symmetrical position. Now, as I shall attempt to prove later, it is not improbable that *Apera* may have been evolved from a group of

¹ Cf. Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, pl. xxxvii, fig. 102.

² The effect of the slightly asymmetrical origin of the buccal retractor would be counteracted by the pressure of the reproductive organs on the right side.

carnivorous snails with dextral heliciform or depressed shells; therefore it seems possible that the above explanation of the asymmetry of the nerves of the odontophore may be not very far from the truth.

THE VENTRAL GROUP OF GANGLIA.—Beneath the odontophore or the posterior part of the buccal mass, and a little further back than the cerebral ganglia, there lie six ganglia very close to each other. These are the two pedal, the two pleural, and the two visceral ganglia. In *Apera purcelli* the limits of each of these ganglia can be clearly seen, although they are very near together; but in some of the larger forms, such as *A. gibbonsi*, the separate ganglia can only be distinguished with difficulty, so closely are they aggregated (Pl. XIV, fig. 67). These ganglia are joined to the cerebral ganglia by the cerebro-pedal and cerebro-pleural connectives, the length of which varies directly with the size of the buccal mass and odontophore. Thus in *A. gibbonsi* these connectives are very long, so as to permit of the protrusion of the enormous odontophore (Pl. XIII, fig. 52), while in *A. burnupi* and *A. sexangula* they are fairly short. The connectives are sometimes slightly, but rather abruptly, swollen at their junctions with the pedal and pleural ganglia (Pl. XIV, fig. 68).

The most anterior of these ganglia are the pedal ganglia, which are also more ventrally situated than the others. These are the largest ganglia in the nervous system, being even larger in *Apera* than the cerebral ganglia. They are somewhat oval in shape, and very close together. Two short commissures connect them, one anterior and dorsal, the other further back and more ventrally situated (Pl. XV, fig. 74). The first of these is usually termed the pedal commissure, and is shown in section in Pl. XIV, fig. 68; the second is known as the parapedal commissure, and is seen to be rather thinner than the other in vertical section. Beutler¹ has found both commissures in *Paryphanta hochstetteri* (*Pfr.*), and it is probable that they occur in all the Euthy-

¹ *Op. cit.*, p. 402.

neura, both Pulmonates and Opisthobranchs.¹ The anterior commissure appears to be of mixed origin, for an examination of serial sections through the region of this commissure in *A. dimidia* seems to show that at least in its upper half it is largely composed of nerve-fibres emanating from the pleural ganglia. It is interesting to notice that in the *Neritidæ* and *Helicinidæ* the commissure connecting the pleural ganglia, instead of traversing the pedal ganglia, as it seems to do in most forms, remains quite separate from them.²

The pleural ganglia are oval structures less than half the size of the pedal ganglia. They are situated more laterally than the other ventral ganglia, but overlap the posterior part of the outer sides of the pedal ganglia, with which they are intimately united by extremely short connectives. Pl. XIV, fig. 68, shows a section of the right pleural ganglion just behind the pleuro-pedal connective.

The two visceral ganglia lie partly between and partly behind the pleural ganglia, to which they are joined by very short connectives. An equally short visceral commissure unites them. They overlap the hind ends of the pedal ganglia, but it need hardly be said that they have no direct nervous connection with these centres. Both visceral ganglia are larger than the pleural ganglia and considerably smaller than the pedal ganglia, but the left is always slightly larger than the right, and gives off a larger number of nerves. For, while the right one is simply the right parietal or supra-intestinal ganglion, the left is to be regarded as formed by the union of the left parietal ganglion with the median abdominal ganglion and is therefore composite. And it is only because the right parietal ganglion is usually much larger than the left that the difference in size between the two visceral ganglia of *Apera* is not greater. A similar fusion between the left parietal and the abdominal ganglia occurs in the *Helicidæ*, but so far as I am aware the only

¹ Pelseeneer, P., 'Mém. Acad. Roy. Belg.', 1901, ex vol. liv, pp. 43-45.

² Bourne, G. C., 'Proc. Zool. Soc. Lond.', 1908, pl. lv, figs. 36, 37, pl. lvi, fig. 38; and 1911, pp. 791, 792, pl. xxxviii, figs. 49, 50.

carnivorous form in which this has hitherto been observed is *Rhytida inæqualis* (*Pfeiffer*).¹ In *Selenochlamys*,² *Testacella*, *Euglandina*, *Streptostyla*,³ *Salasiella*,⁴ and *Paryphanta*⁵ the three visceral ganglia remain distinct, and I have found that this is also the case in *Natalina* and in *Rhytida capillacea* (*Fér.*). In *Daudebardia* the abdominal is fused with the right parietal ganglion.⁶ Lastly, in the *Streptaxidæ*, the three visceral ganglia are all more or less fused to form a single mass, which is separated from the pleural ganglia by long connectives.⁷

Some of the nerve-cells in the ventral group of ganglia are remarkably large, especially those in the posterior parts of the visceral ganglia (Pl. XIV, fig. 67). One of the cells in the right parietal ganglion of a specimen of *Apera gibbonsi rubella* measures $\cdot 18$ mm. \times $\cdot 143$ mm., and its nucleus is no less than $\cdot 16$ mm. \times $\cdot 11$ mm. Fig. 69 represents a photomicrograph of a section through one of these large cells in the right parietal ganglion of *A. dimidia*, and shows the granular appearance of the large nucleus and its prominent nucleolus.

THE NERVES OF THE VENTRAL GANGLIA.—The numerous pedal nerves arise in an irregular longitudinal line along the ventral surface of each pedal ganglion (Pl. XV, figs. 73, 74),

¹ Fischer, P., 'Journ. de Conchyl.' (3rd ser.), 1873, vol. xiii, p. 8, pl. iii, fig. 6.

² Simroth, H., 'Festschrift Leucharts,' 1892, p. 55, pl. vi, fig. 15. According to Simroth, the three visceral ganglia also remain separate in *Phrixolestes*, but in the other genera of the *Trigono-chlaminae* they tend to fuse with one another, and even with the pleural ganglia in *Trigono-chlamys* itself (see Bronn's 'Klassen u. Ordn. Tier-Reichs III, Gastr. Pulmonata,' 1910, p. 257, fig. 80).

³ Crosse and Fischer, 'Mission scientifique au Mexique,' 1878, pl. iv, fig. 5.

⁴ Strebel, H., 'Beitrag z. Kenntniss d. Fauna Mexik. L.-u. Süßwasser-Conchylien,' 1878, vol. iii, pl. x, fig. 7.

⁵ Beutler, op. cit., p. 403, pl. xxix, fig. 59.

⁶ Plate, op. cit., p. 590, pl. xxxvi, figs. 94, 97.

⁷ Wiegmann, F., 'Mitt. Zool. Samml. Mus. Nat. Berlin,' 1898, vol. i, p. 61.

and are distributed to all parts of the foot. The most posterior nerves, which arise from the extreme hind end of the ganglia, are the largest, and run back for almost the whole length of the animal, as will be seen from fig. 75. This figure also shows that the other pairs of pedal nerves are not arranged quite symmetrically. The pedal gland is innervated by a pair of nerves which branch from the inner sides of the most anterior pair of pedal nerves. The size of these nerves to the pedal gland is in direct proportion to the size of the gland itself; thus in *Apera dimidia*, with its highly developed pedal gland, the nerve is larger than in *A. sexangula*, as will be seen by comparing figs. 73 and 74.

From the sides of the ventral group of ganglia a large number of nerves radiate to the skin on each side of the body and head, passing below the tentacular retractors, but above the vagina and the adjacent part of the vas deferens on the right side (Pl. XIII, fig. 57). These are the nerves that de Lacaze-Duthiers termed the "nerves of the neck." The most posterior of these nerves can be seen running back on each side along the inner surface of the body-wall sometimes nearly as far as the diaphragm, thus confirming the hypothesis that all this region of the skin corresponds to that of the neck of ordinary snails and slugs. The posterior ends of the common retractors of the tentacles also receive nerves belonging to this group. All these lateral nerves appear to arise by repeated branching from three main roots on each side of the ventral ganglia. The most anterior root springs from the outer edge of the pedal ganglion a little behind the cerebro-pedal connective. The second arises from the junction of the pedal and pleural ganglia—that is to say, from the very short pleuro-pedal connective. The third and most posterior root arises from the pleural ganglion itself. Fischer's figures of the nervous system in *Rhytida inæqualis* (*Pfr.*) and the *Oleacinidæ* also show nerves arising from the pleural ganglia, but according to de Lacaze-Duthiers, Plate, Wiegmann, and Beutler, no nerves arise from the pleural ganglia in *Testacella*, *Daudebardia*, *Ennea* (*Edentu-*

lina) and Paryphanta.¹ It must be remembered that at least some of these authors believed that the pleural ganglia never did give rise to nerves in the Pulmonata, a belief that Amaudrut² has shown to be altogether erroneous. At the same time it is unlikely that all these careful observers would have figured the "nerves of the neck" as arising solely from the pedal ganglia, if in all carnivorous forms they arise partly from the pleural ganglia, as they undoubtedly do in *Apera*. Moreover the fact that the central roots of these nerves arise in *Apera* exactly from the junction of the pedal and pleural ganglia also suggests that the more posterior "nerves of the neck" arise indifferently either from the outer side of the pedal ganglia or from the pleural ganglia. This seems to uphold the theory that the outer dorsal portions of the so-called pedal ganglia of most Gastropods are in reality parts of the pleural nerve-centres which have become united with the pedal ganglia, and that all the "nerves of the neck" therefore spring from the pleural division of the central nervous system. The composite nature of the pedal ganglia has been shown to be specially evident in some of the most primitive Gastropods, such as *Pleurotomaria*;³ and the fact that the so-called pedal commissure contains, as we have seen, nerve-fibres emanating from the pleural ganglia affords additional evidence in favour of this theory.⁴

The nerves arising from the visceral ganglia are fewer

¹ For references, see p. 148.

² 'Ann. Sci. Nat., Zool.,' 1898, vol. vii, p. 128.

³ Bouvier and Fischer, 'Journ. de Conchyl.,' 1899, vol. xlvii, pp. 109-143.

⁴ It is interesting to note that in *Aplysiella* and some species of *Aplysia*, as well as in the *Gymnosomata*, the cervical nerves also arise partly from the pleural and partly from the pedal ganglia, although they anastomose to form a single plexus (Pelseener, 'Mém. Couronné Acad. Roy. Belg.,' 1893, ex vol. liii, p. 27, pl. x, fig. 81); while in the *Auriculidæ* these nerves may arise either from the pleural ganglia or from the pleuro-pedal connectives (Bouvier, 'Comptes Rendus Soc. de Biologie' (9th ser.), 1892, vol. iv, p. 990).

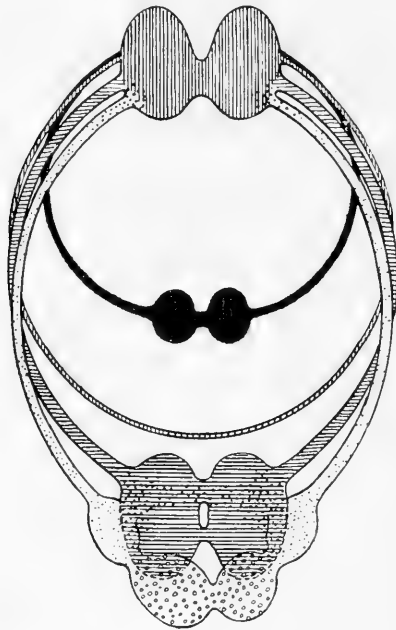
than in most genera, probably because they innervate a region of the body which is greatly reduced in *Apera*. The origin of these nerves is shown in Pl. XV, figs. 73 and 74, and their distribution in *A. dimidia* will be seen from fig. 75.

One important nerve arises from the right parietal or supra-intestinal ganglion, not far from its junction with the other visceral ganglion, and innervates the right wall of the mantle-cavity. This may be regarded as the right pallial nerve. The corresponding left pallial nerve is more slender, and arises from the outer or parietal portion of the left visceral ganglion. This nerve innervates the left wall of the mantle-cavity. From the median or abdominal portion of the left visceral ganglion two large nerves arise close together. That to the left becomes closely united for some distance with the buccal retractor in *Apera dimidia*, and then runs back on the right side of the rectum, and eventually branches around the anus and respiratory orifice. The right abdominal nerve is joined to the aorta for almost the whole of its length, but at its hind end the nerve leaves the blood-vessel and enters the diaphragm, which it probably innervates. Beyond this the nerve becomes attached to the adjacent wall of the pericardium, and can be traced backwards to a point just behind the opening of the reno-pericardial duct. The other nerves from the visceral ganglia are also attached to the aorta for some distance, the left pallial nerve being the first to become free. One or two small additional nerves can be seen with a strong objective to leave the visceral ganglia and run along in the tissue surrounding the aorta, but these are so extremely fine that I was unable to trace them far. Thus only four nerves of any importance arise from the visceral ganglia in *Apera*—two pallial and two abdominal; and inasmuch as the abdominal portion of the left ganglion is probably itself formed from the union of the sub-intestinal ganglion with the original median abdominal ganglion,¹ it follows that there is but one nerve corresponding to each original ganglion on the visceral loop.

¹ Pelseneer, P., 'Mém. Acad. Roy. Belg.,' 1901, ex vol. liv, pp. 47, 48.

THE NERVOUS SYSTEM AS A WHOLE.—It will have been seen from the above account that the central nervous system of *Apera* may be regarded as formed of five sections, each

TEXT-FIG. 2.

Diagram of the central nervous system of *Apera*.

with a single pair of ganglia. These five sections are diagrammatically represented in the accompanying text-figure. There is first the buccal section, which is the most anterior only in *A. burnupi* and *A. sexangula*. This innervates the anterior part of the alimentary canal, including the odontophore and salivary glands. Secondly, there is the

cerebral division, which is connected with the sense-organs of the head,¹ and is the only section in which the nerve-cells are aggregated to form ganglia on the dorsal side of the alimentary canal. Thirdly, there is the pedal section, which innervates the foot and pedal gland. Fourthly, there is the pleural section, innervating the sides of the body and head. And fifthly, there is the visceral section, which innervates the neighbourhood of the mantle-cavity.

And just as there are five pairs of ganglia, so also are there five commissures ventral to the alimentary canal, as will be clearly seen from the diagram. Now some authors have thought that there were only three such commissures in the Pulmonata, and very few have found more than four. Must we then regard *Apera* as exceptional in this respect? I think not. For it seems probable that further researches will show that there are normally five commissures ventral to the alimentary canal in the Euthyneura, although the slender sub-cerebral commissure may have entirely disappeared in some Pulmonates, just as in the Streptoneura the corresponding labial commissure seems to have disappeared in many of the Pectinibranchia.

THE STRUCTURE OF THE UPPER TENTACLES, AND THE TENTACULAR RETRACTORS.

In Pl. XVI, the figs. 80–86 represent photomicrographs of serial sections through the left upper tentacle of *Apera dimidia* in its retracted condition. It will be seen that the olfactory organ is large and extends forwards in front of the eye, thus reducing the width of the cavity in the retracted tentacle. The eye itself appears to be of the usual structure, the small size of the lens being possibly due to contraction. The retina is very deeply pigmented. The

¹ It is not improbable that the motor nerve to the buccal retractor should be regarded as belonging to the pleural section, for it arises close to the origin of the cerebro-pleural connective.

nerves from the different parts of the olfactory organ converge and unite behind the level of the eye to form the large olfactory nerve, which runs back for a considerable distance in the centre of the posterior part of the tentacle. The much smaller optic nerve is situated laterally, being embedded in the muscle-fibres on the outer side of the olfactory nerve. These longitudinal muscle-fibres make their appearance just behind the sense-organs, and are chiefly restricted to the peripheral part of the retracted tentacle; but as they are traced backwards they gradually increase in number, and become united into muscular strands, which coalesce with one another to form the retractor of the tentacle. In the spaces between these strands, before they all coalesce, large cells occur, as will be seen from fig. 84. These large cells stain rather deeply, and have rounded nuclei, containing prominent nucleoli. They are evidently homologous with the somewhat similar cells that Beutler¹ found in the tentacles of *Paryphanta hochstetteri* (*Pfr.*). In this region the tentacle is rather darkly coloured; yet the pigment-granules are not contained in these large cells, but are confined to narrow filaments which surround the cells and the different strands of muscle. Moreover the pigment extends a little further back, even slightly beyond the point shown in fig. 86, where the olfactory and optic nerves emerge from the tentacular retractor and curve over to the cerebral ganglion (Pl. XIII, figs. 52-55).

Not more than 2 or 3 mm. further back the retractor of the upper tentacle is joined by that of the lower tentacle, which is narrower and lies more ventrally. The common retractor thus formed is of no great length. It arises from the side of the body-wall between a quarter and a third of the distance from the head to the hind end of the animal. The common tentacular retractors of each side have no connection with each other or with the buccal retractor; on the contrary, the three retractors have become unusually widely separated in their origin. On the right side the retractors of the upper

¹ 'Zool. Jahrb.,' 1901, vol. xiv, p. 404, pl. xxix, figs. 63, 64.

and lower tentacles are separated by the penis, which projects between them (Pl. XIII, figs. 52-57; see p. 190).

In one specimen of *Apera sexangula* I found that the retracted upper tentacles were joined by a transverse connection slightly anterior to their junction with the olfactory and optic nerves (Pl. XV, fig. 76). The transverse connection was pigmented in the same way as the tentacles themselves. This remarkable abnormality reminds one of the more striking monstrosity figured by Forbes and Hanley,¹ in which the upper tentacles of a specimen of *Agriolimax agrestis* (*Lin.*) were united throughout their entire length.

The posterior ends of the common tentacular retractors receive nerves arising from the pleural ganglia (or possibly from the short pleuro-pedal connectives); and the retractors of the lower tentacles are innervated, as already described, by nerves issuing from the sides of the nerve-collar between the cerebro-pedal and cerebro-pleural connectives, but probably emanating from the cerebral ganglia by the same roots as the nerves to the buccal retractors.

Beneath the tentacular retractors a few smaller muscles arise on each side and run forward to the anterior part of the head. These are best seen in Pl. XIII, fig. 57. The largest of these minor cephalic retractors is inserted in the upper lip of the pedal gland. It is doubtless the contraction of these muscles, together with the combined action of the buccal and tentacular retractors, which causes the front of the head to be invaginated in some specimens.

THE DIGESTIVE SYSTEM.

THE MOUTH AND THE RADULA-SAC.—As in most carnivorous genera, the mouth has three main lips, one dorsal and two lateral, arranged like the sides of an inverted isosceles

¹ 'Hist. Brit. Mollusca,' 1853, vol. i, pl. JJJ, fig. 4.

triangle. But it will be seen from Pl. XV, fig. 77, and Pl. XVI, fig. 88, that the buccal cavity has four sides, and only appears somewhat triangular owing to the narrowness of the ventral wall. These figures also show the great thickness of the sides of the buccal mass—a feature which is still better seen in Pl. XVI, fig. 87. Externally there is a layer of longitudinal muscles, which is thin in *Apera dimidia* and *A. sexangula*, but somewhat thicker in *A. gibbonsi*. Within this there is a very thick layer consisting chiefly of circular muscles, but also containing some radial and a few longitudinal fibres. The last become more numerous towards the inner surface, so as almost to form a third muscular layer in which the longitudinal predominate over the circular fibres. Lastly, the cavity is lined by a compact cubical epithelium which is continuous over the lips with the epidermis of the skin. The cells composing this epithelium are small, and their nuclei are situated towards their outer ends—that is to say, the ends turned away from the cavity. Towards the opening the epithelial cells become taller, and the translucent cuticle which they secrete is considerably thickened on the lips. There is, however, no jaw in *Apera*.

At its hind end the buccal cavity extends into a long tubular diverticulum, which opens into the centre of the posterior wall of the cavity. This is the radula-sac, and is shown in longitudinal section in Pl. XVII, fig. 92, and in transverse section in Pl. XVIII, figs. 116–120. It will be seen that a broad fold or cushion projects like a typhlosole from the upper wall into the cavity, and renders the latter crescentic in section. Towards the hind end of the radula-sac the edges of this cushion are spirally rolled (fig. 119). Further forward a narrow longitudinal ridge occurs dorsally at each side of the cushion. The epithelium on the sides and floor of the radula-sac consists of small cubical cells, compactly arranged, and not unlike those lining the buccal cavity itself; but the epithelium on the cushion is of a quite different character, being composed of very tall and remarkably irregular cells

(Pl. XVI, fig. 89). The centre of the cushion is loosely filled with connective tissue. Immediately surrounding the whole radula-sac is a thin layer of circular muscles.

Around the periphery of the hind wall of the buccal cavity there is a circular groove, which is deepened dorsally and ventrally (Pl. XVIII, figs. 115, 116). The dorsal pocket is of no great depth, and is connected with the opening of the radula-sac by a median vertical groove. The ventral pocket, on the other hand, is much deeper, and contains the anterior end of the radula, which is thus folded back below the remaining part in the radula-sac (Pl. XVII, fig. 92). Between the opening of the radula-sac and that of the ventral pocket there is a slight projection formed by the front end of the odontophoral support covered by the radula, and it is this projection that is the first to appear when the odontophore is protruded through the mouth.

THE RADULA.—The general appearance of the radula, when freed from the surrounding tissue, is shown in Pl. XVII, figs. 97, 98, 99, 102, 107, and 114. It is long and relatively narrow, its breadth being sometimes less than one-sixth of its length. The teeth are thorn-shaped with narrow bases, and they are arranged in rows which diverge obliquely forwards on each side of the middle line. In other words, the radula of *Apera* is of the same general type as is found in the Rhytididæ, the Oleacinidæ, the Testacellidæ, and, indeed, in all the families of carnivorous snails and slugs excepting the Streptaxidæ, in which the teeth are of a slightly different shape. Nevertheless, the radula of *Apera* is exceptionally interesting, and shows a diversity which is scarcely surpassed in any genus of the Pulmonata containing so few species.

In the first place, the size of the radula varies enormously. In *Apera gibbonsi* and *A. parva* the radula is extremely large; when flattened out it measures about a third of the total length of the animal, and in the former species it is proportionately broader than in the other members of the genus. In *A. dimidia* the radula is scarcely a sixth of the length

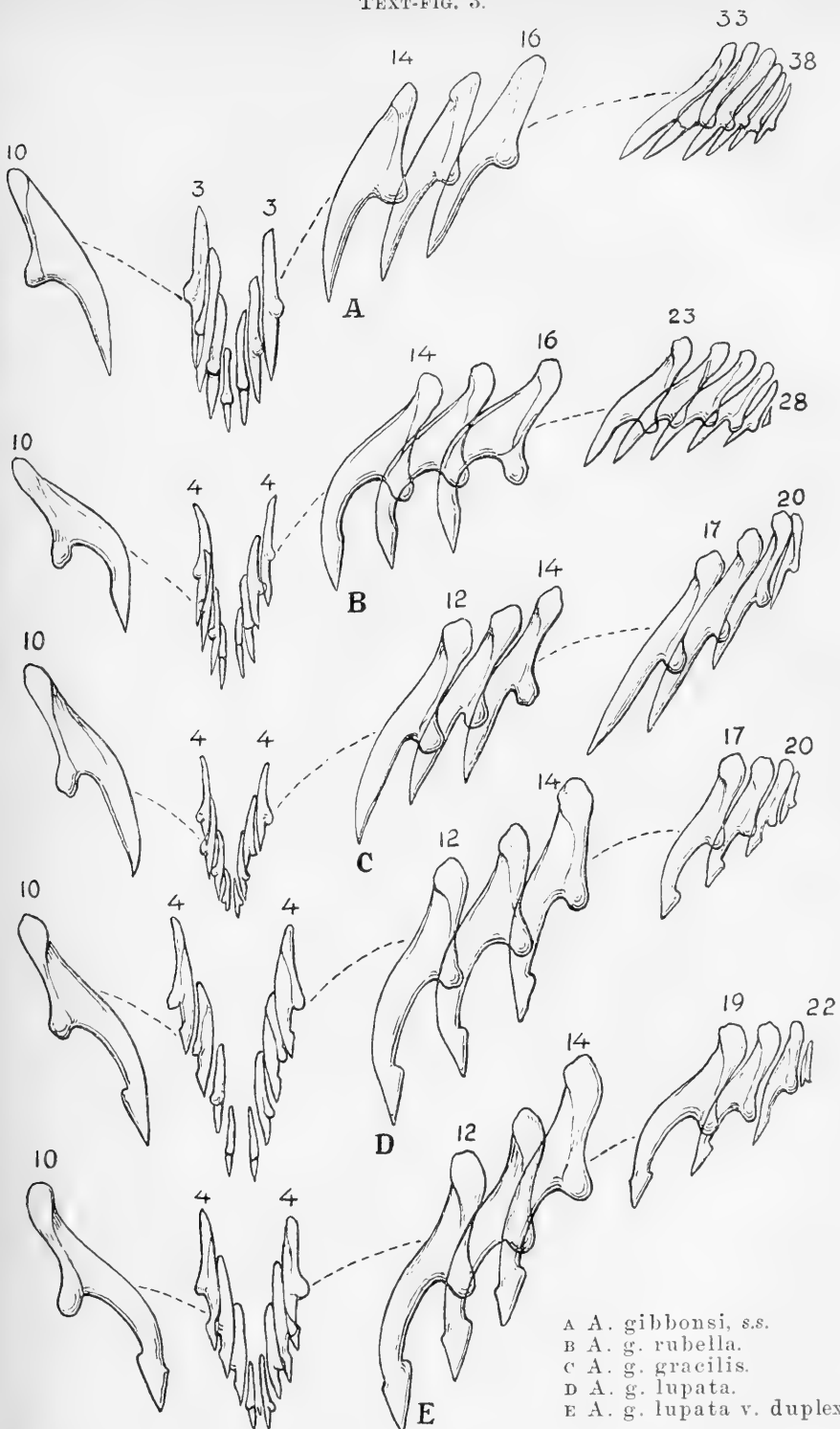


of the animal. In *A. purcelli* it is about a ninth, while in *A. burnupi* and *A. sexangula* it is only about a twelfth of the length of the slug.

The diversity in the size of the teeth is even greater. In *Apera burnupi* and *A. sexangula* the animal is about 550 times the length of the largest tooth in its radula. In *A. dimidia* and *A. purcelli* the proportion is 335 : 1. In a typical example of *A. gibbonsi* it is about 115 : 1; while in *A. parva* and *A. gibbonsi lupata* the animal is only about 66 times as long as its largest tooth, which attains a length of more than 0.6 mm. in the latter form.

But the diversity found in the radula of *Apera* extends to other features besides its dimensions. Even in the closely related forms which I am provisionally regarding as subspecies of *A. gibbonsi*, there is a remarkable variation in the form and number of the teeth (Pl. XIX, figs. 123, 124, Pl. XX, 125, 126, and text-fig. 3, A-E). The typical form has the most primitive type of radula, and the others show a progressive adaptation to vermivorous habits. A slug that feeds on worms—and it is known that this species does so—uses its radula, not for rasping off pieces from its victim, but for catching hold of it and drawing it back through the mouth into the crop. For this purpose the teeth must be large, with long sharp points for piercing the worm's skin and firm cuticle; and secondly, the teeth must be shaped so as to retain their position in the skin of the worm when they are pulling it back into the mouth. Accordingly we find, first, a progressive increase in the size of the larger teeth compared with the size of the animal, and especially in the length of their cusps. And in order to make room for these the number of rows is diminished, and the smaller teeth towards the outer edges of the radula, as well as those down the centre, become still less and eventually disappear (cf. Pl. XX, fig. 125, and Pl. XIX, fig. 123, and see also the numbers of the rows, and of the teeth in each row, given on pp. 195–201). Again, we find that the attachment of the teeth to the basal membrane of the radula also increases in length and forms a projecting apophysis, thus

TEXT-FIG. 3.



A *A. gibbonsi*, s.s.
 B *A. g. rubella*.
 C *A. g. gracilis*.
 D *A. g. lupata*.
 E *A. g. lupata* v. *duplex*.

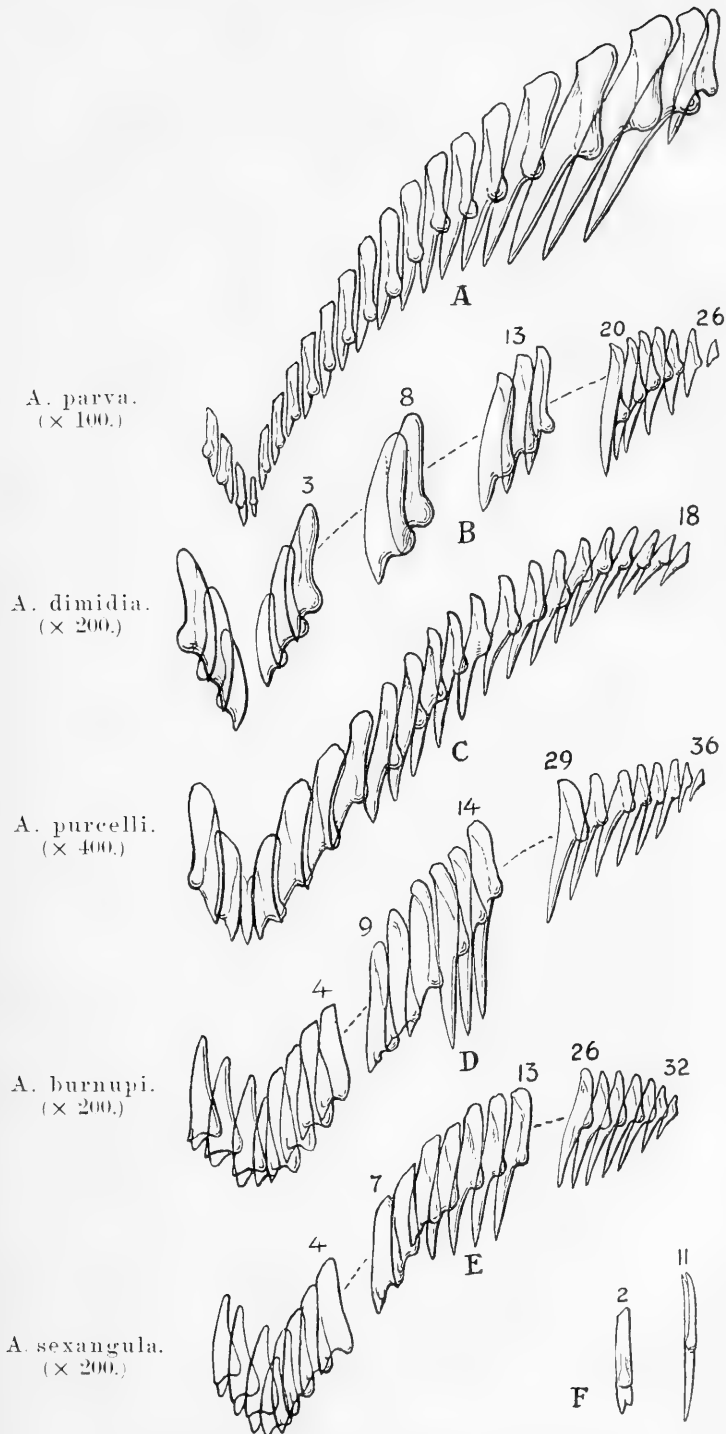
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1mm

Representative teeth from the radulae of *Apera*.

making it more difficult for the teeth to be pulled out of position and keeping them rigidly in place. Lastly, the teeth become modified in one of two ways in order to prevent the worm that they have transfixed from escaping. In *A. gibbonsi rubella* the cusps are strongly curved so as to form veritable hooks (text-fig. 3, B), and they are also slightly broadened towards the points. On the other hand, in *A. gibbonsi lupata* the cusps are barbed on the lower side, as in *Testacella*—a remarkable case of parallel evolution (cf. Pl. XXIV, fig. 157, and text-fig. 3, D). Still more highly specialised is the var. *duplex* of the same form. In this variety all the larger teeth are doubly barbed, there being a small barb on the upper side of the cusp nearer to the point than that on the lower side (text-fig. 3, E). I do not know of any other Pulmonate in which the radula has become so highly specialised along these lines as it has in this variety. We have to go to the marine carnivorous genera, such as *Conus*, to find such formidable doubly barbed teeth, and here also we notice that one barb is nearer the point of the tooth than the other. In *Conus*, however, the barbs are pointed instead of being merely square as in *Apera*, and the distal barb appears to have been developed first, for the other is often absent or merely represented by a flange. And of course the bases and arrangement of the teeth in *Conus* are quite different.

The radula of *Apera parva* bears a general resemblance to that of *A. gibbonsi*, but the bases of the teeth are not so narrow, the cusps of the inner teeth are slightly shorter, and the teeth become relatively larger towards the edges of the radula (text-fig. 4, A). None of the transverse rows contain more than thirty-five teeth in this species, and some have only thirty-four, as the vestigial central tooth is absent from some of the rows. On the whole the radula of *A. parva* is less unlike the type found in the genus *Rhytida* than are the radulæ of the other species of *Apera*.

In *Apera purcelli* and *A. dimidia* the central tooth also degenerates. It is present, though small, in *A. purcelli*



Representative teeth from the radulae of *Apera*.

(text-fig. 4, c), but no trace of it remains in *A. dimidia* (Pl. XX, fig. 127, and text-fig. 4, b). The outer teeth of these two species have rather long, slightly curved cusps, and are not very unlike the teeth of the typical form of *A. gibbonsi* on a smaller scale; but the cusps of the inner teeth are remarkably short and broad, and the teeth have therefore a quite different appearance. In the more primitive species, *A. purcelli*, only the first three or four teeth on each side are thus modified, but in *A. dimidia* half the teeth are of this shape. Hence the teeth of these species, unlike those of nearly all other carnivorous forms, are differentiated into laterals and marginals, although there are one or two on each side which might be regarded as transitional. The figures of the radula of *A. dimidia* (Pl. XX, fig. 127, and text-fig. 4, b) show that in this species the corresponding teeth on each side are not opposite to each other, the right half of the row being in front of the left. A similar displacement occurs in *A. parva* (text-fig. 4, a), and it is also often observable in *A. gibbonsi* (Pl. XX, fig. 125); but it occurs occasionally in other carnivorous genera, for I have noticed it in *Testacella halio-tidea* *Drap.*, *T. scutulum* *Sow.*, *Euglandina truncata* (*Gmel.*), *E. corneola* (*Binn.*), and *Rhytida franklandi-ensis* (*Forbes*).

In *Apera sexangula* and *A. burnupi* the differentiation into lateral and marginal teeth is still more marked (Pl. XX, fig. 128; text-fig. 4, d, e). The marginal teeth are more than twice as numerous as the laterals, and their cusps are long, slender, and nearly straight, those of one row overlapping the bases of the teeth in the row behind. The lateral and central teeth have short broad cusps, and the central tooth—which is only slightly smaller than those on each side of it—is not unlike the lateral teeth of *A. purcelli* and *A. dimidia*, though perhaps a little shorter. The cusps of the lateral teeth, however, are not only very short, but they are bifid and end in two points, the inner of which is the longer (text-fig. 4, d-f). Bentler¹ has shown that in *Pary-*

¹ 'Zool. Jahrb.,' 1901, vol. xiv, p. 380, pl. xxvii, fig. 23a.

phanta hochstetteri (*Pfr.*) one of the teeth in each row may abnormally develop a double cusp; but I believe that I am right in saying that in no carnivorous genus excepting *Apera* are some of the teeth normally provided with double cusps, for I regard the bicuspid teeth of *Pseudosubulina lirifera* (*Morelet*) as something quite different. What is the reason for this remarkable modification of the inner teeth in these two species? Perhaps it may be found that *Apera burnupi* and *A. sexangula* live chiefly on some special kind of food, and have their radulæ specially modified in consequence. Or possibly we have here an instance of carnivorous slugs reverting to a partly vegetarian diet, and the lateral teeth are used in eating vegetable and the marginals in eating animal food. The fact that Collinge has found both animal and vegetable remains in the intestine of *A. sexangula* is in favour of the latter view. In case this hypothesis should prove to be correct, it is interesting to compare the type of radula found in these species with that which is characteristic of the *Limacidæ*, *Zonitidæ*, and other omnivorous families. These also have developed thorn-shaped marginal teeth, very similar to those in *Apera*, and here, too, we find that the lateral and central teeth are shorter and broader with one or two less pointed cusps. Nevertheless, these inner teeth are very different to those of *Apera burnupi* and *A. sexangula*, for they are of the ordinary type with broad oblong bases, such as is found in the great majority of herbivorous snails, whereas in the species of *Apera* the teeth have narrow bases and have obviously been derived from the thorn-shaped type. This difference, however, could be easily explained by supposing that in the *Zonitidæ*, etc., we have a group of herbivorous snails which have become adapted to a partially carnivorous diet, while in these species of *Apera* we are dealing with carnivorous slugs which have become partially herbivorous.

Further details about the radula of *Apera* will be found under the head of the different species. I need only add here that the teeth towards the hind end of the radula are more or

less tinged with brown, as is so commonly the case among the carnivorous genera.

THE ODONTOPHORE.—The hind end of the buccal mass is prolonged beyond the opening of the œsophagus to form the cylindrical muscular odontophore containing the radula-sac. In most carnivorous snails the hind end of the odontophore is curved abruptly downwards, but in *Apera*, as in *Testacella*, it has become quite straight, probably owing to the degeneration of the spiral shell. The size of the odontophore—and, to a less extent, the size of the buccal mass in front of it—is proportionate to the size of the radula. In *A. burnupi* (Pl. XXI, fig. 133) and *A. sexangula* (fig. 134) it is quite small, being only about 4 mm. long; in *A. purcelli* (Pl. XIII, fig. 55) and *A. dimidia* (Pl. XXI, fig. 132) it is much larger; finally, in *A. gibbonsi* and *A. parva* (figs. 129–131) the odontophore attains an enormous size, being one of the largest organs in the body. Yet the structure of the odontophore is remarkably constant throughout the genus, the differences between the arrangement of its muscles in the various species being quite insignificant.

The odontophoral support or cartilage is a semi-cylindrical structure which extends along almost the entire length of the odontophore. It is crescentic in section, the convex surface being ventral. In the hollow formed by its upper surface lie the radula-sac and the muscles immediately surrounding it, while the ventral pocket containing the front end of the radula is situated beneath the anterior part of the support, the radula being folded over its anterior end (Pl. XVII, fig. 92, and Pl. XVIII, figs. 115–122). The upper edges of the support are parallel throughout the greater part of its length, but anteriorly they curve inwards towards each other, and then diverge again and slope downwards at the front end, thus leaving an oblique oval aperture where the opening of the radula-sac is situated (Pl. XVII, figs. 95, 100, 105, 112). As might have been expected, this aperture is largest in *Apera gibbonsi*, and the front end of the support is rounded in this species and in *A. parva*. On the other

hand, in *A. burnupi* and *A. sexangula* the aperture is very small, and the front end of the support is pointed (see fig. 112). The hind end of the odontophoral support is rather abruptly truncated. Along the inner surface of the support there runs a median longitudinal furrow, which can be best seen in transverse sections of the odontophore of *A. dimidia* (Pl. XVIII, figs. 116–121). In the other species it is not usually so well marked.

The odontophoral support is flexible, but much firmer than ordinary muscular tissue; and it is usually semi-translucent; yet it does not contain any cartilage, but is entirely composed of long narrow cells stretching radially from the inner to the outer surface (Pl. XVI, fig. 90). The nuclei of these cells are also lengthened, and are rather more numerous towards the outer than the inner surface of the support, doubtless because the cells are on an average slightly broader towards the outside. Most authors have regarded these long cells which occur in the odontophoral support of carnivorous snails and slugs as being muscle-fibres; but Beutler¹ has disputed this view, and has maintained that in *Paryphanta hochstetteri* (*Pfr.*) this tissue is not muscular. Now, I should certainly not be inclined to consider these cells as being of the nature of ordinary muscular fibres in *Apera*, but they might perhaps be regarded as muscle-fibres which have become modified for a supporting or skeletal purpose, and, if this is so, it is possible that they have become more modified in genera such as *Paryphanta* and *Apera* than in the types studied by Plate. In *Testacella* and *Daudebardia* there are longitudinal muscle-fibres and other cells intercalated among the radial elements of the support,² and I have found that this is also the case in *Euglandina venezuelensis* (*Preston*); but these are entirely absent in *Apera*, as in *Paryphanta*³ and *Natalina*.⁴

¹ *Op. cit.*, pp. 380, 381.

Plate, L. H., 'Zool. Jahrb.', 1891, vol. iv, pl. xxxiii, figs. 30, 31, 39, 41, pl. xxxiv, fig. 51.

³ Beutler, *op. cit.*, p. 380.

⁴ Woodward, M. F., 'Proc. Mal. Soc.', 1895, vol. i, p. 273.

A longitudinal muscle runs along the upper edge of the support on each side towards its anterior end (Pl. XVI, fig. 90; Pl. XVIII, figs. 116-118), and probably serves to bend up the front of the support, as shown in Pl. XVII, fig. 108, and may therefore be termed the flexor muscle of the odontophoral support. In *Apera gibbonsi* there is also a very thin layer of longitudinal muscle-fibres covering the ventral surface of the support, and possibly the flexor muscles might be regarded as a special thickening of this layer.

The most important muscles in the odontophore are the powerful retractors, which arise from the odontophoral support and are inserted in the radula-sac. These may be divided into lateral retractors, median retractors, and terminal retractors. The numerous lateral retractors are attached in front to the radula-sac, chiefly around its anterior end, and pass obliquely backwards and outwards on each side, curving over the edges of the support and becoming attached to its outer sides (Pl. XVII, figs. 92, 93, 96, 101, 106, 109, 111, 113, and Pl. XVIII, figs. 116-121). The median retractors are a pair of specially thick muscles, which are attached for some distance to the floor of the radula-sac towards its anterior end, and pass backwards to the extreme hind end of the support (Pl. XVII, figs. 92, 106, and Pl. XVIII, figs. 118-122). They belong to the same series as the lateral retractors, of which they might be regarded as forming the innermost pair. No muscles are attached to the posterior part of the radula-sac, excepting at its hind end, where there is another pair of retractors, which I am calling the terminal retractors. These are not so thick as the median retractors, and pass backwards above them to the hind end of the support (Pl. XVII, fig. 92, and Pl. XVIII, figs. 121, 122). All these retractor muscles have the same function—that of pulling back the radula. In *A. gibbonsi* some of the more posterior strands of muscle are attached to the inner surface of the support, close to its hind end, while others are not attached to the support at all, but to the hind end of the sheath of the odontophore opposite to the insertion of the extrinsic buccal retractors.

Numerous muscles arise in two rows, one on each side of the mid-dorsal line of the outer sheath of the odontophore, and, passing downwards outside the lateral retractors, are attached to the outer sides of the support just below them (Pl. XVII, figs. 91, 104, and Pl. XVIII, figs. 115-121). These muscles I am terming the suspensor muscles of the support. They are nowhere of any great thickness, but are decidedly thinner behind than in front.

A thin layer of ventral muscles arises from the hind end of the odontophoral support, and is inserted in the anterior part of the radula, or rather in the walls of the ventral pocket which contains it (Pl. XVII, figs. 91, 92, 101, 104, and Pl. XVIII, figs. 117-121). These muscles do not only run longitudinally beneath the centre of the support, but the more lateral strands diverge radially from the ventral pocket of the radula and unite with the suspensor muscles of the support on each side. They serve to pull back the anterior part of the radula over the front edge of the support, and thus to pull forward the radula-sac when its retractors are relaxed, so that the radula assumes the form shown in Pl. XVII, figs. 92, 97, 102, 114. Then, when the teeth have become imbedded in the skin of the prey, these ventral muscles will be relaxed, and the powerful retractors will draw back the radula until it has the form shown in fig. 98.

A slender median dorsal muscle is inserted in the sheath of the odontophore, between the suspensor muscles, a short distance behind the opening of the œsophagus, and is attached posteriorly to the front end of the terminal retractors, its sides also becoming connected with the neighbouring lateral retractors (Pl. XVII, fig. 92, and Pl. XVIII, figs. 116-120). This is evidently homologous with the muscle that Amaudrut terms the "papillaire supérieur." It may assist the ventral muscle in pulling forward the radula-sac, but its chief function is probably to pull back the posterior lip of the opening of the œsophagus when the retractor muscles are brought into play, thus making a wide passage towards the crop.

The sheath of the odontophore is composed of three layers of muscle-fibres. Externally there is a thin layer of longitudinal muscles; within this lies a layer of circular muscles, which is equally thin throughout the greater part of the length of the odontophore, but becomes a little thicker towards the front end; lastly, there is a very thin layer of longitudinal muscles lining the whole of the sheath excepting the dorsal part which lies between the attachment on each side of the suspensor muscles of the support. At its hind end the sheath of the odontophore becomes intimately united with the support and the posterior ends of the retractor muscles, but throughout nearly the whole of its length its only connection with the underlying tissues is by means of the suspensor muscles.

I have examined the arrangement of the muscles of the odontophore in all the species of *Apera* excepting *A. purcelli*, and the amount of variation is so small, notwithstanding the diversity of the radulæ, that it must be admitted that these muscles are of considerable systematic importance. It will, therefore, be of special interest to compare the arrangement of the odontophoral muscles of *Apera* with that which is found in other families of carnivorous snails and slugs.

As an example of the Rhytididæ we may choose *Natalina*. Nineteen years ago M. F. Woodward¹ published an account of the anatomy of *Natalina caffra* (*Fér.*), with special reference to the structure of the odontophore; but unfortunately his account shows evidence of inaccuracy. I shall therefore ignore his description and figures, and compare the odontophoral muscles of *Apera* with those of a species of *Natalina*, nearly allied to *N. caffra*, which I have been able to examine myself, namely *N. quekettiana* (*M. & P.*). On the whole the odontophore of this species resembles that of *Apera* very closely; it differs, however, in the following features.—(1) Instead of being straight the odontophore is slightly curved towards the left; moreover its hind

¹ 'Proc. Mal. Soc.,' 1895, vol. i, pp. 270-277, pl. xvii.

end is abruptly bent downwards, and the outer longitudinal muscles of the sheath form a pad extending from the recurved end a short distance forwards along the ventral surface. (2) The lateral retractors towards the posterior end of the odontophore are attached to the odontophoral support just within its edges; further forward they are attached to the outer sides of the support as in *Apera*. (3) The median dorsal muscle is extremely slender, and the terminal retractor is also very weak, being almost devoid of muscular fibres. (4) The circular muscles of the sheath are much thicker laterally and ventrally, and the suspensor muscles of the support are also much thicker than in *Apera*. In all other respects the structure of the odontophore is strikingly similar to that found in *Apera*, and especially to that of *A. gibbonsi*; for in *Natalina quekettiana* a thin layer of longitudinal muscles covers the lower surface of the odontophoral support, and some of the posterior retractors are not attached to the support, but arise from the sheath of the odontophore opposite to the insertion of the upper branches of the extrinsic buccal retractors—features which are also found in *A. gibbonsi*.

The chief differences mentioned above may be easily explained. The curvature of the odontophore is doubtless due to the fact that *Natalina* possesses a large spiral shell. The greater thickness of the constrictor muscles running in a circular direction, both those in the sheath and those beneath it, is probably connected with the circumstance that *Natalina* feeds on snails rather than on worms; for, as Woodward has pointed out, the contraction of these muscles will press the radula against the body of its prey, as it tears the teeth through its victim's flesh, a thing that a vermivorous form does not do. The reduction of the median dorsal muscle and the terminal retractor, which might be regarded as its continuation, may be due to the fact that *Natalina* rasps off portions of its prey, and therefore does not require to enlarge the opening of the œsophagus to such an extent as an animal that swallows worms whole. We see, therefore, that the

differences between the structure of the odontophore in *Apera* and *Natalina* are of little morphological importance, and are certainly less striking than the differences between the radulæ of the two genera, for the radulæ of *Natalina* and *Apera* have become highly specialised in different directions.

Turning now to the Testacellidæ, we find slugs which are vermivorous like *Apera gibbonsi* and have radulæ remarkably similar to the var. *lupata* of that species. Yet an examination of the odontophore of *Testacella maugéi* *Fér.* reveals many features in which the arrangement of its muscles is quite different from anything that we have found in *Apera* or *Natalina* (Pl. XXIV, figs. 155, 156). The structure of the odontophore of *Testacella maugéi* differs from that which I have described as characteristic of *Apera* in the following respects.—(1) There is no terminal retractor (unless it is represented by the small connections between the floor of the radula-sac and the median retractor). (2) Perhaps in consequence of this the radula-sac is shorter than the ventral pocket, instead of being much longer. (3) The median dorsal muscle is short, very oblique, and divided into three or four fine strands. (4) The median retractors curve together above the radula-sac to form a tube which is continued to the hind end of the odontophore. (5) The muscles which form the top of this tube are not only firmly attached to the lateral retractors on each side, but also to the sheath of the odontophore; and they are continuous with the extrinsic buccal retractors, which join the posterior half of the odontophore on each side of the mid-dorsal line. (6) The lateral retractors are scarcely divided into separate strands. (7) There seem to be no flexor muscles along the upper edges of the support, but on its inner surface there is a slight median longitudinal ridge which disappears towards the hind end and is connected with the median retractors by a few slender strands. (8) The ventral muscles are rather stouter than in *Apera* and more definitely split up into separate strands. (9) Anterior to these the suspensor muscles are free, but directed obliquely downwards

and backwards from the sides of the roof of the odontophore to the support, parallel to the lateral retractors; further back, however, they are either absent or completely fused with the lateral retractors. Taking into consideration the similarity of the radula of *Testacella* to that of *Apera*, it is surprising that there should be so many differences in the muscles which control its movements.

In the *Oleacinidæ* the odontophore resembles that of *Testacella* in some of its features, and that of *Natalina* in others, although it often possesses more primitive characters than can be found in either of these genera. Strebel¹ has given a detailed account of the odontophore of *Euglandina sowerbyana* (*Pfr.*), from which it will be seen that in this species the median retractors enclose the hind end of the radula-sac and become continuous posteriorly with the extrinsic buccal retractor. In this respect, therefore, *Euglandina sowerbyana* resembles *Testacella*. But this is not the case with many of the other forms, such as *E. venezuelensis* (*Preston*) or *Streptostyla shuttleworthi* (*Pfr.*),² for in these the radula-sac is long, and its posterior part has not yet become entirely surrounded with muscles, but projects slightly from the hind end of the odontophore. In most genera the posterior end of the odontophore is curved downwards as in *Natalina*. The median dorsal muscle resembles that of *Apera*, and the ventral muscles are also like those of *Apera* and *Natalina*. On the other hand, the suspensor muscles are like those of *Testacella*, and I found that *Euglandina venezuelensis* also resembled that genus in having the retractors fused with the sheath of the odontophore towards the hind end. No median ridge or furrow occurs along the inner surface of the support in *E. venezuelensis*, and I did not find any flexor muscles along its edges. Possibly the longitudinal muscle-fibres within the support take the place in *Testacella* and

¹ 'Beitrag z. Kenntniss d. Fauna Mexikanischer L. u. Süswasser-Conchylien,' 1878, vol. iii, pp. 40-42, pls. xvii, xviii.

² Strebel, *op. cit.*, pl. v, fig. 7a.

Euglandina of the flexor muscles in *Apera* and *Natalina*. It is interesting to notice that while the odontophore in the *Oleacinidæ* is usually curved as in the *Rhytididæ*, in several features of its internal structure it appears to resemble the odontophore of *Testacella* more than does that of *Apera*.

THE BUCCAL RETRACTORS AND PROTRACTORS.—In all the species of *Apera* excepting *A. gibbonsi* and *A. parva*, the extrinsic buccal retractor consists of a long, narrow muscle, arising from the right side of the floor of the body-cavity at the entrance to its funnel-shaped prolongation beneath the mantle-cavity or lung. The origin of the buccal retractor is thus nearly as far back as the heart, and is slightly asymmetrical (Pl. XV, fig. 75). In front the muscle bifurcates just before reaching the odontophore, and the two branches are inserted one on each side of its posterior extremity (Pl. XXI, figs. 132–134). As might have been expected, the retractor is narrower in *A. burnupi* and *A. sexangula* than in *A. dimidia* with its larger odontophore.

In *Apera gibbonsi* and *A. parva* the retractor is split up into a number of powerful muscles, which radiate from the hind end of the odontophore, and are attached to a considerable area of the floor and the lower part of the sides of the body-cavity (Pl. XXI, figs. 129–131). In *A. gibbonsi* these muscles originate towards the hind end of the body-cavity, though further forward than the origin of the single buccal retractor in the other species (Pl. IX, fig. 27), but in *A. parva* the muscles have become shorter and arise from about the middle of the cavity (fig. 28). These muscles are often forked and neighbouring strands occasionally anastomose, but there is frequently a slight gap dividing those on the right side from those on the left. It is easy to see that the same carnivorous habits which have led to the enlargement of the radula and odontophore in *A. gibbonsi* and *A. parva* would produce a corresponding development and multiplication of the buccal retractors; and it is also evident that it would be an advantage if the ends of

these muscles were distributed over a considerable area, so that the strain produced by the contraction of the muscles was not concentrated on a small patch of the body-wall. But although it is not difficult to derive the many radially disposed retractors of *A. gibbonsi* and *A. parva* from the single retractor of the other forms, I would emphasize the fact that the difference is a very great one, and not likely to have been completed within a short space of time. So far as I am aware the only other form which has developed radial buccal retractors at all similar to those of *Apera* is *Selenochlamys*.¹

Since the buccal retractor is inserted in the hind end of the odontophore, it might have been expected that it would receive nerves from the buccal ganglia, which innervate the odontophore and the posterior part of the buccal mass. Yet this is not the case; for while the posterior end of the retractor receives nerves emanating from the right pedal ganglion, the front end is innervated by a pair of nerves from the cerebral ganglia in all the forms with a single retractor. This apparently anomalous innervation may be explained by assuming that the buccal retractor belongs to the same series of muscles as the tentacular retractors, with which it is united posteriorly in the great majority of snails; and that it was originally inserted, like the tentacular muscles, far forward, and in the region innervated by the cerebral ganglia. Later the anterior part, which consists of a right and left division, would become applied to the sides of the odontophore and fused with them, so that the retractor would appear to be inserted in the hind end of the odontophore. This theory is supported by the facts (1) that the nerves to the buccal retractor and to the retractors of the lower tentacles arise from the cerebral ganglia by the same roots, and (2) that the longitudinal muscle-fibres forming the outer layer of the sheath of the odontophore are directly continuous on each side with those of the buccal retractor behind (Pl. XVIII,

¹ Simroth, H., 'Festschrift Leuckarts,' 1892, p. 55.

fig. 122). This view would also explain how it is that in *A. gibbonsi* the nerves which innervate the buccal retractor in the other species merely unite with the sheath of the odontophore towards the anterior end of that organ. For we may suppose that in *A. gibbonsi* and *A. parva* the odontophore has grown back further than in the other species between the two halves of the buccal retractor, which have thus become applied to its sides, and consequently the free radial retractors of these forms are homologous with only the posterior half of the long retractor found in the remaining species.

We have seen that the origin of the buccal retractor in such forms as *Apera dimidia* is to the right of the middle line, and that its posterior end is innervated exclusively by branches of the right posterior pedal nerve (Pl. XV, fig. 75). Now the foot is a symmetrical organ, and the anterior part of the retractor is certainly symmetrical, as is proved by its innervation; it might, therefore, have been expected that the posterior part of the buccal retractor would have been symmetrical also, unless it had shifted somewhat to the left because of the pressure of the reproductive organs on the right side, as in the case of *Daudebardia saulcyi* (*Bgt.*) and *Testacella gestroi* (*Issel*).¹ Why, then, does the buccal retractor spring from the right side of the floor of the body-cavity in *Apera*? When an animal possesses a feature which is asymmetrical for no apparent reason, the explanation of that asymmetry is usually to be found by a consideration of the animal's phylogeny. It is highly probable that *Apera* has been evolved from a snail possessing a depressed or heliciform dextral shell. Now when such a shell is in its natural position upon the back of the animal, its columella is to the right of the aperture. Consequently the columellar muscle, from which the buccal retractor springs, will be towards the right side of the animal. Then, when the shell degenerates, all the upper part of the columellar muscle will disappear, and only the lower part, or

¹ Plate, L. H., 'Zool. Jahrb.,' 1891, vol. iv, p. 596.

“tail muscle,” in connection with the foot, will remain as the direct continuation of the buccal retractor, but it will still be situated towards the right side of the animal. In *Schizoglossa* we have a slug in which the degeneration of the shell has only partially taken place, and the chief muscle-fibres are still attached to the reduced columella; and it would be difficult to draw a diagram illustrating the theory which I have just set forth more aptly than does Murdoch's figure of the retractor muscles of *Schizoglossa novoseelandica* (*Pfr.*).¹

Several pairs of buccal protractors stretch from the outer layer of the walls of the buccal mass to the skin of the anterior part of the head. The longest and most important of these are inserted on each side just in front of the odontophore and below the opening of the œsophagus (Pl. XXI, figs. 129–134). These protractor muscles, together with the intrinsic muscles of the buccal mass, serve to protrude the odontophore, which seems to be protrusible in all the species of *Apera*. But even in *A. gibbonsi* the protractors are not very thick; and this is not surprising, for it is evident that less powerful muscles will be required to protrude the odontophore than to retract it after the teeth have become fixed in the skin of a worm.

THE ŒSOPHAGUS AND CROP.—In *Apera gibbonsi* and *A. parva* the œsophagus is very short and broad, and merges imperceptibly into the crop (Pl. XXI, figs. 129–131). The latter is fusiform in these species, and after increasing in width it gradually tapers again towards the openings of the hepatic ducts, its broadest part being about twice as far from these ducts as from the opening of the œsophagus into the buccal mass.

In the remaining species the œsophagus is long and narrow, as will be seen from figs. 132 to 134. At its posterior end it enlarges rather abruptly to form the crop, which is usually widest near the front end, but remains fairly broad almost as far back as the ducts of the liver, and then narrows

¹ ‘Proc. Mal. Soc.,’ 1900, vol. iv, pl. xvii, fig. 10.

rather suddenly; but, as might have been expected, the crop is much more distended in some specimens than in others.

The walls of the œsophagus and crop are very similar in structure (Pl. XV, figs. 78, 79, and Pl. XXII, fig. 135). The epithelial lining is normally thrown into longitudinal folds, and consists of columnar cells without any cilia. Outside the epithelium of both œsophagus and crop there are three layers of muscle-fibres. The fibres of the inner and outer layers are longitudinal, while those of the intermediate layer run in a circular direction.

THE STOMACH, INTESTINE, AND RECTUM.—Beyond the crop in *Apera parva* the alimentary canal enlarges to form a small stomach, into which the hepatic ducts open (Pl. XXI, fig. 131). In the other species of *Apera* (with the possible exception of *A. purcelli*) there is no true stomach, but the crop passes directly into the intestine at the openings of the hepatic ducts.

At first the intestine bends abruptly upwards and towards the right side of the animal. In *A. gibbonsi* it then describes a curve on the upper surface of the liver like a reversed **S** (Pl. IX, fig. 27; Pl. XXI, figs. 129 and 130). The posterior curve towards the left side is somewhat shallower than that towards the right, and beyond it the alimentary canal continues backwards low down on the right side of the posterior end of the liver. In *A. parva* the intestine, after curving over to the right side of the liver, passes straight backwards, the second curve towards the left side being absent (Pl. IX, fig. 28; Pl. XXI, fig. 131).

In *Apera burnupi* and *A. sexangula* the first curve is much deeper, and forms a loop which extends the whole way down the right side of the liver, in which it is partially embedded (Pl. IX, figs. 30, 31, and Pl. XXI, figs. 133, 134). The anterior portion of this loop lies further forward than the openings of the hepatic ducts. The posterior curve is shallow in these species, and the alimentary canal is continued on the right side, as in *A. gibbonsi* and *A. parva*. The

intestine is considerably narrower in *A. burnupi* and *A. sexangula* than in the other species.

In *Apera dimidia* and *A. purcelli* the first curve of the intestine lies in a more nearly vertical plane, and does not extend so far towards the right side (Pl. IX, fig. 29, and Pl. XXI, fig. 132). Then, after curving down on the left side, the intestine continues backwards on that side of the liver instead of on the right (cf. Pl. X, fig. 32, and Pl. XI, figs. 34, 35).

Beyond the region of the liver the alimentary canal continues backwards as the rectum beneath the mantle-cavity. It is at first surrounded by the funnel-shaped prolongation of the body-cavity, but further back it curves towards the right side of the animal, and bends up the right wall of the mantle-cavity on reaching the level of the respiratory opening. As will be seen from Pl. X, fig. 33, the anus is immediately below the respiratory opening, and the space between them is partially separated from the rest of the mantle-cavity by an oblique fold of the wall of the cavity, which projects forward on the left side of the space.

The epithelium lining the intestine is composed of very irregular columnar cells, the appearance of which is well shown in Pl. XXII, fig. 137. The inner walls of these cells are produced into a delicate fringe of extremely minute cilia. Outside the epithelium there is a thin layer of circular muscles, and external to this a thin layer of longitudinal muscles. The structure of the rectum is very similar to that of the intestine, excepting that the epithelium is normally thrown into deep folds (Pl. XXII, fig. 136). At the anus, however, the epithelial cells become more regular and oblong in section, and their cilia become far longer and less delicate.

THE SALIVARY GLANDS AND DUCTS.—The salivary glands are fairly compact, and are situated above and on each side of the crop near its junction with the œsophagus. There are always two glands, but in *Apera gibbonsi* and *A. dimidia*, and to some extent in *A. parva* and *A. purcelli*, they are united above the crop, as in so many of the carnivorous snails

(Pl. IX, figs. 27-29, and Pl. XXI, figs. 129-132). In *A. burnupi* and *A. sexangula* the glands are separate, but they are joined to each other by blood-vessels in such a way as to suggest that they may possibly have been more closely united in the ancestors of these species (Pl. IX, figs. 30, 31, and Pl. XXI, figs. 133, 134). The glands are never united underneath the crop, as in many of the *Oleacinidæ*, but remain widely separate below (Pl. XV, fig. 78).

The salivary ducts are long and very slender, and discharge into the buccal mass on each side of the opening of the œsophagus. The structure of the ducts is shown in Pl. XXII, fig. 138. It will be seen that the epithelial cells are of a peculiar shape and provided with long cilia. The epithelium is immediately surrounded by a layer of circular muscles, and outside these there is a layer of longitudinal muscles in which is embedded the salivary nerve. Within the gland the duct splits up into numerous branches, and in these also the epithelium is surrounded by circular muscles. One of these branches is shown in fig. 139, which also shows the appearance of the glandular cells of which the gland itself is almost entirely composed.

THE LIVER.—The greater part of the posterior half of the body-cavity is occupied by the liver or digestive gland (Pl. IX, figs. 27-31). In *Apera gibbonsi*, *A. parva*, *A. burnupi*, and *A. sexangula* the liver consists of two very distinct divisions, one anterior, dorsal, and to the right, the other posterior, ventral, and to the left (Pl. XXI, figs. 129-131, 133 and 134). Not only do these divisions discharge their secretions into the alimentary canal by quite separate ducts, but they are supplied with blood by different arteries, the right division being supplied by one or two branches from the anterior aorta, while the left division is supplied by the so-called posterior aorta. The right division of the liver is divided by the intestine into three main lobes, one lying within the anterior loop of the intestine, another in front of it, and the third behind it, as shown in the figures. Of these the anterior lobe, lying above the hind end of the crop, is the

most distinct. Each lobe is again subdivided into a number of lobules, the arrangement of which varies in different individuals. The left division of the liver lies entirely to the left of the intestine, and is about equal in size to the right. It also is divided and subdivided into lobes and lobules, but not so distinctly as is the right division.

In *Apera dimidia* the liver is also divided into two main divisions, one right and anterior, the other left and posterior; and, as in the other species, these divisions have separate ducts. They are not, however, quite so distinct from each other as in the species mentioned above, and they both receive their blood from a single branch of the anterior aorta, the so-called posterior aorta being absent. Moreover, the disposition of these divisions with regard to the intestine is quite different to that which I have described as characteristic of *A. gibbonsi*, *A. parva*, *A. burnupi*, and *A. sexangula*. The anterior or right division lies above the crop, entirely in front of the intestine, while the posterior or left division, which is divided into two lobes, occupies a position corresponding to that held in the other species by the two posterior lobes of the right division of the liver (Pl. XXI, fig. 132). This fact suggests that possibly the whole of the liver of *A. dimidia* corresponds to the right division of the liver in the other species. If this theory be correct, it would explain, not only the anomalous position of the liver with regard to the intestine in *A. dimidia*, but also its still more surprising blood-supply. We would have to suppose, however, that the origin of the branch of the right hepatic duct coming from the anterior lobe had shifted inwards as far as the intestine itself; but this might have been caused by the greater separation of the lobe due to the lengthening of the right division of the liver as it came to occupy also the position of the left division. And this separation of the two principal branches of the hepatic duct would be merely a case of reversion, for H. Fischer¹ has shown that each division of the liver was probably originally subdivided into two or more lobes,

¹ 'Bull. Sci. France et Belg.,' 1892, vol. xxiv, p. 331.

which opened separately into the alimentary canal. But it is more difficult to explain why half the liver should disappear in this way. It is known, however, that the reduction of that part of the body-cavity which usually occupies the spire of the shell sometimes produces a corresponding reduction of the left lobe of the liver which it contains.¹ It seems possible, therefore, that in *A. dimidia* the left division of the liver, instead of merely pushing forward the right, as in the other species of *Apera*, has disappeared altogether, just as the right division has disappeared in some of the *Pectinibranchia*.

On the other hand, it is possible that the two divisions of the liver in *A. dimidia* are actually homologous with the two divisions in the other species. Blood-vessels are always very subject to variation, and if by some mutation the so-called posterior aorta had disappeared, the arteries supplying the right division of the liver would probably extend to the left also. Further, the posterior aorta passes to the left of the intestine, and may to some extent hold it in position (Pl. IX, fig. 27). When, therefore, this vessel is not present, there is nothing to prevent the intestine shifting to the left and coming to occupy the position that it holds in *A. dimidia*.

Possibly an examination of the liver of *Apera purcelli* may show which of these views is correct. In this species the intestine seems to occupy a similar position to that of *A. dimidia*, but unfortunately the liver of the only specimen of *A. purcelli* which I have been able to examine was in a state of partial disintegration.

Sections through the liver of *Apera dimidia* show that the food is not confined to the alimentary canal itself, but passes up the hepatic ducts into the lobes of the liver, and probably digestion takes place chiefly inside this organ in *Apera* as in *Atopus*.² Perhaps the disappearance of a stomach in these genera may be partly explained by this fact.

¹ Pelseneer, P., 'Mém. Acad. Roy. Belg.,' 1901, ex vol. liv, p. 55.
Simroth, H., 'Naturwiss. Wochenschr.,' 1901, vol. xvii, p. 121.

THE VASCULAR SYSTEM.

THE HEART AND PULMONARY VEINS.—The genus *Apera* is opisthopneumatic, the greater part of the respiratory tissue being behind the heart. Unlike *Daudebardia*, the auricle has moved round with the pulmonary veins so as to lie obliquely behind and to the right of the ventricle (Pl. IX, figs. 27–31), but it has not rotated so far as in *Testacella*. The pulmonary veins form a complicated network, variable in its structure; but it is generally possible to distinguish three main vessels converging towards the auricle, namely, the right anterior pulmonary vein, from the corner of the mantle-cavity to the right of the pericardium; the right posterior pulmonary vein, from the region between the pericardium and the anus; and the left posterior pulmonary vein, from the part of the mantle-cavity behind the kidney. Owing to the absence of the respiratory tissue from the left anterior corner of the mantle-cavity there is no left anterior pulmonary vein.

The walls of the auricle are very thin (Pl. XI, fig. 35), but those of the ventricle are extremely thick and muscular (fig. 34). The cardiac muscle-fibres are arranged in bundles passing in various directions, and leaving spaces between them which communicate freely with the central cavity of the ventricle (Pl. XXII, fig. 140). The muscles are thus well supplied with blood without the intervention of any cardiac arteries.

THE ARTERIAL SYSTEM.—The distribution of the principal arteries is shown in Pl. IX, figs. 27–29 and 31. The single aorta leaves the posterior end of the ventricle, passes through the diaphragm, and then bends abruptly to the right and curves downwards, so that it comes to lie on the right side of the liver. In *Apera gibbonsi*, *A. parva*, *A. burnupi*, and *A. sexangula* the so-called posterior aorta branches off to the left within 3 or 4 mm. of the diaphragm. This vessel passes forwards on the right side of the left division of the liver, keeping to the left side of the intestine. It divides into two or three branches supplying the left division of the liver, but the most anterior branch first passes through the

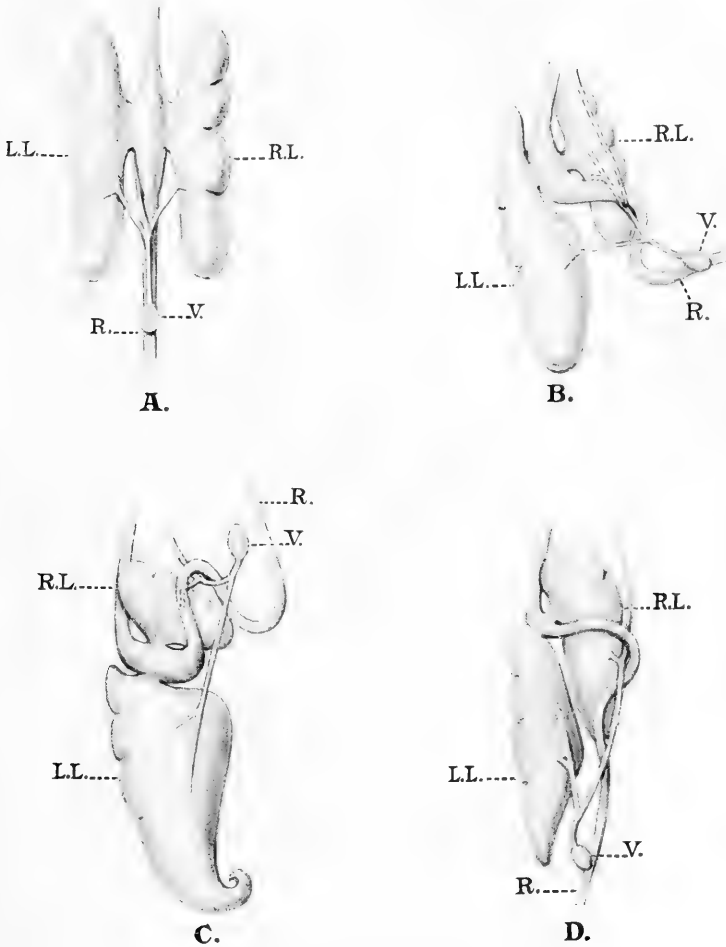
hermaphrodite gland, to which it also supplies blood. In *A. burnupi*, but not in the other species, this branch also gives off a small artery to the hind end of the right division of the liver. In *A. parva* the posterior aorta divides immediately into three branches at the point where it separates from the anterior aorta, but in the other species the division of the vessel takes place further forward. No posterior aorta is present in *A. dimidia*, and there is probably none in *A. purcelli* either.

I would suggest that perhaps this so-called posterior aorta may be merely the left hepatic artery which has become displaced, and that the Gastropoda (with the possible exceptions of *Haliotis* and *Fissurella*¹) resemble the Amphineura and the more primitive members of the Pelecyopoda in having no true posterior aorta. The posterior position of this artery would be accounted for by the posterior position which the left division of the liver has come to occupy owing to the torsion of the visceral hump. Its comparatively large size in most genera might be due to the fact that the left division of the liver is generally much larger than the right, since it extends up the spire of the shell. And as the hermaphrodite gland is usually more or less embedded in the left division of the liver, it would be likely to be supplied with blood by the same artery. This view will be made clear by the accompanying diagrams A to D. Diagram A represents a primitive symmetrical arrangement, and C the condition after the torsion has taken place; B shows a hypothetical stage between A and C, while D represents the most usual arrangement of the arteries and liver in *Apera*.

The anterior aorta continues forward on the right side of the liver, crossing over the intestine in *A. gibbonsi*, *A. burnupi*, and *A. sexangula*. In *A. gibbonsi*, *A. dimidia*, and probably in *A. purcelli*, it gives off a single artery to the liver on reaching the level of the anterior loop

¹ See Wegmann, H., 'Arch. Zool. Expér.' (2nd ser.), 1884, vol. ii, pp. 352, 353, pl. xviii, figs. 1-4; and Boutan, L., *ibid.*, 1885, ex vol. iii bis suppl., pp. 34, 130, pl. xxxiii, figs. 5, 6.

TEXT-FIG. 5.



Diagrams illustrating the hypothetical evolution of the "posterior aorta."
 (Diagram D shows the arrangement in *Apera gibbonsi lupata*.)

L.L. = Left division of liver. R. = Rectum.
 R.L. = Right division of liver. V. = Ventricle.

of the intestine. This hepatic artery soon divides into two branches. In *A. gibbonsi* the anterior branch chiefly supplies the anterior lobe of the right division of the liver, while the remainder of the right division is supplied by the posterior branch. In *A. dimidia* the anterior branch supplies the anterior division of the liver, while the posterior branch supplies not only the posterior division, but also the hermaphrodite gland which it traverses. In *Apera burnupi* and *A. parva* the blood-supply of the right division of the liver is similar to that in *A. gibbonsi*, excepting that the two branches arise separately from the anterior aorta, though very close together. In *A. sexangula* these arteries also arise separately from the anterior aorta, and their origins are much further apart.

The anterior aorta passes through the loop formed by the intestine in *Apera burnupi*, *A. sexangula*, *A. parva*, and in *A. gibbonsi gracilis* and *A. g. lupata* (Pl. IX, figs. 28, 31, and text-fig. 5, D); but in *A. dimidia*, *A. purcelli*, *A. gibbonsi s. s.*, and *A. g. rubella*, the aorta passes straight forward on the right side of the loop (figs. 27, 29). It is very remarkable to find this important difference separating forms which seem to be so closely related that I have not ventured to regard them as distinct species. For the difference amounts to this: that in the first group the aorta, on its way from the dorsally situated heart to the ventral ganglia, passes on the left side of the alimentary canal, while in the second group the aorta passes on the right.¹

The aorta then runs forward between the digestive and reproductive organs, being often closely applied to the left side of the albumen gland. It gives off to the left three or four arteries to the crop and salivary glands, and to the right at least one artery to the albumen gland and another to the common duct, a branch of the latter going forward to the receptaculum seminis. The aorta then becomes more ventrally situated and

¹ A similar variation in the course of the aorta has been found by Köhler in the genus *Siphonaria* ('Zool. Jahrb.,' 1893, vol. vii; compare fig. B, p. 27, with figs. A and C, p. 32).

runs forward towards the ventral group of ganglia. Just before reaching these a pair of arteries is given off to the tentacular retractors (Pl. XIII, figs. 52 and 54-57). In most of the species these arteries unite with the common tentacular retractors just behind the points where the latter divide; but in *Apera dimidia* they unite with the upper tentacular retractors, and give off small branches to the retractors of the lower tentacles, which join the nerves from the sides of the "nerve-collar" (fig. 54). Finally the aorta fuses with the ventral group of ganglia.

From this point radiate numerous short vessels to the various parts of the central nervous system, etc., as well as two longer arteries, namely, the buccal and pedal arteries.

The buccal artery passes upwards and divides into two branches, one running forwards and the other backwards. In *Apera dimidia* the posterior branch is about twice as long as the other (Pl. XVII, fig. 103); it runs back to the posterior extremity of the odontophore, which it enters, and then bends round the hind end of the odontophoral support (Pl. XVIII, fig. 122). The anterior branch runs forward and divides into a pair of arteries which apply themselves to the sides of the buccal mass, dividing again as they do so into anterior and posterior vessels. In *A. burnupi* and *A. sexangula* the buccal artery branches in a similar manner, but owing to the small size of the odontophore, the posterior branch is no longer than the anterior branch (Pl. XVII, fig. 110). In *A. gibbonsi* and *A. parva*, on the other hand, the posterior branch is very long, and in the former species the right and left anterior arteries do not branch from a single median vessel, but arise separately (Pl. XIII, fig. 52).

In *Testacella* the artery supplying the odontophore with blood behaves differently, for, instead of running straight to the hind end of the organ, it divides into lateral vessels which pass through the sides of the sheath as shown in de Lacaze-Duthier's admirable figures.¹ On the other hand, in *Natalina quekettiana* (*M. & P.*), this artery behaves in the

¹ 'Arch. Zool. Expér.' (2nd ser.), 1887, vol. v, pls. xxxv, xxxvi.

same way as it does in *Apera*. In *Euglandina* we have an intermediate arrangement, as will be seen from Strebel's figures¹; for the structure that he described and figured as a median odontophoral nerve from the ventral group of ganglia, is, in reality, the buccal artery, as I have found from an examination of *E. venezuelensis* (*Preston*).

The pedal artery runs backwards above the pedal gland, to which it gives off branches on each side. In *Apera gibbonsi*, *A. dimidia*, and *A. sexangula*, I have found a very slender vessel uniting the anterior aorta with the pedal artery about half way along the pedal gland (Pl. XIII, figs. 52, 54, and 57). After uniting with the terminal vesicle of the pedal gland, the pedal artery continues backwards and downwards, and becomes more or less embedded in the muscular connective tissue of the foot.

The venous system is largely lacunar, apart from the pulmonary veins already described. Indeed, the only well-defined vessel containing venous blood is the body-cavity itself. I have already dealt with the dermal veins and their curious sphincters, when treating of the structure of the skin.²

THE EXCRETORY SYSTEM.

The pericardium communicates with the mantle-cavity by means of a single renal cœlomoduct, divided into an ascending glandular portion, which forms the kidney, and a descending non-glandular portion, which forms the ureter. It will be seen from Pl. IX, figs. 27-31, Pl. XI, figs. 34, 35, and Pl. XII, fig. 36, that the kidney is applied to the left side of the pericardium, and also extends over its posterior part towards the right side, thus broadly connecting the pericardium with the wall of the mantle-cavity, with which the kidney fuses a little further back. Ventrally the kidney is prolonged backwards in the floor of the mantle-cavity on

¹ 'Beitrag z. Kenntn. d. Fauna Mexikan. L. - u. Süßwasser-Conchylien,' 1878, vol. iii, pl. xvi, fig. 5, pl. xviii, figs. 1, 6, 10; pl. xix, fig. 1, pl. xx, fig. 1.

² See pp. 126, 127.

the left side of the rectum and even beyond the anus (Pl. X fig. 33). The walls of the kidney are very much folded internally (see especially Pl. XI, fig. 35), and are lined by an epithelium consisting of glandular excretory cells with conspicuous round nuclei (Pl. XXII, fig. 141).

The reno-pericardial duct is very narrow, but projects some distance into the kidney. Its position is shown in Pl. XI, fig. 35. The epithelial cells lining the duct are provided with very long cilia.

The kidney communicates with the ureter by a minute pore situated in the centre of a slightly raised papilla at the right end of its dorsal extension (Pl. XII, fig. 36). The ureter, as in other sigmurethrous *Stylommatophora*, is doubled back upon the kidney, and curves round its inner posterior side. Ventrally it is continued backwards beside the ventral prolongation of the kidney, and extends to the extreme end of the mantle-cavity, where it bends abruptly upwards and opens. The ureter is lined by a cubical epithelium, the appearance of which is shown in Pl. XXII, fig. 141. This epithelium becomes thinner over the papilla in which the opening of the kidney is situated; elsewhere it is remarkably like the epithelium which lines the lower surface of the shell-sac.

As in *Testacella* and the *Rhytididæ*, there is no secondary ureter; but a rather irregular groove runs forwards from the opening of the ureter along the roof of the mantle-cavity. This groove reaches nearly to the point where the ureter begins, and then bends round and runs obliquely backwards and to the right, to end in the cleft in the inner lip of the respiratory opening. The epithelium lining this groove is similar to that lining the ureter itself, and the groove is probably to be regarded as an incipient secondary ureter, such as is found in many other forms. The somewhat peculiar course of the groove might be explained on the assumption that the respiratory orifice was originally situated further forwards.

THE REPRODUCTIVE ORGANS.

The genital or reproductive organs of *Apera* are of a simple generalised type, at least so far as their external structure is concerned (Pl. XXIII, figs. 143, 144, 146-149). As up to the present only a very few fully mature specimens have been collected, I have thought it advisable to preserve the reproductive organs of these almost intact, and not to cut them up in order to examine their histology. The following account, therefore, deals chiefly with the external morphology of the genital system. The reproductive organs of *Apera purcelli* are unknown, the only dissected specimen being immature.

THE HERMAPHRODITE AND FEMALE ORGANS.—The hermaphrodite gland or ovotestis is partially embedded in the right side of the posterior division of the liver (see especially Pl. IX, fig. 31). It is a racemose gland composed of a cluster of oval or pear-shaped follicles. These follicles are smallest in *Apera burnupi* and *A. sexangula* (Pl. XXIII, figs. 148, 149). In the other species they are larger and tend to be fewer in number, until in *A. parva* the entire hermaphrodite gland consists of only about four follicles (fig. 146). The very slender ducts from the different follicles unite to form the hermaphrodite duct, which is long, and usually more or less convoluted and slightly swollen towards the middle of its length, especially in *A. dimidia*. But the convolution is not so pronounced as in many other genera. In front the hermaphrodite duct becomes embedded in the albumen gland. At the extreme anterior end it is swollen so as to form a minute spherical vesicle, which is doubtless to be regarded as a rudimentary vesicula seminalis.

The albumen gland varies enormously in size according to the exact state of maturity of the individual (cf. Pl. IX, figs. 27, 31). In some specimens it reaches a very large size indeed (Pl. XXIII, fig. 144). The common duct, or ovispermatoduct, is very long and much convoluted and twisted in *Apera burnupi* and *A. sexangula* (Pl. XXIII, figs.

148, 149); in *A. gibbonsi*, *A. parva*, and *A. dimidia* it is shorter and generally broader (figs. 143, 144, 146, 147). In some specimens the female or oviducal portion is greatly swollen, as in the example of *A. dimidia* of which the reproductive organs are shown in fig. 147. The free oviduct is rather long and narrow, and is directly continuous with the vagina, which is also rather narrow but usually somewhat shorter. The vestibule or genital atrium is extremely short.

THE RECEPTACULUM SEMINIS AND ITS DUCT.—The spermatheca or receptaculum seminis is an oval vesicle, situated, in *A. parva*, beside the anterior end of the free oviduct, the receptacular duct in this species being extremely short (fig. 146). In the other forms the receptaculum seminis lies against the anterior end of the common duct, and the length of the receptacular duct is therefore about equal to that of the free oviduct, since the anterior opening of the receptacular duct marks the junction of the free oviduct with the vagina. In *Apera gibbonsi* the receptacular duct is a simple narrow tube (figs. 144, 145). In *A. sexangula* it becomes swollen towards its union with the vagina, so that the anterior part of the duct is fusiform (fig. 149). In *A. burnupi* the anterior part of the duct is still more swollen (fig. 148). Lastly, in *A. dimidia* the swollen end of the duct has become attached to the adjacent part of the body-wall by a number of muscles on each side (fig. 147). And as we pass up this series the receptaculum itself becomes progressively smaller, and it seems as though the receptacular duct were taking its place. If this tendency were to proceed still further we should have a vesicle which would be indistinguishable from a sessile receptaculum seminis, although in reality it was the swollen anterior end of the receptacular duct, the rest of the organ having disappeared. Possibly this may have happened in some of the genera which are usually described as having a sessile receptaculum.

THE MALE ORGANS.—The vas deferens arises from the anterior end of the common duct, and passes forwards close to the free oviduct and vagina as far as the vestibule. It then

bends round and runs up the side of the penis. In *Apera gibbonsi* the vas deferens is rather thick excepting near the vestibule, where it has the more usual form of a very slender duct. In this species, and also in *A. dimidia*, before the vas deferens unites with the posterior end of the penis, it is slightly swollen for a distance equal to about one-third of the length of that organ, thus forming a rudimentary epiphallus. In *A. sexangula* this swollen part is very much shorter, and bears at its anterior end a minute flagellum, which, like the vas deferens itself, is closely applied to the side of the penis (Pl. XXIII, fig. 149).

The penis passes between the retractor muscles of the right upper and lower tentacles (Pl. XIII, figs. 52-57). In this respect *Apera* resembles *Testacella*, *Trigonochlamys*, *Poiretia*, *Streptostyla*, *Strebelia*, *Rhytida*, and *Paryphanta*, and differs from *Daudebardia*, *Plutonia*, *Selenochlamys*, *Natalina*, *Delos*, and the *Strep-taxidæ*, in which the reproductive organs are on the right of both retractors, as was first shown by Pfeffer, Simroth, and Murdoch. In *Apera dimidia* the penis is fairly short, but a little swollen posteriorly (Pl. XXIII, fig. 147). In *A. parva* it is about 4 mm. in length, and somewhat fusiform (fig. 146). In typical specimens of *A. gibbonsi* from Zululand, the penis is also short (fig. 143), but in the other races of that species it is very long and twisted in a peculiar manner (fig. 144). In *A. sexangula* the penis is long and very narrow, excepting at the posterior end, where it is broad and somewhat flattened (fig. 149). In *A. burnupi* the anterior part of the penis is also narrow, but it is much shorter than in *A. sexangula*, and more or less twisted. The posterior broader portion, on the other hand, is longer, and appears to be double, owing to the presence of a deep longitudinal groove on one side; and the vas deferens disappears into this groove about 5 mm. in front of the end of the penis (fig. 148). Possibly this peculiar arrangement may be due to the broad sides of the penis having arched over the end of the vas deferens and joined each other above it; but

this hypothesis must remain very doubtful until a sufficient number of specimens of this rare species has been collected in order to justify the dissection of the penis. In a full-grown example of *A. gibbonsi rubella* from Durban, the penis was found to be quite vestigial.

As so few full-grown specimens of *Apera* have been collected, I have only felt justified in examining the internal structure of the male organs in two forms, namely, *A. dimidia* and *A. gibbonsi rubella*. No penis-papilla is present in either of these species, but in both forms the inner surface of the muscular wall of the penis is completely covered by numerous small papillæ, as shown in Pl. XXIII, fig. 145. These papillæ are diamond-shaped in transverse section, and each ends in a short point. The structure of the papillæ is very similar in the two species, and is shown in Pl. XXII, fig. 142, which represents a photomicrograph of the inner half of a single papilla from the penis of *A. gibbonsi rubella*. In this form the papillæ become considerably smaller around the opening of the epiphallus, and within the opening they become much narrower in proportion to their length, changing, in fact, from papillæ into filaments. These filaments occur throughout the entire length of the epiphallus. They do not, however, arise from all parts of the inner surface of the wall of the epiphallus, but are arranged in longitudinal rows, of which there are about fourteen in the specimen that I examined. Between the rows the wall of the epiphallus is extremely thin. In *Apera dimidia* the epiphallus has a different structure, being lined by numerous minute papillæ, closely arranged, and not unlike the papillæ lining the penis, only much smaller. It is somewhat remarkable that while the inside of the penis is so very similar in the two species, the inside of the epiphallus should present such a marked contrast.

The retractor of the penis is attached to its posterior end, and arises from the roof of the body-cavity near the mid-dorsal line. In *Apera burnupi*, *A. sexangula*, *A. purcelli*, and *A. parva*, it is very long and narrow, arising in *A.*

sexangula and *A. parva* less than 4 mm. in front of the diaphragm, and only a very short distance further forwards in the other two species (Pl. IX, figs. 28, 30, 31). On the other hand, in *A. gibbonsi* and *A. dimidia* it is broader and very much shorter, the exact position of its origin depending on the length of the penis (figs. 27 and 29). Probably the retractor originally arose in the neighbourhood of the diaphragm; but owing to the posterior position which the diaphragm has come to occupy, the origin of the retractor has moved forward. If this view be correct, the condition found in *A. sexangula* and *A. parva* would be the most primitive.

THE SPERMATOCYTES.—Pl. XXIII, fig. 151, shows the anterior end of a spermatozoon of *Apera dimidia* magnified 1200 diameters. It will be seen that the head is curved into the shape of a hook, and is about $\cdot 0035$ mm. in length. The "middle-piece," or proximal portion of the tail, is surrounded by a spiral filament or flange, very loosely coiled, the whorls being about $\cdot 0045$ mm. apart. The posterior portion of the tail is extremely long. In *Apera sexangula* and *A. gibbonsi* the head of the spermatozoon is straighter and broader, though pointed in front. Fig. 150 shows the anterior end of a spermatozoon of the latter variety. It will be seen that in this form the whorls of the spiral filament are a little nearer together than in *A. dimidia*, being separated by a distance equal to the length of the head, namely, $\cdot 0037$ mm.

The spermatozoa of *Testacella* are very different from those of *Apera*, as may be seen from Pl. XXIV, fig. 160. In *Testacella* the head is globular, and there are two spiral filaments surrounding the proximal portion of the tail. Moreover the filaments are much more closely coiled than in *Apera*, adjacent whorls being only about $\cdot 0009$ mm. apart in *T. maugei*. In *Rhytida capillacea* (*Fér.*) I find that there are also two filaments, but they are not so closely coiled, the whorls being separated by about $\cdot 00165$ mm.; and in this species, as well as in *Natalina quekettiana* (*M. & P.*), the

head is not unlike that of *Apera sexangula* and *A. gibbonsi rubella*. On the other hand, in *Streptaxis funki* Pfr. the head is even more strongly curved than in *Apera dimidia*; and, as in the Testacellidæ and Rhytididæ, I have found two spiral filaments encircling the proximal portion of the tail, the distance separating adjacent whorls in this species being about .00115 mm.

The embryology of *Apera* is unknown.

DISTRIBUTION.

The genus *Apera* is only known to inhabit the maritime provinces of South Africa. One species—*A. purcelli*—occurs on the slopes of Table Mountain close to Cape Town; the other forms have only been found in Natal and in the eastern districts of the Cape Province. *A. parva* is at present only known to occur near Grahamstown; *A. sexangula* extends from that neighbourhood as far east as Pietermaritzburg; the various races of *A. gibbonsi* are known to inhabit an area stretching from Pondoland to Zululand; while *A. burnupi* and *A. dimidia* have only been found in Natal.

The animals are usually found in the bush, either amongst dead leaves or under stones or logs; but none of the species are at all common. *Apera sexangula* and *A. gibbonsi* seem to be the least rare. Of the others only six examples of *A. dimidia*, four of *A. burnupi*, two of *A. purcelli*, and one of *A. parva* are known to have been collected. It is to be hoped that South African naturalists will gather further specimens of this interesting genus, which not improbably contains more species than are at present known.

THE DIFFERENTIAL CHARACTERS OF THE SPECIES AND SUBSPECIES OF APERA.

Apera gibbonsi (Binney).

Chlamydephorus gibbonsi Binn., Bull. Mus. Comp. Zool. Harvard, 1879, vol. v, p. 331, pl. ii, figs. *a, b*; Binney, Ann. N. Y. Acad.

- Sci., 1884, vol. iii, p. 81, pl. xvii, fig. a; Tryon, Man. of Conch. (2nd ser.), 1885, vol. i, pp. 17, 251, pl. ii, fig. 95; Cockerell, Ann. Mag. Nat. Hist. (6th ser.), 1890, vol. vi, p. 390.
- Chlamydophorus gibbonsi* *Binn.*; Tryon, Struct. and Syst. Conch., 1884, vol. iii, p. 13, pl. ci, fig. 47.
- Apera gibbonsi* (*Binn.*); Heynemann, Jahrb. d. Deutsch. Mal. Ges., 1885, vol. xii, p. 17, pl. ii, figs. 5-7; Collinge, Ann. S. Afr. Mus., 1900, vol. ii, p. 4; Collinge, Ann. Natal Mus., 1910, vol. ii, p. 165; Connolly, Ann. S. Afr. Mus., 1912, vol. xi, p. 63.

EXTERNAL CHARACTERS (Pl. VII, figs. 1, 2; Pl. VIII, figs. 14, 15).—Animal slender, tapering to an acute angle at the hind end. Back rounded, without keels. Outer lip of respiratory opening almost concealing the inner lip. Skin coarsely reticulated. Dorsal grooves usually about 1 mm. apart, separated by a single row of rugæ, but united for about 4 or 5 mm. in front of the respiratory opening. Lateral grooves irregular, rather near the dorsal grooves, and seldom extending as far as the head. Radial grooves conspicuous, some being forked. Oblique sub-lateral grooves also conspicuous, and rather numerous; these and the radial grooves terminating in the single peripodial groove.

In the typical form the body is mottled with brown, the small patches of colour being chiefly concentrated dorsally, but leaving a paler band, very sparsely mottled, along the centre of the back from the head to the respiratory opening. Laterally the brown pigment becomes confined to the sides of the grooves in the skin, and dies out completely some distance above the peripodial groove. The ground-colour is pale yellow in specimens preserved in spirit, but living examples are tinged with dull orange, the colour being deepest on the back.

The type was described by Mr. Gibbons as being rather more than 3 in. long when fully extended. The following are the dimensions (in alcohol) of two specimens that I have examined, but the reproductive organs of the smaller one were not quite fully developed.

Length	62 mm.	. 66.5 mm.
Breadth in middle	9.5 "	. 12.5 "
Breadth at respiratory opening	7 "	. 9 "
Breadth of foot-sole	5 "	. 5 "
Greatest height	9.5 "	. 12.5 "
Distance from respiratory opening to hind end	13 "	. 13.5 "

INTERNAL CHARACTERS.—Skin very thick. Shell 4×2.5 mm., usually thick, depressed, with the apex in front of the posterior margin; sinus deep.

Pedal gland.—Slender; glandular tissue gradually dying out some distance in front of the terminal vesicle; duct closely convoluted posteriorly; fold in terminal vesicle divided into narrow lamellæ.

Nervous system.—Cerebral ganglia closely united; buccal ganglia large, close together, situated posteriorly, and joined to the cerebral ganglia by extremely long connectives; cerebro-pedal and cerebro-pleural connectives also long; nerves corresponding to those of buccal retractors in other species uniting with anterior end of sheath of odontophore, and joined to cerebro-buccal connectives for most of their length; nerves to pedal gland very slender.

Digestive System (Pl. XVII, figs. 91, 92; Pl. XX, fig. 125; text-fig. 3, A, p. 159; Pl. XXI, fig. 129).—Radula exceedingly large, sometimes attaining a length of 21 mm.; central tooth typically present; others not differentiated into laterals and marginals, very large excepting near the edges and the centre; cusps in typical form simple, slightly curved; bases very narrow; apophyses typically not prominent. Formula of type: $(27 + 1 + 27) \times 52$, of a Zululand example: $(37 + 1 + 38) \times 60$. Odontophore also extremely large; posterior end joined to the floor and sides of the body-cavity towards its hind end by numerous radial buccal retractors; odontophoral support rounded in front. Oesophagus short and broad, merging into a broadly fusiform crop. Anterior loop of wide intestine not much deeper than posterior loop; intestine continued posteriorly on right side of liver. Salivary

glands united above crop. Liver of two approximately equal divisions, the intestine only traversing the right.

Vascular System.—Pulmonary veins greatly branched. "Posterior aorta" supplying left division of liver and hermaphrodite gland; two arteries of right division of liver arising from anterior aorta as a single vessel; anterior aorta passing to right of intestine in typical form; anterior branches of buccal artery separate throughout.

Reproductive System (Pl. XXIII, fig. 143).—Hermaphrodite gland with rather large follicles; common duct rather short, curving twice to the right and twice to the left; vagina narrow; receptaculum seminis rather large; receptacular duct of moderate length and slender throughout. Vas deferens rather thick excepting near the vestibule, somewhat swollen near the posterior half of the penis to form an epiphallus; penis short and curved posteriorly in specimens from Zululand; penial retractor short.

HABITAT.—Typical form: Umgeni valley, Natal (under a stone in a wood; Gibbons); Pietermaritzburg (? Burnup, Ponsonby); Hlabisa, Zululand (Burnup).

TYPE.—The type is in the Academy of Natural Sciences, Philadelphia. Other specimens will be found in the Natal Museum, Pietermaritzburg.

AFFINITIES, ETC.—This species is the type of the genus. It differs from all the other species in its radula, buccal retractors, receptacular duct, etc. At the same time it shows a remarkable diversity in some of its organs, specimens found in different localities, and even, in one case, in the same locality, constituting races which differ markedly from each other in their radulæ and in a few other important characters. Indeed, it is not at all improbable that these forms will prove to be distinct species. For the present, however, until further specimens have been collected, I have thought it better to treat them provisionally as subspecies of *Apera gibbonsi*; for although their differences are undoubtedly of considerable importance, in most of their anatomical features they appear to be identical, and it is impossible to distinguish them merely

by their external characters, excepting in the case of one form, of which only a single specimen has been collected.

Apera gibbonsi rubella n. subsp.

EXTERNAL CHARACTERS (Pl. VII, figs. 3, 4, 5; Pl. VIII, figs. 16, 17).—Animal broader than the typical form of *Apera gibbonsi*, tapering more abruptly at the hind end. Back usually slightly flattened just behind the respiratory opening. Reticulation of skin very similar to that of the typical form of *A. gibbonsi*, but not so coarse, the grooves being more numerous and less deep. Dorsal grooves usually less than 1 mm. apart, and united for about 4 mm. in front of the respiratory opening.

Body thickly mottled with dark grey (which sometimes has a bluish tinge in specimens preserved in spirit). The small patches of colour are usually ill-defined, and tend to coalesce dorsally, where they are most abundant; but a narrow paler band, more sparsely mottled, is generally left along the centre of the back from the head to the respiratory opening. Laterally the dark pigment is chiefly concentrated on the sides of the grooves in the skin, but it dies out completely a short distance above the peripodial groove. The ground-colour of specimens preserved in spirit is whitish, tinged with dull red dorsally, but living examples are deeply coloured with an unstable orange-red pigment, so that the animal is usually reddish-brown above, merging into deep reddish orange on the sides, while the foot-sole is of a paler orange colour.

The following are the approximate dimensions (in alcohol) of the smallest specimen with fully developed reproductive organs, and of the largest specimen, which I have examined.

Length	49·5 mm.	. 67	mm.
Breadth in middle	10	„ . 13·5	„
Breadth at respiratory opening	9	„ . 11	„
Breadth of foot-sole	5·5	„ . 6	„
Greatest height	9·5	„ . 13·25	„
Distance from respiratory opening to hind end	10	„ . 13	„

INTERNAL CHARACTERS.—Glandular tissue of pedal gland reaching nearly as far back as the terminal vesicle. Radula (Pl. XX, fig. 126; text-fig. 3, B, p. 159) without central tooth; cusps of teeth very strongly curved, slightly broadened towards the points; apophyses very prominent; formula of a specimen from Equeefa: $(28 + 0 + 28) \times 51$; of a young example from Equeefa: $(24 + 0 + 24) \times 44$; of a specimen from Durban: $(34 + 0 + 35) \times 48$. Liver sometimes shorter and broader than in typical form (Pl. XXI, fig. 130). Penis long and twisted (Pl. XXIII, fig. 144). The anterior aorta passes on the right of the intestine (Pl. IX, fig. 27), and all the other anatomical characters seem to be identical with those of the typical form (Pl. X, figs. 32, 33; Pl. XIII, figs. 41, 42, 52; Pl. XIV, figs. 63–65, 67; Pl. XV, figs. 70, 77–79; Pl. XVII, figs. 93–98; Pl. XXII, figs. 138, 139, 142; Pl. XXIII, figs. 145, 150).

HABITAT.—Equeefa, Natal (Burnup); Durban (under dead leaves in the bush which fringes the shore; Burnup).

TYPE.—The type of subspecies is in the Natal Museum, Pietermaritzburg. Another specimen will be found in the British Museum.

AFFINITIES, ETC.—The chief characters which distinguish this form from *Apera gibbonsi* s. s. are its broader shape and darker colour, its radula, and its penis (although it is not known whether the penis of the typical form is always as short as it is in the Zululand specimens). It is possible that this may be a geographical variety of *A. gibbonsi*, as the two forms are not known to occur in the same district, but the radulae are so different as to suggest that this may prove to be a distinct species. The single specimen from Durban differs from those found at Equeefa in being without a paler dorsal band, in having more teeth in each row in its radula, and in the penis being abnormally reduced to a minute vestige. The resemblance of this specimen to certain dead leaves amongst those under which it was found has already been referred to (see p. 122). Mr. Burnup informs me that this subspecies contracts after the usual manner when about to rest, instead of merely

bending its body at various angles like the typical form of *A. gibbonsi*.

Apera gibbonsi gracilis n. subsp.

EXTERNAL CHARACTERS (Pl. VII, fig. 6).—Animal even more slender than the typical form of *Apera gibbonsi*, tapering to a very acute angle at the hind end. Outer lip of the respiratory opening not concealing so much of the inner lip as in the other forms of *A. gibbonsi*. Reticulation of skin coarse, as in the typical form; dorsal grooves united for 6 mm. in front of the respiratory opening.

Body rather sparsely mottled with brown, as in *A. gibbonsi, s. s.*; the patches of colour, however, are not concentrated on each side of the mid-dorsal area, but extend across it, so that there is no median paler band.

The following are the measurements of the only specimen that has been found:

Length	. . . 44 mm.	Greatest height	. . . 6 mm.
Breadth in middle	6 ,,	Distance of resp.	
Breadth at resp.		opening from hind	
opening	. . . 4.5 ,,	end	. . . 11 ,,
Breadth of foot-sole	3 ,,		

INTERNAL CHARACTERS.—Shell (Pl. XIII, fig. 43) rather longer and narrower at the posterior end than in the other forms of *A. gibbonsi*. Radula (Pl. XIX, fig. 123; text-fig. 3, c, p. 159) with fewer teeth than that of any of the other forms; central tooth absent; first on each side extremely small; outer teeth larger than in the preceding forms; cusps only slightly curved, not broadened or barbed; apophyses very prominent; formula: $(19 + 0 + 20) \times 34$. Anterior aorta passing through loop of intestine; branches of pulmonary veins not very numerous. Penis rather long and twisted. Other characters agreeing with those of *A. gibbonsi s. s.*

HABITAT.—Equeefa, Natal (Burnup).

TYPE.—The type of subspecies is in the Natal Museum, Pietermaritzburg.

AFFINITIES, ETC.—The single specimen of this form differs greatly from the last subspecies, although it was found in the same locality. In some respects it is intermediate between *Apera gibbonsi s.s.* and the next subspecies, but it seems impossible to associate it with either of these forms, and it must therefore stand alone until further examples have been collected. It will be noticed that owing to the length of the posterior extremity the respiratory opening is proportionately further forward than in the other forms.

Apera gibbonsi lupata n. subsp.

EXTERNAL CHARACTERS (Pl. VIII, figs. 18, 19).—Animal intermediate between *A. gibbonsi s.s.* and *A. g. rubella* both in shape and in the reticulation of the skin, being usually a little broader and less coarsely reticulated than the typical form of *A. gibbonsi*, and a little narrower and less finely reticulated than *A. g. rubella*. Colour variable; sometimes dark like *A. g. rubella*, sometimes light as in *A. gibbonsi s.s.* In the typical form the mottling is inconspicuous and there is only a very slight trace of the paler median dorsal band.

This form (and possibly also the last subspecies) may be slightly smaller than *A. gibbonsi s.s.* The following are the measurements of a specimen which seemed to be practically mature:

Length	. . . 46 mm.	Greatest height	. . . 7 mm.
Breadth in middle	7.5 „	Distance of resp.	
Breadth at resp.		opening from hind	
opening	. . . 6 „	end 8 „
Breadth of foot-sole	4 „		

INTERNAL CHARACTERS.—Shell much depressed. Radula (Pl. XVII, fig. 99; Pl. XIX, fig. 124; text-fig. 3, D, p. 159) with a comparatively small number of very large teeth; central tooth typically absent; cusps somewhat curved and

conspicuously barbed on the lower side; apophyses prominent; formulæ of two specimens (the second slightly immature): $(20 + 0 + 20) \times 44$, $(21 + 0 + 21) \times 38$. Anterior aorta passing through loop of intestine (text-fig. 5, D, p. 183); pulmonary veins not very numerous. Penis long and twisted. Other characters agreeing with those of *A. gibbonsi s. s.*

HABITAT.—Port Shepstone, Natal (Burnup).

Var. *duplex n. var.*

CHARACTERS.—Back distinctly mottled, with a well-marked paler median band, the coloration being very similar to that of *Apera gibbonsi s. s.* Cusps of teeth rather longer than in the typical form of the subspecies, and having an additional barb on the upper side near the point (excepting in the smaller teeth); apophyses very prominent; a vestigial central tooth is present in most of the rows (text-fig. 3, E, p. 159); formula: $(22 + (1) + 22) \times 42$. Otherwise similar to the Port Shepstone specimens of *A. gibbonsi lupata*.

HABITAT.—Port St. John's, Pondoland (one specimen; Mrs. E. Warren).

TYPE.—The types of subspecies and variety are in the Natal Museum, Pietermaritzburg. Another specimen of the subspecies will be found in the British Museum.

AFFINITIES, ETC.—This subspecies is especially characterised by its large barbed teeth. The course of the anterior aorta also serves to separate it from the typical form of *Apera gibbonsi*, as well as from *A. g. rubella*. But although the average shape of this subspecies is slightly different from either of these forms, the differences are so small that in practice I find that it is quite impossible to distinguish, without dissection, light specimens of the present subspecies from *A. gibbonsi s. s.*, and dark examples from *A. g. rubella*, unless, perchance, the odontophore is sufficiently protruded to enable one to see the teeth. It follows, therefore, that none of these three forms can be identified with

certainly from an examination of their external characters only. It will be noticed that this race of *A. gibbonsi* seems to have a more westerly distribution than the preceding forms.

Apera parva *n. sp.*

EXTERNAL CHARACTERS (Pl. VIII, figs. 22, 23).—Animal very slender, tapering to an acute angle at the hind end. Back rounded, without keels. Outer lip of respiratory opening almost concealing the inner lip. Skin coarsely reticulated. Dorsal grooves about $\frac{1}{3}$ mm. apart, separated by a single row of rugæ, but united for 3 mm. in front of the respiratory opening. Lateral grooves near the dorsal grooves and extending forwards to the head, the right one ending in the genital opening. Radial grooves well-marked, but fewer than usual, only three arising from the respiratory opening on each side (in addition to the two median grooves). Oblique sub-lateral grooves less numerous than in *A. gibbonsi*, being absent from the anterior third of the animal. Both radial and sub-lateral terminate in the single peripodial groove.

Mr. Farquhar informs me that the living animal is fawn-coloured; dark dorsally, but much lighter below. In alcohol the specimen has become yellowish brown, as shown in the figures.

The following are the dimensions of the slug in alcohol; but when alive and moving. Mr. Farquhar tells me that it attained a length of about 35 mm.

Length	25 mm.	Greatest height	3 mm.
Breadth in middle	3 „	Distance from resp.	
Breadth at resp.		opening to hind	
opening	2.4 „	end	5.5 „
Breadth of foot-sole	1.9 „		

INTERNAL CHARACTERS.—Skin very thick. Shell (Pl. XIII, fig. 44, 45) 1.6 × .9 mm., thick, depressed, with a flattened

apex in front of the posterior margin; sinus of moderate depth; left posterior angle obliquely truncate.

Pedal gland (Pl. XIII, fig. 53).—Slender; glandular tissue gradually dying out a little behind the middle of the gland; duct less convoluted posteriorly than in *A. gibbonsi*.

Nervous system.—Cerebral ganglia clearly separate; buccal ganglia situated posteriorly and joined to the cerebral ganglia by long connectives; cerebro-pedal and cerebro-pleural connectives rather long.

Digestive System (Pl. XVII, figs. 100–102; text-fig. 4, A, p. 161; Pl. XXI, fig. 131).—Radula very large, 8 mm. long; central tooth very small, absent in some rows; others scarcely differentiated into laterals and marginals, becoming extremely large towards the edges of the radula; cusps simple, very slightly curved, short towards the centre of the radula, longer towards the edges; bases broader than in *A. gibbonsi*; corresponding teeth not opposite to each other; formula: $(17 + 1 + 17) \times 48$. Odontophore also very large; posterior end joined by numerous short radial buccal retractors to the sides and floor of the body-cavity about the middle of its length; odontophoral support rounded in front. Oesophagus short and broad, merging into a fusiform crop. Between the crop and the wide intestine is an oval stomach, into which the hepatic ducts open. Second loop of intestine absent, the alimentary canal curving over to the right side of the liver and then passing straight backwards. Salivary glands contiguous above the crop, but less closely fused than in *A. gibbonsi*. Liver in two approximately equal divisions, the intestine only traversing the right.

Vascular System (Pl. IX, fig. 28).—Pulmonary veins not very numerous. “Posterior aorta” dividing at its origin into three branches which supply the left division of the liver and the hermaphrodite gland; right division of liver supplied by two arteries from the anterior aorta, which arise separately but close together; anterior aorta passing through loop of intestine; anterior branches of buccal artery leaving the posterior branch as a single median vessel.

Reproductive System (Pl. XXIII, fig. 146).—Hermaphrodite gland composed of only about four follicles, which are relatively very large; albumen gland in the specimen examined extending to the left side of the body-cavity, passing between some of the posterior buccal retractors; common duct rather short, curving twice to the right and once to the left; vagina rather narrow; receptaculum seminis further forward than in the other species; receptacular duct broad and extremely short. Vas deferens not enlarged to form an epiphallus; penis straight, rather short, and slightly swollen in the middle; penial retractor long and narrow.

HABITAT.—Near Fern Kloof, about three miles south of Grahamstown, Cape of Good Hope (in a stony place with very little grass, at least 200 yards away from the bush; Farquhar).

TYPE.—The type is in the Natal Museum, Pietermaritzburg.

AFFINITIES, ETC.—The only example of this species at present known was discovered by Mr. John Farquhar, of Grahamstown, on October 12th, 1913. In many respects the slug bears a close resemblance to *Apera gibbonsi*, and it might easily be mistaken for a young specimen of that species. Nevertheless, it differs from all the forms which I have included under *A. gibbonsi* in so many characters that there can be very little doubt that it is specifically distinct. The following are the features in which some of the most important differences occur: the size; the number of the radial and sub-lateral grooves; the distance between the cerebral ganglia; the size of the teeth towards the edges of the radula, and the width of the bases of all the teeth; the position of the origin of the buccal retractors; the stomach; the course of the intestine; the division of the arteries to both portions of the liver; the hermaphrodite gland; and the length of the receptacular duct and of the penial retractor, these last features being perhaps the most striking of all.

Apera dimidia n. sp.

EXTERNAL CHARACTERS (Pl. VII, figs. 7-9; Pl. VIII, figs. 20,

21, 24).—Animal sometimes slightly swollen towards the middle, tapering to a blunt point at the hind end. Back rounded, without keels. Outer lip of respiratory opening narrow, exposing the inner lip. Skin covered with a network of grooves, among which the main grooves are less conspicuous than in the other species of *Apera*. Dorsal grooves about 1 mm. apart (notwithstanding the small size of the species), usually separated by a double row of rugæ, but united for about 3 mm. in front of the respiratory opening. Lateral grooves rather near the dorsal grooves, irregular, but sometimes extending as far as the head. Oblique sub-lateral grooves also irregular, seldom reaching the peripodial groove, and less numerous than in *A. gibbonsi*, being usually absent from the anterior third of the animal. Radial grooves fairly well marked dorsally, but like the sub-lateral grooves they cannot always be traced as far as the peripodial groove. The upper limits of the lowest rugæ on each side often form an irregular longitudinal groove near the peripodial groove and parallel to it.

Body conspicuously mottled with greyish-brown pigment, which is chiefly concentrated to form an irregular and somewhat discontinuous dark band along each side of the animal. Between these bands is a much paler dorsal area only sparsely mottled, darkest around the anterior border of the respiratory opening and lightest at the edges next to the dark bands. Below these the skin is darker than it is dorsally, being more thickly mottled, especially next to the dark band, though the pigmentation extends down to the peripodial groove. Both dorsally and laterally there is a tendency for some of the pigment to be concentrated in the dermal grooves, thus emphasizing the reticulation. Small patches of the same pigment are sparsely scattered over the foot-sole. The ground-colour of specimens preserved in spirit is yellowish white.

The following are the dimensions (in alcohol) of two specimens, in both of which the reproductive organs were fully developed:

Length	32.5 mm.	. 33.5 mm.
Breadth in middle	6.5 „	. 7.5 „
Breadth at respiratory opening	4 „	. 4.75 „
Breadth of foot-sole	3.75 „	. 4.25 „
Greatest height	6 „	. 6.5 „
Distance from respira- tory opening to hind end	6 „	. 6.25 „

INTERNAL CHARACTERS.—Skin not quite so thick as in most of the species (Pl. XI, figs. 34, 35; Pl. XII, figs. 36–39; Pl. XIII, fig. 40). Shell (Pl. XIII, fig. 46) 3×1.8 mm., thin and translucent, convex; apex rounded, quite at the posterior end; sinus rather shallow.

Pedal gland (Pl. XIII, figs. 54, 59–62; Pl. XIV, fig. 66).—It has the glandular tissue entirely concentrated in the anterior half, which is very broad in consequence; fold of terminal vesicle not divided into narrow lamellæ.

Nervous System (Pl. XIV, figs. 68, 69; Pl. XV, figs. 71, 73, 75; Pl. XVI, figs. 80–86).—Cerebral ganglia with prominent accessory lobes; buccal ganglia normally situated posteriorly, joined to cerebral ganglia by comparatively short connectives; nerves to pedal ganglia large.

Digestive System (Pl. XVI, figs. 88–90; Pl. XVII, figs. 103–107; Pl. XVIII, figs. 115–122; Pl. XX, fig. 127; text-fig. 4, B, p. 161; Pl. XXI, fig. 132; Pl. XXII, figs. 136, 137).—Radula 4.8 mm. long; central tooth absent; about thirteen laterals with very short curved cusps, and the same number of marginals with longer narrower cusps, on each side; corresponding teeth not opposite to each other; formula: $(25 + 0 + 26) \times 61$. Odontophore rather large, with a single buccal retractor. Œsophagus narrow and as long as the salivary ducts; crop swollen anteriorly; loops of wide intestine nearly vertical, mainly on the left side of the posterior division of the liver. Salivary glands united above anterior end of crop. Anterior division of liver above crop and in front of intestine.

Vascular System (Pl. IX, fig. 29; Pl. XXII, fig. 140).—Pulmonary veins not very numerous; no "posterior aorta"; two main arteries of liver arising from anterior aorta as a single vessel, posterior artery supplying hermaphrodite gland as well as posterior division of liver; anterior aorta passing to right of intestine.

Reproductive System (Pl. XXIII, figs. 147, 151).—Hermaphrodite gland oblong, with moderately large follicles; hermaphrodite duct rather more convoluted and swollen in the middle than in the other species; common duct rather short, curving twice to the right and twice to the left; vagina broader than in *A. gibbonsi*; receptaculum seminis small; receptacular duct much swollen anteriorly, the swollen part being attached to the adjacent body-wall by short transverse muscles on each side. Vas deferens becoming slightly swollen near the posterior half of the penis to form an epiphallus; penis short, broadened posteriorly; penial retractor also short.

HABITAT.—Port Shepstone, Natal (Burnup); Town Bush, Pietermaritzburg (on a mossy stone; Mrs. Warren); Equeefa, Natal (Burnup).

TYPE.—The type is in the British Museum. Other specimens will be found in the Natal Museum, Pietermaritzburg.

AFFINITIES, ETC.—This species may be distinguished at a glance from young specimens of any of the forms of *Apera gibbonsi* by its dark lateral bands, while the absence of keels separates it from the other species found in Natal. Internally it differs widely from *A. gibbonsi* and *A. parva* in its radula, buccal retractor, œsophagus, liver, receptacular duct, etc.; while in no other species is the pedal gland so broad in front and so slender behind.

This species was first discovered by Mr. Burnup in March, 1903.

Apera purcelli Collinge.

Apera purcelli Collge., Ann. S. Afr. Mus., 1901, vol. ii, p. 230, pl. xiv, figs. 1, 2; Comolly, Ann. S. Afr. Mus., 1912, vol. xi, p. 63.

EXTERNAL CHARACTERS (Pl. VIII, fig. 25; and 'Ann. S. Afr. Mus.,' vol. ii, pl. xiv, figs. 1, 2).—Animal rather broad anteriorly, tapering to a blunt point at the hind end. Back rounded, without keels. Outer lip of respiratory opening narrow, exposing the inner lip. Skin with well-marked reticulation, the rugæ being rather large for the size of the slug. Dorsal grooves less than $\frac{1}{2}$ mm. apart, separated throughout their length by a single row of rugæ, not united in front of the respiratory opening. Radial grooves well-developed, and extending down to the single peripodial groove, which is not very deep. The most anterior radial grooves branch from the dorsal grooves near the respiratory opening, instead of arising from the opening itself. There is not even a trace of lateral grooves, excepting perhaps for a very short distance; but irregular oblique grooves occur in front of the radial grooves, and these correspond to the sub-lateral grooves of other species.

Body dark grey or bluish black, the pigment being chiefly concentrated in the dermal grooves and thus emphasizing the reticulation. On each side there is a suggestion of a slightly darker lateral band, the intervening dorsal area being a little paler, although it tends to be darker towards the centre than next to the obscure lateral bands. Below these the skin becomes much lighter, the pigment dying out completely before it reaches the peripodial groove. The foot and the ground-colour of the back is whitish yellow in the case of specimens preserved in spirit, but in living examples the foot is said to be ferruginous.

According to Mr. Collinge the type (in alcohol) is 25 mm. long, and its foot-sole is 4 mm. in breadth. I have only seen a young specimen, of which the following are the measurements:

Length	16 mm.	Greatest height	3.5 mm.
Breadth in middle	3.75 ,,	Distance from resp.	
Breadth at resp.		opening to hind	
opening	2.25 ,,	end	3.75 ,,
Breadth of foot-sole	2 ,,		

INTERNAL CHARACTERS.—Skin thick. Shell (Pl. XIII, figs. 47, 48) 1·2 × ·6 mm. (in the immature specimen whose measurements are given above), thin and translucent, very convex; apex rounded, overhanging the posterior margin to a considerable extent; sinus shallow.

Pedal gland (Pl. XIII, fig. 55).—Glandular throughout its entire length.

Nervous system.—The various ganglia more distinctly separate than in most species of *Apera*; buccal ganglia situated posteriorly, joined to cerebral ganglia by comparatively short connectives.

Digestive System (Pl. XIII, fig. 55; text-fig. 4, c, p. 161).—Radula (of immature specimen) 1·8 mm. long; teeth less numerous than in most species; central tooth small; three or four laterals with very short cusps, and about four times as many marginals with longer narrower cusps, on each side; formula (of immature specimen): $(18 + 1 + 18) \times 41$. Odontophore with single buccal retractor. Œsophagus narrow; loops of intestine nearly vertical, mainly on the left side of the liver. Salivary glands more or less united.

Anterior aorta passing to the right of the intestine, "posterior aorta" probably absent. Penial retractor long, as in the next species.

HABITAT.—Table Mountain, Cape Town (scarce; Lightfoot).

TYPE.—The type is in the South African Museum, Cape Town. An immature specimen will be found in the Cambridge University Museum of Zoology.

AFFINITIES, ETC.—This rare species is the only member of the genus that is known to occur in the west of the Cape Province. In some respects it resembles *Apera dimidia* more than any of the other species, but it differs from both *A. dimidia* and *A. gibbonsi* in having the dorsal grooves separate throughout their entire length, in the glandular tissue extending to the terminal vesicle of the pedal gland, and in the long penial retractor. In these features the present form resembles the keeled species of *Apera*. Unfortunately the reproductive organs of this species are practically

unknown, and it is to be hoped that further specimens will be discovered so that these organs may be described.

Apera burnupi *Smith*.

Apera burnupi *Smith*, *Ann. Mag. Nat. Hist.* (6th ser.), 1892, vol. x, p. 466.

Apera natalensis *Collinge*, *Ann. S. Afr. Mus.*, 1900, vol. ii, p. 3, pl. i, figs. 3, 4, pl. ii, figs. 14, 15; *Simroth*, *Naturwiss. Wochenschr.*, 1901, vol. xvii, p. 111, fig. 7; *Simroth*, *Brom's Klass. u. Ordn. d. Tier-Reichs III*, *Gastr. Pulm.*, 1909, p. 143, fig. 42 c, pl. iv, figs. 9, 10; *Collinge*, *Ann. Natal Mus.*, 1910, vol. ii, p. 167; *Simroth*, *Brom's Klass. u. Ordn. d. Tier-Reichs III*, *Gastr. Pulm.*, 1912, p. 611; *Connolly*, *Ann. S. Afr. Mus.*, 1912, vol. xi, p. 63.

EXTERNAL CHARACTERS (Pl. VII, figs. 10, 11; Pl. VIII, fig. 26; and 'Ann. S. Afr. Mus.,' vol. ii, pl. i, figs. 3, 4).—Animal broad and flattened towards the hind end, tapering anteriorly, with four longitudinal keels, two on each side of the body. Notwithstanding the two pairs of keels the animal is squarish in section, excepting posteriorly, as the lower keels are not far from the edges of the foot. Upper keels prominent though blunt, nearly parallel to each other in the middle of the body and separated by about seven-eighths of the breadth of the animal. Anteriorly they converge a little towards the head. In the posterior three-eighths of the slug the upper keels become very prominent, at first diverging and then curving round to meet in a very obtuse angle above the posterior extremity of the foot (but the angle is probably less obtuse in young than in adult specimens). They thus enclose a large flattened oval area, sloping downwards and backwards, and having the respiratory opening slightly in front and to the right of its centre. Lower keels less prominent, twice as far from the upper keels as from the edges of the foot, extending for nearly three quarters of the length of the animal but not reaching the hind end. Foot rather broad, but tapering behind as in the other species, so that the posterior dorsal expansion of the body overhangs the edges of the foot on each side. Outer lip of respiratory opening rather narrow, exposing the

inner lip. Skin coarsely reticulated, the rugæ being especially prominent on the anterior part of the back. Dorsal grooves very conspicuous, about 1 mm. apart (or rather more in the centre), separated by a row of rugæ which is usually double in the middle of the body, converging as they approach the respiratory opening, but not uniting with each other. Lateral grooves deep but rather irregular, extending along each side of the body as far as the head, a little nearer the upper than the lower keels, the right one terminating in the genital opening. Below each lateral groove another more irregular groove branches from the most anterior radial groove and runs forward above the lower keel until it unites with the lateral groove on the side of the head. There are two or three irregular sub-lateral grooves on each side, and also three or four equally irregular supra-lateral grooves, parallel to the most anterior radial grooves and connecting the dorsal grooves with the lateral grooves on each side of the back. The upper keels are notched by these supra-lateral grooves as they cross them, but the keels are more deeply notched by the radial grooves, which are rather numerous and very conspicuous. Both radial and sub-lateral grooves terminate below in a longitudinal groove, parallel to the peripodial groove, but separated from it by a narrow row of rugæ. In addition to the usual transverse grooves there is an obscure longitudinal groove on the foot-fringe, also parallel to the peripodial groove.

Body mottled with greyish-brown patches of colour, which sometimes have a greenish-blue tinge. The mottling is chiefly concentrated on the sides of the body between the keels, but patches of colour also occur between the lower keels and the peripodial groove, and more sparsely on the dorsal area. The ground-colour of specimens preserved in spirit is usually pale yellow slightly tinged with reddish-brown dorsally; but in living examples the skin is more deeply coloured, the back being reddish-brown, and the sides and foot-sole tinted with orange-red.

The following are the dimensions (in alcohol) of the type

of *A. natalensis* according to Collinge, and of the still larger specimen belonging to the South African Museum shown in Pl. VII, fig. 10:

Length	65 mm.	. 77 mm.
Breadth between upper keels		
in middle	10 ,,	. 12·5 ,,
Breadth between upper keels		
behind respiratory opening .	13·5 ,,	. 17 ,,
Breadth between lower keels		
in middle	—	. 14·5 ,,
Breadth of foot-sole	9·5 ,,	. 11·5 ,,
Greatest height (15 mm. in front		
of respiratory opening) .	—	. 14 ,,
Distance from respiratory open-		
ing to hind end	—	. 18·5 ,,

INTERNAL CHARACTERS.—Skin extremely thick, especially towards the hind end (Pl. IX, fig. 30). Shell (Pl. XIII, fig. 49) 5·5 × 3·2 mm., of moderate thickness, convex, with a conical apex projecting slightly beyond the posterior margin; sinus rather deep.

Pedal gland (Pl. XIII, fig. 56).—Exceptionally large, its loops wrapping round the other organs; glandular tissue extending throughout its entire length.

Nervous system.—Buccal ganglia situated anteriorly; connectives short.

Digestive System (Pl. XVII, figs. 108, 109; Pl. XX, fig. 128; text-fig. 4, D, p. 161; Pl. XXI, fig. 133).—Radula (of large specimen) 6 mm. long; central tooth present, with a very short single cusp; eleven laterals with short double cusps, and more than twice as many marginals with long, narrow, nearly straight cusps, on each side, the transition between laterals and marginals being abrupt; formula (of large specimen): (25 + 11 + 1 + 11 + 25) × 77. Odontophore small, with a single slender buccal retractor; odontophoral support bluntly pointed in front. Œsophagus narrow and as long as the salivary ducts; crop cylindrical; intestine narrow, first loop deep, posterior continuation on right side of liver. Salivary

glands separate. Liver of two approximately equal divisions, the intestine only traversing the right.

Vascular System (Pl. IX, fig. 30).—Pulmonary veins forming a network. "Posterior aorta" supplying left division of liver and hermaphrodite gland, and sending a small branch to posterior end of right division of liver; remainder of right division supplied by two arteries from the anterior aorta, which arise separately, but close together; anterior aorta passing through loop of intestine.

Reproductive system (Pl. XXIII, fig. 148).—Hermaphrodite gland composed of relatively smaller follicles than in *A. dimidia*; hermaphrodite duct convoluted; common duct very long, rather narrow, and much convoluted and twisted; vagina bent at right angles towards its anterior end; receptaculum seminis small; receptacular duct greatly swollen towards the anterior end. Penis moderately long; anterior part narrow and more or less twisted, posterior part broad and appearing as though it were double owing to the presence of a longitudinal groove along one side; vas deferens disappearing into this groove about 5 mm. from the posterior end of the penis; penial retractor long and narrow.

HABITAT.—Chase Bush, Pietermaritzburg (Burnup); Richmond, Natal (nearly in the centre of a rotten log; Ward).

TYPE.—The type of *A. burnupi* is in the British Museum, of *A. natalensis* in the South African Museum, Cape Town. Another specimen will be found in the Natal Museum, Pietermaritzburg.

AFFINITIES, ETC.—This striking form differs widely from all the preceding species not only on account of its conspicuous keels, but also in the double cusps of the lateral teeth of the radula and the separate salivary glands.

Apera sexangula n. sp.

Apera burnupi "Smith"; Collinge, Ann. Mag. Nat. Hist. (6th ser.), 1897, vol. xx, p. 221, pl. v, figs. 1-6; Pilsbry, Nautilus, 1898, vol. xii, p. 12; Collinge, Ann. S. Afr. Mus., 1900, vol. ii, p. 4, pl. i, figs. 5, 6; Collinge, Journ. of Mal., 1901, vol. viii, p. 71, fig. 1; Collinge, Journ.

of Mal., 1902, vol. ix, pl. vi, fig. 66; Simroth, Bronn's Klass. u. Ordn. d. Tier-Reichs III, Gastr. Pulm., 1909, pl. iv, fig. 11; Collinge, Ann. Natal Mus., 1910, vol. ii, p. 166; Simroth, Bronn's Klass. u. Ordn. d. Tier-Reichs III, Gastr. Pulm., 1912, p. 611; Connolly, Ann. S. Afr. Mus., 1912, vol. xi, p. 62.

EXTERNAL CHARACTERS (Pl. VII, figs. 12, 13; and 'Ann. S. Afr. Mus.,' vol. ii, pl. i, figs. 5 and 6).—Animal rather slender, approximately hexagonal in section, owing to the presence of four prominent longitudinal keels, two on each side of the body. Upper keels separated by about three-fifths of the breadth of the slug, and nearly parallel to each other, excepting posteriorly, where they diverge very slightly just in front of the respiratory opening, and then gradually converge behind it, until they unite to form a single median keel, 3 or 4 mm. in length, at the hind end of the animal. Lower keels extending along the whole length of the slug, about half way between the upper keels and the edges of the foot, but sloping downwards towards the hind end. The areas between the keels are nearly flat when the animal is in motion, but when it contracts they become deeply concave. Body, as seen from above, tapering to an acute angle posteriorly, but when viewed from the side the hind end appears blunter owing to the short median keel (though not always so rounded as in fig. 13). Outer lip of respiratory opening narrow, exposing the inner lip. Rugæ minutely subdivided. Dorsal grooves well marked, usually about 1 mm. apart, separated by a row of rugæ which is single in front and behind but often becomes irregularly double towards the middle, converging slightly as they approach the respiratory opening, but not uniting with each other. Lateral grooves also conspicuous, extending along each side of the body as far as the head about half way between the upper and lower keels, the right one ending in the genital opening. Sub-lateral grooves few and irregular, only two or three being traceable on each side. Radial grooves well marked, forming slight notches in the keels where they cross them. Both radial and sub-lateral grooves terminate below in a longitudinal groove, parallel to

the peripodial groove, but separated from it by a narrow row of rugæ.

Body mottled with greyish-brown pigment, excepting along the edges of the keels. The colour tends to be more concentrated towards the hind end, and along the sides of the animal just below the upper keels, although it extends down to the peripodial groove. As a rule, minute reddish-brown specks are also thickly scattered over the body, and these, unlike the greyer patches of colour, occur also on the foot-sole, though much less abundantly than on the back. The ground-colour of specimens preserved in spirit is yellowish-white, very slightly tinged with dull red dorsally; but in life the skin is more deeply stained with dull red pigment, the general colour of the living animal being usually chestnut or reddish-brown, paler on the keels and foot.¹

The following are the dimensions (in alcohol) of a small but mature specimen, whose reproductive organs are shown in Pl. XXIII, fig. 149, of a slightly larger example in which the genital system is not quite fully developed, and of an unusually large specimen in the Natal Museum, of which Mr. Burnup has kindly given me the measurements.

	mm.	mm.	mm.
Length	52·5	56	77
Breadth between upper keels in middle	4·5	6	10·5
Breadth between upper keels at respiratory opening	4	4	8·5
Breadth between lower keels in middle	7·5	10	16
Breadth of foot-sole	4	4·5	10·5
Greatest height (in middle)	7	9	15·5
Distance from respiratory opening to hind end	11·5	13	16

INTERNAL CHARACTERS.—Skin thick, especially towards the hind end. Shell (Pl. XIII, figs. 50, 51) 4 × 2 mm., of

¹ For a description of the living animal, see 'Ann. Natal Mus.,' 1910, vol. ii, pp. 166, 167.

moderate thickness, convex, laterally compressed, with a prominent conical apex projecting beyond the posterior margin; sinus of moderate depth.

Pedal gland (fig. 57).—Much smaller than in the last species, curving alternately to the right and to the left in a comparatively regular manner; glandular tissue extending throughout its entire length.

Nervous system (Pl. XV, figs. 72, 74, 76).—With buccal ganglia situated anteriorly; connectives short; nerves to pedal gland rather slender.

Digestive System (Pl. XVI, fig. 87; Pl. XVII, figs. 110–114; Text-fig. 4, E, F, p. 161; Pl. XXI, fig. 134, Pl. XXII, fig. 135).—Radula 4 or 5 mm. long; central tooth present, with a very short, broad, single cusp; eight or nine laterals with short double cusps, and more than twice as many marginals with longer narrower cusps, on each side, the transition between laterals and marginals being rather abrupt; formula (of a Port Shepstone specimen): $(23 + 9 + 1 + 9 + 23) \times 63$. Odontophore small, with a single slender buccal retractor. Oesophagus narrow, shorter than the salivary ducts; crop swollen between the salivary glands; intestine narrow, first loop deep, posterior continuation on right side of liver. Salivary glands separate. Liver of two approximately equal divisions, the intestine only traversing the right.

Vascular System (Pl. IX, fig. 31).—Pulmonary veins forming a network. "Posterior aorta" supplying left division of liver and hermaphrodite gland; right division supplied by two arteries from the anterior aorta which arise at some distance from each other; anterior aorta passing through loop of intestine.

Reproductive System (Pl. XXIII, fig. 149).—Hermaphrodite gland consisting of a cluster of small follicles; hermaphrodite duct only very slightly convoluted; common duct very long and much convoluted and twisted; vagina rather broad; receptaculum seminis rather small; receptacular duct fusiform, swollen towards the anterior end. Penis long and narrow excepting at the posterior end, where it is

broadened; end of vas deferens swollen to form an epiphallus about 2.5 mm. long, which bears anteriorly a minute flagellum; penial retractor long and narrow.

HABITAT.—Port Shepstone, Natal (Burnup); Hilton Road, near Pietermaritzburg (Burnup); Grahamstown, Cape of Good Hope (Farquhar, French).

TYPE.—The type is in the British Museum. Other specimens will be found in the Natal Museum, Pietermaritzburg, in the South African Museum, Cape Town, and in the Academy of Natural Sciences, Philadelphia.

AFFINITIES, ETC.—This species resembles *Apera burnupi* in many respects, and was at one time confused with that species. Nevertheless, the two forms can be very easily distinguished by their external characters alone, for in the present species the upper keels meet at an acute angle behind, where they form a short median keel, and the lower keels are equally prominent and extend the whole way to the hind end of the animal. The colour of the two forms is also different. Internally the most conspicuous features in which the present species differs from the last are to be found in the pedal gland and the reproductive organs.

Hitherto this species has usually been known as "*Apera burnupi*," but an examination of the type-specimen of *A. burnupi* leaves no doubt that that name should be applied to the preceding species, which Collinge subsequently named *A. natalensis*, and it has therefore been necessary to give a new name to the present form.

THE PHYLOGENY OF THE SPECIES OF APERA.

It is evident that *Apera burnupi* and *A. sexangula* are closely related to each other. Of these it is probable that the former is the more highly specialised; for in the pedal gland, the reproductive organs, and the keels, *A. sexangula* seems to be rather more primitive than *A. burnupi*. A wide gap separates these two species from those without keels; nevertheless, *A. purcelli* resembles *A. burnupi* and *A.*

sexangula in not a few characters, notably the pedal gland, the long penial retractor, and the complete separation of the dorsal grooves. Moreover, it is probable that the ancestral form from which *A. burnupi* and *A. sexangula* have been evolved resembled *A. purcelli* still more closely, since the keels and the double cusps of the lateral teeth of these species cannot be regarded as primitive characters. Yet it is not likely that in *A. purcelli* we have the direct ancestor of these two species, for *A. purcelli* has in some respects become modified in a different direction, its central tooth having become smaller and the course of the intestine having become quite different from what we must regard as the more primitive arrangement found in *A. burnupi*, *A. sexangula*, and *A. gibbonsi*. It is therefore probable that *A. purcelli* must be regarded as having diverged somewhat from the branch which gave rise to the keeled species.

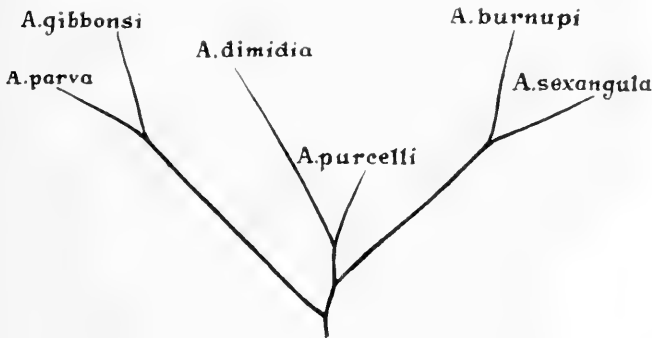
Apera dimidia in some respects resembles *A. purcelli*, but it is much more highly specialised. The glandular tissue of the pedal gland has become entirely concentrated around the anterior half of the duct; the central tooth of the radula has disappeared, and the laterals have become more numerous; the penial retractor has become quite short; the dorsal grooves are united posteriorly: in fact, while *A. dimidia* has probably been derived from the same branch as *A. purcelli*, it has diverged very far from both *A. purcelli* and the keeled species.

Apera gibbonsi and *A. parva* differ widely from the other species in their enormous radula and numerous radial buccal retractors, as well as in the œsophagus, receptacular duct, shell, coloration, etc., and apparently in the structure of the terminal vesicle of the pedal gland. In some respects they resemble *A. dimidia* most closely, especially in the absence of glandular tissue from the posterior end of the pedal gland, the short common duct, the union of the dorsal grooves in front of the respiratory opening, and the position of the lateral grooves; and it might be possible to regard *A. gibbonsi* and *A. parva* as being derived from the

same branch as *A. dimidia*, but having become still more highly specialised in many ways. On the other hand, we find that these species seem to be more primitive than either *A. dimidia* or *A. purcelli* not only in the uniformity of the teeth of the radula and the presence of a well-developed central tooth in typical examples of *A. gibbonsi*, but also in the arrangement of the intestine and liver. Now the nature of these characters renders it improbable that if they had once become so much modified they would revert to their original condition; and I am therefore inclined to regard the resemblances between *A. gibbonsi* and *A. parva* on the one hand, and *A. dimidia* on the other, as due to parallel evolution.

Apera gibbonsi and *A. parva* are probably even more closely related to each other than are *A. burnupi* and *A. sexangula*. But *A. parva* is decidedly more primitive than *A. gibbonsi* in its nervous system and long penial retractor, and in possessing a true stomach. On the other hand, in a few features, such as the buccal retractors and hermaphrodite gland, we must regard *A. parva* as being more highly specialised than *A. gibbonsi* or any other member of the genus.

If these views be correct, the phylogeny of the species of



Apera might possibly be somewhat as shown in the above genealogical tree.

THE OCCURRENCE AT CAPE TOWN OF
TESTACELLA MAUGEI FÉR.

This well-known species¹ is the only carnivorous slug, in addition to those belonging to the genus *Apera*, which is known to occur in South Africa, for it is probable that *Ceratocoeloceras schultzei* (*Simroth*) is the larva of a fly.²

The genus *Testacella* can be distinguished at a glance from all the other genera of slugs known to inhabit South Africa, because in this form alone the hind end of the back is covered by an external shell. In some respects the anatomy of *Testacella* resembles that of *Apera*, but it is so well known that it is unnecessary for me to describe it here. More than a hundred years ago Cuvier³ gave an account of the internal organs of one member of the genus; and since then the researches of Gassies and Fischer, de Lacaze-Duthiers, Plate, Simroth, and others, have given us a fuller knowledge of the anatomy of *Testacella* than of almost any other carnivorous snail or slug.

The following are the principal characters by which *Testacella maugéi* can be distinguished from the other species of the same genus: (1) the comparatively large size of the shell, and its length and convexity; (2) the widely separated origin of the lateral grooves; (3) the presence of a central tooth in the radula; (4) the small number of the buccal retractors; (5) the unusual length of the tentacular retractors, and the fact that they both arise to the left of the middle line; (6) the swollen anterior end of the receptacular

¹ See Appendix for the more important references to *Testacella maugéi*.

² Simroth, H., 'Zool. Anz. Leipzig,' 1907, vol. xxxi, pp. 794, etc.; Simroth, H., 'Deutsche Südpolar Exped.,' 1910, vol. xii, Zool. iv, p. 172; Böttger, O., 'Abhandl. Senckenb. Naturf. Ges. Frankfurt,' 1910, vol. xxxii, p. 433.

³ 'Ann. Mus. d'Hist. Nat.,' 1804, vol. v, pp. 435-444, pl. xxix, figs. 6-11.

duct, its comparatively great length, and its lateral junction with the receptaculum seminis; (7) the convolution of that part of the vas deferens which lies next to the free oviduct; (8) the length of the narrow anterior part of the penis, and its broader posterior end, without any flagellum.

It will be seen from Pl. XXIV that the specimens of *Testacella* from Cape Town which I have examined possess all these characters, and I have, therefore, no hesitation in assigning them to *T. maugei*. Nevertheless the South African examples of this genus have usually been named "*T. aurigaster* Layard."¹ Now, although Major Connolly² believes that Layard published a description of this supposed species, I have not been able to find any such description, nor any type-specimens, and I cannot therefore state definitely that *T. aurigaster* is a synonym of *T. maugei*, as it is conceivable that more than one species of *Testacella* may have found its way to Cape Town during the last sixty years. At the same time, all the specimens that I have seen labelled "*T. aurigaster*" have proved to belong to *T. maugei*, and I think that *T. aurigaster* may be safely expunged from the list of South African Mollusca.

The slug occurs in gardens at Cape Town, and I have little doubt that it has been introduced into South Africa by man, notwithstanding Dr. Simroth's arguments in favour of the possibility of *Testacella* being a native of that country.³ I believe that the natural distribution of the genus *Testacella* is limited to the western part of the Palearctic region, from Great Britain and Hungary to the Canary Islands, and that

¹ The following is a copy of a manuscript note written by Layard himself, for which I am indebted to Major Connolly: "*Testacella aurigaster* Layard. I only found this shelled slug in the Gardens round Cape Town. It was common in the grounds of the South African Museum, which was built at the lower end of the Botanical Garden in Cape Town. The belly of the animal was a rich golden yellow, hence the name selected. It devours large worms, & will assimilate individuals far larger than itself!"

² 'Ann. S. Afr. Mus.,' 1912, vol. xi, p. 64.

³ 'Zool. Anz. Leipzig,' 1907, vol. xxxi, p. 796.

its occurrence in Philadelphia, Cape Town, and Auckland is due to the agency of man. *Testacella maugéi* occurs not only in the south-west of England, but also in Portugal, Madeira, and the Canaries; and it seems to me that it might easily have been transported to South Africa from any of these localities, amongst the roots of plants. For the species of *Testacella* are especially common in the rich soil of gardens where worms are abundant; and it is known that under adverse conditions a specimen can surround itself with a sort of cocoon of hardened slime which protects it from drought, and may remain dormant in this state for several weeks.

It will be seen from Pl. XXIV, fig. 159, that in some of the South African specimens the posterior end of the penis is curved round in a peculiar manner, and the retractor muscle is attached to the vas deferens, a short distance in front of it.¹ Possibly this unusual arrangement may have been partly caused by the way in which the animal contracted when it was killed, for it only occurred in some shrivelled specimens, which, in other respects, seemed to be identical with the rest.

Figs. 157 and 158 represent two of the shells labelled "*T. aurigaster*" in the MacAndrew collection at Cambridge. The first shows the usual shape of the shell in *T. maugéi*, while the second may be assigned to the variety *aperta Taylor*,² a form which was originally described from the Azores.

THE AFFINITIES OF APERA AND TESTACELLA.

THE EVOLUTION OF CARNIVOROUS CHARACTERS.

Both *Apera* and *Testacella* undoubtedly belong to the group of the *Stylommatophora* comprising the carnivorous

¹ The junction of the retractor muscle with the vas deferens is also shown in Webb's figure of the genital organs of *T. maugéi* ('*Journ. of Malac.*,' 1897, vol. vi, pl. vi, fig. 3).

² '*Monog. L. and F.-W. Mollusca Brit. Isles*,' 1902, vol. ii, p. 24, pl. i, fig. 15.

snails and slugs, a group which is usually known as the *Agnatha*, since very few of these forms possess a jaw. But to state this is to say very little about the affinities of these genera, for it is doubtful whether the various carnivorous snails are at all closely related to one another, some authorities asserting that the tribe *Agnatha* is polyphyletic.

Certain eminent malacologists have held that the *Stylomatophora* may be divided into two groups, one mainly herbivorous, the other mainly carnivorous; and they would account for the diversity of the carnivorous forms by supposing that they had evolved in a manner parallel to the gnathophorous families, which show a similar diversity. This view was well expressed by Fischer, who, writing so long ago as 1873, said: "Je suis persuadé qu'on pourra constituer, dans quelques années, une série d'Agnathes ou Testacellidæ ayant une grande extension, et dont les genres seront représentatifs de ceux des Helicidæ, ainsi que, chez les Mammifères, certains groupes des Marsupiaux représentent d'autres groupes des Monodelphes."¹ On the other hand, many modern authorities maintain that the various families of carnivorous snails and slugs have been evolved independently from different families of the *Gnathophora*, and that they are in reality no more nearly related to one another than are the European and Tasmanian wolves. The characters which the agnathous families undoubtedly possess in common they would explain as being due to convergence, brought about by their common acquisition of carnivorous habits.² Now there is no *à priori* objection to this second view, for we know that many gnathophorous forms occasionally devour animal food, and there seems to be no reason why this should not have become the usual diet in some cases. The question, therefore, can only be settled by a careful examination of the comparative anatomy of the various families included in the

¹ 'Journ. de Conchyl.,' vol. xxi, p. 12.

² See an interesting paper by Dr. Simroth ('Naturwiss. Wochenschr.,' 1901, vol. xvii, pp. 109-114, 121-127, 137-140), in which he has ably advocated the polyphyletic origin of the carnivorous snails and slugs.

Agnatha. If we find that two agnathous families only resemble each other in those features which are likely to have been acquired through carnivorous habits, and are very similar to different gnathoporous families in their other characters, then we may assume that they are probably of different origin; but if we find that the resemblances between two families of agnathous snails cannot all be explained in this way, and that these families are in their most important features more similar to each other than to any families of the *Gnathophora*, the probability is that they are closely related. It is evident, however, that before we can discuss the affinities of any particular genus, we must have a clear idea as to how a snail is likely to become modified if it adopts carnivorous habits, and which of the features characteristic of *Apera*, *Testacella*, and the other genera included in the *Agnatha*, are likely to be due to their animal food.

Snails and slugs find their food chiefly by means of their sense of smell, and one might expect this sense to be especially well developed in the carnivorous forms, because animals which move slowly enough for snails to catch them must be very much more difficult to find than plants. Now in many of the *Agnatha*, and more especially in the *Rhytididæ* and the *Oleacinidæ*, the olfactory organs at the tips of the upper tentacles are so large that the eye comes to occupy a position some distance behind the extremity.¹ Moreover Plate has shown that *Testacella*, unlike most of the *Stylommatophora*, retains a pallial olfactory organ. The unusual development of these sense-organs might be expected to lead to a corresponding development and concentration of the sensory nerve-centres, and accordingly we find that in nearly all the carnivorous forms the cerebral ganglia are large and close together, *Phrixolestes* being perhaps the most notable exception.

Carnivorous snails and slugs prey chiefly upon the herbi-

¹ See Strebelt, H., 'Beitrag z. Kenntn. d. Fauna Mexikan. L.- u. Süßwasser-Conchyl.', 1878, vol. iii, pl. xv, fig. 1 c; Suter, H., 'Journ. of Mal.', 1899, vol. vii, pl. iii, fig. 1 a.

vorous forms and on worms, for most arthropods move too quickly and are too well protected by their chitinous exoskeleton to fall a prey to snails. Now worms burrow in the soil, and snails hide themselves in crevices and retire deeply within their shells when attacked; it is therefore evident that a carnivorous snail will find the presence of a bulky unyielding shell on its back a great inconvenience when it is trying to get near its victim. In order to obviate this difficulty the shell has become modified in various ways. In the first place we find that in *Paryphanta* it has become more or less flexible owing to the degeneration of the inner calcareous layer. Secondly, the shape of the shell has become altered in many of the carnivorous genera. In *Diplomphalus*, for example, the shell has become greatly flattened. This will enable the animal to penetrate into crevices, but it is obvious that the breadth of the shell will have to be reduced as well as its height, if the snail is to crawl into narrow holes. Now the only way in which both the height and breadth of a depressed or heliciform shell can be reduced is by the curvature of the axis or columella, until its direction corresponds more nearly with that in which the animal moves; and this is what has occurred in that remarkable genus of carnivorous snails, *Streptaxis*. If, however, the shell has a raised spire, the columella naturally takes up a position parallel to the direction in which the animal moves, and in this case it is only necessary for the height of the spire to be increased in order to reduce the diameter of the shell. This is what has taken place in the large genus *Ennea*, in which only the young form retains a comparatively low spire. In *Diaphora* this principle is carried to an extreme, some species having shells with greatly produced spires composed of as many as twenty whorls. Indeed, so long does the spire become that the animal can no longer occupy the whole of it, and secretes a new internal wall cutting off part of the upper whorls, which may become decollated, as in *D. telescopium* *Muldff.* A more efficient method of reducing the diameter of the shell (but one

which probably necessitates a greater change in the structure of the animal) is for the whorls themselves to become laterally compressed. This has taken place to some extent in *Streptosteles* and *Obeliscella* among the *Streptaxidæ*, but it is especially characteristic of the *Oleacinidæ*. In some members of this family, such as *Streptostyla gracilis Pilsbry*, the whorls have become so narrow that the form of the shell closely resembles that of the marine carnivorous genus *Conus*—a striking example of convergence due to the acquisition of similar habits. Thirdly, the position of the shell may be altered, so that the part of the animal in front of the shell becomes lengthened. This is admirably shown in Hedley's figure of *Rhytida lampra (Pfr.)*,¹ but it occurs to some extent in most of the carnivorous genera. A variety of this modification is found in such forms as *Ennea densecostulata Mlldff.* and *Diaphora eutrachela Mlldff.*, in which the greater part of the shell has moved further back by the elongation of the last whorl towards the mouth. Fourthly, the shell may not only be moved backwards, but it may become reduced and flattened, until it either disappears altogether as in *Selenochlamys*, or sinks into the skin as in *Apera*. No projection will then remain to impede the animal's progress when it follows worms into their burrows, and it is more especially in the vermivorous genera that this extreme modification seems to have occurred. We see, then, that the acquisition of carnivorous habits may lead to a great alteration in the structure, form, position, or size of the shell.

The movement of the shell to the hind end of the body, and its gradual degeneration, will greatly modify the animal itself. Many of the organs will be subject to partial detorsion. The lung and respiratory orifice will move back with the shell and mantle, so that the animal will become opisthopneunic; and it is probable that it is a direct advantage to a carnivorous form to have its respiratory opening near the hind end of the back, because this is the part which is least likely to be

¹ 'Proc. Linn. Soc. N.S.W.' (2nd ser.), 1891, vol. vi, pl. iii, fig. 3.

covered when the greater portion of the body is under the surface of the ground or inside its victim's shell. The anus will move back with the respiratory opening, and the rectum will thus be directed posteriorly (text-fig. 5, cf. c and d, p. 183). With the degeneration of the shell the pallial organs will become modified, and the posterior position of the pulmonary veins may pull round the auricle until it lies posterior to the ventricle, as in *Testacella* and a few other genera (text-fig. 6, p. 244). The organs which formerly occupied the visceral hump will become reduced in size and pushed forward into the general body-cavity. The pressure of these will retard the backward growth of other organs such as the receptaculum seminis, and it is therefore not surprising to find that the slugs have as a rule shorter receptacular ducts than the snails to which they are probably most nearly allied. The columellar muscle will disappear with the degeneration of the shell, and the various retractors that originally arose from it will become attached to different parts of the skin, which will become thickened to take the place of the shell (see p. 126). And as the anterior part of the body becomes lengthened, the origins of the tentacular and penial retractors will tend to move forwards. Thus the mere fact that animal food is less easily accessible than vegetable food may lead to profound changes in the anatomy of a snail which becomes carnivorous.

When the snail has approached its victim it will require to feel exactly where to attack it with its radula, and will, if possible, try to prevent the animal escaping until the teeth are fixed in its flesh. Accordingly we find that nearly all the carnivorous genera have a pair of special feelers at each side of the mouth beneath the lower tentacles. In *Euglandina* these feelers are very long and are supposed to be used for prehension, but according to F. M. Woodward¹ their function in *Natalina caffra* (*Fér.*) is probably purely tactile. Miss Davies² has recently discovered that in *Paryphanta com-*

¹ 'Proc. Mal. Soc.,' 1895, vol. i, p. 271.

² 'Proc. Roy. Soc. Victoria,' 1913, vol. xxv, p. 225.

pacta Coë & Hedley and *P. atramentaria* (Shuttl.) these papillæ are glandular in structure. Now in *Peripatus*, an arthropod genus whose habits are not unlike those of the carnivorous snails and slugs, there are two large slime-glands which open on the oral papillæ, and their secretion is used to entangle the prey. The carnivorous slug *Atopus* also possesses two large glands opening one at each side of the mouth; and Simroth,¹ who first discovered them, has suggested that their function may be similar to that of the slime-glands of *Peripatus*. We have already seen that the pedal gland is developed to an unusual extent among the carnivorous genera. Now this gland also opens close to the mouth, and I would suggest that its secretion may play some part in overpowering the prey. The form of the pedal gland in *Apera* has come to resemble in some respects that of Simroth's glands in *Atopus*, and nearly twenty years ago André² suggested that the secretion of the pedal gland in the *Stylommatophora* might be used in feeding as well as in locomotion. We may at least say this: that the remarkable development of the pedal gland in the *Agnatha*, as well as the presence of the labial feelers, may not improbably be due to their predaceous habits.

It is unnecessary to attempt to prove that the acquisition of carnivorous habits might lead to a modification of the radula and the surrounding structures: obviously these would be among the first organs to be affected. It will be sufficient, therefore, if I point out the chief ways in which the radula has become transformed. In the first place, it has increased in size, and especially in length, and become capable of far greater protrusion than in the herbivorous forms. Secondly, the individual teeth have become much larger, especially those occupying an analogous position in the radula to that held by the canine teeth in the jaw of the *Mammalia*; and to make room for these, the central teeth and those at the extreme edges of the radula have become vestigial or have

¹ 'Naturwiss. Wochenschr.', 1901, vol. xvii, p. 122.

² 'Revue Suisse de Zoologie,' vol. ii, p. 332.

entirely disappeared. Thirdly, the main cusps of the teeth have become far longer and more sharply pointed, so as to penetrate the victim's skin, and the secondary cusps have completely gone, excepting in some of the more primitive genera of the *Oleacinidæ*. And as all the teeth have become simplified in this manner, the differentiation between laterals and marginals has been lost, though it has been re-acquired in most of the species of *Apera* and *Natalina*, and to some extent in *Guestieria*. Fourthly, the bases have also become lengthened in order to prevent the teeth from being bent outwards. Fifthly, the rows of teeth have become sharply angled in the centre, owing to the way in which the radula is forcibly drawn back over the anterior edge of the odontophoral support into the narrow radula-sac.

The muscles of the odontophore have become correspondingly enlarged. In the more primitive forms the hind end of the radula-sac still projects from between these muscles; but in those that are more completely adapted to a carnivorous existence the odontophoral muscles have entirely surrounded the radula-sac, and form a very large cylindrical structure.

This growth of the odontophore leaves little room for the development of other bulky organs in the anterior part of the body, especially as it is an advantage to a carnivorous form not to have a very large head and neck. I therefore suggest that this is the reason why the genital ducts of carnivorous snails and slugs are without large accessory organs. There would be no room for the development of a dart-sac, for example, in a snail with a very large odontophore.

The growth of the odontophore would also tend to increase the size of the body-whorl of the shell. If this were laterally flattened as in the *Oleacinidæ*, it is evident that when the snail withdrew into its shell, the hind end of the odontophore would come to press against the outer side of the shell in the neighbourhood of the posterior end of the mantle-cavity. The result of this would be that the posterior limit of the cavity would be pushed forwards in the middle, and with it the heart and the lower end of the kidney. The upper end

of the kidney, being near the suture of the shell, would remain in its original position; and accordingly we find that in the *Oleacinidæ* the kidney is obliquely lengthened in a very characteristic manner.

The cerebral, buccal, and ventral ganglia would be pushed further apart by the growth of the buccal mass and odontophore, and thus we find that in many of the carnivorous forms the cerebro-buccal, cerebro-pedal, and cerebro-pleural connectives are unusually long (see pp. 141, 146).

The extrinsic buccal retractors would become strongly developed at the same time as the intrinsic muscles of the odontophore. So long as they sprang from the columellar muscle, they would undergo little change beyond an increase in their thickness, although I have found that their anterior ends tend to split up into a number of separate strands in the *Rhytididæ*. But in those forms in which the shell is degenerate and the skin is taking its place, we frequently find that the retractors of the odontophore arise from a large area of the integument; as, for example, in *Apera gibbonsi*, *Testacella haliotidea* *Drap.*, and the *Trigonochlaminae* (see pp. 172, 173).

A jaw becomes superfluous in a snail or slug in which the radula is protruded far beyond it, and Simroth¹ has shown that it would be a positive disadvantage in a vermivorous form, because if it bit off pieces from its prey, the latter would escape. Accordingly the jaw is absent or extremely degenerate in nearly all carnivorous genera excepting *Plutonia*, in which Simroth states that the sharp edge is covered by a softer downward growth.

As in other carnivorous animals, the digestive region of the alimentary canal becomes reduced in size. This is most apparent in the slugs, for in these the pressure of the organs which formerly occupied the visceral hump tends to diminish anything in the body-cavity that is unnecessarily large. In *Atopus* and *Apera* the true stomach has almost completely disappeared, the crop passing straight into the intestine; and

¹ *Op. cit.*, p. 113.

in these forms, and possibly in others also, digestion takes place partially within the lobes of the liver. In nearly all the carnivorous genera the length of the intestine and rectum is more or less reduced.

Finally, Simroth considers certain peculiar connections between the genital ducts of a few of the carnivorous genera to be modifications to facilitate self-fertilisation, and he attributes this to the somewhat isolated life which a vermivorous slug is likely to lead. But I have not found these modifications in the forms which I have examined, and it remains to be proved whether they are at all general among the Agnatha.

Such are the changes which are likely to take place in the organisation of a snail when it acquires carnivorous habits. We are now in a position to discuss whether *Apera*, *Testacella*, and other predaceous forms, are really closely related to one another, or whether their resemblance is merely due to the fact that they have all become carnivorous.

THE PHYLOGENY OF *APER*A AND OTHER NAKED CARNIVOROUS SLUGS.

I think that Simroth is the only author who has suggested that the genus *Apera* has been evolved directly from an herbivorous slug. As already mentioned, he put forward the theory that *Apera* might have been derived from the Janellidæ. But Plate¹ has shown that the slugs belonging to this family differ from most of the *Stylommatophora*, not only in being without lower tentacles, but in other important characters, such as the respiratory tissue, which takes the form of numerous fine tubes radiating from the mantle-cavity and recalling the tracheæ of arthropods. Now *Apera* possesses none of these features. Moreover, it would be difficult to imagine a radula more unlikely to develop carnivorous characters than that of *Janella*, with its

¹ 'Zool. Jahrb.,' 1898, vol. xi, pp. 193-280, pls. xii-xvii.

myriads of minute multicuspid teeth. I have therefore no hesitation in saying that *Apera* is in no way allied to the *Janellidæ*.

Nor do I know of any other herbivorous family from which *Apera* is at all likely to have been derived. And the fact that the carnivorous characters are so highly developed in *Apera* is against the theory that the genus has been directly evolved from any herbivorous form. It seems certain that the ancestors of *Apera* must have been carnivorous for a very long time; and it is not likely that these ancestors would all die out without leaving any descendants excepting this single genus. The question is whether we can find any carnivorous genus of slugs or snails resembling *Apera* in characters which are not likely to have been developed independently through the common acquisition of predaceous habits.

Collinge has already pointed out how improbable is the theory of P. and F. Sarasin that *Apera* is closely allied to *Atopus*.¹ This genus and the other members of the *Rathousiidae* differ widely from *Apera* and every other carnivorous form in a number of important characters, such as the wide separation of the male and female openings, the presence of Simroth's glands, the structure of the foot, the very large mantle, and the structure of the liver; while they only resemble them in the radula, the absence of a jaw, and a few other points connected with their carnivorous habits. I agree with Simroth in regarding the *Rathousiidae* as being more nearly related to the *Veronicellidae* than to any monotrematous carnivorous family; indeed, I have little doubt that, with the exception of the *Veronicellidae* and the *Onchidiidae*, no family of the *Stylommatophora* is less closely related to *Apera* than the *Rathousiidae*.

Plutonia, a carnivorous slug found in the Azores, is perhaps less unlike *Apera* than is *Atopus*; but it differs from it in the mantle, the laterally compressed form of the body, the presence of a jaw, the absence of a penial retractor,

¹ For references, see pp. 111-113.

the presence of a secondary ureter, and other characters.¹ On the whole it is extremely improbable that *Apera* is related to *Plutonia*. It is possible that the latter genus may be allied to the *Trigonochlaminæ*, but Simroth has given weighty reasons in favour of its having been evolved from the species of the *Vitrininæ* inhabiting the shores of the Atlantic, and not from any carnivorous group.

The only other carnivorous forms without external shells which are known to science are the genera from Transcaucasia placed in the *Trigonochlaminæ*. One of these—*Selenochlamys*—bears a very striking resemblance to *Apera*, as will be seen from Simroth's figures.² Almost the only external differences between *Selenochlamys* and *Apera* are that in the former genus the visible mantle is a little larger, the foot is more distinctly tripartite, and there is a median dorsal keel extending from the mantle to the hind end of the animal. This last difference is the most conspicuous, and yet it is not greater than the difference between *Apera sexangula* and *A. gibbonsi*, *dimidia*, or *purcelli*. And when we turn to Simroth's description and figures of the internal anatomy of *Selenochlamys*, we at once notice the similarity between the radial buccal retractors in this genus and those of *Apera gibbonsi* and *A. parva*. A closer inspection, however, reveals many differences. The nerve ganglia of *Selenochlamys* are all separate; the pedal gland is narrow, straight, and almost entirely embedded in the foot; the vagina is extremely short; the right tentacular retractor does not cross the penis. Moreover there appears to be no shell, so that the morphology of the mantle must be quite different to that of *Apera*. Indeed, I think that there can be little doubt that we have in the superficial resemblance between *Apera* and *Selenochlamys* a remarkable instance of convergence due to the acquisition of similar carnivorous habits; and that the only affinities of *Selenochlamys* are with the

¹ Simroth, H., 'Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur.,' 1891, vol. lvi, pp. 223-229.

² 'Festschrift Leuckarts,' 1892, pl. vi.

other members of the Trigonochlaminae, which Simroth has shown to have probably been derived from the Parmacellinae. This view is confirmed by the geographical distribution of the genera.

We may now consider the carnivorous genera which still retain an external shell, for it seems certain that the shell of *Apera* was originally external.

The New Zealand genus *Schizoglossa* resembles *Apera* in many ways, but it differs in its reproductive system, for in *Schizoglossa* the male organs are much reduced, and there is no receptaculum seminis.¹ These features alone render it improbable that *Apera* has been derived from *Schizoglossa*. According to Murdoch² the reproductive organs of *Paryphanta busbyi* (*Gray*) bear a considerable resemblance to those of *Schizoglossa*, and I think that there can be little doubt that the latter genus has been evolved in New Zealand from that section of the Rhytididae to which *Paryphanta busbyi* belongs.

Strebelia possesses a receptaculum seminis, but in this genus the penial retractor is attached to the vas deferens instead of to the penis itself. And, judging from Strebel's figures, the salivary glands are united below the crop, and not above it as in *Apera*.³ Moreover, it does not seem likely that a purely South African genus should have been evolved from a slug which is only found in Mexico.

There remain the European carnivorous slugs, *Daudebardia* and *Testacella*. Of these *Daudebardia* differs widely from *Apera* in its pedal gland, nervous system, reproductive organs, excretory system, etc. There can be no doubt that *Apera* has not been evolved from *Daudebardia*. On the other hand, *Testacella* has many points in common

¹ Hedley, C., 'Proc. Linn. Soc. N.S.W.' (2nd ser.), 1893, vol. vii, p. 390, pl. ix, fig. 4, pl. x, fig. 9; Collinge, W. E., 'Ann. Mag. Nat. Hist.' (7th ser.), 1901, vol. vii, p. 72, pl. ii, fig. 30.

² 'Trans. N. Z. Inst.', 1903, vol. xxxv, pp. 260, 261, pl. xxvii, figs. 4, 5.

³ 'Beitrag. z. Kenntn. d. Fauna Mexican. L.-u. Süßwasser-Conchylien,' 1878, vol. iii, pls. i, ii.

with *Apera*; indeed, if we take into consideration both the internal and external characters, I do not think that any other genus resembles *Apera* so closely as does *Testacella*. The pedal gland of *Testacella* lies free in the body-cavity as it does in *Apera*. Both genera are opisthopneumic, and in both the primary ureter opens at the posterior end of the mantle-cavity. The reproductive organs of the two genera are on the whole very similar, and in both the right tentacular retractor crosses the penis. But if we compare the genera more closely we find that there are several small differences which it is not easy to explain away. In the first place, the auricle in *Testacella* has come to lie directly behind the ventricle, whereas in *Apera* the heart has not been rotated so far. Yet *Testacella* cannot be derived from *Apera*, because it still retains an external shell. Secondly, the foot of *Testacella* contains numerous dermal mucous glands, while that of *Apera* has none. Thirdly, the pedal gland of *Testacella* has no terminal vesicle. Fourthly, the left parietal ganglion has not become fused with the abdominal ganglion in *Testacella*, but all the visceral ganglia remain separate. Fifthly, the arrangement of the odontophoral muscles, and the structure of the odontophoral support, and even the blood-supply of the odontophore, show surprising differences in the two genera, as we have already seen. And, lastly, there is the difference in the geographical distribution of the two genera. On the other hand, the resemblances are found to be largely of a negative character, if we except those which might be due to the common acquisition of vermivorous habits by both forms. Therefore it will be well to look further before we assume that *Apera* is related to *Testacella*. It is true that there are no other carnivorous genera in which the shell has become reduced, but it is possible that the nearest living allies of *Apera* may have quite large shells, for when once the presence of a shell is found to be a disadvantage, its degeneration probably takes place rather rapidly.

Pilsbry has suggested that *Apera* may possibly be allied



to the Rhytididæ, and I am inclined to believe that Pilsbry is right. Beutler has examined the histology of the skin of Paryphanta, and has found that the foot is without dermal mucous glands, as it is in Apera. The pedal gland in the Rhytididæ not only lies freely in the body-cavity, but it is often somewhat contorted, and, as in Apera, it ends in a vesicle containing a broad fold. In Paryphanta, Natalina, and Rhytida capillacea (*Fér.*), the visceral ganglia are all separate, as in Testacella, but in Rhytida inæqualis (*Pfr.*) Fischer has shown that the left parietal ganglion is united with the abdominal ganglion exactly as in Apera. I have already shown that the arrangement of the odontophoral muscles in at least one member of the Rhytididæ is very similar to that found in Apera, and, judging from Beutler's account, the structure of the odontophoral support is also similar. The reproductive organs of Rhytida and Paryphanta are on the whole very like those of Apera, and in these genera the right tentacular retractor crosses the penis. The members of the Rhytididæ also resemble Apera in having no secondary ureter. Indeed, almost the only differences that I know of between Rhytida and Apera are those which would be likely to be brought about by the degeneration of the shell and its further retrogression to the hind end of the animal, and we have seen that this is a modification which is especially liable to occur in carnivorous forms.

Another fact in favour of the theory that Apera has been evolved from the Rhytididæ is to be found in the geographical distribution of that family, for it occurs not only in the Australian region, but also in South Africa itself. It is true that Apera has almost certainly not been evolved from those members of the Rhytididæ which are now found in South Africa: these have retained their separate visceral ganglia, but have become specialised in another direction, as is shown both by their radula and their reproductive system, in which the penis lies to the right of the tentacular retractors. But the presence of these snails in Africa renders it not at all

improbable that forms more like *Rhytida inæqualis* may also have once extended into that region, and given rise, by the degeneration of the shell, to *Apera*, just as in New Zealand another branch of the family has probably given rise to *Schizoglossa*.

It is not unlikely that the Rhytididæ originated in early Mesozoic times, or perhaps even before the end of the Palæozoic era, in Gondwanaland—that great Southern continent which is supposed to have extended from Australia and New Zealand across the Indian Ocean, through Africa, and even as far as South America.¹ A little later the more highly specialised Streptaxidæ may have arisen in the same region. These did not reach Australia, perhaps because it was already cut off by the sea, but in other regions we may suppose that they would enter into competition with the Rhytididæ. In South Africa, where only the small pupiform Streptaxidæ occur, the Rhytididæ were able to withstand their competition by becoming more specialised themselves, either by the degeneration of the shell (*Apera*), or merely by an increase in the size of their teeth and a slight modification of their reproductive organs (*Natalina*). But further north, where we find the heliciform Streptaxidæ, with their oblique columella, the Rhytididæ were almost entirely exterminated, only leaving *Natalina morrumbalensis* (*M & P.*), *N. permembranacea* *Preston*, and possibly the species of *Tayloria*,² as relics of their former distribution. Whether the Rhytididæ ever reached South America is at present unknown. They may have done so, and have then been exterminated by the heliciform Streptaxidæ, which are not uncommon in South America. I

¹ Hedley has suggested that the Rhytididæ are of Antarctic origin ('Proc. Linn. Soc. N.S.W.,' 1899, vol. xxiv, p. 398), but, while admitting the possibility of this theory, I agree with Pilsbry in being unable to find any evidence in its favour ('Rep. Princeton Univ. Exped. Patagonia, 1896-1899,' vol. iii, Zoöl., 1911, p. 631).

² Thiele, J., 'Deutsch. Zentral-Afrika Exped. 1907-8,' vol. iii, 1912, p. 187.

would suggest, however, that it is quite possible that some of the South American carnivorous genera such as *Guestieria*, which Kobelt places in the *Streptaxidæ*, may prove to belong to the *Rhytididæ* when their anatomy has been examined.

Even if this view of the phylogeny of *Apera* is accepted, I would not advocate the placing of the genus in the *Rhytididæ*. The gap which separates *Apera* from any known member of that family is a very wide one, and the isolation of the genus is by no means over-emphasized by placing it in a family by itself.

THE PHYLOGENY OF TESTACELLA AND ITS POSSIBLE ALLIES.

Most modern malacologists are agreed that *Testacella* is allied to *Daudebardia*, and that these genera have been derived from *Hyalinia* or some closely related form. Now it must be admitted that the resemblance between *Daudebardia* and *Hyalinia* is very striking. Whether we regard the nervous system or the reproductive system or the excretory system, the similarity is equally remarkable. Even in the digestive system the difference is not very great, for *Hyalinia* is frequently carnivorous, and most of its teeth have become thorn-shaped, while *Daudebardia* still retains a small jaw, and the odontophoral muscles in this genus do not completely surround the radula-sac. Moreover, the evolution of *Daudebardia* from *Hyalinia* is to a great extent recapitulated in development, young specimens of *Daudebardia* having a shell very like that of *Hyalinia*, into which the animal can withdraw itself.¹ In my opinion the evidence of *Daudebardia* alone is almost sufficient to prove that the carnivorous snails and slugs are not monophyletic; for I think that we must admit that *Daudebardia* has been evolved from *Hyalinia* or some closely allied form, and I do not

¹ See Simroth, H., 'Nova Acta Acad. Cæs. Leop.-Carol. Germ. Nat. Cur.,' 1891, vol. lvi, p. 270.

suppose that anyone would maintain that all the carnivorous snails and slugs, including such genera as *Atopus* and *Varicella*, had been derived from this source.

But while I agree that *Daudebardia* has probably arisen from the *Zonitidæ*, I cannot admit that *Testacella* is closely allied to *Daudebardia* and has had a similar origin.

Testacella differs widely from *Daudebardia* in many respects. In *Testacella* the apex of the shell is directed backwards, the columella being parallel to its greatest length (Pl. XXIV, fig. 161); in *Daudebardia* the columella is nearly at right angles to the length of the animal and the major diameter of the shell, as in *Hyalinia*. In *Testacella* the pedal gland lies freely in the body-cavity, and is very different in structure from that of most snails and slugs, a fact that has been specially emphasized by André¹; in *Daudebardia* the pedal gland is embedded in the foot, and Plate² has shown that it has the usual structure, the duct having two ventral longitudinal folds enclosing a furrow into which the gland-cells open. In *Testacella* the epidermal cells have their walls thickened on the outer side only; in *Daudebardia* they are thickened all round.³ *Testacella* has no jaw; in *Daudebardia* a jaw is present. In *Testacella* the radula-sac does not extend nearly to the hind end of the odontophore (Pl. XXIV, fig. 156); in *Daudebardia* it projects beyond the odontophoral muscles. In *Testacella* the visceral ganglia are all separate from one another; in *Daudebardia* the abdominal ganglion is united with the right parietal ganglion, as is the case to some extent in *Hyalinia* also. In *Testacella* the auricle is behind the ventricle; in *Daudebardia* the auricle is in front of the ventricle, as in *Hyalinia*. In *Testacella* the heart is to the right of the kidney; in *Daudebardia* and *Hyalinia* it is to the left. *Testacella* has no secondary ureter; *Daudebardia* agrees with *Hyalinia* in possessing one. In *Testacella* the receptacular duct is moderately long;

¹ 'Revue Suisse de Zoologie,' 1894, vol. ii, pp. 318-321.

² 'Zool. Jahrb.,' 1891, vol. iv, p. 524, pl. xxxii, fig. 16.

³ *Ibid.*, pp. 527, 529.

in *Daudebardia* it is extremely short. In *Testacella* the vagina is not surrounded by any glandular tissue; in *Daudebardia* the anterior end of the vagina is encircled with glandular tissue, as in *Hyalinia*. In *Testacella* the penis passes between the right tentacular retractors; in *Daudebardia*, as in *Hyalinia*, it lies outside both retractors. In *Testacella* the genital opening is on the side of the head; in *Daudebardia* and *Hyalinia* the opening is further back. In short, the two genera only resemble each other in a few features which would be likely to be developed in any vermivorous form, and they differ in nearly every other respect.

The dissimilarity in the nervous system is alone almost sufficient to prove that the carnivorous characters of *Testacella* have been acquired independently of those of *Daudebardia*. It is a general rule in the animal kingdom that nerve-ganglia tend to unite and not to separate; therefore we cannot derive *Testacella*, with its distinctly separate abdominal and right parietal ganglia, from forms in which these ganglia are more or less united; and this is the case in *Hyalinia* as well as in *Daudebardia*, notwithstanding Plate's statement to the contrary.

Now, if *Testacella* is not allied to *Daudebardia*, there is no reason for supposing it to have been derived from the *Zonitidæ*. This has only been thought to be the case because *Daudebardia* has almost certainly been evolved from that family, and *Testacella* was supposed to be related to *Daudebardia*. In *Testacella*, as in *Apera*, the carnivorous characters have reached a very high state of specialisation, and it is therefore more probable that *Testacella* has been evolved from some family of carnivorous snails.

Beutler¹ considers that *Paryphanta* may be ancestral to *Testacella*. Now *Paryphanta* certainly resembles *Testacella* much more closely than does *Daudebardia*. Indeed in its visceral ganglia it is more like *Testacella* than *Apera*. But *Testacella* differs from *Paryphanta*,

¹ 'Zool. Jahrb.,' 1901, vol. xiv, p. 407.

just as it differs from *Apera*, in the pedal gland having no terminal enlargement, and in the presence of longitudinal fibres in the odontophoral support and of dermal glands in the foot. And if a shell of the shape of that of *Paryphanta* degenerated, it would assume a form like that of *Schizoglossa*, and not like that of *Testacella*. Moreover, while it is easy to attach too much importance to geographical distribution, it does not seem probable that a western Palæarctic genus of slugs should have been evolved from a snail found in New Zealand.

But is there no family of carnivorous snails inhabiting Europe, in which the columella is parallel to the greatest length of the shell, and the odontophoral support contains longitudinal fibres? The *Oleacinidæ* possess these characters, and in many other ways bear a close resemblance to *Testacella*, and it is from the *Oleacinidæ* that I believe *Testacella* has been evolved.

Although the majority of the recent species of the *Oleacinidæ* are found in Central America and the West Indies, in Tertiary times the family was represented by many forms in Western and Central Europe, and one genus—*Poiretia*—still lingers in the Mediterranean region. We know that the shell is liable to degenerate and recede to the posterior end of the animal in the *Oleacinidæ* as in other carnivorous families, for it has done so in *Strebelia*. If the degeneration were to proceed further than it has done in this American genus, the shell would assume the form found in *Testacella maugéi*. This is seen from the parallel case of the degeneration of a shell with a pointed spire found in the *Succineidæ*, which is well illustrated on plate lxxiii of H. and A. Adams' 'Genera of Recent Mollusca.' Further, we find that the abrupt truncation of the columella which is characteristic of *Poiretia*, *Euglandina*, *Oleacina*, etc., occurs also in *Testacella scutulum* *Sow.* It is significant also that as early as the Eocene period the aperture in some of the European *Oleacinidæ* had already become as large as that of any of the recent American members of the family

excepting *Strebelia*¹; for as a general rule, the larger the size of the aperture, the smaller is the size of the shell as a whole in proportion to that of the animal.

It is not only in the shell, however, that the *Oleacinidæ* resemble *Testacella*. In both, a deep cleft in the mantle-edge extends forwards from the respiratory opening beneath the right lip of the shell; and Simroth has found that in *Poiretia* this cleft contains an olfactory organ, resembling the similarly situated olfactory organ of *Testacella*. *Poiretia* also has small labial feelers, very like those of *Testacella*. So far as I am aware, the histology of the foot and pedal gland in the *Oleacinidæ* has not been described; but, judging from Strebel's figures,² the pedal gland lies freely in the body-cavity in the more highly specialised members of the family, just as it does in *Testacella*. A jaw is absent in nearly all the *Oleacinidæ*, as in *Testacella*. We have already seen that the odontophoral muscles in the *Oleacinidæ* are more like those of *Testacella* than are the muscles of any other form which has been examined; and I have found that in *Euglandina* the structure of the odontophoral support agrees exactly with that of *Testacella*. In most of the *Oleacinidæ* the salivary glands are united, but according to Raymond³ they are separate in the European genus *Poiretia*, as in *Testacella*. This, however, is not a very important character, for, as we have seen, the glands may be separate or united in different species of the same genus. The nervous system in the *Oleacinidæ* is also identical with that of *Testacella*, all the visceral ganglia remaining separate, although they are sometimes very closely aggregated in *Euglandina*. The similarity of the reproductive system is equally striking. It is true that the receptacular duct of *Testacella* is shorter

¹ See 'Jahresh. Ver. Naturkunde Württemb.,' 1907, vol. lxiii, pl. ix, fig. 8.

² 'Beitrag z. Kenntn. d. Fauna Mexikan. L.-u. Süßwasser-Conchylien,' 1878, vol. iii, pl. xix, fig. 1.

³ 'Journ. de Conchyl.,' 1853, vol. iv, pp. 16-29, pl. i, fig. 1.

than in most genera of the Oleacinidæ excepting *Strebelia*, but I have already shown that this is what we might expect in a genus with a degenerate shell. The other female organs seem to be identical. The penis often ends in a caecal diverticulum in the Oleacinidæ, which, however, is quite short in *Poiretia*, and absent in *Euglandina*, *Salasiella*, *Streptostyla*, and *Strebelia*. In *Testacella* we frequently find a vestige of this diverticulum, especially in *T. haliotidea* *Drap.* In the Oleacinidæ an epiphallus is usually, though not invariably, inserted between the penis and the attachment of the penial retractor; this is also the case in *Testacella haliotidea*, and sometimes in *T. maugei* (Pl. XXIV, fig. 159). Pfeffer has shown that in *Euglandina liebmanni* (*Pfr.*) the retractor springs from the apex of a flagellum, exactly as it does in *Testacella haliotidea*, and the same author has demonstrated that the internal structure of the penis of *Euglandina* is not unlike that of *Testacella*.¹ Indeed, the similarity between *Testacella* and the Oleacinidæ seems to me to be even closer than the similarity between *Apera* and the Rhytididæ.

The fact that the heart in *Testacella* is on the right side of the kidney, with the auricle directly behind the ventricle, affords further evidence in favour of this view, as will be seen from the accompanying diagram. The usual position of the heart in *Hyalinia*, *Rhytida*, and similar genera, is shown in text-fig. 6, A—drawn from a specimen of *Hyalinia draparnaudi* (*Beck*). In *Daudebardia*, according to Plate, the heart is turned slightly to the right as shown in diagram B; but it will be seen that the auricle is still in front of the ventricle, and the kidney is still mainly on the right side of the heart, though the shell no longer extends far beyond these organs. In *Apera* the heart has rotated further in the same direction and is not protected by the shell (diagram C); the auricle has now come to lie further back than the ventricle, and the kidney is behind and to the

¹ 'Jahrb. d. Deutsch. Mal. Gesell.,' 1878, vol. v, p. 81.

TEXT-FIG. 6.



A.



D.



B.



E.



C.



F.

Diagrams illustrating the rotation of the heart in the evolution of carnivorous slugs from snails.

- A. *Hyalinia*, *Rhytida*, etc. B. *Daudebardia*. C. *Apera*.
D. *Englandina*, etc. E. *Strebelia*. F. *Testacella*

left of the heart. Turning now to the Oleacinidæ, we find that in *Euglandina*, *Streptostyla*, etc., the heart already occupies a position similar to that which it holds in *Apera*, as is evident from diagram D.¹ This is probably due partly to the pushing forwards of the ventricle owing to the pressure of the hinder portion of the odontophore,² and partly to the shape and consequent orientation of the shell.³ Diagram E shows the position of the heart and kidney in *Strebelia*, so far as I can judge from Strebel's figures, and it will be seen that with the reduction in the size of the shell and its retrogression to the hind end of the animal, the heart has rotated a little further. It is but a short step from this to the condition shown in diagram F, which illustrates the position of the heart in *Testacella*, with the auricle directly behind the ventricle. Sixty years ago Reymond expressed the opinion that *Testacella* was "a *Glandina* with a rudimentary shell," and if we substitute the word "vestigial" for "rudimentary," I believe that Reymond expressed the truth.

At the same time I am aware that the most eminent modern authorities have expressed a contrary opinion. Dr. Pilsbry⁴ states emphatically that the relationships of the European carnivorous slugs (including *Testacella*) are with the Aulacopoda, and not with the other carnivorous families; and Simroth entertains the same view. The only facts which Pilsbry brings forward in support of this hypothesis are (1) that the European carnivorous slugs have lateral and pedal grooves, which he states that the other families do not possess, and (2) that the cerebral ganglia are generally united by a rather long commissure in the European slugs, while in the other families the cerebral ganglia are in close contact. Let us examine these points.

In the first place, lateral grooves occur not only in *Testa-*

¹ See also Strebel, *op. cit.*, vol. iii, pl. v, fig. 5.

See p. 229.

³ Cf. Naef, A., 'Ergebn. d. Fortschr. d. Zool.', 1911, vol. iii, p. 131, fig. 19.

⁴ 'Manual of Conch.' (2nd ser.), 1908, vol. xix, p. viii.

cella, Daudebardia, and the Trigonochlaminae, but sometimes also in the Oleacinidae, Rhytididae, and Aperidae. I have already described them in *Apera*, where they may be very conspicuous (Pl. VII, figs. 11 and 13). Collinge¹ shows them in his figures of *Schizoglossa novoseelandica* (*Pfr.*), and they are present on both sides in *Natalina quekettiana* (*M. & P.*), though rather ill-defined. In *Euglandina venezuelensis* (*Preston*) I have also found both lateral grooves, but the right groove is more conspicuous than the left. In these genera, however, the right lateral groove ends in the genital opening, whereas in *Daudebardia* it passes below the genital opening and unites with the peripodial groove.² Now, *Testacella* differs from *Daudebardia* in this respect, and agrees with the other families of carnivorous snails.³

In *Daudebardia* there is a deep peripodial groove, cutting off a broad foot-fringe, which is cleft at the hind end by a short groove probably representing the lost mucous pore.⁴ A peripodial groove is also present in the *Aperidae* and *Streptaxidae*, and although it is often absent or only slightly developed in the *Rhytididae* and *Oleacinidae*, *Reymond* states that it is fairly deep in *Poiretia*. In these forms, however, there is no trace of a caudal mucous pore. This is also the case in *Testacella*, which possesses a peripodial groove shallower than that of *Daudebardia* and nearer the edge of the foot.⁵

Lastly, *Daudebardia* resembles the *Trigonochlaminae*, *Limacinae*, and related groups, in having two conspicuous longitudinal grooves on the foot-sole, approximately parallel to each other. As a rule no such grooves are found in the other families of agnathous snails and slugs, but we have seen that occasionally similar grooves occur towards the hind end

¹ 'Ann. Mag. Nat. Hist.' (7th ser.), 1901, vol. vii, pl. ii, figs. 26, 27.

² Plate, L. H., 'Zool. Jahrb.', 1891, vol. iv, pl. xxxii, fig. 1.

³ See de Lacaze-Duthiers, 'Arch. Zool. Expér.', 1887, vol. v, pl. xxx, fig. 11.

⁴ Wiegmann, F., 'Mitt. Zool. Samml. Mus. Berlin,' 1898, vol. i, p. 62.

⁵ Compare Plate's figs. 3 and 11 on pl. xxxii, op. cit.

of the foot in *Apera* and *Natalina*; they are, however, very inconstant, and instead of being parallel they diverge forwards and seldom extend for more than half the length of the animal. Authorities differ with regard to the foot-sole of *Testacella*: Plate states that longitudinal grooves are present; Taylor¹ says that they are absent; Pfeffer² found them only in the anterior two-thirds of the foot-sole; Simroth³ saw traces of them towards the hind end of the foot in a few individuals only. I have examined the foot-sole in about a dozen examples of *Testacella maugei* from various localities, and I found that about half the specimens showed no trace of longitudinal grooves, while in the others the grooves were present, but they were much less conspicuous than in *Daudebardia*, etc., and diverged forwards from the hind end as in *Apera*. In other words, the grooves on the foot-sole of *Testacella*, instead of being constant and approximately parallel, as in the other European carnivorous slugs, are divergent and very inconstant. We see, then, that the evidence of the various dermal grooves of *Testacella* is against Pilsbry's hypothesis instead of in favour of it.

Turning now to the evidence afforded by the length of the cerebral commissure, we find that while in *Daudebardia* and the *Trigonochlaminae* the commissure is moderately long, in *Testacella*, as in the *Oleacinidae*, *Streptaxidae*, *Rhytididae*, and *Aperidae*, the commissure is quite short, and the cerebral ganglia are in consequence close together. This fact was clearly stated by Strebel⁴ thirty-six years ago, and has been abundantly confirmed by subsequent investigations. It is therefore evident that the only features upon which Pilsbry seems to base his theory of the affinities of *Testacella* are found on examination to support the contrary hypothesis.

¹ 'Monog. L. and F.-W. Mollusca Brit. Isles,' 1902, vol. ii, p. 2.

² *Op. cit.*, p. 75.

³ 'Nova Acta Acad. Cæs. Leop.-Carol. Germ. Nat. Cur.,' 1891, vol. lvi, p. 241.

⁴ *Op. cit.*, vol. iii, p. 5.

If the views which I have brought forward are correct, all the carnivorous genera of slugs, with the exception of those belonging to the *Trigono-chlaminae* and to the *Rathouisiidae*, have been derived independently from different snails by the parallel degeneration of the shell. This will be made clear from the following table :

American <i>Oleacinidae</i>	→	<i>Strebelia</i> .
European <i>Oleacinidae</i>	→	<i>Testacella</i> .
Southern <i>Rhytididae</i>	→	<i>Schizoglossa</i> .
Northern <i>Rhytididae</i>	→	<i>Apera</i> .
European <i>Zonitinae</i>	→	<i>Daudebardia</i> .
Atlantic <i>Vitrininae</i>	→	<i>Plutonia</i> .
Transcaucasian <i>Parmacellinae</i>	→	<i>Trigono-chlaminae</i> .
Oriental <i>Ditremata</i>	→	<i>Rathouisiidae</i> .

But even if we admit that *Apera* has probably been evolved from the *Rhytididae* and *Testacella* from the *Oleacinidae*, the question of the affinities of these genera is not yet settled; for Pilsbry¹ states that the *Oleacinidae* and *Rhytididae* are closely related to each other, and if this be the case *Apera* and *Testacella* might still have been derived from a common predaceous ancestor, instead of their carnivorous characters having been acquired independently.

Now it is true that the *Oleacinidae* and the *Rhytididae* have many characters in common, but if we except those which would be likely to be caused by their carnivorous habits the remaining features are chiefly such as are possessed by nearly all the more primitive sigmurethrous *Stylommato-phora*. And there are at least two important differences between the families—their distribution and their shells. The difference in distribution, however, is less important than it appears, for, on the one hand, it is quite conceivable that the *Oleacinidae* may have once inhabited tropical Africa, and, on the other hand, we have already seen that the *Rhytididae* may occur in tropical America. But the difference in the shells cannot be so easily explained away. In the *Oleacinidae* the

¹ *Op. cit.*, vol. xix, p. xiii.

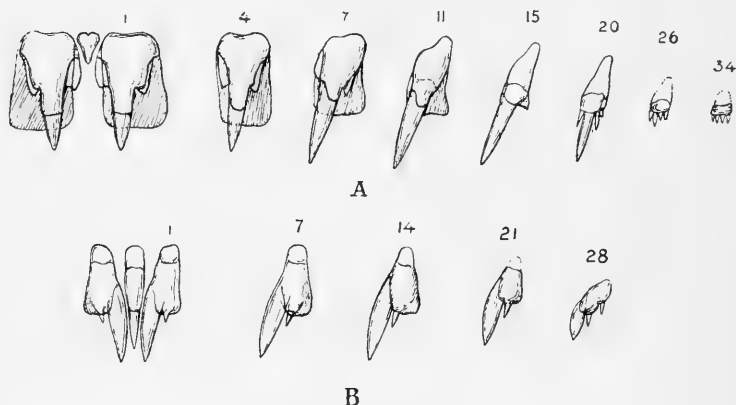
shell is elongate, with a pointed spire and laterally compressed whorls, and the columella is truncated or folded. In the Rhytididæ, on the other hand, the shell is heliciform or depressed, with a very obtuse spire and laterally expanded whorls, and the columella is neither truncated nor folded. I fail to see how it is possible to derive the shell of the Oleacinidæ directly from that of the Rhytididæ or vice versâ. If these families are really related, it can only be indirectly, and we must postulate a large number of intervening forms, with shells intermediate in shape.

But it might be asked whether we do not find such a series of intermediate forms in the Streptaxidæ; and as a matter of fact in this family we have every gradation from heliciform shells such as *Artemon* and *Imperturbatia* to cylindrical shells like *Ennea*, and from these to pointed shells with laterally compressed whorls such as *Streptosteles* and *Obeliscella*. May it not be that the Streptaxidæ have been derived from the Rhytididæ and the Oleacinidæ from the Streptaxidæ? In my opinion the Streptaxidæ may possibly have been derived from the Rhytididæ, for I have recently dissected a form which proves to be in some ways intermediate between the two families. The great majority of the Streptaxidæ, however, have come to differ widely from both the Rhytididæ and the Oleacinidæ in their nervous system, their reproductive organs, and even in their radula; and I think that there can be no doubt at all that the Oleacinidæ have not been derived from that family. Therefore, if Pilsbry's view is correct, we must suppose that all the forms intermediate between the Rhytididæ and the Oleacinidæ have died out completely, which does not seem a probable hypothesis.

Dr. Simroth has suggested that the Oleacinidæ may have been derived from the Achatinidæ. Now I regard the striking resemblance between the shell of the American genus *Euglandina* and the African genus *Achatina* as almost certainly due to convergence; because *Euglandina*, with its long labial papillæ and closely aggregated nerve-

ganglia, is probably one of the most recently evolved genera of the Oleacinidæ. Indeed, its distribution suggests that it may not have arisen until after the final separation of the West Indian Islands from the mainland. I think that most zoologists who have studied the Oleacinidæ will agree that the most primitive genera in the family are those with long spires, namely *Spiraxis*, *Pseudosubulina*, and *Varicella*. These genera are very unlike *Achatina*, but they

TEXT-FIG. 7.



A. *Curvella caloraphe* Preston, Brit. E. Africa.

B. *Varicella nemorensis* Ads., Jamaica.

Representative teeth from the radula. $\times 400$.

are exceedingly similar to the more primitive members of the Achatinidæ, if we include the *Stenogyrinæ* and *Cœliaxinæ* in that family. It is, in fact, almost impossible to say whether some groups of species should be placed in the *Stenogyrinæ* or *Oleacinidæ* until their radula has been examined. I believe, therefore, that the *Oleacinidæ* have been derived from gnathophorous snails closely allied to the *Stenogyrinæ* or even belonging to that subfamily.

The chief differences between the internal anatomy of the *Stenogyrinæ* and that of the *Oleacinidæ* are to be found in the radula. We know, however, that the *Stenogyrinæ*

are sometimes predaceous,¹ and that their teeth are liable to alter in form and acquire carnivorous characters. This is well shown in text-fig. 7, A, which represents part of the radula of an African member of the *Stenogyrinae*; and Crosse and Fischer² have figured the radula of an American species—*Leptinaria lamellata* (*Pot. & Mich.*)—in which the outer lateral teeth have become similarly lengthened. Moreover, we find that the radula of the more primitive genera of the *Oleacinidæ* is not of the specialised carnivorous type found in the higher members of the family and in the *Rhytididæ*. Thus in *Varicella* the radula is usually quite small, the rows of teeth are nearly straight, the bases of the teeth are broader and shorter than in the usual carnivorous type, and there is a small additional cusp outside the main cusp (text-fig. 7, B). This last character is especially significant, as the small cusp is obviously a vestigial ectocone, such as we find in so many herbivorous genera. I am indebted to the Rev. Prof. Gwatkin for kindly allowing me to examine the mounted radulæ of a large number of carnivorous forms, and I find that this additional cusp occurs in all the species of *Varicella* represented in his collection, namely, *V. nemorensis* *Ads.*, *phillipsi* *Ads.*, *dissimilis* *Pilsbry* (= *similis* *Ads.*) and *venusta* *Ads.*, although it is extremely minute in the last species. It is therefore very surprising that it has been entirely overlooked by previous observers, who have figured the radulæ of *V. phillipsi* and *V. nemorensis*. Unfortunately I have not had an opportunity of studying the radula of *Spiraxis*, a genus which may be even more primitive than *Varicella*; but I have examined that of *Pseudosubulina lirifera* (*Morelet*), and find that in this form the second cusp is also present and is larger than in *Varicella*, although in other ways the radula has become more highly specialised. Strebel has shown, however, that in *Pseudosubulina* there is a vestigial jaw, the structure of which is not unlike that of the jaw in the *Achatinidæ*.

¹ Johnson, C. W., 'Nautilus,' 1900, vol. xiii, p. 117.

² 'Mission scientifique au Mexique,' pt. 7, 1877, pl. xxviii, figs. 8-10.

In my opinion these facts are sufficient to prove that the Oleacinidæ have not been evolved from the Rhytididæ, but have arisen directly from a gnathoporous family.

Perhaps it might be said that the Oleacinidæ cannot have been evolved from the Achatinidæ, because in the latter family the central teeth of the radula are almost invariably much smaller than the laterals, whereas in the more primitive members of the Oleacinidæ the central teeth are sometimes nearly as large as those on each side of them, notwithstanding that the teeth in the middle of the radula tend to diminish in size among carnivorous genera (cf. figs. 7, A and B). But I do not maintain that the Oleacinidæ have been evolved from any of the recent genera of the Achatinidæ. It must be remembered that already in Upper Cretaceous and Eocene times the Oleacinidæ were represented by forms which can hardly be regarded as primitive; the family, therefore, cannot have arisen very much later than the Jurassic period. Now the small central teeth are not an absolutely constant feature of the Achatinidæ even at the present day, and it is not improbable that in Mesozoic times the radula was still of the more generalised type found in the closely allied family Megaspiridæ. Indeed, it is possible that in the Jurassic period the Achatinidæ may not yet have definitely separated from the Megaspiridæ. *Callionepion* may perhaps be regarded as a descendant of a form intermediate between these two families, and in this genus the central teeth are nearly as large as the laterals. Moreover, the penis has a continuation in *Callionepion*, which reminds us of the similar structure found in *Euglandina liebmanni* (*Pfr.*), and other members of the Oleacinidæ.¹ Lastly, the shells of the typical section of *Spiraxis* in some respects resemble the Megaspiridæ quite as much as the *Stenogyrinæ*, which also suggests that the Oleacinidæ may have diverged from the Acha-

¹ Pilsbry and Vanatta, 'Proc. Acad. Nat. Sci. Phila.,' 1899, pp. 371-373, pl. xv, figs. 3, 8, and Pilsbry, 'Man. of Conch.,' 1904, vol. xvi, p. 178, pl. xxxi, figs. 7, 8.

tinidæ when this family was scarcely distinct from the Megaspiridæ. Nevertheless, until further anatomical investigations have been made, it is impossible to say exactly to which group now living the Oleacinidæ are probably most nearly related.

It is equally difficult to form an opinion as to the place of origin of the family, for both the Achatinidæ and the Megaspiridæ have an extremely wide distribution. Perhaps the Oleacinidæ may have arisen near the southern or south-eastern shores of that continent which geologists believe to have stretched from Western Europe to America during a large part of the Mesozoic era. If this were the case, the south-eastern expansion of the area of distribution would be prevented by the extensive "Mediterranean Sea" which then existed; the gradual growth of the North Atlantic would separate the European from the American forms, and the subsequent incoming of the Glacial Period would restrict the northern distribution of the family. On the other hand, the Oleacinidæ may possibly have arisen further south, and have entered America by way of the old land-connection which probably extended from Africa to Brazil. The absence of the Oleacinidæ from the Ethiopian Region is a possible objection to this theory; but perhaps the family may have once extended into that area, and may have there been exterminated by the elongate Streptaxidæ—*Ennea*, *Streptosteles*, and their allies—which would probably enter into competition with them, but appear to have arisen just too late to follow the heliciform Streptaxidæ across to the Neotropical Region. The limited distribution of the Oleacinidæ in South America is, however, another objection to the theory of their southern origin, and the first view that I have given seems to me to be the more probable. I am therefore glad to see that Pilsbry now upholds the more northerly origin of the family,¹ although seven years ago he thought that the probabilities favoured the hypothesis that the Olea-

¹ 'Rep. Princeton Univ. Exped. Patagonia 1896-1899,' vol. iii, Zoöl., 1911, p. 625.

cinidæ arose in the Brazil-African continent.¹ All this is highly problematical; but the uncertainty which surrounds the precise origin of the Oleacinidæ does not affect the general conclusion that the family is probably more nearly related to the Achatinidæ and their allies than to any of the other carnivorous forms excepting Testacella.

It is not necessary for me to discuss at length the phylogeny of the Rhytididæ; this family is evidently of very ancient origin—possibly it is the oldest of all the carnivorous families—and I do not suppose that anyone would maintain that it had arisen from the Oleacinidæ. I hope to deal in greater detail with the affinities of the Rhytididæ and Strep-taxidæ when treating of the South African members of these families; and I have already said enough to show that in all probability the carnivorous characters of the Rhytididæ and Oleacinidæ, and therefore of Apera and Testacella, have been acquired independently. The remarkable resemblance between Apera and Testacella seems only to be another example of convergence due to the common acquisition of carnivorous habits.

One thing is quite clear from the preceding argument: the tribe Agnatha is not a natural group, and should therefore find no place in the classification of the Pulmonata. The Rathouisiidæ should be placed with the Veronicellidæ among the Ditremata, as some authors have already done. The Trigonochlaminae, Plutoniinae, and Daudebardiinae should be placed among the Aulacopoda or Oxygnatha, next to the Parmacellinae, Vitrininae, and Zonitinae. The Oleacinidæ and Testacellidæ should form a group by themselves, near the Achatinidæ and Megaspiridæ, if my views are correct; and to this small group Mörch's term Agnatha may well be applied, for his original description is simply: "Agnatha. Ohne Kiefer: Oleacina, Testacella."² The Rhytididæ, Aperiidæ, and probably the Streptaxidæ, should be placed in another

¹ 'Man. of Conch.,' vol. xix, p. xiv.

² 'Mal. Blätt.,' 1859, vol. iv, p. 109.

group, for which we may adopt Pilsbry's term *Agnathomorpha*.¹ Whether the purely American family *Circinariidæ* should also be placed in this group I am unable to say. Pilsbry considers that it is allied to the *Streptaxidæ*, but Simroth believes it to be related to the *Zonitidæ*. There are possible objections to both these views, but as I have not had an opportunity of examining any members of the *Circinariidæ* myself, I will refrain from expressing an opinion upon its affinities.

Thus the carnivorous snails and slugs should probably be classified as follows:

Sigmurethra	{	Agnatha	{	Testacellidæ.
				Oleacinidæ.
		Agnathomorpha	{	Aperidæ.
				Rhytididæ.
				Streptaxidæ.
				Circinariidæ.
		Aulacopoda	{	Daudebardiinæ.
		or		(Zonitinæ).
		Oxygnatha		Plutoniinæ.
				(Vitrininæ).
				Trigonochlaminæ.
				(Parmacellinæ, etc.).
Ditremata				Rathousiidæ.

While it is hoped that this classification rests on a firmer basis than previous attempts of a similar nature, it must be remembered that we still know very little of the comparative anatomy of the carnivorous snails and slugs. To give a single example: about a hundred species of the genus *Ennea* are known to occur in South Africa alone, and I believe that I am right in saying that not a single feature of the anatomy of any of these species has been described. As we are equally ignorant of the anatomy of many other carnivorous genera, it is at present impossible to do more than give a rough outline of their probable affinities. Let us hope that the time will soon come when collectors of shells will cease to throw away

¹ 'Proc. Acad. Nat. Sci. Phila.,' 1900, p. 564.

the animals when cleaning their specimens, but will study their anatomy instead.

APPENDIX.

REFERENCES TO *TESTACELLA MAUGEI FÉR.*

The literature on *Testacella maugei* is so extensive that it has been deemed more convenient to give the following list of some of the principal references to this species in the form of an appendix. Those references in brackets relate to fossil shells which have been assigned to *T. maugei*, although it is possible that some of them, such as *T. asinina*, may have belonged to species which, while nearly allied to this form, were really distinct from it. Most modern writers place the form found in New Zealand in this species, notwithstanding that Hutton stated that its radula differed slightly from the type usually found in *T. maugei*; I have therefore included the references to it in the following list, although I have not had an opportunity of examining a New Zealand example myself.

- Testacella haliotoides* Lam., Sys. An. s. Ver., 1801, p. 96; Woodward, Man. Moll., 1854, p. 169, fig. 94.
- Testacella haliotide* (pars) Drap., Hist. Nat. Moll. Fr., 1805, pl. viii, figs. 46-48; Lowe, Rep. Brit. Assoc., 1883, p. 549.
- Testacella haliotide* var. *scutulum* Moq.-Tand., Hist. Moll. Fr., 1855, pl. v, figs. 20, 21.
- Testacella maugei* Fér., Hist. Moll., 1819, vol. ii, pp. 94, 95, pl. viii, figs. 10-12; Miller, Ann. Philos. (new ser.), 1822, vol. iii, p. 380; Sowerby, Genera Shells, 1822, *Testacella*, figs. 7-10; Fleming, Hist. Brit. Anim., 1828, p. 257; Desh., Dict. Class. d'Hist. Nat., 1830, vol. xvi, p. 179; J. D., Mag. Nat. Hist., 1833, vol. vi, p. 45, fig. 8, c, d; Lukis and J. D., Mag. Nat. Hist., 1834, vol. vii, pp. 225, 229, figs. 40, c, d, 41, f, g; d'Orbigny, Moll. des Iles Canaries, 1834, p. 48; Gray, Turton's Man. L. and F. W. Shells, 1840, pl. iii, fig. 18; Encycl. Brit. (7th ed.), 1842, vol. xv, pl. cccclxvii, fig. 5; Penny Cyclopædia, 1842, vol. xxiii, p. 246, figs. a, a, b; Reeve, Conch. Syst., 1842, vol. ii, pl. clxi, figs. 7-10; Morelet, Moll. Terr. et Fluv. Portugal, 1845, pp. 48, 49; Forbes and Hanley, Hist. Brit. Moll., 1853,

vol. iv, p. 28; Albers, *Malacographia Maderensis*, 1854, pp. 13, 14, pl. i, figs. 9-11; H. & A. Adams, *Gen. Rec. Moll.*, 1854, vol. iii, pl. lxxii, figs. 7, 7a; Grat., *Distr. Géogr. des Limaciens*, 1855, pp. 15, 16; Tapping, *Zoologist*, 1856, vol. xiv, p. 5102; Woodward, *Man. Moll.*, 1856, p. 465, fig. 262; Gassies and Fischer, *Actes Soc. Linn. Bordeaux*, 1856, vol. xxi, pp. 36-39, pl. i, figs. 2, 5; Grat., *Distr. Géogr. Moll. Girond.*, 1858, p. 72; Morelet, *L'Hist. Nat. Açores*, 1860, p. 143; Norman, *Proc. Somerset Arch. and Nat. Hist. Soc.*, 1861, *ex* vol. x, pp. 11, 12; Bourg., *Rev. and Mag. Zool.* (2nd ser.), 1861; vol. xiii, p. 514; Jeffries, *Brit. Conch.*, 1862, vol. i, pp. 147, 148; Reeve, *Brit. Moll.*, 1863, pp. 32, 33; Paiva, *Mon. Moll. Ins. Mader.*, 1867, pp. 6, 7; Massot, *Ann. de Malac.*, 1870, vol. i, pp. 145, 146; Mousson, *N. Mém. Soc. Helv. Sci. Nat.*, 1873, *ex* vol. xxv, p. 11; Wollaston, *Testacea Atlantica*, 1878, pp. 13, 14, 72, 73, 310, 311; Tryon, *Man. Conch.* (2nd ser.), 1885, vol. i, p. 8, pl. i, figs. 1-3; de Lacaze-Duthiers, *Arch. de Zool. Expér.* (2nd ser.), 1887, vol. v, pp. 469, etc., pl. xxix, figs. 7, 8; Pollon., *Boll. Mus. Zool. Anat. Torino*, 1889, vol. iv, No. 57, pl. i, fig. 1; Simroth, *Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur.*, 1891, vol. lvi, pp. 230-245, 266, etc., pl. x, figs. 1, 2, 5-7; Plate, *Zool. Jahrb.*, 1891, vol. iv, pp. 518, 519, 524, 542-552, 560-562, 566, 588, 594, 595, 614, 618-620, etc., pl. xxxiii, figs. 44, 46, 47, pl. xxxiv, figs. 62-65, pl. xxxvi, fig. 91, pl. xxxvii, figs. 101, 115, 116; Collinge, *An. Mag. Nat. Hist.*, 1893, vol. xii, p. 24, pl. i, fig. 3; Locard, *Coquilles Ter. France*, 1894, p. 18, figs. 5, 6; Webb, *J. of Malac.*, 1895, vol. iv, p. 74, pl. ii, figs. 1, 4, pl. iii, figs. 7, 8; L. E. Adams, *Coll. Man. Brit. L. and F.-W. Shells* (2nd ed.), 1896, pp. 41, 42, pl. ii, fig. 3, pl. vii, fig. 12; Webb, *J. of Malac.*, 1897, vol. vi, pp. 49, 52, 56, pl. vi, fig. 3; Taylor, *Mon. L. and F.-W. Moll. Brit. Is.*, 1902, vol. ii, pp. 21-27, figs. 32-42, pl. i, figs. 9-16, pl. iv; L. E. Adams, *J. of Conch.*, 1911, vol. xiii, p. 212.

[*Testacella asinum de Serres*, *Ann. Sci. Nat.*, 1827, vol. xi, p. 409.]

[*Testacella asinina de Serres*; Gassies and Fischer, *Actes Soc. Linn. Bordeaux*, 1856, vol. xxi, pp. 41, 42, pl. ii, fig. 3.]

[*Testacella lartetii Dupuy*, *J. de Conch.*, 1850, vol. i, pp. 302-304, pl. xv, figs. 2, a-d; Gassies and Fischer, *Actes Soc. Linn. Bordeaux*, 1856, vol. xxi, pp. 40-41, pl. ii, fig. 2.]

[*Testacella bruntoniana de Serres*, *Mem. Terr. Transp.*, 1851, p. 51; Gassies and Fischer, *Actes Soc. Linn. Bordeaux*, 1856, vol. xxi, p. 42.]

[*Testacella deshayesii Mich.*, *Désc. Coq. Foss.*, 1855, p. 3, pl. ii, figs. 10, 11.]

Testacella burdigalensis Gassies & Rautin, *Cat. Moll. Ter. and Fluv. Fr.*, 1855, p. 2.

Testacella oceanica Grat., *Distr. Géogr. des Limaciens*, 1855, p. 15.

- Testacella canariensis* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.
 [*Testacella monspessulana* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.]
 [*Testacella browniana* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.]
 [*Testacella occitaniæ* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.]
 [*Testacella altæ-ripæ* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.]
 [*Testacella aquitanica* *Grat.*, *Distr. Géogr. des Limaciens*, 1855, p. 16.]
 [*Testacella nouleti* *Bourg.*, *Hist. Mal. Colline de Sansan*, 1881, p. 15].
Daudebardia novoseelandica *Hutton*, *Trans. N. Z. Inst.*, 1881, vol. xiv, pp. 152, 153, pl. iii, fig. E; pl. iv, fig. M.
Testacella vagans *Hutton*, *Trans. N. Z. Inst.*, 1882, vol. xv, p. 140; 1883, vol. xvi, p. 209, pl. x, fig. T; *Tryon, Man. Conch.* (2nd ser.), 1885, vol. i, pp. 11, 12; *Musson, Proc. Linn. Soc. N. S. W.*, 1890, p. 885; *Suter, Trans. N. Z. Inst.*, 1892, vol. xxiv, p. 279.
Testacella aurigaster *Layard*; *Connolly, Ann. S. Afr. Mus.*, 1912, vol. xi, p. 64.

According to Gassies and Fischer, and Simroth, *Plectrophorus orbigny* *Fér.*, 1819, is also probably founded on specimens of this species.

EXPLANATION OF PLATES VII-XXIV,

Illustrating Mr. Hugh Watson's paper on "The Carnivorous Slugs of South Africa."

PLATE VII.

FIG. 1.—× 1·1. *Apera gibbonsi* s.s.; dorsal view; probably from Lower Umfolosi Drift, Zululand.

FIG. 2.—× 1·1. *A. gibbonsi* s.s.; side view; Hlabisa, Zululand.

FIG. 3.—× 1·1. *A. gibbonsi rubella*, young; side view; Equeefa, Natal.

FIG. 4.—× 1·1. *A. gibbonsi rubella*; dorsal view; Equeefa, Natal.

FIG. 5.—× 1·1. *A. gibbonsi rubella*; side view; Equeefa, Natal.

FIG. 6.—× 1½. *A. gibbonsi gracilis*, type; side view; Equeefa, Natal.

FIG. 7.—× 1½. *A. dimidia*, type; dorsal view; Equeefa, Natal.

FIG. 8.—× 1½. *A. dimidia*; side view; Port Shepstone, Natal.

FIG. 9.—× 1½. *A. dimidia*; ventral view; Equeefa, Natal.

FIG. 10.—× 1½. *A. burnupi*; dorsal view; Richmond, Natal.

FIG. 11.—× 1½. *A. burnupi*; side view; Chase Bush, Pietermaritzburg.

FIG. 12.—× 1½. *A. sexangula*; dorsal view; Port Shepstone, Natal.

FIG. 13.—× 1½. *A. sexangula*; side view; Port Shepstone, Natal.

PLATE VIII.

FIG. 14.¹—× 1. *Apera gibbonsi s.s.*; dorsal view; Zululand.

FIG. 15.—× 1. *A. gibbonsi s.s.*; side view; Zululand.

FIG. 16.—× 1. *A. gibbonsi rubella*; dorsal view; Equeefa, Natal.

FIG. 17.—× 1. *A. gibbonsi rubella*; side view; Equeefa, Natal.

FIG. 18.—× 1. *A. gibbonsi lupata*; dorsal view; Port Shepstone, Natal.

FIG. 19.—× 1. *A. gibbonsi lupata*; side view; Port Shepstone, Natal.

FIG. 20.—× 1. *A. dimidia*; dorsal view; Equeefa, Natal.

FIG. 21.—× 1. *A. dimidia*; side view; Equeefa, Natal.

FIG. 22.—× 1¼. *A. parva*; dorsal view; near Fern Kloof, Grahamstown.

FIG. 23.—× 1¼. *A. parva*; side view; near Fern Kloof, Grahamstown.

FIG. 24.—× 3. *A. dimidia*; dorsal view of hind end; Equeefa, Natal.

FIG. 25.—× 3½. *A. purcelli*; dorsal view of hind end; Table Mt., Cape Town.

FIG. 26.—× 2. *A. burnupi*; dorsal view of hind end; Chase Bush, Pietermaritzburg.

¹ Figs. 14-23 show the colours of specimens preserved in alcohol.

PLATE IX.

FIG. 27.— $\times 2\frac{1}{2}$. *Apera gibbonsi rubella*; general dissection from above.¹

FIG. 28.— $\times 5$. *A. parva*; general dissection from above.

FIG. 29.— $\times 4\frac{1}{2}$. *A. dimidia*; general dissection from above.

FIG. 30.— $\times 2$. *A. burnupi*; general dissection from above.

FIG. 31.— $\times 2\frac{3}{4}$. *A. sexangula*; general dissection from above.

PLATE X.

FIG. 32.— $\times 25$. *Apera gibbonsi rubella*, young; transverse section through the region of the buccal retractors.²

FIG. 33.— $\times 25$. *A. gibbonsi rubella*, young; transverse section through the region of the anus.

PLATE XI.

FIG. 34.— $\times 25$. *Apera dimidia*; transverse section through the region of the heart.

FIG. 35.— $\times 25$. *A. dimidia*; transverse section through the region of the reno-pericardial duct.

PLATE XII.

FIG. 36.— $\times 25$. *Apera dimidia*; transverse section through the region of the anterior end of the ureter.

FIG. 37.— $\times 128$. *A. dimidia*; transverse section through the skin of the back.

FIG. 38.— $\times 300$. *A. dimidia*; transverse section through the skin of the foot-sole.

FIG. 39.— $\times 118$. *A. dimidia*; transverse section through the right corner of the lung.

PLATE XIII.

FIG. 40.— $\times 300$. *Apera dimidia*; transverse section through a sphincter of a dermal blood-vessel.

¹ The specimens shown in figs. 27-31 have been cut open a little to the left of the mid-dorsal line, and, excepting in *A. burnupi*, the digestive and reproductive organs have been slightly separated in order to show the course of the anterior aorta.

² The sections represented on Plates X to XII are shown as viewed from the front.

FIG. 41.—× 3. *A. gibbonsi rubella*; dorsal view of shell; Equeefa.

FIG. 42.—× 3. *A. gibbonsi rubella*; side view of shell; Durban.

FIG. 43.—× 4. *A. gibbonsi gracilis*; dorsal view of shell.

FIG. 44.—× 6. *A. parva*; dorsal view of shell.

FIG. 45.—× 6. *A. parva*; side view of shell.

FIG. 46.—× 4. *A. dimidia*; dorsal view of shell.

FIG. 47.—× 7. *A. purcelli*; dorsal view of shell.

FIG. 48.—× 7. *A. purcelli*; side view of shell.

FIG. 49.—× 2. *A. burnupi*; dorsal view of shell.

FIG. 50.—× 3. *A. sexangula*; dorsal view of shell.

FIG. 51.—× 3. *A. sexangula*; side view of shell.

FIG. 52.—× 3. *A. gibbonsi rubella*; dorsal view of pedal gland, central nervous system, etc.¹

FIG. 53.—× 8. *A. parva*; dorsal view of pedal gland, central nervous system, etc.

FIG. 54.—× 6. *A. dimidia*; dorsal view of pedal gland, central nervous system, etc.

FIG. 55.—× 8½. *A. purcelli*; dorsal view of pedal gland, central nervous system, etc.

FIG. 56.—× 3. *A. burnupi*; dorsal view of pedal gland, central nervous system, etc.

FIG. 57.—× 5. *A. sexangula*; dorsal view of pedal gland, central nervous system, etc.

FIG. 58.—× 6. *A. gibbonsi lupata*; posterior end of pedal gland.

FIG. 59.—× 46. *A. dimidia*; transverse section through glandular part of pedal gland.

FIG. 60.—× 46. *A. dimidia*; transverse section through duct of pedal gland behind glandular part.

FIG. 61.—× 46. *A. dimidia*; transverse section through anterior end of terminal vesicle of pedal gland.

FIG. 62.—× 46. *A. dimidia*; transverse section through terminal vesicle of pedal gland, showing blood-vessel entering the fold.

PLATE XIV.

FIG. 63.—× 114. *Apera gibbonsi rubella*; transverse section through one side of pedal gland near its anterior end.

¹ In the specimens shown in figs. 52-57 the œsophagus, penis, etc. have been turned aside in order to display the underlying organs.

FIG. 64.— $\times 22$. *A. gibbonsi rubella*; side view of part of pedal gland.

FIG. 65.— $\times 119$. *A. gibbonsi rubella*; transverse section through fold in terminal vesicle of pedal gland.

FIG. 66.— $\times 114$. *A. dimidia*; transverse section through fold in terminal vesicle of pedal gland.

FIG. 67.— $\times 25$. *A. gibbonsi rubella*; ventral group of nerve ganglia.

FIG. 68.— $\times 60$. *A. dimidia*; section through pedal ganglia and pedal commissure, cut slightly obliquely, and showing pleural ganglion on the right and cerebro-pedal connective on the left.

FIG. 69.— $\times 120$. *A. dimidia*; sections of nerve-cells in right parietal ganglion.

PLATE XV.

FIG. 70.— $\times 16$. *Apera gibbonsi rubella*; cerebral and buccal ganglia.

FIG. 71.— $\times 32$. *A. dimidia*; cerebral and buccal ganglia.

FIG. 72.— $\times 25$. *A. sexangula*; cerebral and buccal ganglia.

FIG. 73.— $\times 30$. *A. dimidia*; left half of ventral group of ganglia.

FIG. 74.— $\times 33$. *A. sexangula*; right half of ventral group of ganglia.

FIG. 75.— $\times 6$. *A. dimidia*; semi-diagrammatic figure showing the distribution of the nerves from the ventral group of ganglia.

FIG. 76.— $\times 5$. *A. sexangula*; tentacular retractors of an abnormal specimen.

FIG. 77.— $\times 26$. *A. gibbonsi rubella*; transverse section through mouth.

FIG. 78.— $\times 15$. *A. gibbonsi rubella*; transverse section through crop and salivary glands.

FIG. 79.— $\times 100$. *A. gibbonsi rubella*; transverse section through wall of crop.

PLATE XVI.

FIG. 80.— $\times 50$. *Apera dimidia*; transverse section through retracted upper tentacle in front of eye.

FIG. 81.— $\times 50$. *A. dimidia*; transverse section through retracted upper tentacle, showing anterior part of eye.

FIG. 82.—× 50. *A. dimidia*; transverse section through retracted upper tentacle, showing posterior part of eye.

FIG. 83.—× 50. *A. dimidia*; transverse section through retracted upper tentacle just behind eye.

FIG. 84.—× 50. *A. dimidia*; transverse section through retracted upper tentacle behind eye.

FIG. 85.—× 50. *A. dimidia*; transverse section through retracted upper tentacle considerably behind eye.

FIG. 86.—× 50. *A. dimidia*; transverse section through retracted upper tentacle at entrance of olfactory and optic nerves.

FIG. 87.—× 60. *A. sexangula*; longitudinal section through mouth.

FIG. 88.—× 60. *A. dimidia*; transverse section through mouth.

FIG. 89.—× 118. *A. dimidia*; transverse section through radula sac.

FIG. 90.—× 118. *A. dimidia*; transverse section through part of odontophoral support.

PLATE XVII.

FIG. 91.—× 2 $\frac{1}{8}$. *Apera gibbonsi s.s.*; side view of odontophore without its sheath.

FIG. 92.—× 2 $\frac{1}{8}$. *A. gibbonsi s.s.*; longitudinal section of odontophore.

FIG. 93.—× 2. *A. gibbonsi rubella*; dorsal view of odontophore without its sheath.

FIG. 94.—× 2. *A. gibbonsi rubella*; ventral view of odontophore without its sheath.

FIG. 95.—× 2. *A. gibbonsi rubella*; dorsal view of odontophoral support.

FIG. 96.—× 2. *A. gibbonsi rubella*; side view of radula with its retractor muscles.

FIG. 97.—× 2. *A. gibbonsi rubella*; side view of radula without its muscles.

FIG. 98.—× 2. *A. gibbonsi rubella*; side view of radula without its muscles (retracted).

FIG. 99.—× 3. *A. gibbonsi lupata*; side view of radula without its muscles.

FIG. 100.—× 5. *A. parva*; dorsal view of odontophoral support.

FIG. 101.—× 5. *A. parva*; side view of radula with its retractor muscles.

- FIG. 102.—× 5. *A. parva*; side view of radula without its muscles.
 FIG. 103.—× 6. *A. dimidia*; ventral view of odontophore.
 FIG. 104.—× 6. *A. dimidia*; side view of odontophore without its sheath.
 FIG. 105.—× 6. *A. dimidia*; dorsal view of odontophoral support.
 FIG. 106.—× 6. *A. dimidia*; side view of radula with its retractor muscles.
 FIG. 107.—× 6. *A. dimidia*; side view of radula without its muscles.
 FIG. 108.—× 4. *A. burnupi*; side view of odontophoral support.
 FIG. 109.—× 4. *A. burnupi*; dorsal view of odontophore without its sheath.
 FIG. 110.—× 6½. *A. sexangula*; ventral view of odontophore.
 FIG. 111.—× 6½. *A. sexangula*; dorsal view of odontophore without its sheath.
 FIG. 112.—× 6½. *A. sexangula*; dorsal view of odontophoral support.
 FIG. 113.—× 6½. *A. sexangula*; side view of radula with its retractor muscles.
 FIG. 114.—× 6½. *A. sexangula*; dorsal view of radula without its muscles.

PLATE XVIII.

- FIGS. 115-122.—× 55. *Apera dimidia*; serial transverse sections through the odontophore.

PLATE XIX.

- FIG. 123.—× 30. *Apera gibbonsi gracilis*; front end of radula.
 FIG. 124.—× 30. *A. gibbonsi lupata*; front end of radula.

PLATE XX.

- FIG. 125.—× 25. *Apera gibbonsi s. s.*; part of radula.
 FIG. 126.—× 25. *A. gibbonsi rubella*; part of radula.
 FIG. 127.—× 127. *A. dimidia*; part of radula.
 FIG. 128.—× 127. *A. burnupi*; part of radula.

PLATE XXI.

FIG. 129.— $\times 2$. *Apera gibbonsi* s. s.; general view of digestive system.¹

FIG. 130.— $\times 1\frac{3}{4}$. *A. gibbonsi* rubella; general view of digestive system.

FIG. 131.— $\times 5$. *A. parva*; general view of digestive system.

FIG. 132.— $\times 3\frac{1}{2}$. *A. dimidia*; general view of digestive system.

FIG. 133.— $\times 1\frac{3}{4}$. *A. burnupi*; general view of digestive system.

FIG. 134.— $\times 2\frac{1}{5}$. *A. sexangula*; general view of digestive system.

PLATE XXII.

FIG. 135.— $\times 113$. *Apera sexangula*; transverse section through œsophagus.

FIG. 136.— $\times 125$. *A. dimidia*; transverse section through rectum.

FIG. 137.— $\times 135$. *A. dimidia*; transverse section through wall of intestine.

FIG. 138.— $\times 135$. *A. gibbonsi* rubella; transverse section through salivary duct.

FIG. 139.— $\times 119$. *A. gibbonsi* rubella; transverse section through part of salivary gland.

FIG. 140.— $\times 119$. *A. dimidia*; section through wall of ventricle.

FIG. 141.— $\times 135$. *A. dimidia*; section through part of kidney and wall of ureter.

FIG. 142.— $\times 194$. *A. gibbonsi* rubella; side view of the end of a papilla from inside penis.

PLATE XXIII.

FIG. 143.— $\times 2$. *Apera gibbonsi* s. s.; reproductive organs.

FIG. 144.— $\times 2$. *A. gibbonsi* rubella; reproductive organs.

FIG. 145.— $\times 8$. *A. gibbonsi* rubella; interior of penis and epiphallus.

FIG. 146.— $\times 6$. *A. parva*; reproductive organs.

FIG. 147.— $\times 4$. *A. dimidia*; reproductive organs.

¹ In the specimens shown in figs. 129–134 the right division of the liver, with the adjacent parts of the alimentary canal, is lying to some extent on its right side, in order to show the origin of the hepatic ducts, etc. (Compare figs. 27–31, in which the lobes of the liver are shown more nearly in their natural position as seen from above.)

FIG. 148.— $\times 2\frac{1}{2}$. *A. burnupi*; reproductive organs.

FIG. 149.— $\times 2\frac{1}{2}$. *A. sexangula*; reproductive organs.

FIG. 150.— $\times 1200$. *A. gibbonsi rubella*; anterior part of a spermatozoon.

FIG. 151.— $\times 1200$. *A. dimidia*; anterior part of a spermatozoon.

PLATE XXIV.

FIG. 152.— $\times 1\cdot8$. *Testacella maugei*; dorsal view; Cape Town.

FIG. 153.— $\times 1\cdot8$. *T. maugei*; side view.

FIG. 154.— $\times 3\cdot4$. *T. maugei*; general dissection, viewed obliquely from the right side.¹

FIG. 155.— $\times 3\cdot3$. *T. maugei*; side view of odontophore without its sheath.

FIG. 156.— $\times 3\cdot3$. *T. maugei*; longitudinal section of odontophore.

FIG. 157.— $\times 100$. *T. maugei*; representative teeth from the radula.

FIG. 158.— $\times 4$. *T. maugei*; side view of junction of penis with vas deferens and penial retractor in specimen shown in fig. 154.

FIG. 159.— $\times 4$. *T. maugei*; side view of junction of penis with vas deferens and penial retractor in another specimen from Cape Town.

FIG. 160.— $\times 1100$. *T. maugei*; anterior part of a spermatozoon.

FIG. 161.— $\times 1\cdot5$. *T. maugei*; ventral view of shell; Cape Town.

FIG. 162.— $\times 1\cdot5$. *T. maugei*, var. *aperta*; ventral view of shell; Cape Town.

EXPLANATORY REFERENCES.

alb. gl. Albumen gland. *ant. aor.* Anterior aorta. *aur.* Auricle.

b. art. Buccal artery. *b. c.* Buccal cavity. *b. gang.* Buccal ganglion.

b. mass. Buccal mass. *b. mass. n.* Nerve to sides of buccal mass.

b. protr. Buccal protractors. *b. retr.* Buccal retractors. *b. retr. n.* Nerve to buccal retractor.

c.-b. con. Cerebro-buccal connective. *cer. gang.* Cerebral ganglia.

c. m. Circular muscles of sheath of odontophore. *com. d.* Common duct.

c.-ped. con. Cerebro-pedal connective. *c.-pl. con.* Cerebro-pleural connective. *c. r.* Circular muscles of radula-sac.

¹ The liver is shown turned over to the left, and the reproductive system (excepting the penis) is displaced to the right; the arteries are omitted.

- diaph.* Diaphragm. *♂ d.* Hermaphrodite duct. *d. m.* Dorsal median muscle. *d. ped. gl.* Duct of pedal gland.
- epiph.* Epiphallus.
- f.* Flexor muscle of odontophoral support. *f. ov.* Free oviduct.
- gen. atr.* Genital atrium. *♀ gl.* Hermaphrodite gland.
- hep. d.* Hepatic ducts.
- i. l.* Inner longitudinal muscles of sheath of odontophore. *int.* Intestine. *i. od. n.* Inner odontophoral nerves.
- lab. n.* Labial nerves. *l. abd. n.* Left abdominal nerve to anus. *l. hep. d.* Left hepatic duct. *l. liv.* Left liver. *l. pal. n.* Left pallial nerve. *l. par. + abd. gang.* United left parietal and abdominal ganglia. *l. ped. gang.* Left pedal ganglion. *l. pl. gang.* Left pleural ganglion. *l. r.* Lateral retractors. *l. sal. d.* Left salivary duct. *l. sal. gl.* Left salivary gland. *l. tent. n.* Lower tentacular nerve. *l. t. retr.* Lower tentacular retractor. *l. t. retr. n.* Nerve to lower tentacular retractor.
- m.-cav.* Mantle-cavity. *m. r.* Median retractors.
- n. n.* Nerves of the neck.
- od.* Odontophore. *od. s.* Odontophoral support. *oes.* Œsophagus. *oes. n.* Nerves to Œsophagus. *o. l.* Outer longitudinal muscles of sheath of odontophore. *olf. n.* Olfactory nerve. *o. od. n.* Outer odontophoral nerve. *opt. n.* Optic nerve.
- ped. art.* Pedal artery. *ped. n.* Pedal nerves. *ped. gl.* Pedal gland. *ped. gl. n.* Nerve to pedal gland. *pen. n.* Penial nerve. *pen. retr.* Penial retractor. *perit. n.* Peritentacular nerves. *post. aor.* Posterior aorta.
- r. abd. n.* Right abdominal nerve to pericardium. *rd. s.* Radula-sac. *rec. d.* Receptacular duct. *rec. sem.* Receptaculum seminis. *r. liv.* Right liver. *r. pal. n.* Right pallial nerve. *r. par. gang.* Right parietal ganglion. *r. ped. gang.* Right pedal ganglion. *r. pl. gang.* Right pleural ganglion. *r. sal. d.* Right salivary duct.
- sal. d.* Salivary duct. *sal. gl.* Salivary gland. *sh. od. n.* Nerve to sheath of odontophore. *sh.-sac.* Shell-sac. *s. m.* Suspensor muscles of support. *st.* Stomach. *subc. com.* Subcerebral commissure.
- tent. art.* Tentacular artery. *tent. retr.* Tentacular retractor. *t. r.* Terminal retractors.
- ur.* Ureter. *u. t. retr.* Upper tentacular retractor.
- vag.* Vagina. *vas def.* Vas deferens. *ventr.* Ventricle. *ves. ped. gl.* Vesicle of pedal gland. *v. m.* Ventral muscles. *v. p.* Ventral pocket.

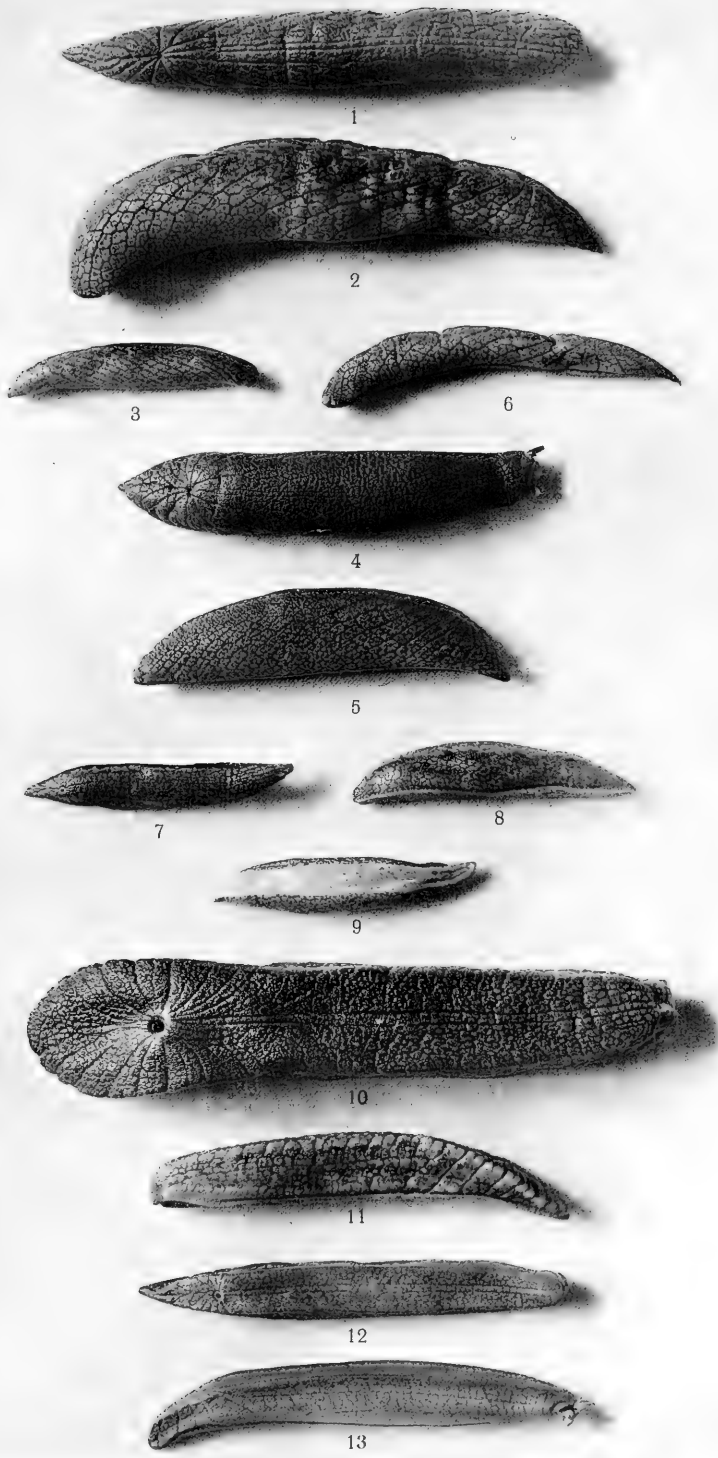
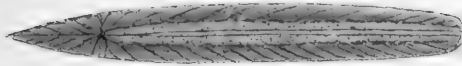


Photo. by Watson.

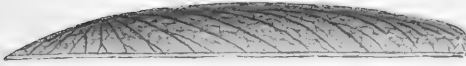
Species of *Apera* from Natal. $\times 11$.

Collotype.

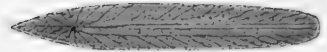
Figs. 1, 2, *A. gibbosi* s.s. ; 3-5, *A. g. rubella* ; 6, *A. g. gracilis* ; 7-9, *A. dimidiata* ; 10, 11, *A. burnupi* ; 12, 13, *A. sexangula*.



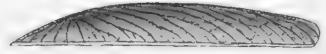
14.



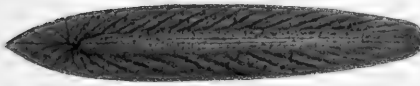
15.
A. gibbonsi.



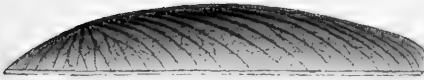
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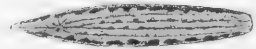
19.
A. g. lupata.



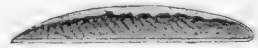
16.



17.
A. g. rubella.



20.



21.
A. dimidia

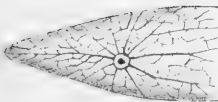


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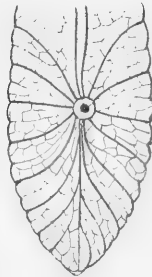


23.

A. parva. x 1 1/4.



24.
A. dimidia. x 3.

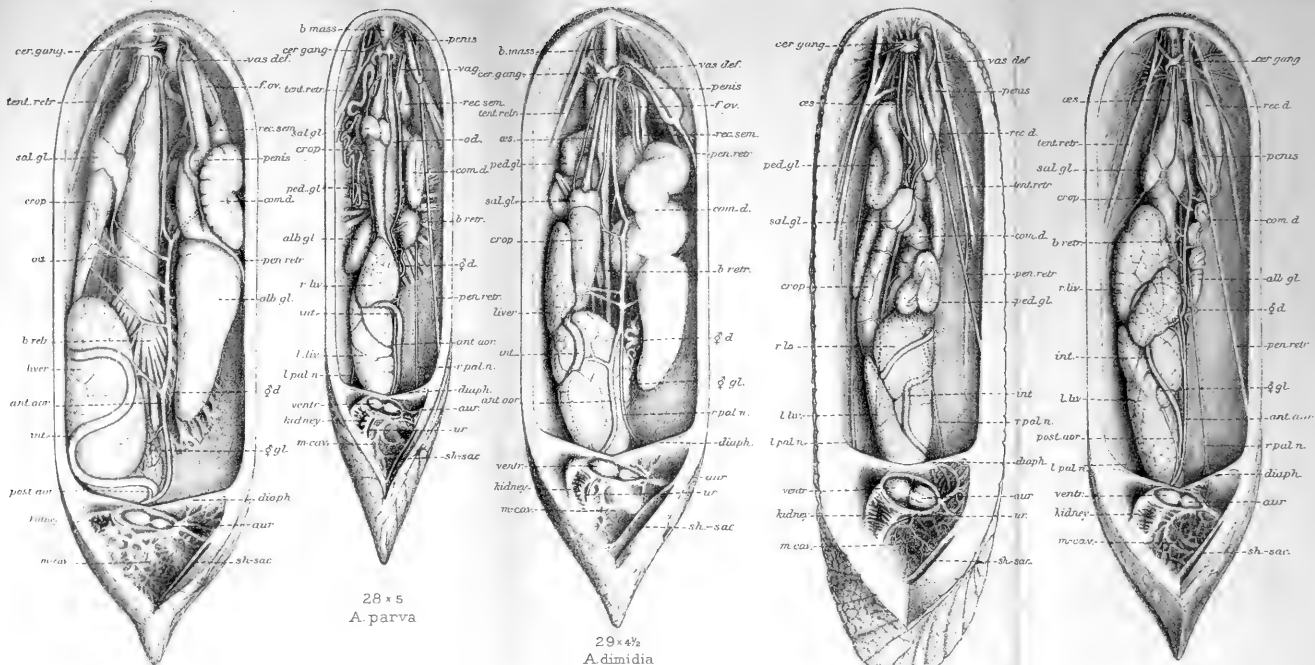


26.
A. burnupi. x 2.



25.
A. purcelli. x 3 1/2.

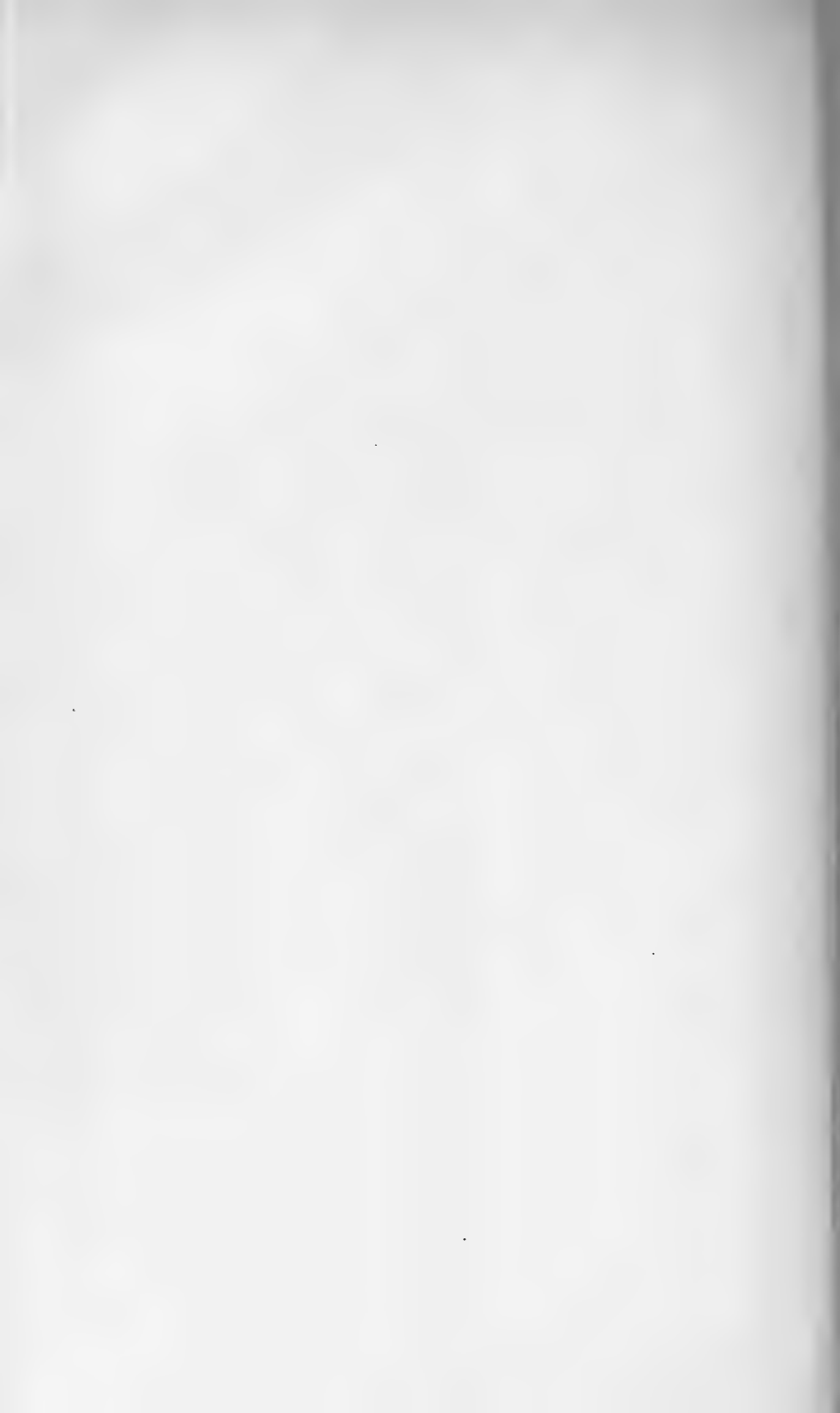


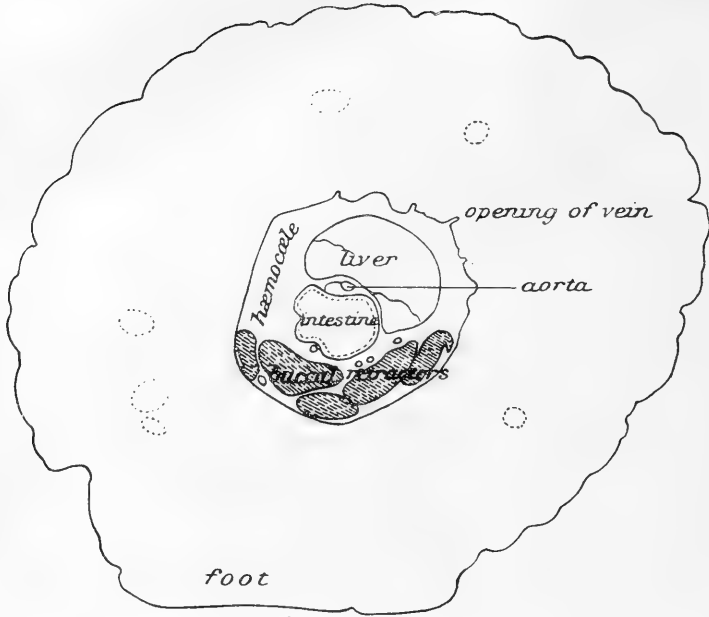


W. 11. 1.

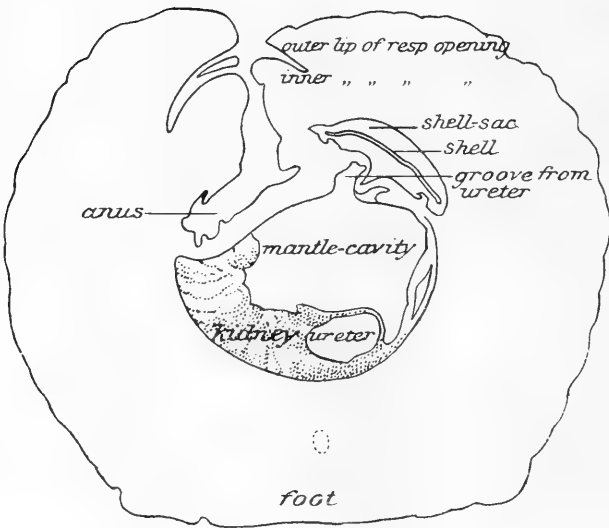
Apera: general dissections

Huth, London





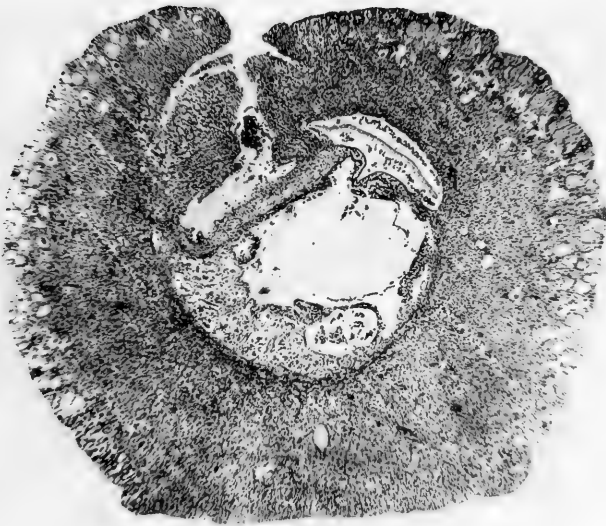
32.



33.



32.

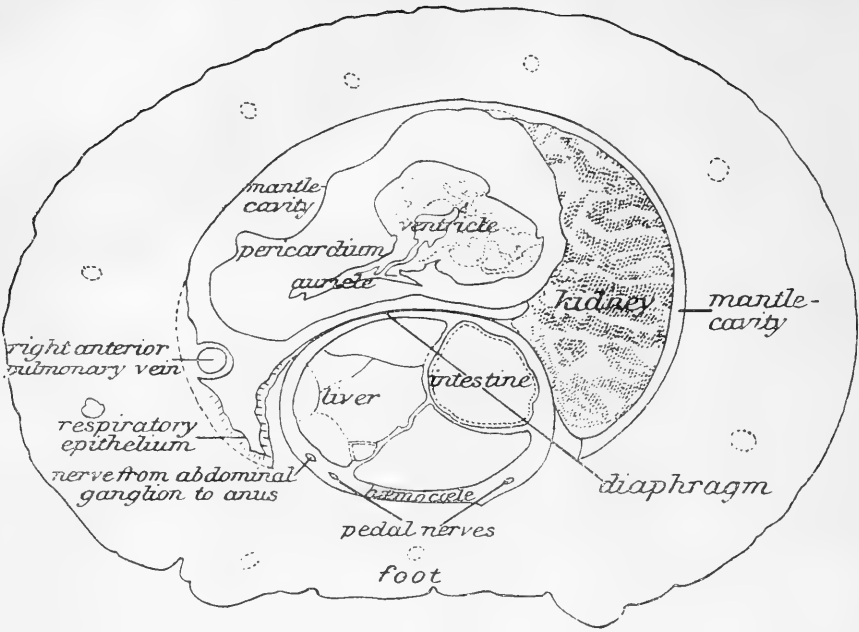


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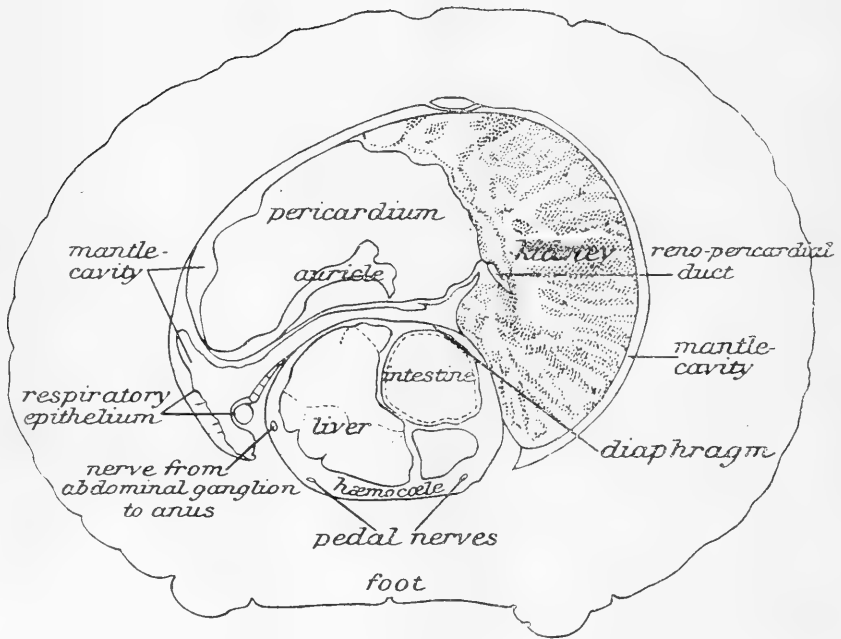
Photo. by Watson.

Collotype.

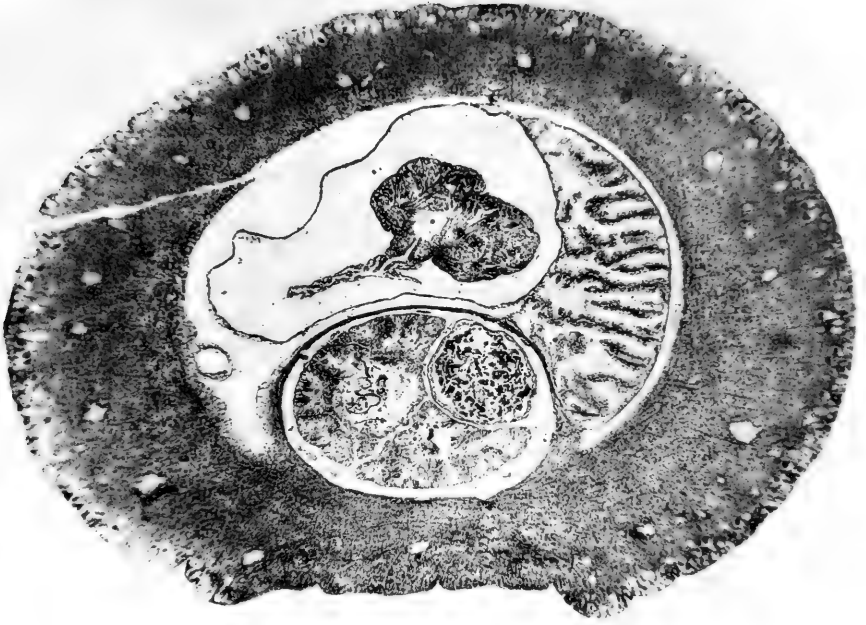
Sections of *Apera gibbonsi rubella*. $\times 25$.



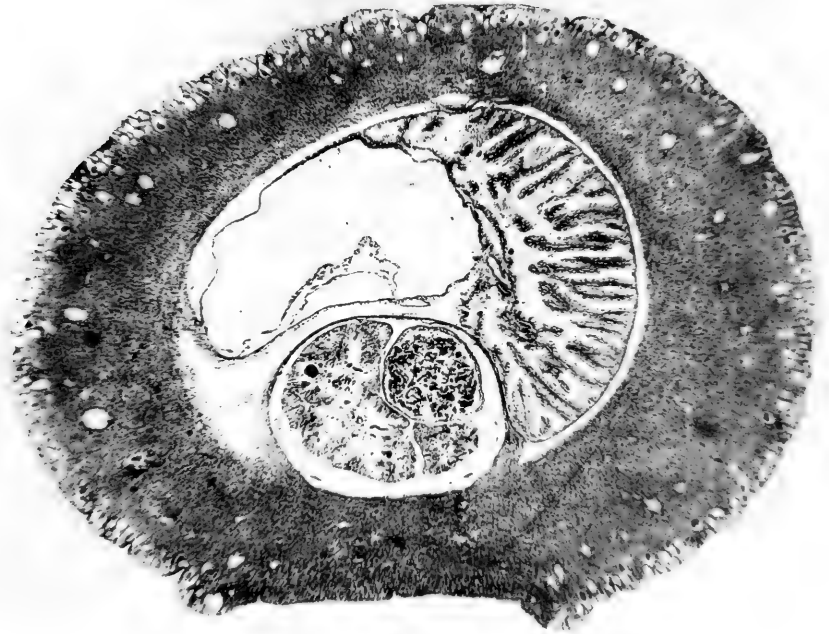
34.



35.



34.



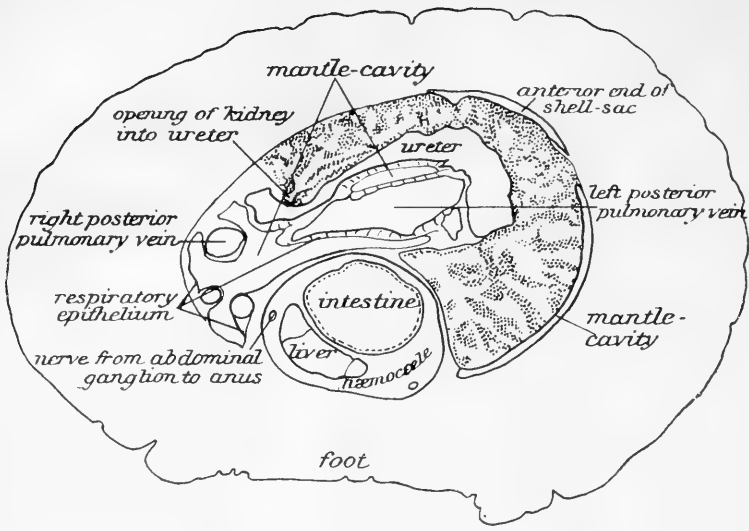
35.

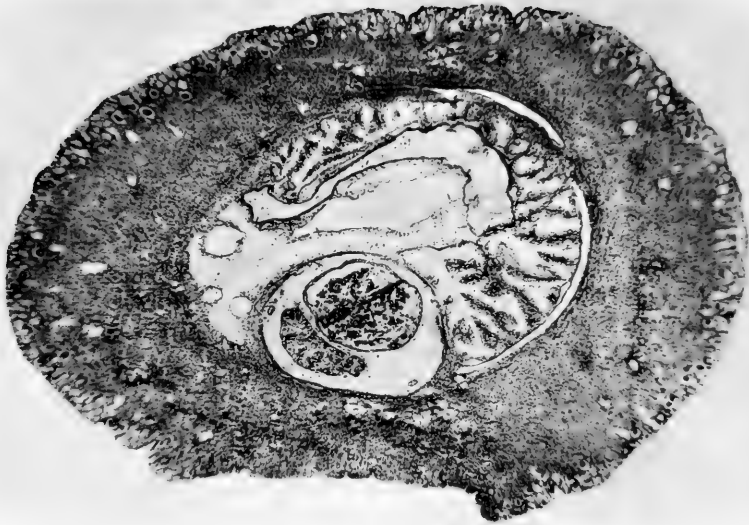
Photo. by Watson.

Collotype.

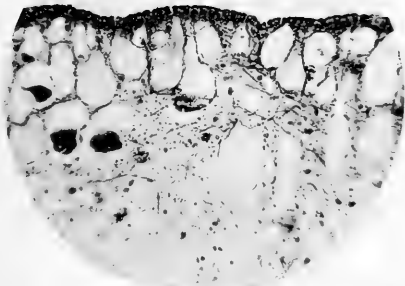
Sections of *Apera dimidia*. $\times 25$.



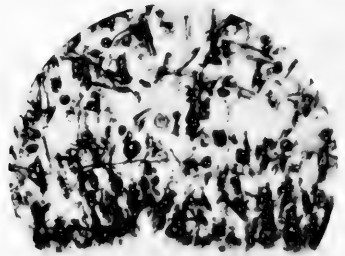




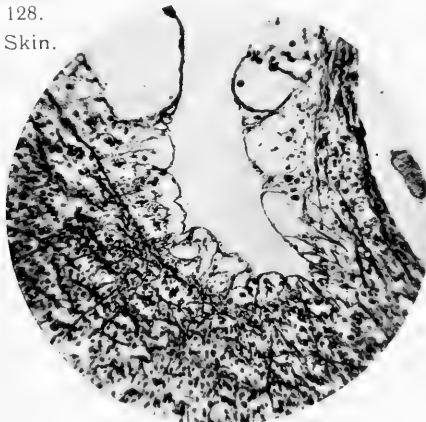
36, x 25.



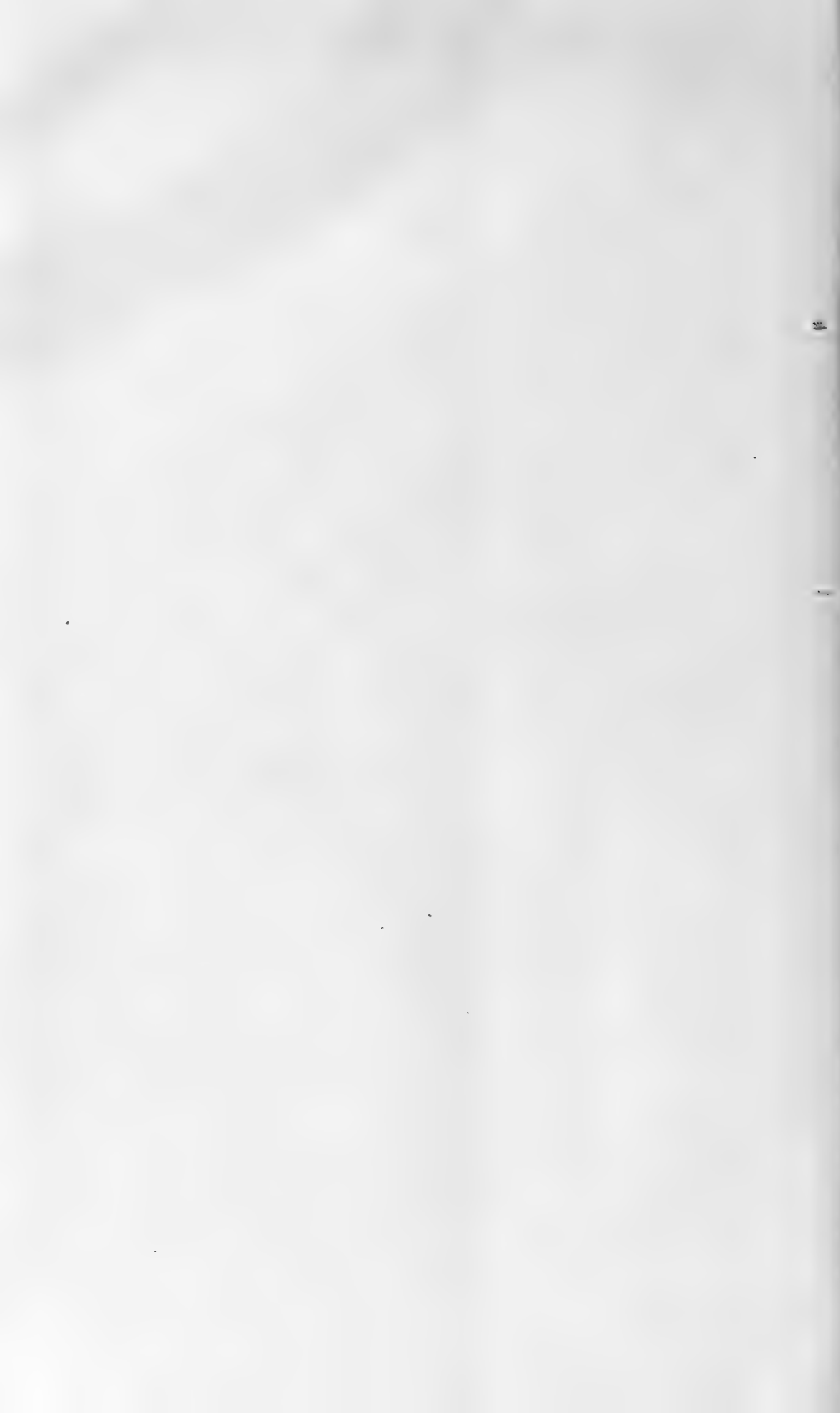
37, x 128.
Dorsal Skin.



38, x 300.
Foot-sole.



39, x 118.
Corner of Lung.



l. ped. gang.

r. ped. gang.

l. pl. gang.

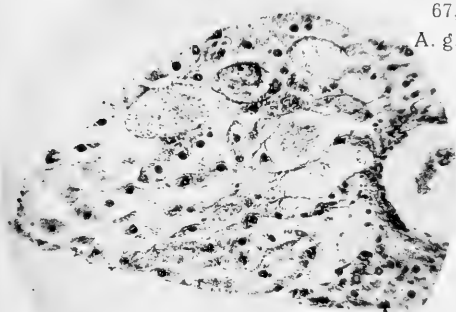
r. pl. gang.

l. par. +
abd. gang.

r. par. gang.



67, x 25,
A. g. rubella.



63, x 114,
A. g. rubella.



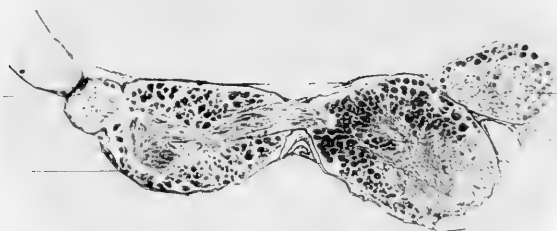
65, x 119,
A. g. rubella.

c.-ped. con.

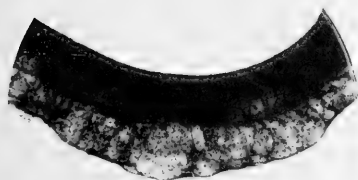
r. pl. gang.

l. ped. gang.

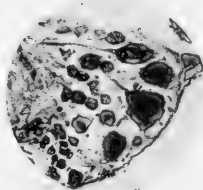
r. ped. gang.



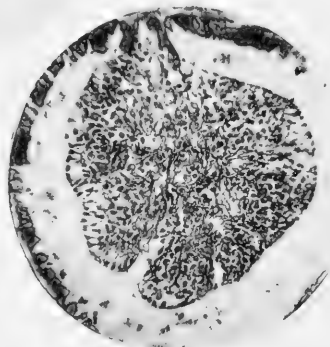
68, x 60. A. dimidia.



64, x 22, A. g. rubella.
Photo. by Watson.

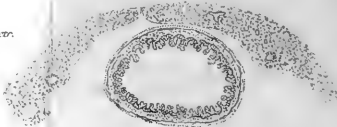
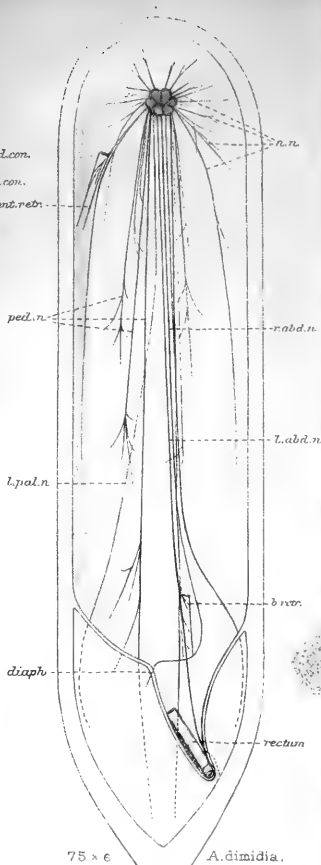
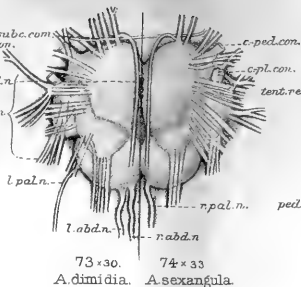
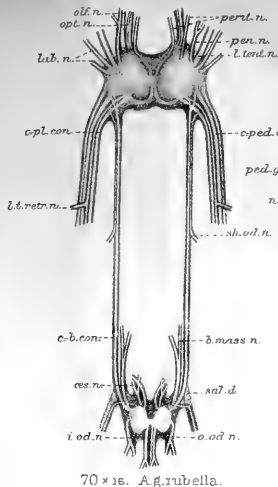


69, x 120, A. dimidia.



66, x 114, A. dimidia.
Collotype.





Watson del.

Huth Londn



80



81



82

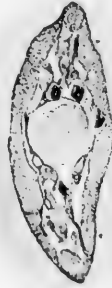


83



84

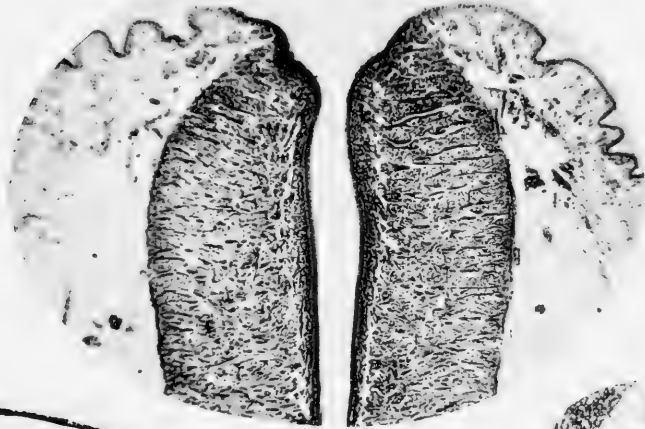
Upper
Tentacle,
× 50



85



86



87. Mouth, × 60



89, × 118.
Radula-Sac.



88, Mouth, × 60



90, × 118,
Odontophoral Support.

Figs. 80-86, 88-90, *A. dimidiata*.

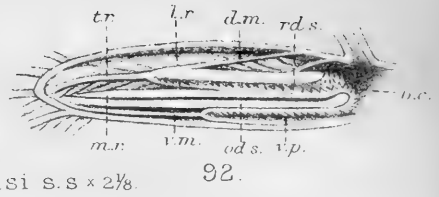
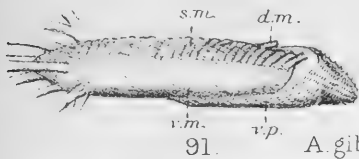
Fig. 87, *A. sexangula*.

Photo. by Watson.

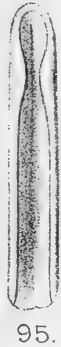
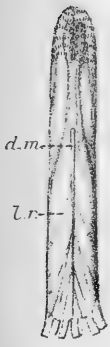
Collotype.

Apera: Sections of Tentacle and Buccal Mass.





A. gibbonsi s.s. $\times 2\frac{1}{2}$.



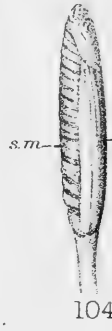
A. g. rubella $\times 2$.



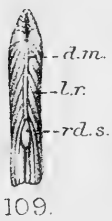
A. g. lupata $\times 3$.



A. parva $\times 5$.



A. dimidia $\times 6$.

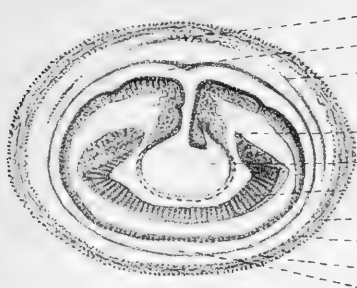


A. burnupi $\times 4$.

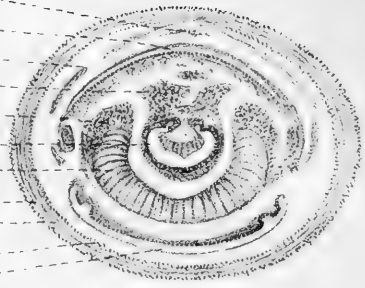


A. sexangula $\times 6\frac{1}{2}$.



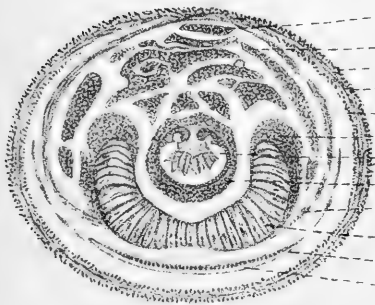


115.

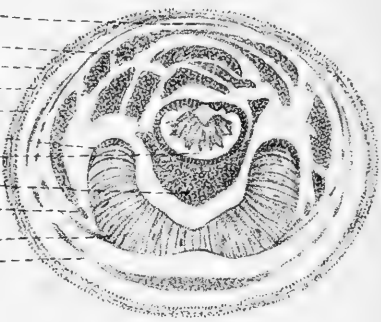


116.

d.m.
b.c.
s.m.
l.r.
f.
r.d.s.
o.d.s.
o.l.
c.m.
i.l.
v.p.

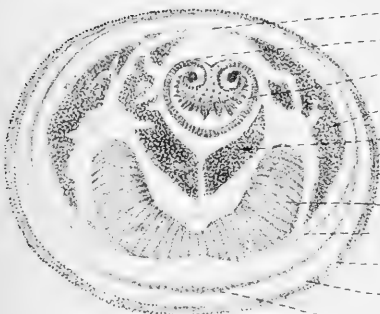


117.

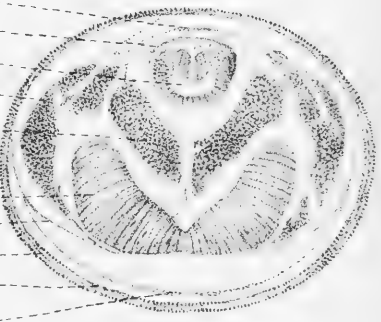


118.

d.m.
l.r.
o.l.
c.m.
i.l.
f.
r.d.s.
m.r.
s.m.
o.d.s.
v.m.
v.p.

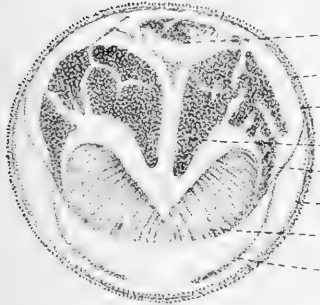


119.



120.

d.m.
c.r.
r.d.s.
l.r.
m.r.
o.l.
o.d.s.
s.m.
c.m.
i.l.
v.m.



121.



122.

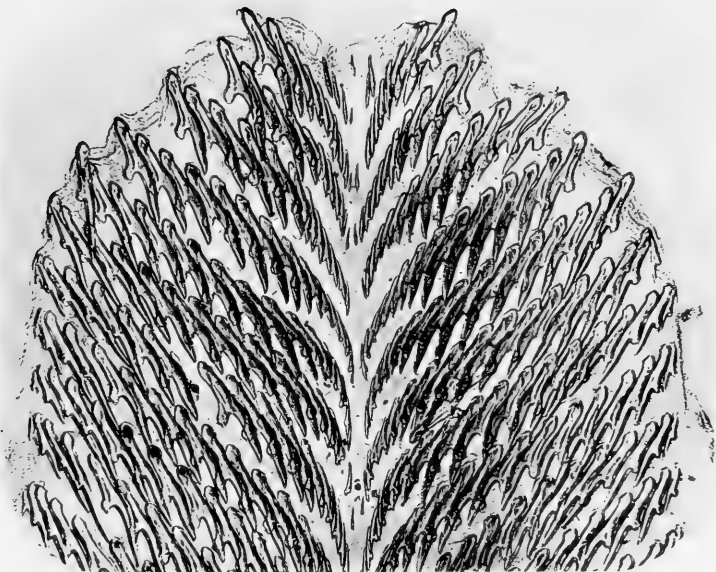
t.r.
o.l.
c.m.
m.r.
l.r.
i.l.
o.d.s.
v.m.
b.a.r.t.

Watson del.

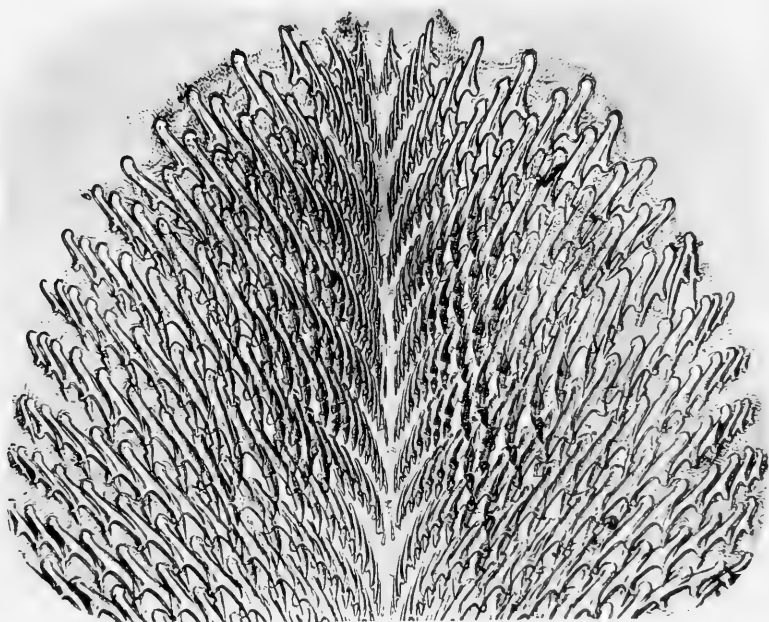
Hath, London.

Apera dimidia: trans.sections through the odontophore.





123, *A. gibbonsi gracilis*, $\times 30$.

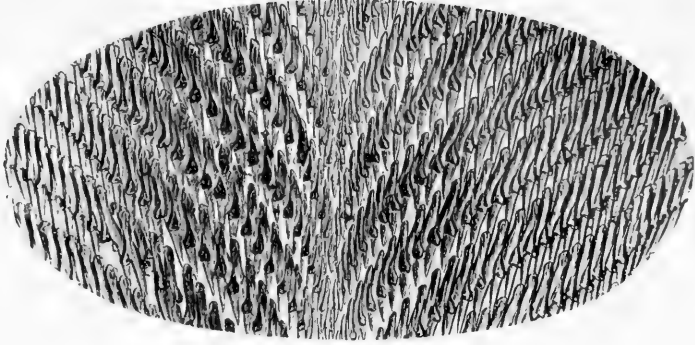


121, *A. gibbonsi lupata*, $\times 30$.

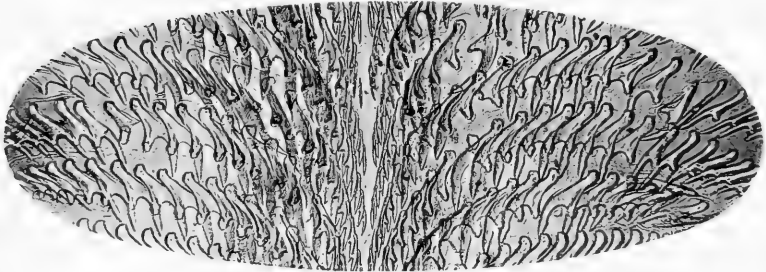
Photo. by Watson

Collotype.

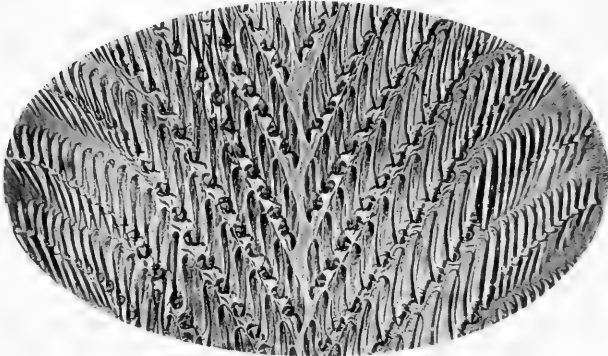
Apera : Radulæ.



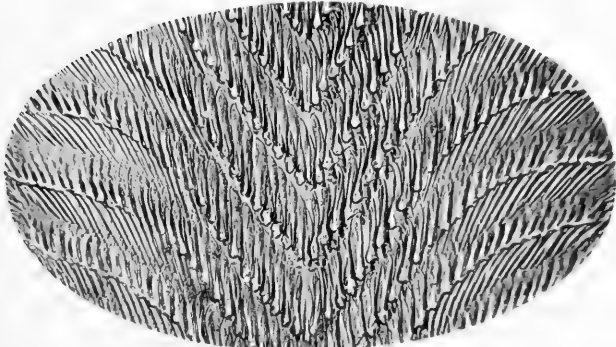
125, *A. gibbonsi* s.s., $\times 25$.



126, *A. g. rubella*, $\times 25$.



127, *A. dimidia*, $\times 125$.

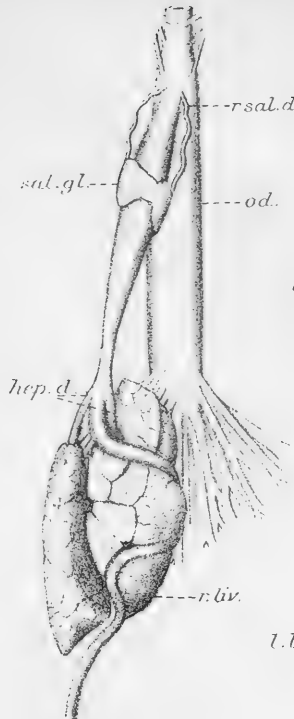


128, *A. burnupi*, $\times 125$.

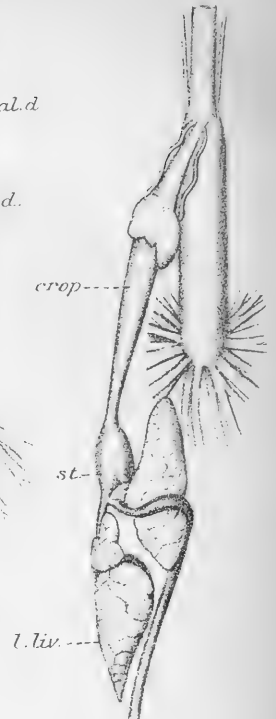




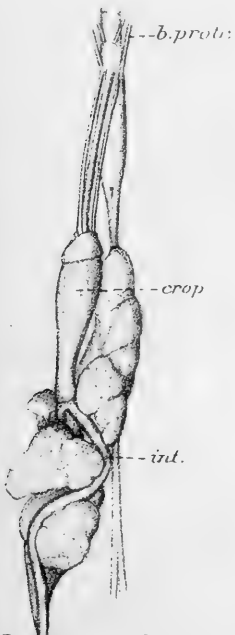
129 x 2 A. gibbonsi s. s.



130 x 1 1/4 A. grubella.

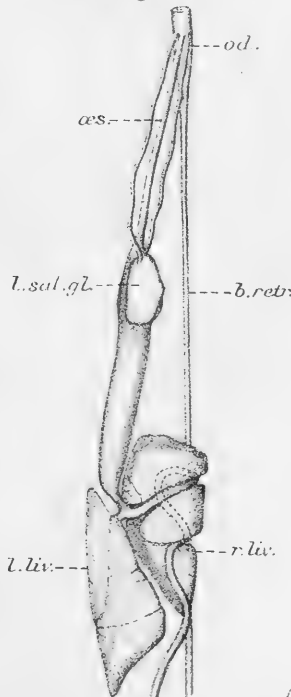


131 x 5 A. parva.

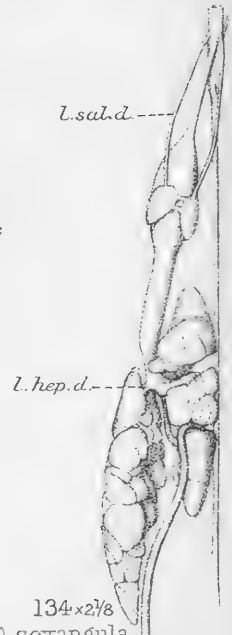


132 x 3 1/2 A. dimidia

Watson, del.



133 x 1 1/2 A. burnupi.



134 x 2 1/8 A. sexangula.

Huth, London

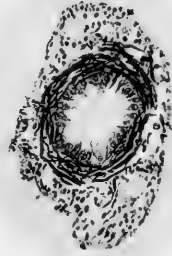
Apera: digestive system.



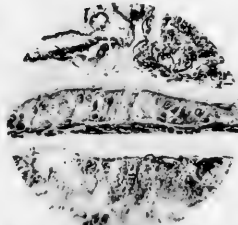
135, x 113,
Œsophagus.



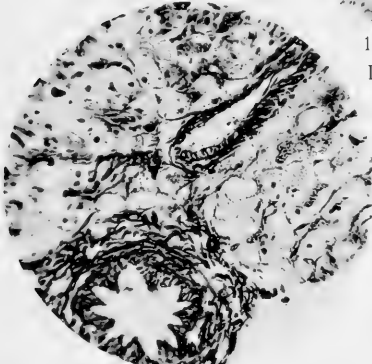
136, x 125,
Rectum.



138, x 135,
Salivary Duct.



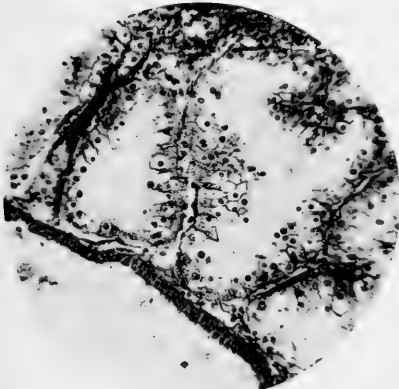
137, x 135,
Intestine.



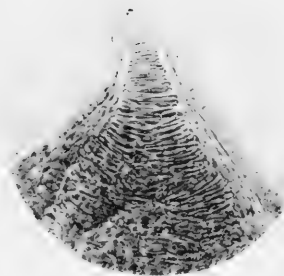
139, x 119,
Salivary Gland.



140, x 119,
Ventricle.



141, x 135,
Kidney.



142, x 194,
Papilla
in Penis.

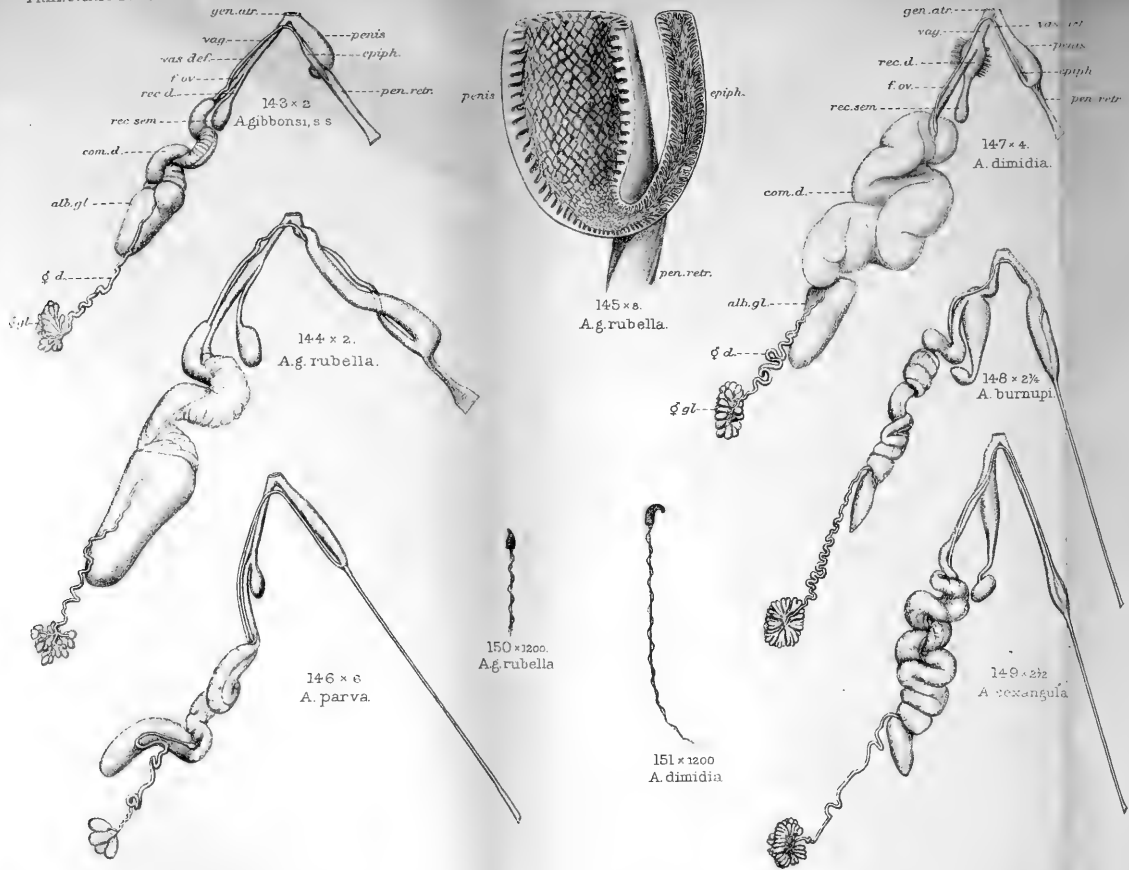
Photo by Watson.

Collotype.

Apera : Histology.

Fig. 135, *A. sexangula* ; 136, 137, 140, 141, *A. dimidia* ; 138, 139, 142, *A. g. rubella*.

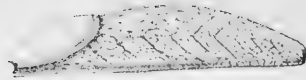








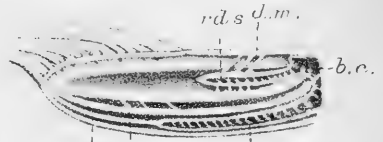
152 x 1.8.



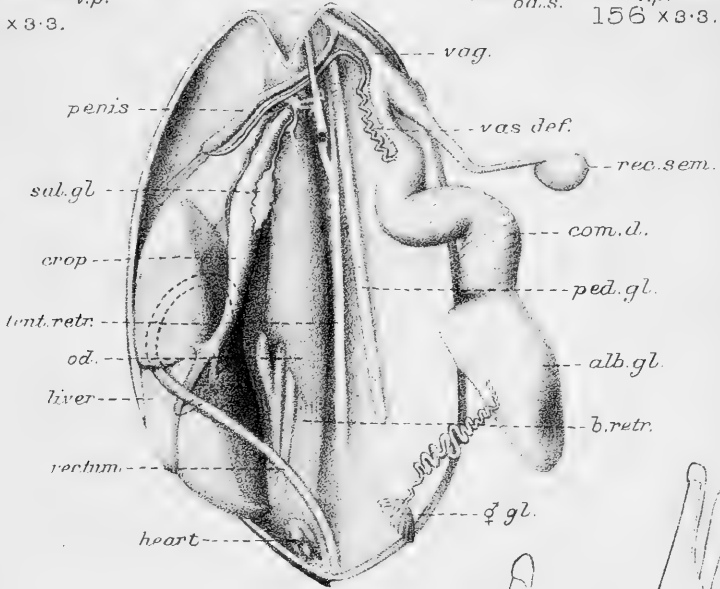
153 x 1.8.



155 x 3.3.



156 x 3.3.



13



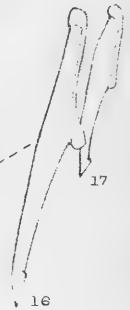
8

154 x 3.4.

157 x 100.



10



17

16



3

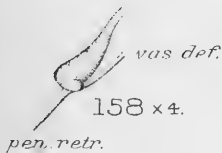
2

1

3

2

1



158 x 4.

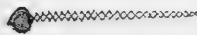
pen. retr.



159 x 4.



161 x 1.5.



160 x 1100.



162 x 1.5.



The Parthenogenetic Tendency in the Moth, *Melanocera menippe* (Westwood).

By

Ernest Warren, D.Sc.(Lond.).

CERTAIN attempts have been made recently at the Natal Museum to cross several species of Saturniid moths for the purpose of investigating the relationships of hybrids to the parents. It was hoped that if healthy hybrids could be raised it might be possible to cross them among themselves and to discover if any definite segregation of characters occurred. The experiments were effectually closed in connection with the species selected owing to the fact that crossing did not readily occur, and no healthy offspring were secured. Nevertheless, results of some interest were obtained.

It was found that in one of the species, *Melanocera menippe* (*Westwood*), there is a slight, but definite, tendency for parthenogenesis. In this species there occurred some indication of an increased parthenogenesis induced by the male of another species. In a second case the male of one species certainly appeared to influence the female of another, but it was not possible to judge whether this was induced parthenogenesis or incipient hybridism.

Material.—In the Black Wattle (*Acacia mollissima*) plantations of Natal the moth *Gynanisa maia* (*Klug*) is at some seasons very abundant, and the caterpillar is capable of doing considerable damage to the trees. During last season, October, 1913, to March, 1914, the moth was very common in the environs of Pietermaritzburg, and Mr. H. F. Pentland, manager of the town wattle plantations, very kindly caused about 130 pupæ to be collected for me from the bases of the trees. The pupæ were obtained in the month of July.

I am much indebted to Mr. C. B. Hardenberg, Government Entomologist, Natal, for a supply of pupæ of *Melanocera menippe* bred at New Hanover, Natal, and for other specimens; also for kind assistance and co-operation.

The larvæ of *menippe* are found on *Ficus cordata* *Thb.*, and Mr. Hardenberg's caterpillars, obtained from the eggs of several moths, were fed on the same plant. With a view to discover a potential wattle pest Mr. Hardenberg experimented with the wattle foliage and found that the older larvæ would eat it, but that the newly hatched caterpillars were unable to do so. About fifty newly hatched larvæ were supplied with leaves of the wattle; some refused to feed, while others nibbled a little, but all the individuals died in the course of several days.

The change of environment due to domestication or to the slightly different climatic conditions of Pietermaritzburg and New Hanover would appear to have, however, an influence on the larvæ in this connection, as the following experience indicates.

On pairing a male and female *menippe*, obtained from the pupæ bred by Mr. Hardenberg, fertile eggs were laid, and the larvæ on hatching were mostly placed on the leaves of *Ficus cordata*. A few (some seven in fact) were placed on the leaves of the Black Wattle; but from Hardenberg's experiment it was confidently expected that they would refuse to feed. On the contrary, however, those placed on the wattle grew much more quickly and appeared healthier than those on *Ficus cordata*. Of sixty-three larvæ placed on *Ficus* forty-four gradually died in the course of three weeks, although they were supplied with both young and tender leaves, and with older leaves, and were carefully attended to. The remaining nineteen scarcely grew at all, and, as it was anticipated that all would die, the food was changed to wattle. In the next few days eight died, but the remaining eleven soon assumed a more healthy aspect and began to grow. At the present time (Nov., 1914) these eleven specimens are in a perfectly healthy condition, but not

so large as the individuals which have been fed on wattle from the first.

Of the seven specimens placed on the wattle at the time of hatching none have died.

The experiment should be repeated, but the observations, as far as they go, show the adaptability of the larva and the ease with which the moth might become a wattle pest.

In the following table is recorded the fate of the pupæ of the wild specimens of maia and the bred specimens of menippe.

Species.	No. of specimens.	Males.				Females.			
		No.	Emerged.	Failed to emerge through disease, etc.	Stung by a large ichneumon.	No.	Emerged.	Failed to emerge through disease, etc.	Stung by a large ichneumon.
Maia	128	60	40 ¹	17 ²	3	68	38 ³	24 ⁴	6
Menippe	25	11	10	1 ⁵	0	14	14	0	0

¹ Three individuals greatly deformed. ² One individual fully formed in pupa-case.
³ One individual deformed. ⁴ Four individuals fully formed in pupa-case.
⁵ Fully formed in pupa-case.

In comparing these two series it will be at once obvious that the bred specimens had been shielded from the adverse influences which proved fatal to a large percentage of the wild specimens.

Out of 128 wild pupæ of maia fifty (39 per cent.) failed to produce moths for one reason or another, while with the twenty-five bred pupæ of menippe only one individual failed.

On opening the pupæ from which imagos did not emerge it was noticed that generally the contents had mostly dried, and it was clear that the development of the moth had not proceeded to any considerable extent. The contents were, as a rule, thoroughly impregnated with a fungus; but it is not known whether the fungus was the cause of the death of the pupa, or whether it appeared later. Quite possibly the cause of death was some bacterial disease. In any case in Natal the pupæ of Saturniid moths die in great numbers in this way,

and the percentage of deaths is sometimes much larger than in the case of maia cited above.

In this connection a short digression may be allowable. Several years ago some forty full-grown, wild, and apparently healthy caterpillars of *Nudaurelia belina* were collected and placed in cages with earth. Pupation occurred in a normal manner, but only four moths were ultimately obtained. The majority of the pupæ dried up without any appreciable development of the moth. The question as to the actual cause of death requires investigation, but the present point of interest to note is the great natural mortality which occurs, and therefore the absolute necessity for great reproductive power in the species.

An analogous case was observed with the so-called Army Worm, which is the caterpillar of a Noctuid, *Caradrina exigua*. The caterpillar feeds on grasses, but it is moderately omnivorous, and will consume vegetables and other plants. In the middle of May, 1914, a plague of these caterpillars occurred in certain areas of Pietermaritzburg and its environs. From a piece of veld about half a mile from the town 140 caterpillars were collected from the grasses. These were mostly full-grown and were on the point of pupating. They were placed in large wooden boxes with a layer of soil at the bottom, and were supplied with food in case some of the caterpillars had not quite finished feeding. Care was taken that the food supplied was dry, as the bad effect of wet food is well known. Ninety-two of the caterpillars died without pupating, and became covered with a whitish mould; the remainder burrowed very superficially into the ground and duly pupated. Of these only nineteen emerged as moths, nine had been stung by a large dipteran parasite, and the remainder (twenty) of the pupæ dried up. Thus in this case only about 13 per cent. of the full-grown larvæ produced moths.

The only other available Saturniid moth in addition to the specimens of wild maia and bred menippe for use in these breeding experiments were four wild male specimens of *Nudaurelia belina* caught in Pietermaritzburg.

To recapitulate, the moths used in these experiments included forty male and thirty-eight female *Gynanisa maia*, ten male and fourteen female *Melanocera menippe* and four male *Nudaurelia belina*.

Pairing of the Moths.—The pupæ were all carefully sexed and buried under soil in muslin cages which were placed in a well ventilated shed. At the advent of the wet season the soil was occasionally damped.

The imagos of *maia* began to emerge first (September 17th, 1914), and before any of those of *menippe* had appeared about fifty of the *maia* moths had become decrepid. The last moth to emerge appeared on November 5th, and it was deformed. The *menippe* began to emerge on October 6th, and the last moth emerged on October 25th.

Only fresh moths were used for pairing, and since it frequently happened that fresh individuals of opposite sex of the two species were not available at one and the same time the number of possible pairings was greatly reduced.

The total number of pairings that could be effected were:

- A. 5 (*menippe* ♀ × *maia* ♂),
- B. 1 (*menippe* ♀ × *menippe* ♂),
- C. 7 (*maia* ♀ × *menippe* ♂),
- D. 2 (*maia* ♀ × *belina* ♂),
- E. 1 (*menippe* ♀ × *belina* ♂),

leaving 7 unpaired ♀ *menippe* and 29 unpaired ♀ *maia*. The paired moths were placed in cubical muslin cages of a capacity of about $1\frac{1}{4}$ cubic feet. A small branch of wattle and a glass pot of diluted honey were placed in each cage. It appears that the copulation of Saturniid moths occurs at night, and in no case was it observed in these experiments. From the account to be given below of the development of the eggs laid by the females it would appear that copulation occurred in at least four of the pairs *menippe* ♀ × *maia* ♂, in the pair *menippe* ♀ × *menippe* ♂, and in one of the pairs *maia* ♀ × *belina* ♂. Whether it occurred in any of the other pairings is more doubtful.

Unpaired *Maia*.—The unpaired *maia* females laid eggs

freely. These eggs usually began to shrivel in about twenty days. If cut open about fourteen days after laying, the contents were seen to consist of a fluid, greenish-yellow, homogeneous yolk. In about five weeks the yolk had contracted and dried, but as a rule it did not appear to decompose or turn black. The number of eggs laid by an unpaired female varied from about 100 to 200, with a mean of about 150. Eggs laid by the unpaired moths were cut open daily and examined with a hand-lens magnifying 20 diameters, but no trace of development or segmentation could be detected. The unpaired female died in about eleven days, and the unpaired male in about seven days.

Unpaired Menippe.—The behaviour of unpaired menippe females was markedly different. There was the greatest reluctance to lay eggs, and one individual died in about twelve days without laying any. The eggs of menippe are of somewhat larger size than those of maia, and the number produced by a female is about 130. The average number laid by unpaired menippe did not exceed thirty-two as against 150 of maia.

The unpaired menippe remained phlegmatic and lived about as long as the paired moths. On dying, the abdomens were mostly filled with unlaidd eggs. A number of these eggs were opened and examined some five weeks after the death of the insect. The egg-shells were thin and not so hard as those of the laidd eggs. Generally the yolk was still fluid and apparently fresh and normal in character, but no trace of development could be detected.

The contents of the laidd egg were of a bright yellow colour, and in the majority of unfertilized eggs the yolk gradually dried, and the egg-shell became somewhat indented in the course of four or five weeks. The yolk, as a rule, did not appear to decompose in any way. On one occasion artificial fertilisation was attempted. The spermatophores removed from a fresh male maia were rubbed over the eggs removed from a recently emerged female menippe. In about three weeks the eggs began to shrivel and darken, and on opening

them the yolk was found to be very fluid, blackish, and decomposed; thus the condition of the yolk was in marked contrast with that of normally laid unfertilised eggs.

The eggs obtained from six unpaired female menippe, after they had been laid for seven weeks, were cut open with scissors and examined with a strong hand-lens. In a small percentage of the eggs distinct traces of development could be detected. The condition of the egg as seen by a lens may be indicated by numbered stages.

Stage 1, when there is no obvious development.

Stage 2, when there is some sign of a blastoderm.

Stage 3, when there is an obvious embryo and a few hairs may be visible.

Stage 4, when the development of the embryo is considerably advanced and many hairs are visible.

Stage 5, when the embryo actually hatches.

Ordinary fertilised eggs of menippe hatch in about three weeks after being laid. In the case of the pairing of menippe ♀ × menippe ♂, which occurred on October 22nd, the eggs hatched on November 16th.

With regard to the eggs laid by unpaired female menippe it was quite clear that the maximum development possible had occurred at the time of examination, since considerable desiccation had taken place, and a few of the eggs were quite dry.

In the accompanying table the details with respect to the eggs of the unpaired menippe are given.

Development.	Eggs laid by six specimens of unpaired menippe.						Total.	Per-centage
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.		
Stage 1.	32	37	24	25	20	43	181	93·8
Stage 2.	1	1	1	0	2	3	8	4·1
Stage 3.	1	1	1	0	0	1	4	2·1
Stage 4.	0	0	0	0	0	0	0	0
Stage 5.	0	0	0	0	0	0	0	0
Totals . . .	34	39	26	25	22	47	193	100

The four embryos in Stage 3 possessed a few unmistakable hairs.

Thus in 193 eggs laid by six unpaired females 4·1 per cent. exhibited some sign of development, and 2·1 per cent. reached a further stage in the formation of an embryo.

There is, therefore, a slight, but quite definite, parthenogenetic tendency in *menippe*.

We have seen above in the case of *maia* that the unpaired moths laid eggs freely, and an average number of about 150 was produced. After the eggs had been laid some four weeks about 150 eggs from a number of different moths were opened in addition to those examined daily, but no trace of development could be detected. Thus no parthenogenetic tendency was demonstrated in this species.

Menippe ♀ × *Maia* ♂.—We now return to the paired moths (see list, p. 273, A), and the accompanying table gives the necessary details.

Development.	Eggs laid by 5 paired females, <i>menippe</i> ♀ × <i>maia</i> ♂.					Total.	Percentage (including No. 6).	Percentage (excluding No. 6).
	No. 3 (paired Oct. 9th).	No. 5 (paired Oct. 9th).	No. 6 (paired Oct. 13th).	No. 8 (paired Oct. 23rd).	No. 13 (paired Oct. 18th).			
Stage 1	45	84	128	37	101	395	61·3	51·9
Stage 2	45	20	2	8	68	143	22·2	27·4
Stage 3	17	27	0	5	10	59	9·2	11·5
Stage 4	12	30	0	3	1	46	7·1	8·9
Stage 5	0	1	0	0	0	1	·1	·2
Totals.	119	162	130	53	180	644	99·9	99·9

On comparing the above two tables it will be seen at once that with the exception of the pair No. 6 there is very great increase in the degree with which development occurred, and also in the number of eggs in which such development was present. This is shown in the accompanying comparative table.

♀ menippe.	Total.	Stage 1.	Stage 2.	Stage 3.	Stage 4.	Stage 5
Eggs of 6 unpaired moths	193	181	8	4	0	0
Eggs of 5 paired moths	644	395	143	59	46	1

It may be noticed that (1) the average number of eggs laid by the unpaired menippe was only thirty-two, but by the paired moths it was 129; (2) with unpaired moths the percentages of eggs reaching the 2nd, 3rd, 4th, and 5th stages of development were 4·1 per cent., 2·1 per cent., 0 per cent., and 0 per cent. respectively; while with the paired moths the percentages were about 22 per cent., 9 per cent., 7 per cent., and 0·1 per cent. respectively.

On examining these two series it was believed at first that the eggs of the paired moths had been duly fertilised with the exception of those of No. 6, in which the amount of development exhibited by the eggs was almost negligible. It was expected that the single larva which hatched would exhibit on close examination characters intermediate between those of menippe and maia.

The eggs remaining in the abdomen of some of the paired moths were examined five weeks after death. In No. 3 (see table, p. 276) sixteen eggs were found; one close to the external aperture contained an embryo in Stage 3, three were in Stage 2, and twelve showed no sign of development. The twelve eggs were placed anteriorly in the abdomen.

In No. 5 three anteriorly placed eggs were found, and these showed no sign of development.

In No. 13 two eggs were in Stage 2, and thirty-six showed no sign.

The eggs which occurred in the middle and front regions of the abdomen were thin-shelled; and in some cases the yolk was dry, but in an undecomposed condition.

It is possible that in No. 3 the eggs which exhibited development had come into contact with the stimulating semen of the male in the body of the female, although they were not actually laid.

The Larva.—In the case of No. 5, where one caterpillar hatched, the moths were paired on October-9th and the larva hatched on November 16th, thus the development occupied a period of thirty-eight days, while the time taken by a batch of pure-bred eggs was only twenty-five days, a difference of thirteen days. Strictly speaking, about four days should be deducted from the periods of thirty-eight and twenty-five days as representing the time between pairing and the actual laying of the eggs.

On hatching, the young larva was singularly lifeless and languid. It was carefully placed on the leaf of *Ficus cordata*, but during the first day it refused to feed. Subsequently it fed to a slight extent, but no appreciable growth occurred, and the creature died on November 26th, living just ten days altogether.

The larva passed but very few faecal pellets, perhaps seven or eight altogether, and these did not appear to be normally black, but they were greenish brown and irregularly shaped. It would seem that the digestive functions were not normal.

In general aspect the larva was indistinguishable from that of a pure-bred menippe, but on closer examination it was seen that it was not quite normal. Some of the hairs were less black than in the majority of young menippe larvæ that I have examined; also several of the tubercles bearing the long hairs of the body were yellowish and translucent instead of being black and opaque. The lateral, roundly triangular, black, raised areas at the extreme posterior end of the body were rather smaller than normal, and the one on the right hand side was only black around the periphery, the central portion being pale. The posterior right thoracic leg was pale brown instead of dark brown or black. The median dorsal raised area over the anus, which bears tubercles and hairs, did not project posteriorly as far as usual, owing to its antero-posterior median axis being exceptionally short. In addition to these peculiarities the penultimate segment of the body and the segment in front were not separated off from one another on the right side of the body, and on this side

where there should have been two lateral rows of tubercles there was only one. The outer lateral surface of the fourth right hand false foot was abnormally swollen and not marked off from the body in the usual manner, and the normal pigmented bar on the side of this foot was absent.

Thus, this larva was asymmetrical, there being some deficiency in pigmentation, especially on the right hand side, and some deformity of the body on the same side.

Comparison of Larvæ.—It will be seen, however, that the differences between this larva and a normal larva of *menippe* do not appear to connect in any way the former with the caterpillar of *maia*.

The larvæ of some of the Saturniid moths are wonderfully alike at the first instar, but there are certain well-marked differences between the young caterpillars of *maia* and *menippe*.

(1) In *maia* the general ground-colour is yellowish-brown, with a wide hoop-like blackish band in the middle of the segment. In *menippe* the general colour is reddish-brown, with sometimes a faintly defined darker transverse band in the middle of the segment. In the present offspring the general coloration was like that of *menippe*, but it tended to be somewhat paler.

(2) In *maia* the tubercles on the body are bright yellow, in *menippe* they are black. In the present offspring they were mostly black, but three were pale and two were black at the base and pale above.

(3) In *maia* the hairs are yellow and translucent. In *menippe* there is some variation in this matter, more usually they are black, but some tend to be translucent and brown particularly on and around the head. In the present offspring a considerable number were translucent and light brown, especially towards the apex of the hair.

(4) In *maia* the median dorsal posterior raised area above the anus carries large tubercles and a number of equidistant small tubercles along the posterior margin; these latter carry one hair apiece. In *menippe* the area is relatively larger

and projects further back over the anus, the tubercles are smaller, and the little marginal tubercles are fewer and not regularly arranged as in maia. In the present offspring the area was not normal in shape, and perhaps on the whole in general outline it was intermediate between that of maia and menippe. The condition of the tubercles and hairs, however, was in no way intermediate; it was rather peculiar, but obviously it was a modification of the menippe type and had no connection with the maia arrangement.

The fact that the arrangement of the tubercles and hairs in no way resembled that in maia renders it extremely probable that the more or less intermediate shape of the area was a quite accidental occurrence, due to the slight deformity of the posterior portion of the body.

(5) The lateral raised area at the sides of the last false foot in the present offspring was like that of menippe and not like that of maia in general outline and arrangement of hairs, but it was rather small. On the right side of the body, as already remarked, the area was yellowish except along its margin which was dark brown.

(6) In maia the head is relatively narrower than in menippe. In the present offspring the head resembled that of menippe.

(7) In maia the mean lengths of first, second, and third joints of the true walking legs are in the proportions of 100 : 84 : 48, in menippe 100 : 94 : 70; in the present offspring the proportions did not differ appreciably from those of menippe; they were 100 : 105 : 74, thus they showed no hint of a shortened terminal joint, which is characteristic of maia.

(8) In maia the terminal claws of the thoracic legs are brighter in colour and considerably larger than in menippe, while in the present offspring they did not differ in the least from those in menippe.

(9) In all other characters that were observed no differences could be detected between the present offspring and the young larvæ of menippe.

On the whole it may be said that no influence of the male

moth could be definitely detected in the offspring. There was a certain deficiency of pigment, which, however, was doubtless associated with the unhealthy state of the larva, and was not due, as was at first thought, to the influence of the male. In all the more important characters the present larva was so completely menippe and not maia in character that it is extremely doubtful if the offspring can be regarded as a genuine hybrid.

Pseudogamy.—We have already seen that the presence of the male maia had an undoubted influence on the female menippe; it caused the female to lay a good supply of eggs, and these exhibited a greatly increased power of development. The only obvious explanation of this rather remarkable result would appear to be that copulation of the moths actually took place; and that the semen from the male exerted a stimulating action on the normal, weak parthenogenetic power without real fertilisation, or fusion of male and female pronuclei, occurring. This has been termed pseudogamy, and it is the explanation offered by Hans Przibram¹ in the case of the artificial application of the semen of *Mantis religiosa* to the eggs of female *Sphodromantis bioculata*. Some of the eggs were rendered fertile, but the offspring appeared to be entirely like the mother, and there was no direct influence from the male.

In the present example it is to be regretted that there is no cytological evidence to support this view, but careful consideration of the facts renders any other supposition still more difficult to accept.

If the offspring was a true hybrid the almost complete absence of any of the male characteristics is totally unlike that which is found in the vast majority of the hybrids between distinct species, since these so usually tend to be more or less intermediate between the two parents.

A possible explanation with respect to the absence of a re-enforced parthenogenetic tendency in the pair No. 6 (table,

¹ Przibram, Hans, 'Experimental Zoologie, Phylogenese,' p. 25, 1910.

p. 276) is that no copulation occurred, but that the close proximity of a male nevertheless influenced the female to lay a good supply of eggs. These eggs simply exhibited the normal amount of parthenogenesis inherent in the eggs of this species. The parthenogenetic power, like any other character, would be expected to vary to a certain extent from individual to individual; but the laws of probability are against the supposition that the generally much increased parthenogenesis, and the freedom of egg-laying observable in the paired moths arose purely accidentally through the chance selection of such individuals, while none of the unpaired individuals possessed these characters in a high degree. It may be added that the further evidence that will be adduced from some of the other pairings is entirely against such an explanation.

A few observations on the remaining pairings that were effected may be made here.

Menippe ♀ × *Menippe* ♂.—The moths (list, p. 273, B) were paired on October 22nd, 1914, and 121 eggs were laid. The majority of the eggs were hatched on the morning of November 16th, the same day as that on which the parthenogenetic individual emerged. It was a damp, warm morning. The eggs of one of the batches laid by the female did not duly hatch. In this batch there were forty-six eggs. These were opened and examined, and only one showed any sign of development. Of the remaining seventy-five eggs there were twelve irregularly scattered through the different batches which did not hatch. On opening them eight showed no sign of development and four contained well-formed dead embryos.

The batch of forty-six eggs which did not hatch were presumably laid before copulation, and the partial development which occurred in the case of one egg was due to the normal parthenogenesis.

Maia ♀ × *Menippe* ♂.—In the case of these seven pairings (see list, p. 273, c) it is less clear that copulation occurred, and, if it did, the resulting effect was much less marked than in the reciprocal cross of *menippe* ♀ × *maia* ♂. Whether

paired or not the female of maia lays freely, but more eggs were, on the whole, laid by females placed with males.

It was noticed that the eggs of one of the paired moths were very exceptionally slow in shrivelling, and on this account it was thought that possibly copulation had occurred and more or less normal development was taking place. There was very little shrivelling in five weeks after laying, although unfertilised eggs are obviously indented after a period of fourteen to twenty days. After the eggs had been laid seven weeks, shrivelling had become more marked, and seventy-five eggs were opened and examined with a hand-lens. In eighteen eggs a whitish granular lump or lumps on the periphery of the yolk could be seen. An examination with the microscope showed that these consisted chiefly of dense clusters of needle-shaped crystals. The crystals dissolved in 50 per cent. hydrochloric acid. They doubtless arose by the concentration of the salts in solution in the egg through evaporation, and their formation appears to depend largely on the slowness of evaporation. In rapidly drying eggs the crystals were not found. In 150 eggs from several unpaired maia females only one egg was found containing such crystals.

The microscopic examination of the contents of the eggs which so successfully resisted desiccation revealed no definite sign of segmentation.

Without much more investigation it cannot be said whether the formation of such crystals was in any way connected with an unsuccessful attempt at development after copulation. An egg stimulated by contact with the male fluid, even without actual fusion of nuclei, might be able conceivably to resist desiccation much better than an unstimulated egg. The power of resisting desiccation is undoubtedly a vital act not directly explainable in ordinary chemical and physical terms.

With respect to the remaining six paired moths, about fifty eggs from each—that is, about 300 in all—were examined, and only six exhibited any obvious crystal formation, and even in these it was less marked than in the case above described. These eggs began to shrivel in about twenty days.

The formation of such crystals also occurred in eggs laid by a female maia paired with a male belina, as will be seen in the account given below.

Maia ♀ × belina ♂.—In one of the pairings a female maia was placed with a captured, wild, fresh-looking male belina (see list, p. 273, D). There is here more evidence that copulation occurred, and that the semen exerted an influence on the eggs of the female maia. The moths were placed together on October 16th, and the female soon began to lay very freely. Two hundred and one eggs were laid, and these were very slow in shrivelling. On November 10th some of these eggs were examined, and on December 3rd, when it was obvious that hatching would not take place, all the remaining eggs were opened. Altogether forty-eight (i. e. about 24 per cent.) showed with a hand-lens an opacity on one side of the yolk. Examination with the microscope proved that a certain amount of segmentation of the yolk had occurred; large rounded or polygonal cells crowded with yolk-globules were present. On treatment with weak methyl blue, a deeply staining blue spot became defined in each area in the course of a day, and there appears little doubt that this was the nucleus. There was not much difference in the condition of the eggs on November 10th and on December 3rd, except that on the latter date drying was taking place and death of the large yolk-cells was occurring. The nucleus had become less defined and was of inflated size and of irregular shape. Portions of the cells had apparently disintegrated into an opaque, white, finely granular substance. In some of the eggs clumps of needle-shaped crystals were found, and they were quite the same as those mentioned above, and occurred among, but apparently not inside, the yolk-containing cells.

In the case of the second pairing, a female maia was placed with a very shabby, wild male belina. The male soon died. Fairly numerous eggs were laid, but these shrivelled rather quickly and there was no sign of development. Doubtless the male was spent and no copulation took place.

Menippe ♀ × belina ♂.—Only a single pair was available (see list, p 273, E). There was probably no copulation, or, at any rate, there was no effect; the moths died in the normal time, and no eggs were laid.

Summary.—To summarise the general differences observed in eggs laid by unpaired moths and paired moths, the accompanying table is instructive.

Moths.	Unpaired menippe ♀ (6 individuals).	Menippe ♀ × maia ♂ (5 pairs).	Unpaired maia ♀ (9 individuals).	Maia ♀ × menippe ♂ (7 pairs).	Maia ♀ × belina ♂ (1 pair).	Maia ♀ × belina ♂ (oldshabby male) (1 pair).
No. of eggs examined.	193	644	300	375	201	170
Percentage showing some development	6.2	38.7	0	0	24.0	0

Gerstaecker¹ gives a list of species of moths in which parthenogenesis has been observed:

- Fam. Sphingidæ — Sphinx, Smerinthus.
- Fam. Euprepiadæ — Euprepia.
- Fam. Saturniidæ — S.-fam. Saturniinae — Telea.
- Fam. Bombycidæ — Gastropacha, Bombyx.
- Fam. Liparidæ — Liparis, Orgyia.
- Fam. Psychidæ — Psyche.
- Fam. Tineidæ — Solenobia.

Melanocera menippe belongs to the family Saturniidæ, and the sub-family Sphingicampinæ, in which the larva pupates underground and does not form a silken cocoon as in the sub-family Saturniinae.

It is interesting to note that it is just in these and in related families that hybridism between different species has been most often observed.²

¹ Bronn, H. G., 'Klass. u. Ord. d. Thier-Reichs, Arthropoda,' vol. v. p. 166, 1866-79.

² See Przibram, Hans, 'Experimental Zoologie-Phylogenese,' pp. 41-51, 1910.

The view that a parthenogenetic tendency is favourable to hybridism is also suggested by the fact that hybridism appears to be especially easy in Echinoderms,¹ and it is in this group that the parthenogenetic tendency is strongly marked and artificial parthenogenesis can be most easily effected. Pseudogamy, or the stimulation of parthenogenesis by the semen of the male, without real fertilisation, is, in the case of insects, a phenomenon based, as far as I am aware, on indirect evidence, and not on actual cytological observation; although in Echinoderms some evidence of this nature has been adduced.

In the observations above described there is undoubtedly strong evidence that the females which were placed with the male of another species behaved differently than when unpaired, and the eggs were markedly affected.

In the case of *menippe* ♀ × *maia* ♂, the single larva which hatched was so fundamentally similar to a normal *menippe* larva, that it would appear extremely improbable that it was a hybrid arising from real fertilisation. The only other alternative view which appears admissible is that copulation occurred and that a spermatozoon entered the egg and stimulated the normal parthenogenetic power without actual fusion of the male and female pronuclei, or, possibly, the mere contact of the male fluid acted as a sufficient stimulus. It has been stated, but on whose authority I have not ascertained, that painting the eggs of silkworms with different chemicals stimulates parthenogenesis, and if such is the case it could be readily understood that contact with the male fluid might have an analogous effect.

In one of the pairings, *maia* ♀ × *belina* ♂, the male appears to have had an undoubted influence on the eggs, but without cytological evidence it is impossible to judge whether or not there was true fertilisation, since development did not proceed beyond early segmentation.

¹ See Shearer, C., Morgan, Walter D., Fuchs, H. M., "On the Experimental Hybridization of Echinoids," 'Phil. Trans. Roy. Soc. Lond.' vol. cciv. 1914.

Further experimentation with cytological observations among insects might be expected to lead to interesting results and to an increase in our knowledge of the interrelationships of normal fertilisation, parthenogenesis and hybridism.

New South African Arachnida.

By

John Hewitt,

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With 9 Text-figures.

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INTRODUCTION.

THE miscellaneous assembly of new Arachnids described in this paper are all in the Albany Museum, except when otherwise stated. Perhaps the most noteworthy are the small marine spiders taken by the Rev. N. Abraham at Muizenberg, near Cape Town (*Muizenbergia abrahami* and *Erigonopsis littoralis*), a discovery of some interest seeing that previously only one marine genus, viz., *Desis*, had been known from South Africa. Whether their occurrence on our coast has any special zoo-geographical importance it is impossible to decide at present, as little or nothing is known of the Arachnid fauna of other shores; in any case it seems very probable that quite a new field awaits exploration on the coasts of the southern hemisphere, in worm-tubes and similar habitats between tide-marks.

Some of the descriptions are based on material which has been kindly lent to me by the authorities of the British Museum, London, and of the Natal Museum, Pietermaritzburg; for this courtesy I am especially indebted to Mr. A. S. Hirst, the Arachnologist of the British Museum, and to Dr. E. Warren, the Director of the Natal Museum.

SYSTEMATIC ACCOUNT.

ORDER ARANEÆ.

Fam. AGELENIDÆ.

Sub-fam. AGELENINÆ.

• Group *Cryphœceæ*.Genus *MUIZENBERGIA* *gen. nov.*

This new genus is at once distinguished from any known genus of this group through the position of the tracheal

stigma, which is situated about midway between the genital opening and the base of the inferior spinners. The chelicerae have two teeth on each side of the fang-groove. According to Mn. Simon's¹ key to the genera, *Muizenbergia* should be placed near to *Cicurina Menge*.

Muizenbergia abrahami *sp. nov.* Text-fig. 1, A-G.

The types of this species, a single adult male and a somewhat shrivelled female, were collected at Muizenberg, near Cape Town, in September, 1913, by the Rev. N. Abraham, who presented them to the Albany Museum. Mr. Abraham found them when searching for *Desis*, in the interspaces of the calcareous masses built up by marine annelids; they are, therefore, marine spiders, probably resembling *Desis* in habit.

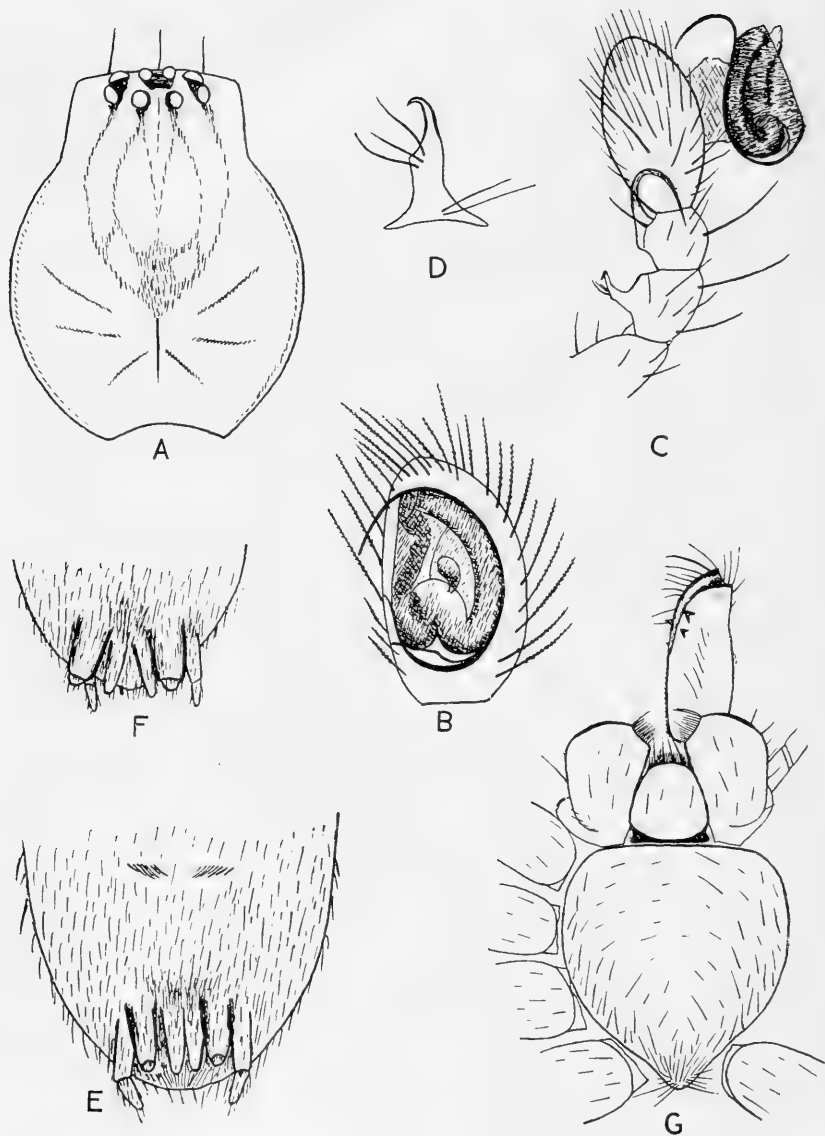
Colour.—Chelicerae and anterior portion of carapace castaneous; hinder portion of carapace pale brown, like the legs and sternum; distal segments of legs more deeply coloured than the basal segments; on the cephalic portion of the carapace there is some slight infuscation, which is only strongly pronounced around the eyes. Abdomen uniformly dull dirty grey.

Carapace.—Longer than wide, the cephalic region fairly strongly convex, gradually becoming much flatter in the thoracic region; these two regions are not sharply separated though their junction is marked on the margin by an obtuse angle. Anteriorly the carapace is squarish, the clypeus being very wide and very low; the distance from an anterior lateral eye to the anterior margin of the carapace is less than the long diameter of the eye. Fovea long and very narrow.

Ocular Area.—Nearly three times as broad as long. Anterior row straight, posterior row slightly procurved. Antero-medians smallest, but not very small, a little nearer to the antero-laterals than to each other. Eyes of posterior row subequally spaced. The laterals of each side very close

¹ Simon, Eugène, 'Histoire Naturelle des Araignés,' tome ii, p. 266. Paris. 1897.

TEXT-FIG. 1.



Muizenbergia abrahami sp. nov.

- A. Carapace of male. $\times 40$. B. Tarsus of male palp with bulb in situ. $\times 75$.
 C. Male palp with bulb of tarsus dislodged. $\times 55$. D. Process of the patella
 of the male palp. $\times 185$. E. Posterior half of abdomen of male in ventral
 view showing spinners and tracheal stigma. $\times 40$. F. Spinners of female.
 $\times 25$. G. Ventral view of sternum, labium, coxae of appendages, and one
 chelicera of the male. $\times 40$.

together. Quadrilateral formed by the four median eyes broader behind than in front, and the posterior breadth exceeds its length.

Chelicerae.—Elongated, a little dilated in the basal half, projecting obliquely forwards. Fang strongly curved, reaching backwards nearly half the length of the chelicera; on each side of the fang-groove there are two teeth, of which the distal one is large, sharply pointed, and triangular, the more proximal one small.

Pedipalp of Male.—Both the patella and tibia carry a strongly projecting process. That of the tibia, which is the longer, is a tapering cylindrical process, strongly curved backwards and ending in a point; that of the patella arises from a broad base and is expanded over half of its length, the expanded portion carrying a group of three bristles, distally to which the process suddenly narrows and eventually ends in a claw-like hook. The tarsus is oval and elongated, but not twice as long as broad; the distal end of the bulb is not far from the apex of the tarsus. Numerous long, plumose, bristly hairs occur on the tarsus.

Legs.—All the hairs, bristles, and spines which invest the legs and the palps are finely plumose. None of the tarsi are spined. The first metatarsus and tibia in the female are quite without spines (in male specimen damaged). The second metatarsus has a pair of long spines, near the apex, and the third metatarsus has two pairs of long spines below; the third and fourth tibiae and fourth metatarsus are beset with a number of long and strong spines. The hairs on the legs are not very densely arranged. The paired tarsal claws of the first leg in the male have nine teeth each, the more basal teeth being minute; the unpaired claw has two teeth, but that of the female has only one. The unpaired claw of the fourth leg of the male has three teeth, that of the female only two.

Labium.—About as broad as long; broadest near the base and tapering gradually towards the anterior margin, which is broadly rounded and carries four long bristles; it

reaches about as far as two-thirds of the distance along the maxillæ.

Sternum.—Only a trifle longer than wide, broadly truncate in front and narrowing to a point posteriorly between the hind coxæ, which are completely separated thereby. It is broadest opposite the coxæ of the second legs.

Abdomen.—Elongated, covered with soft, slender, plumose hairs, all backwardly directed. On its ventral surface the tracheal stigma is placed far forwards, being situated only very slightly posterior to the mid-point between the genital aperture and the bases of the inferior spinners.¹

Spinners.—Inferior spinners widely separated, about twice their own width apart. Superior spinners with the apical segment about half the length of the basal one. Colulus absent. The median and superior spinners arise only very slightly posterior to the inferior spinners, especially in the male, where the whole six are arranged almost in a transverse line; in the female the arrangement is roughly in two transverse lines.

Total length.—Adult male 3·5 mm.

This genus in its spinner arrangement approaches the group Hahniinæ and will probably prove to be closely related to some of the little-known genera of that group. The tibial process of the male palp is very like that figured by Simon² for *Hahnia oreophila* *E. Sim.* The position of the tracheal stigma is also apparently an extreme condition of a tendency obtaining in various genera of this group. I have placed *Muizenbergia* provisionally in the group

¹ Since writing the above, I have examined a large female example from St. James, near Cape Town (coll. J. H. Power). This clearly shows that the median tracheal stigma is double, the actual openings being connected by a short transverse furrow. The tufts of hairs shown on E, text-fig. 1, mark the positions of these openings. Further, the lateral eyes of each side are slightly raised on an obliquely disposed prominence.

Op. cit., p. 273.

Cryphœceæ mainly on account of the dentition of the chelicerae; probably the separation of the two groups is artificial. Whether this genus can be regarded as a direct derivative of the South African terrestrial fauna, or whether, like *Desis*, its allies are widespread over the shores of the southern hemisphere, cannot be stated at present; it does not seem to be closely related to the various known littoral species recorded by Mr. H. R. Hogg.¹

Fam. ARGIOPIDÆ.

Sub-fam. LINYPHINÆ.

Genus ERIGONOPSIS *gen. nov.*

This generic name is proposed for the reception of the species hereafter described, which combines the characters of various members included in Simon's world-wide group *Erigoneæ*, but does not agree entirely with any one of them, and in some respects approaches the group *Linyphiæ*. The characters of the male palp will probably prove sufficient to differentiate this from any other known genus. Other characters are: carapace of male simple, precisely like that of the female; no trace of fovea or median sulcus on carapace; length of quadrilateral formed by the four median eyes slightly greater than its hind width; posterior median eyes very slightly nearer to each other than to the posterior laterals; sternum with a rather broad posterior prolongation, separating the bases of the fourth legs from each other, followed, posteriorly to the coxæ, by a small flat quadrangular piece; abdomen without scute or indurated area; female epigyne comparatively simple; female palp without tarsal claws, the maxillæ not very broad even in the male (more or less intermediate between *Erigone* and *Linyphia*); chelicerae with four teeth on the anterior margin of the fang-groove and three on the posterior margin in both sexes; tarsus of first leg

¹ Hogg, H. R., "Subantarctic Islands of New Zealand," Article IX, Wellington, N.Z., 1909; "Some Falkland Island Spiders," Proc. Zool. Soc., 1913, p. 37.

very slightly longer than the metatarsus or subequal thereto, and the metatarsus very slightly shorter than the tibia.

Erigonopsis littoralis *sp. nov.* Text-fig. 2, A-H.

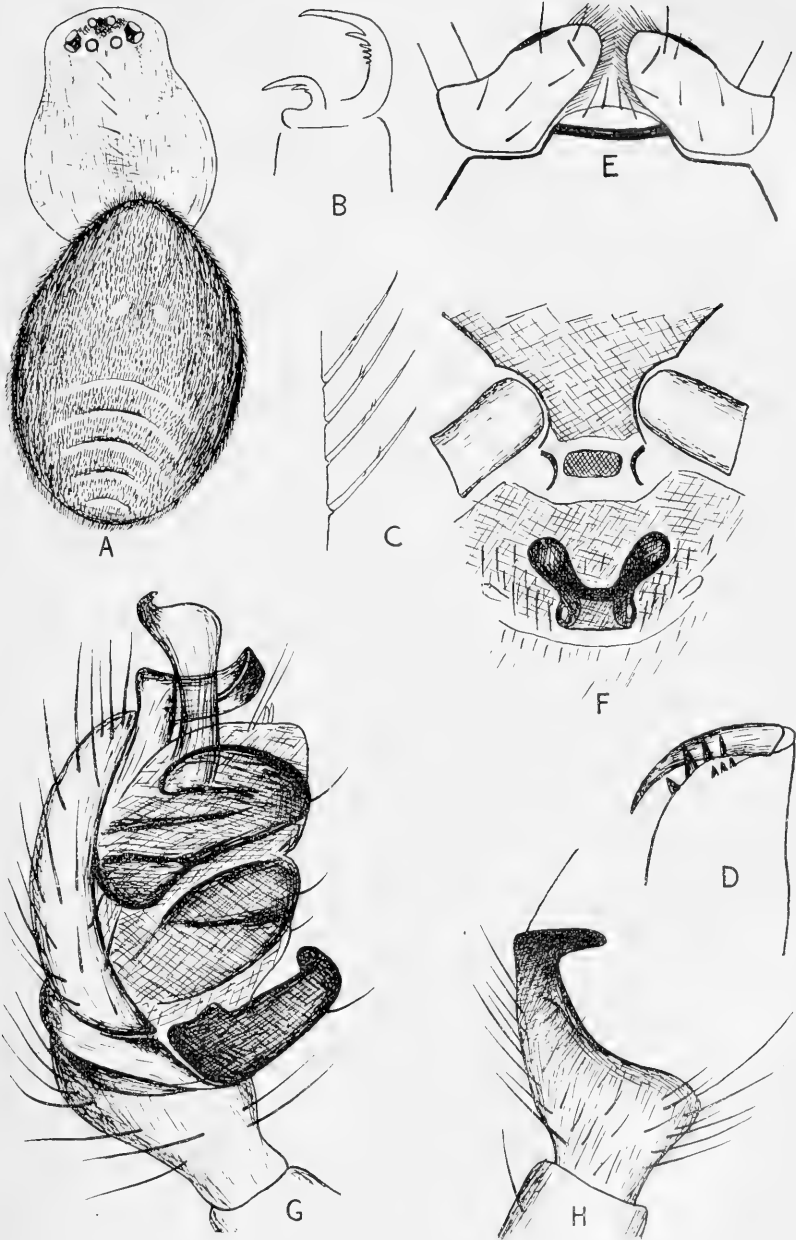
The types of this species are one adult male and several adult females taken at Muizenberg, near Cape Town, by the Rev. N. Abraham in September, 1914. The habitat is the same as that of *Muizenbergia abrahami* *sp. nov.*

Colour.—Carapace, sternum, and appendages brownish, without strong infuscation except around the eyes: the carapace and sternum are lightly infuscated, more especially so about the middle of the carapace. The skin of the abdomen is for the most part infuscated and is covered with black rather bristly hairs; on the hinder half of the abdomen are five pale transverse stripes dorsally, and there is a pair of pale spots about midway between the anterior stripe and the front margin of the abdomen.

Carapace.—Narrowed anteriorly, the front margin broadly rounded; cephalic area fairly strongly convex, gradually passing into the slightly convex thoracic portion, the boundary between the cephalic and thoracic portions of the carapace being very ill-defined both at the margin and elsewhere. Clypeus vertical but not greatly elevated, the anterior lateral eyes being about three diameters distant from the anterior margin of the carapace. Anterior margins of anterior row of eyes in a distinctly recurved line; posterior row only slightly procurved; anterior medians smallest, but not very small, nearer to each other than to the anterior laterals. Along the mid-line of the carapace in its cephalic portion there are four or five weak bristles, and a few stiffish hairs occur on the ocular area, but none on the margin of the carapace.

Chelicerae.—Fairly stout, directed vertically downwards, without spines at the sides and without basal spot; fang strong and rather short; anterior margin of fang-groove carrying four teeth, of which the middle ones are strongest; the posterior margin with three small teeth.

TEXT-FIG. 2.



Erigonopsis littoralis sp. nov.

- A. Dorsal view of carapace and abdomen. $\times 30$. B. Tarsal claws of first leg. $\times 375$. C. Barbed hairs on margin of fourth tarsus. $\times 185$. D. Dentition of chelicerae. $\times 100$. E. Maxillae, labium, and anterior part of sternum. $\times 90$. F. Posterior part of sternum, coxae of fourth pair of legs, and epigyne. $\times 90$. G. Distal portion of male palp. $\times 200$. H. Tibia of same showing the apophysis. $\times 250$.

Legs.—Coxæ I and IV of equal length. Metatarsus IV longer than the tarsus. Apart from a few long spiniform setæ on the femora and tibiæ, the legs are spineless; there are a few long setiform spines on the distal segments of the palps. The legs are clothed with short stiff setæ; most of these are simple, but on the tarsus, and to a less extent on the metatarsus, there are some long stiff setæ, each carrying two or three lateral barbules, usually situated on one side of the hair about the middle of its length. On tarsus IV the stout feathered hairs are arranged in longitudinal rows, about ten in a row. The elongated so-called auditory hair on the fourth metatarsus is present. On tibia IV dorsally there are two projecting hairs, the distal one longer. Onychium present. Paired claws of the first tarsus with only five teeth, the distal one longest, the others much smaller and gradually decreasing in size towards the base; the median claw is fairly long and carries two teeth, the basal one of which is very minute and arises from the base of the larger one. On the claws of the fourth tarsus the teeth are still weaker, the inferior claw being drawn out to a long fine point and carrying only one weak tooth.

Sternum.—Broader than long, quite fused with the labium.

Labium.—Very broad, carrying four bristles anteriorly; there is a strongly thickened slightly concave border anteriorly. The maxillæ have the long axis very obliquely inclined.

Palp.—Male palp short, the femur being about twice as long as the patella, and their conjoint length about equal to the distance from the base of the tibia to the end of the conductor of the style of the bulbal organ. The end of the conductor somewhat resembles a scorpion's vesicle (sting) in shape; immediately beyond the distal extremity of the tarsus the style is bent at right-angles on itself, its distal portion continuing to the apex as a broad slightly curved lamina. Tibial apophysis not bifurcated and not large. External branch of the tarsus (paracymbium) slightly arched, but no spines nor hairs occur on the concavity.

Total length.—Female $2\frac{1}{4}$ mm. Male $1\frac{3}{4}$ mm.

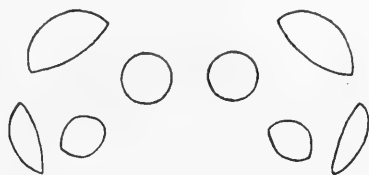
Various members of this group of Argiopidæ are known to live in marshes and on the sides of streams, but no marine forms have been hitherto recorded.

Fam. CTENIZIDÆ.

Pelmatorycter dreyeri *sp. nov.* Text-fig. 3.

The type consists of a single adult male from Bloemfontein, presented to the Albany Museum by Dr. T. F. Dreyer, in August, 1914. The species is related to *P. nigriceps*¹ Purcell, from Johannesburg, but differs therefrom in the

TEXT-FIG. 3.



Pelmatorycter dreyeri *sp. nov.*
Eyes of male. $\times 45$.

ocular arrangement, in the dentition of the claws of the fourth leg, and in some minor points.

Ocular area.—Wider behind than in front, the anterior row of eyes strongly procurved, the laterals much larger than the medians, the long diameter of the former being quite one and two-third times the diameter of the latter. Posterior laterals decidedly longer than the anterior medians, but shorter than the anterior laterals.

Chelicerae.—With seven teeth on the fang-groove.

Pedipalps.—Near the base of the tibia on its inner side is a spine.

Legs.—Tarsus II, without spines; III with four spines on its anterior side, two or three postero-dorsally situated, and one on the posterior side ventrally situated; IV with no spines on its posterior side. Posterior claw of tarsus IV with

¹ Purcell, W. F., 'Trans. South African Philosophical Society,' vol. xi, p. 358.

one tooth only in the outer row and four in the inner row; anterior claw with three small ones in the outer row and four large ones in the inner row. Metatarsus I equal in length to the distance from the centre of the fovea to the anterior margin of the carapace. Patella IV without an apical spine inferiorly. The distal group of spines on femur IV, at its upper outer edge, is composed mostly of weak spines; there are only very few short, fairly stout, spines.

Abdomen.—With a few, rather strong bristles near the base above.

Posterior sternal sigilla.—Not very clearly defined, but apparently rather more than a length apart, and about half a length distant from the sternal margin.

Posterior spinners.—Apical segment a trifle shorter than the penultimate segment.

Measurements.—Total length 18·5 mm., length of carapace 5·5 mm., width of carapace 4·4 mm., length of metatarsus of first leg 3·5 mm.

A female specimen taken at Bloemfontein by Dr. Dreyer, a few days later, presumably belongs to the same species. The characters are detailed below.

Ocular area.—More than twice as broad as long, the posterior row distinctly wider; anterior row with anterior margins moderately procurved, posterior margins in a very lightly procurved line, the medians slightly nearer to the laterals than to each other, their distance apart being distinctly greater than a diameter; posterior row with procurved anterior margin and recurved posterior margin, the laterals oblique and elongated, much longer than the medians and as long as the anterior laterals, posterior medians nearer to the posterior laterals than to the anterior medians; distance between the laterals of each side about one-third the length of the posterior laterals.

Posterior sternal sigilla.—About half a length apart and almost a length distant from the sternal margin.

Chelicerae.—The inner dental series comprises eight teeth.

Pedipalps.—Coxa with five teeth on the inferior surface situated far forwards. Tibia with four apical spines inferiorly, also four on the anterior surface below, but none on the posterior surface. Tarsus with two spines not far from the apex inferiorly, and a longer one on each side near the base.

Legs.—Tarsi and metatarsi of first two pairs of legs scopulate to the base (on the second metatarsus the scopula is absent on the posterior side in its basal half). Tarsus I without spines, excepting one near the apex inferiorly; II with one or two spines inferiorly on the posterior side; III with a row of six spines postero-dorsally, of three antero-dorsally, also about seven antero-inferiorly situated; IV strongly aculeate on the anterior surface and with a number of spines on the posterior surface in its distal half. Metatarsus I with one or three apical spines below, and two or three along the inferior surface; II with three apical spines below and two along the inferior surface; III numerous spined on both anterior and posterior surfaces superiorly, and with four weak spines on the inferior surface, in addition to those at the apex, which are long and strong; IV with numerous spines inferiorly, mostly situated on the anterior side, superiorly with two spines on the posterior side. Tibia I and II each without distinct spines below except one at the apex; III without spines at the apex inferiorly, a supero-anterior band of seven spines, also seven dorsal spines, and two near the supero-posterior edge distally; IV with a single apical spine inferiorly, and with one spine or none on the postero-dorsal edge. Patella III covered with short, stout spines on the anterior surface, the dorsal surface with two stout spines near the posterior edge; IV without spinules on its anterior surface, except two or three immediately at the base of the segment. Femur IV with a dense group of short, strong spines anteriorly at the apex and dorsally. Tarsal claws of first leg with four teeth in the outer rows, and five or six in the inner rows; anterior claw of fourth leg with only one small distal tooth; the posterior claw with one or two distal teeth and one at the base, also a very minute

second basal tooth. Coxa III with a dense tuft of stiffish setæ on the postero-ventral border.

Colour.—For the most part castaneous above, chelicerae blackish, patellæ and more distal segments of first two pairs of legs and of palps pale brown; carapace pallid in its hinder portion at the sides. Abdomen pale except over the median area above, where it is infuscated.

Measurements.—Total length 23·5 mm., length of carapace 8·5 mm., breadth of same 5·5 mm.

According to Dr. Dreyer, the nest has two long blind side passages leading into the central tube one on each side in the upper half of its length; the upper part of the tube projects a little above the surface of the ground, and the distal end is folded inwards, thus closing the entrance to the nest.

Bessia minor Hewitt. Text-fig. 4.

Bessia minor Hewitt, Records, Albany Museum, vol. ii, p. 469, 1913.

An adult male of this species was taken at Alicedale by Mr. F. Cruden on March 12th, 1914, and a description of it is here given.

Carapace.—As long as the metatarsus and tarsus of the first leg; the lateral margins fringed with strong bristles, and the abdomen also is bristly over its median area superiorly. Fovea lightly procurved.

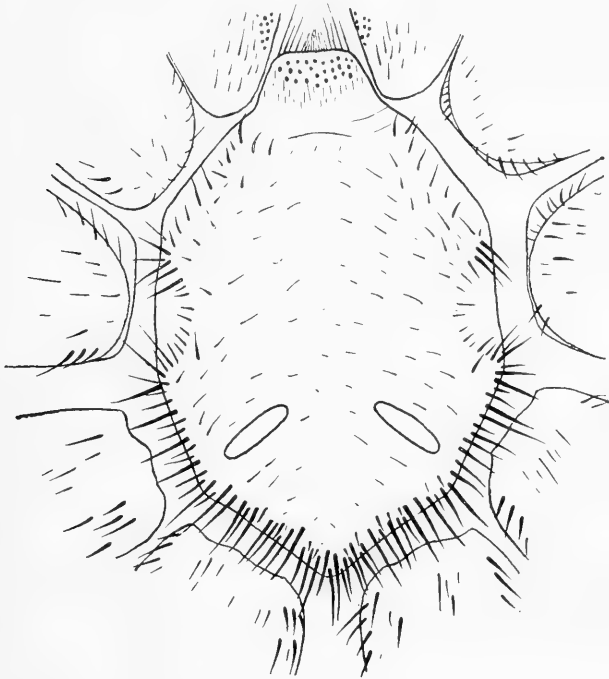
Chelicerae.—Dentition somewhat similar to that of the female, the teeth not arranged in continuous well-defined rows; the larger teeth are roughly arranged in a double series—the inner of which is weaker—in the middle of the group, and a single series at each end.

Pedipalp.—Resembling that of a *Spiroctenus*. The tarsus has numerous short spines distally above; the tibia has long spines below; at the base of the coxa inferiorly is a patch of cusps.

Legs.—Tarsi not spined, all of them scopulate on the sides, the fourth tarsus only weakly so; paired claws with a single spirally curved row of numerous long teeth as in

Spiroctenus. Metatarsus I longer than the tibia, slightly scopulate in its apical third, slightly but distinctly bowed; II with several scopular hairs near the apex; III and IV not scopulate. Apical tubercle of tibia I with a fairly long and

TEXT-FIG. 4.

*Bessia minor* Hewitt.

Sternum, labium, and basal parts of the appendage of the male.
× 18.

stout spur at its apex, and a slightly shorter and less stout spur on its base externally; the proximal tubercle also bears a spur and is situated rather less than a quarter of the length of the segment from the apical border. Anterior surface of patella III with a row of three spines superiorly and two longer ones distally below. All the femora are spined above.

Labium.—With about twenty-four cusps on its anterior half.

Sternum.—Posterior sigilla elongated, about one and a half diameters apart and about half a diameter distant from the sternal margin. At the margin of the sternum opposite the base of the second leg there is a deep circular depression in which is situated the second sigillum; a similar depression also occurs in the female, but is not so noticeable, as the setæ which fringe its margin are not so strong as in the male. Sternal margin fringed with strong bristles, especially posteriorly.

Posterior spinners.—Apical segment about three-quarters the length of the penultimate segment.

Measurements.—Total length 15·2 mm., length of carapace 6·5 mm., breadth of same 4·8 mm., length of first metatarsus 4 mm., of fourth metatarsus 5·8 mm.

Bessia fossoria Poc.

Bessia fossoria Poc., Ann. Mag. Nat. Hist., vol. vii, 6, p. 320, 1900.

I have examined the type, which is very immature, and have now no doubt but that the much larger specimen from Redhouse, referred to in a previous paper,¹ belongs to this species. The dentition of the paired tarsal claws was incorrectly described by Pocock, for the inner distal row is represented by two or three minute teeth on each claw. Moreover the tarsus of the first leg and the distal half of the metatarsus is rather strongly scopulate, the tarsus of the second leg is scopulate at the sides, but the third and fourth tarsi are not scopulate. The teeth on the chelicerae constitute a single row, but the line is irregular, not straight.

The genus is evidently very closely related to *Spirocetus* *Sim.*

¹ Hewitt, J., 'Records, Albany Museum,' vol. ii, p. 471, 1913.

Spiroctenus armatus Hewitt.

Spiroctenus armatus Hewitt, Records, Albany Museum, vol. ii,
p. 467, 1913.

In drawing up the description of this species the following characters were accidentally omitted.

Colour.—Carapace and legs reddish brown, palps pale brown; abdomen pale with ill-defined dark markings above; ventral surfaces pale.

Posterior sternal sigilla.—Elongated, oval, about one and a half diameters apart and about half a diameter distant from the sternal margin.

Measurements.—Total length 15 mm.; length of carapace 6·4 mm.; breadth of same 5·1 mm.; length of metatarsus of first leg 4·2 mm., of fourth leg 6·2 mm.

Acanthodon abrahami (Hewitt).

Gorgyrella abrahami Hewitt, Records, Albany Museum, vol. ii,
p. 473, 1913.

I now prefer to place this species under the genus *Acanthodon*, although formerly I doubtfully referred it to *Gorgyrella*. It is probably closely related to *A. ochreolum Poc.*, of which only the male is known. The male of *abrahami* seems to differ from that of *ochreolum* in the closer approximation of the frontal eyes and in the less strongly bent first metatarsus, but until more Jansenville material is available for comparison the specific distinction of *abrahami* should be held somewhat doubtful. Two adult males of *abrahami* were taken by Mr. F. Cruden at Alicedale on February 15th, 1914, and I here give a description of the sex.

Frontal eyes quite separated, about one-third of a diameter, or slightly less, apart; the quadrangle formed by the frontal and anterior median eyes wider behind, the medians large, about three-fifths to three-quarters of a diameter apart; hind margins of posterior row about in a straight line, the medians two to two and a half diameters apart and a diameter or slightly more distant from the laterals.

Tarsi of all the legs scopulate below throughout their length, the first tarsus being only quite thinly scopulate, the fourth without setae along its middle. Tarsal claws of first leg with three teeth, of fourth leg with two teeth and a third tooth may or may not be just indicated. First metatarsus slightly bowed, with two spines at the apex inferiorly and three along the postero-inferior edge, but none along the antero-inferior edge. First tibia shorter than the metatarsus, with four spines along the postero-inferior edge, with the usual pair of tubercles near the apex, the more proximal one being distant from the apex less than one-sixth the length of the segment. Band of spinules on anterior surface of patella IV stretching two-fifths to one half of the length of the segment and comprising only about eight to ten spinules; III has two to four spines along the distal edge anteriorly, and two to nine on the anterior surface, but only one on the dorsal surface, in addition to one or two on the distal edge.

Tibia of pedipalp barely one and two-third times as long as deep, the band of spines bordering the excavation complete, in three rows proximally, but elsewhere in a single row, except at the distal end; altogether there are nineteen to twenty-four such spines. Tarsus of pedipalp with one long spine at the apex superiorly and one or two weaker ones, the distal inferior lobe on the posterior side rather strongly projecting. Process of palpal organ comparatively short, flattened, and twisted.

Measurements.—Total length 12·5 mm., length of carapace 4·5 mm., breadth of same 3·5 mm., length of tibia of first leg 2·75 mm.

Acanthodon ochreolum Poc.

Acanthodon ochreolum Poc., Ann. Mag. Nat. Hist., 7, x, p. 9, 1902.

This species is probably the same as either *Gorgyrella schreineri* Purcell, or *G. abrahami* Hewitt, for it has three pairs of sternal sigilla.

The following notes on the type specimen will supplement Pocock's rather incomplete description.

Frontal eyes quite separate from each other, about half a diameter or a trifle more apart. The quadrangle formed by the frontal and anterior median eyes is appreciably wider behind. Hind margins of posterior row of eyes in a procurved line. Posterior median eyes three to three and a half diameters apart.

Tarsus of palp with one rather long stout spine at the apex dorsally, and several much weaker ones. Pocock's figure of the tibia of the palp is quite inaccurate in respect to the spinulation of the excavation; the spinules are not arranged in a single row throughout, and are much more numerous than represented in the figure; distally they occupy two or three rows, and proximally the spinules are considerably longer than elsewhere.

All the tarsi are scopulate to the base, the fourth being without spiniform setæ mesially below. Tarsal claws without a comb of teeth, the first having only one large tooth and the fourth one or two. The first tibia has four spines along its outer inferior edge, but none otherwise situated, apart from the two large tubercles.

The inner dental series of the chelicerae comprises five large teeth.

The first pair of sternal sigilla is near to the sternal margin.

Acanthodon hamiltoni Poc.

Acanthodon hamiltoni Poc., Ann. Mag. Nat. Hist., 7, x, p. 320, 1902.

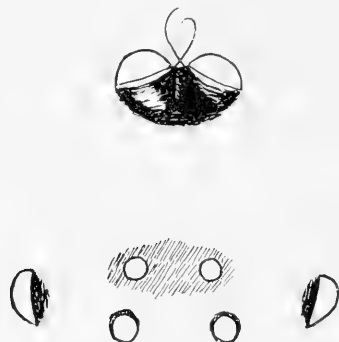
The type of this species is without doubt very juvenile.

The inner dental series comprises five strong teeth and a few small ones basally situated. The coxæ of the legs are without spinules, and along the posterior edge of the third coxa inferiorly is a strip of moderately fine hairs. The second tibia has a row of eight spines on its anterior side. The band of short strong spines on the anterior surface of the fourth patella extends two-thirds of the distance along the segment. The frontal eyes are very close together; the ocular tubercle is deeply grooved above.

Acanthodon grandis sp. nov. Text-fig. 5.

This may be the female of *A. pectinipalpis* *Purc.* (*Annals S. Afr. Mus.*, vol. iii, p. 87) described from Zululand, but I think it is probably distinct on account of the wider separation of the frontal eyes, those of *pectinipalpis* being described as very close together. It is related to a species described by me¹ from Newington, Transvaal, under the name of *Ctenolophus transvaalensis*, but differs in that the third coxa is clothed inferiorly with stout bristles, not spinules, and in other respects also.

TEXT-FIG. 5.



Acanthodon grandis sp. nov.
The eyes of the female. $\times 16$.

The type consists of a single adult female in the collection of the Natal Museum from Umfolosi, Zululand (F. Toppin coll. 1905).

Colour.—Upper surface of appendages and carapace castaneous, the legs with a reddish tinge. Ventral surfaces paler; sternum and coxæ of last two pairs of legs yellowish-brown.

Carapace.—As long as the tibia, metatarsus and half of the tarsus of the fourth leg, or the patella, tibia and three-fifths of the metatarsus of the first leg. Ocular area only slightly wider than long, its width subequal to the length

¹ Hewitt, John, 'Records, Albany Museum,' vol. ii, p. 412, 1913.

of metatarsus I, its length almost two-fifths of the distance from the anterior margin of the carapace to the centre of the fovea. Area formed by the frontal and anterior median eyes slightly wider in front, the medians small, about two diameters apart, the frontals large, about one-third of a diameter apart and situated on a common tubercle which is deeply grooved above. Posterior row about equally spaced, the area formed by the four medians appreciably wider behind; posterior laterals large, the medians considerably larger than the anterior medians, the hind margins in a slightly procurved line.

Legs.—Metatarsus III with three long weak spines below and three stronger ones at the apex inferiorly; IV with six or seven spines along the lower surface and three at the apex inferiorly. Band of spines on anterior surface of tibia I reaching to the base; of II also reaching to the base and including about twenty-two spines; IV with two inferior apical spines and one weak one on the lower surface. Band of spines along anterior surface of patella III including about thirty spines, of which about seven are on the distal edge; on the posterior distal edge there are five spines; IV with a band of short stout spines stretching the whole length of the anterior surface. Coxæ of legs without spinules below, the third having a dense patch of short coarse bristles or weak spines along its posterior border ventrally.

Labium.—With two apical teeth.

Chelicerae.—Inner row of teeth on fang-groove including five large teeth; the outer group without any large teeth.

Sternum.—Three pairs of sigilla, the third pair small and not so conspicuous as the preceding pairs; first pair sub-marginal, second pair their own length distant from the sternal margin.

Measurements.—Total length 25 mm.; length of carapace 10.2 mm., width of same 9 mm.; length of tibia of first leg 4.25 mm. This is the largest species of *Acanthodon* known to me (excluding *Gorgyrella namaquensis* and *G. schreineri*, but *Gorgyrella* is hardly separable from *Acanthodon*).

Idiops pretoriæ (Poc.).

Acanthodon pretoriæ Poc., Ann. Mag. Nat. Hist., vii, 1, p. 319, 1898.

To the description given by Mr. Pocock I can add the following notes, after examination of the type male :

Chelicerae with seven strong teeth in the inner row and four in the outer row ; process of palpal organ strongly flattened throughout and twisted ; the excavation on the tibia of the palp very shallow and not bordered by spines ; band of spinules on anterior side of patella IV stretching five-sixths of the length of the segment and including about thirty short spines ; patella III has a continuous strip of spinules anteriorly including about thirteen as well as four on the distal edge ; frontal eyes one-quarter to one-third of a diameter apart, the anterior medians very large, the area formed by the frontal and anterior median eyes much broader behind, posterior medians very much smaller ; posterior margins of posterior row of eyes slightly recurved, the anterior margins slightly procurved ; the posterior medians about three diameters distant from the posterior laterals, which latter are a little elongated but not greatly so.

Idiops astutus sp. nov. Text-fig. 6.

The type consists of a single adult male taken at Bulawayo, November 15th, 1913, by Mr. G. Arnold, who writes of it " hunting insects under the electric lights, waiting for those that fall."

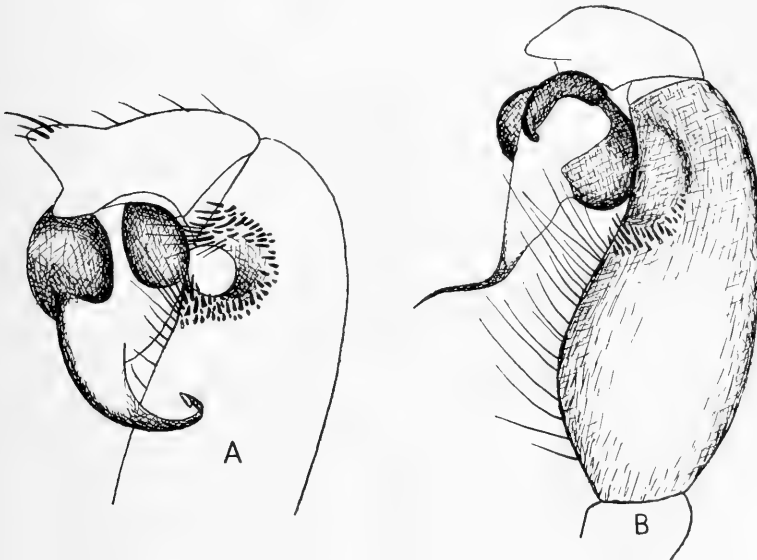
This species can at once be distinguished from *I. arnoldi* Hewitt,¹ which it somewhat resembles, and which also is believed to occur at Bulawayo, through the total absence of a scopula on the fourth tarsus, whereas *arnoldi* has a broad scopula on the swollen fourth tarsus.

Colour.—Upper surfaces brownish-black, lower surfaces somewhat paler, the sternum and coxæ of the third and fourth legs, the genital sternite, lung opercula and spinnerets being pale yellowish-brown.

¹ 'Records, Albany Museum,' vol. iii, p. 21, 1914.

Carapace.—Broad and depressed, its length equal to that of the fourth metatarsus together with two-thirds of the tarsus. Surface coarsely granulated, except on the ocular area and lateral thereto. Ocular area very slightly wider than long, its length slightly less than one-third of the distance from the anterior margin of the carapace to the

TEXT-FIG. 6.



A. *Idiops astutus* sp. nov. B. *I. arnoldi* Hewitt.
Distal portions of male palps. A \times 14. B \times 18.

centre of the fovea; frontal eyes quite separated, about one and a quarter diameters apart. Area formed by frontal and anterior median eyes very slightly wider in front, its length being only slightly greater than its anterior width; the medians about half a diameter apart and much larger than the frontals. Posterior margins of posterior row in a procurved line, the medians about two to two and a half diameters apart and about a diameter distant from the laterals, which are elongated but rather small. Posterior medians

about one-third of a diameter distant from the anterior medians.

Pedipalp.—Tibia slightly more than three times as long as deep, the excavation completely bordered by a band of spines. Tarsus dorsally without spines, except at the apex, where there are several; the apical portion strongly projects upwards (see text-fig. 6, A). Process of bulb flattened throughout its length, obliquely truncate at the apex, curved and slightly twisted.

Legs.—Tibia I shorter than the metatarsus, with a pair of tubercles near the distal end inferiorly, the proximal one short and small, the distal one with a large and long black projection; its under-surface without spines along the median area, about ten or eleven along the posterior edge inferiorly, but none on the anterior edge. Metatarsus I distinctly bowed, with seven or eight short spines inferiorly on the posterior side and three or four on the anterior side (including two near the apex). Tarsus I with eight or nine spines on each side, weakly scopulate in its distal third, II and III broadly scopulate from apex to base, IV without trace of scopula and not swollen. Claws of all the tarsi with two basal teeth, the more distal one larger than the other; on tarsus IV the posterior claw of the left leg (missing on right side) carries three teeth, and such is the case on one of the claws on tarsus II. Band of spinules on anterior side of patella IV extending the whole length of the segment; patella III also has a band of short spines along its anterior surface, ending in a row of about five or six longer ones along the distal edge.

Measurements.—Total length 19 mm., length of carapace 8·8 mm., breadth of same 7·8 mm., length of tibia of first leg 5·4 mm., of metatarsus of same 7·4 mm., length of first leg 33·3 mm., of fourth leg 31 mm.

Hermacha mazœna sp. nov.

The type is a single female specimen from Mazœ, Mashonaland (J. Darling), in the collection of the British Museum.

Colour.—Almost uniformly pale brown, the abdomen superiorly showing indication of a darker tree-pattern.

Carapace.—Slightly longer than the fourth metatarsus and tarsus together. Ocular area a trifle more than twice as broad as long. Anterior margins of anterior row of eyes in a procurved line; the medians rather small, about three-quarters of a diameter apart. Posterior medians rather small, oval, and widely separated, about three and a half times their long diameter apart, their inner margins about in a line with the outer margins of the anterior medians; posterior laterals about as long as the anterior laterals. Fovea straight.

Chelicerae.—With seven teeth in the inner row below, the distal tooth of the outer group being opposite the fifth tooth of the inner row.

Pedipalps.—Coxæ with about sixty teeth arranged in a triangular patch at the base.

Labium.—Quite without apical teeth.

Legs.—Tarsus I with dense undivided scopula, II with scopula divided by a thin median strip of setæ, III and IV not definitely scopulate, but carrying a few scopular hairs at the sides, in IV only distally so. Metatarsus I and II scopulate to the base, III and IV not scopulate; I with two spines at the apex below and two or three along the inferior surface, also one or none on the anterior surface. Tibia I with three weak spines at the apex below and two on the inferior surface, also one on the anterior surface superiorly; very slightly exceeding the metatarsus in length.

Posterior Sternal Sigilla.—Elongated, almost touching the sternal margin.

Posterior Spinners.—With the apical and basal segments subequal in length, being about one and three-fifths times the length of the penultimate segment.

Anterior Spinners.—Not widely separated, less than half their own length apart (the abdomen is somewhat contracted, and in fresh specimens the spinners may perhaps be rather more widely separated); moderately long, being about

four-fifths the length of the basal segment of the posterior spinners.

Measurements.—Total length 15·2 mm., length of carapace 5·6 mm., breadth of same 4·5 mm., length of tibia of first leg 2·5 mm.

No species of this genus has previously been recorded from Rhodesia. The described species to which it is most closely allied are probably *H. caudata* *Sim.* from Delagoa Bay, and *H. bicolor* (*Poc.*) [*Brachytheliscus bicolor* *Poc.*] from Durban; the female of the former is unknown, and the latter species is distinguished from *mazœna* in the following characters: ocular area, dentition of chelicerae and of labium, and separation of anterior spinners.

Genus *HERMACHOLA* *gen. nov.*

This name is proposed for the reception of a small species which has many of the characters of the genus *Hermacha* *E. Sim.*, but differs therefrom principally in the form of the male bulbal organ and in the shape of the fovea as hereafter described.

Hermachola grahami *sp. nov.* Text-fig. 7, A-C.

The type is a single adult male example collected at Grahamstown by Mr. F. C. Graham, September 23rd, 1914, who presented it to the Albany Museum.

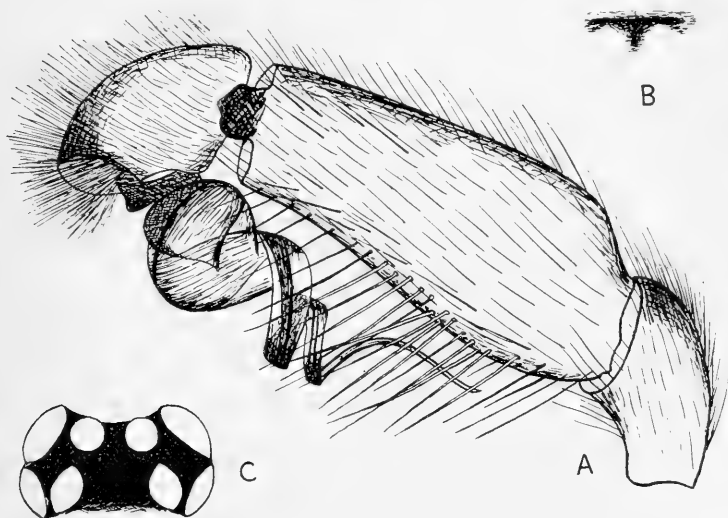
Colour.—Carapace and appendages pale brown, the more distal segments of the first pair of legs with a dull reddish tinge; the hairs which clothe the carapace and appendages are blackish. Abdomen pale dorsally, with a variegated dark pattern. Lower surface pale, but posteriorly just in front of the base of the spinners the abdomen has a dark transverse stripe.

Carapace.—Elongated, about as long as the metatarsus and tarsus of the fourth leg. Fovea transverse at the base, but with a short backwardly directed median extension, which, however, is not so deep as the main portion of the fovea. Near the anterior border of the fovea there are two long spini-

form setæ mesially situated; otherwise no spiniform setæ occur on the carapace except a few on the borders, especially at the postero-lateral corners.

Ocular Area.—Not quite twice as broad as long. Anterior row with their anterior margins strongly procurved, the laterals much larger than the medians or than the postero-laterals. Posterior laterals subcontiguous with the posterior

TEXT-FIG. 7.



Hermachola grahamsi sp. nov.

A. Distal portion of male palp. $\times 55$. B. Fovea. $\times 40$. C. Ocular area. $\times 65$.

medians and with the anterior laterals. Distance of anterior laterals from the margin of the carapace scarcely as much as half of a diameter of an anterior median.

Labium.—With a single small apical tooth.

Chelicerae.—With seven or eight teeth on the inner row below. Anterior surface covered with spiniform setæ which are not elongated; rastellum weak, without spines.

Pedipalps.—Coxa with a small patch of about eighteen small teeth at the base. Femur with two or three weak spines

above; patella without spines. Tibia with numerous elongated spiniform setæ on its ventral surface on the inner side, more strongly developed in the basal half of the segment. Tarsus without spines. Bulb small, process coiled up spirally like a corkscrew; there are two complete coils in addition to the expanded and coiled basal portion which invests the bulb and the narrowed distal portion which also has a strong spiral twist; the process reaches backwards as far as the basal fourth of the tibia.

Legs.—Tarsi unspined. Metatarsus I almost straight, with three strong apical spines below but no other spines elsewhere, II also with three strong apical spines inferiorly, and in addition with two or three on the inner surface and two on the inferior surface posteriorly, III and IV numerous spined. Tibia I stout, with three apical spines, none of which are enlarged, also with six spines on the lower surface, of which one distally situated is specially long and stout; on the anterior surface there is a row of three spines. Tibia II with two or three apical spines inferiorly, three or four on the lower surface, and two or three on the anterior surface superiorly; III with three apical spines below, four on the inferior surface, two on the anterior surface, two dorsally, and two on the posterior surface above, all of them being elongated; IV spined like III except that the dorsal surface has one or no spines. Patella I without spines, II with one on the anterior surface near the apex, III with two on the anterior surface and one on the posterior surface, IV with one on the anterior and one on the posterior surface. Femora armed above with long setiform spines. Tarsi I and II scopulate to the base, the scopula being entire, though not dense, and composed of not very fine setæ; III and IV with a few scopular setæ, but mostly the setæ are long and subspiniform. Metatarsi I and II thinly scopulate from the apex to near the base. Inferior tarsal claw of anterior legs small but easily distinguishable.

Sternal sigilla.—Third elongated, slightly less than its own length distant from the sternal margin; second submarginal, first indistinct.

Measurements.—Total length 8·25 mm., of carapace 3 mm., width of carapace 2·1 mm.

Stasimopus steynsburgensis sp. nov.

This species is closely related to *S. palpiger* Poc. from Graaff Reinet and *S. schreineri* Purc. from Hanover. It differs from both in having shorter palps and in possessing a scopula on the tarsus of the fourth leg of the male.

The type is a single adult male in the collection of the British Museum from Steynsburg, C.C., taken by Miss Leppan.

Colour.—Upper surfaces blackish, excepting the tibia and tarsus of the palps and the tarsi and metatarsi of the legs, which are reddish yellow; also the patella and tibia of the fourth legs are brownish; sternum and coxæ of appendages inferiorly castaneous, abdomen fuscous, the lung opercula and genital sternite yellow, the spinners pale.

Carapace.—Subequal in length to the metatarsus of the fourth leg. The three keels well developed anteriorly, but absent posteriorly, none of them approaching the fovea; hairs are absent therefrom and from the ocular area; the sides of the cephalic area are practically smooth except immediately external to the lateral ridges. Anterior margins of anterior row of eyes distinctly procurved; distance between an anterior lateral and anterior median subequal to the diameter of the latter, but less than the long diameter of the former; posterior lateral almost as long as the anterior lateral, the distance between them about one and three-fifth times the length of the latter; outer lateral margin of anterior lateral about in a line with inner posterior margin of posterior lateral.

Pedipalps.—Stretched forwards, the apex reaches a point three-fifths of the distance along the metatarsus of the first leg. Patella longer than that of first leg, but much shorter than the tibia of that leg or of the palp. Tibia and tarsus together slightly shorter than the carapace. Process of palpal organ longer than the bulb, tapering and slightly twisted.

Legs.—Tarsus I absent from the specimen; II a little

swollen, scopulate below, anteriorly with six spines, posteriorly with seven or eight spines; III with about fourteen spines on each side, scopulate below; IV numerous spined on both sides and scopulate mesially below. Metatarsus I and II without trace of a scopula, but with no spines mesially below though strong spines occur on each side inferiorly. Tibia I shorter than the metatarsus, with only one or two spines mesially below and with about eight spines on the anterior side and four on the posterior side in addition to those at the apex; III with five to seven short spines on or near the distal edge on both anterior and posterior sides superiorly. Patella I with one spine at the apex inferiorly; III with an anterior band of short spines, about six to eight in number, but no distal patch of spinules superiorly; IV with a patch of minute spines extending over about two-thirds to three-quarters of the length of the anterior side. Anterior claw of fourth leg with two large teeth basally situated and with no small ones distal thereto; posterior claw with three large basal teeth.

Measurements.—Total length 18.5 mm., length of carapace 7.8 mm., breadth of carapace 7 mm., length of tibia of palp 4.2 mm., of metatarsus of palp 5.6 mm.

Stasimopus gigas sp. nov.

The type is a single male example in the collection of the British Museum labelled "Vredefort Rd.?, Barrett-Hamilton"; the specimen is in dried condition.

Colour.—Upper surfaces black, except the tarsi and metatarsi of the legs, the tibiae and tarsi of the palps, also the distal portions of the tibiae of the first two pairs of legs, and of the patellae of the palps, all of which are reddish.

Carapace.—Subequal in length to the metatarsus of the fourth leg. The three keels are prominent throughout and reach back almost as far as the fovea. Anterior margins of anterior row of eyes in a very slightly procurved line, subequally spaced, the distance between the medians about one

and a half times the diameter of an eye; inner edges of anterior lateral and posterior median practically in the same line; distance between anterior and posterior laterals quite one and a half times that between an anterior lateral and anterior median.

Pedipalps.—Patella slightly longer than that of the first leg, shorter than the tibia of that leg or of the palp. Tibia and tarsus together considerably shorter than the carapace.

Legs.—All the tarsi scopulate below; no trace of a scopula on the metatarsi. Tarsus I with a single spine on its anterior side and four on the posterior side (II wanting in the specimen); III with numerous spines in a continuous band on both anterior and posterior sides; IV with numerous spines on both sides, especially anteriorly. Metatarsus I with strong spines below, both over the median area and at the sides. Tibia I considerably shorter than the metatarsus, with strong spines below and at the sides; III with a few short spines and spinules on or near the distal edge on both anterior and posterior sides superiorly. Patella I with two spines at the apex inferiorly and one on the lower surface; III with an anterior band of spines, but no distal patch of spinules above apart from those belonging to that band; IV with an anterior patch of spinules extending about three-fifths of the length of the anterior side. Paired claws of tarsus of fourth leg with a basal comb of four large teeth, distal to which is a very small tooth, and on the posterior claw one or two minute teeth occur on the proximal side of the comb.

Measurements.—Length of carapace 11·2 mm., breadth of same 10 mm., length of tibia of palp measured from above 7 mm., of patella of palp 5·5 mm., of first metatarsus 8·4 mm. of first tibia 7 mm., of first patella 5 mm., of fourth metatarsus 11·5 mm.

This species is distinct from *S. nigellus* Poc. (Ann. Mag. Nat. Hist., 7, x, p. 319), which also seems to have been taken at Vredefort Rd. by the late Capt. Barrett-Hamilton, in the following characters: ocular arrangement, keeling of cara-

pace, spinulation of first metatarsus, third tarsus, third patella, in the dentition of the fourth claws, and lastly in size, this being by far the largest male yet recorded in this genus.

Stasimopus minor *sp. nov.*

The type is a single adult male from Bloemfontein collected by Dr. T. F. Dreyer in August, 1914. It was found on the open veld.

This may be identical with *S. oculatus* *Poc.*, which is based on a female example, or may belong to another species, for Dr. Dreyer has taken females of two species at Bloemfontein. It is probably closely related to *S. nigellus* *Poc.* taken at Vredefort Rd., but differs therefrom in the wide separation of the anterior median eyes.

Colour.—Jet-black above, the distal portions of the legs and of the palps paler; sternum, coxæ of appendages, genital plate, lung opercula, and spinners pale.

Carapace.—A little longer than tibia of first leg or metatarsus of palp. Almost quite smooth and shining in its anterior half, lightly sculptured (not coarsely rugose) in its posterior half. The three keels depressed, only the median one reaching back to the fovea. Anterior margins of anterior row of eyes in a straight line, the medians much nearer to the laterals than to each other, being about one and a half diameters apart; anterior laterals subequal in length to the anterior medians and separated therefrom by about half the diameter of a median. Ocular area sparsely hairy.

Pedipalps.—Pressed forwards, the tip reaches a point three-fifths of the distance along the metatarsus of the first leg; patella considerably longer than that of the first leg, but shorter than the tibia of that leg or of the palp; tibia and tarsus together subequal to the carapace in length.

Legs.—All the tarsi scopulate below, but no trace of a scopula on the metatarsi. Tarsus I with two or three spines on the anterior side, two or none on the posterior side; II with two anteriorly and two or three posteriorly; III with

one anteriorly and one or three posteriorly; IV with seven anteriorly and one posteriorly. Metatarsus I without strong spines on the mesial area below. Tibia I subequal in length to the metatarsus, with three spines below besides those at the apex, but none at the sides excepting one near the apex anteriorly; tibia III with about five short spines on or near the distal edge on both anterior and posterior sides superiorly. Patella I without spines below; III with a strip of six to nine weak spines on its anterior side, but no distal patch of spinules above. Patella IV with an anterior patch of spinules extending about three-fifths of the length of the anterior side. Paired tarsal claws of fourth leg each armed with two large basal teeth, with four smaller ones more distally situated on the posterior claw, but only three on the anterior claw, which are weaker than those on the posterior claw.

Measurements.—Total length 8.5 mm., length of carapace 4 mm., breadth of same 3.3 mm., length of palp 12 mm., of first leg 15 mm.

Stasimopus oculatus Poc.

Stasimopus oculatus Poc., Proc. Zool. Soc., 1897, p. 728, pl. xlii, fig. 2.

It has been pointed out to me by Dr. T. F. Dreyer that at least two species of *Stasimopus* occur at Bloemfontein, and Dr. Dreyer has kindly sent to me adult female material of the same.

S. oculatus, the larger species, can be distinguished through the presence of a cluster of spines at the apex of the third metatarsus inferiorly and the presence of stout spinules at the apex of the tibia of the palp superiorly, whereas the smaller species has neither of these characters; there is also a difference in coloration, the smaller species having the abdomen fairly uniformly infuscated above, whilst *oculatus* has the lateral surface of the abdomen and most of the dorsal surface comparatively pale but with a dark mesial blotch anteriorly and some infuscation over the posterior part of the dorsal surface.

Female specimens which seem to be identical with *oculatus* are known to me from Reddersburg (Dr. Broom), Ladybrand (Dr. Dreyer), and Kimberley (Bro. J. H. Power).

Female specimens which are identical with or very closely related to the smaller Bloemfontein species are known to me from Vredefort Rd. (Capt. Barrett-Hamilton), Valsch River near Kroonstad (Prof. H. H. W. Pearson), and Winburg (Miss S. Brown).

A third form characterised by the possession of short stout spinules at the apex of the tibia of the palp but no spines at the apex of the third metatarsus occurs at Kroonstad (Dr. T. F. Dreyer).

A fourth form from Jagersfontein (M. Francis) has a group of stout spines at the apex of the third metatarsus, but no stout spinules at the apex of the tibia of the palp.

Lastly, we have a good series of female specimens from Modder River (Bro. J. H. Power) which seems referable to two species, all the small and immature examples agreeing with *oculatus*, and all the larger ones being similar to the smaller Bloemfontein species in structure, but very much larger than that form; in this case it seems just possible that the small specimens from Modder River are merely the young of the larger ones.¹

Unfortunately we possess no evidence which can serve to connect any of these forms with the species based on male material. Only four male *Stasimopi* are known from the Free State, viz. the type of *S. nigellus* *Poc.* from Vredefort Rd., the type and a co-type of *S. gigas* *sp. nov.* also from Vredefort Rd., and the type of *S. minor* *sp. nov.* from Bloemfontein.

According to Dr. Dreyer, the nests of the two Bloemfontein species are very distinct; the female of *oculatus* makes a D-shaped lid, whilst the other species has a more circular lid; the tube of the nest in *oculatus* is very thickly lined

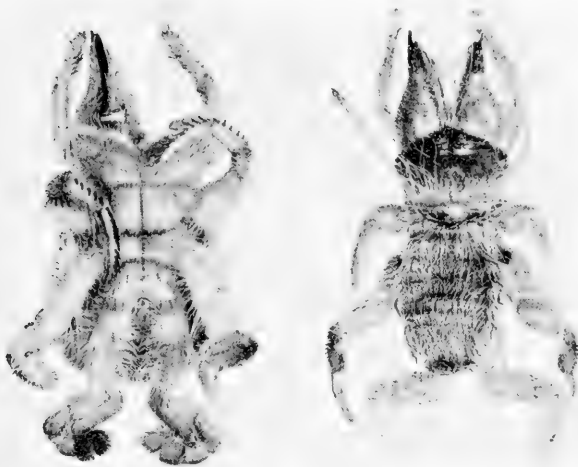
¹ Some of the forms just mentioned will be described by me as new species in 'Records Albany Museum,' vol. iii, pt. ii.

by felt-like silk, forming a much thicker wall than that found in the other species. In a large specimen the longest diameter of the lid of *oculatus* reaches 50 mm., the greatest outside diameter of the tube at the top being 60 mm.

Order SOLIFUGÆ.

Chelypus hirsti *sp. nov.* Text-figs. 8, 9.

TEXT-FIG. 8.



Chelypus hirsti *sp. nov.*

Specimen on left is minus the left chelicera, and is shown in ventral view; specimen on right is in dorsal view. $\times \frac{5}{3}$.

The types consist of four male examples in the Albany Museum collection, two of which came from Rietfontein, Gordonia, presented by Mr. H. Drew, and two are indefinitely located as North-West Gordonia, presented by Mr. C. A. Anderson. Female unknown.

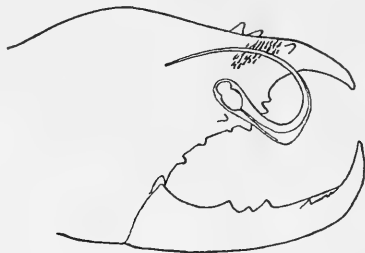
This species is closely related to *C. barberi*¹ Purcell, but differs therefrom as follows.

¹ Purcell, W. F., 'Annals S. Afr. Mus.,' vol. ii, p. 224, 1901.

Flagellum.—Not bifid at the apex, but tapering to a point. Near its base the shaft has a ventral, compressed, and keel-like extension along the greater part of the length of its procurrent portion.

Chelicerae.—Upper finger furnished internally with numerous short stout spines, occupying an elongated obliquely arranged area extending from the neighbourhood of the large basal tubercle on the inner side of the fang to a point near the basal enlargement of the flagellum. Outer row of teeth in the upper jaw comprising six teeth, the fourth one being

TEXT-FIG. 9.

*Chelypus hirsti* sp. nov.

Left chelicera of male viewed from inner side. $\times 4$.

minute. Upper surface of chelicerae covered with small granules, a few of which are spinuliform.

Pedipalps.—The upper surface of the tibia is only finely granulated, and in its basal third is almost free of granules; there is some fine granulation and one or two coarse granules at the base of the metatarsus above.

Colour.—Chelicerae without dark marks at the base above. Cephalothorax infuscated over its anterior half.

Total Length.—27 mm.

This species is named after Mr. A. S. Hirst, who has made important contributions to our knowledge of Arachnida and has described various S. African species.

Order SCORPIONES.

Opisthophthalmus pugnax Thorell, var. natalensis
var. nov.

The types of this variety are two adult specimens, male and female, from Estcourt, Natal, collected by Mrs. E. J. Turner and by Mr. Guy Marshall respectively, who presented them to the British Museum. The Natal Museum has a female example, a trifle larger than the type, from Mooi River, Natal, collected by Mr. C. James.

The variety agrees with the typical form of *pugnax*, as known to me through material from Pretoria, in colour and general structure, but differs as follows.

No stridulatory lamellæ on the chelicerae.

Median eyes more posteriorly situated, their distance from the hind end of the carapace being less than one-third of the total length of the carapace (more than one-third in typical *pugnax*).

Hands much less coarsely granulated, that of the male on its inner portion superiorly being covered with numerous quite small and isolated round granules, the finger keel with one or two coarse pits in its course, but practically continuous throughout, the more external secondary keel quite obsolete and the inner one, for the greater portion of its length, only represented by infuscated scarcely enlarged granules, the outer surface of the hand with only one keel; that of the female without coarse granulation on the inner part of its upper surface, except quite near the finger, but covered with a much flattened meshwork of more or less coalesced ridges and granules in which the secondary keels are quite absent, the whole surface appearing much smoother than in the typical form, the finger keel well defined, continuous in the distal half, more or less broken in the basal half (in the Mooi River example it is continuous almost throughout).

Hand of male slightly narrower in proportion to the length of the hand back than in *pugnax*, and the fingers a little longer.

The granules on the mesial portion of the last abdominal sternite of the male more numerous and not quite so large as in the male of *pugnax* proper (about ten or twelve rows can be roughly counted between the anterior and posterior margins); in the female this area is covered with low granules and irregularly shaped ridges, which occur throughout the whole length of the segment, more or less obscuring the keels (these are quite obsolete in the Estcourt specimen, but present, though indistinct, in the Mooi River specimen).

Infero-median keels of first caudal segment in the male composed of about eight to ten coarse granules, and the space between them also includes about ten coarse granules, but is not obliterated thereby nor are the crests rendered indistinct to any great extent; in the female these keels are pitted and more or less coarsely granular (in the Mooi River specimen the keels are not definitely broken up into coarse granules), with a few granules between the keels.

The abdominal tergites in the female are all granular throughout, coarsely so in the posterior portions of each tergite.

Pectinal teeth: Thirteen to fourteen male, eleven to twelve female (thirteen to fourteen in the Mooi River specimen).

Measurements.—Total length, male 78 mm., female 89 mm.; length of hand, male 17.3 mm., female 18.8 mm.; of movable finger, male 11.75 mm., female 12.3 mm.; of hand back, male 6 mm., female 7 mm.; breadth of hand, male 8 mm., female 10.5 mm.; length of carapace, male 11.7 mm., female 13 mm.; distance of median eyes from posterior margin, male 3.75 mm., female 3.7 mm.; width of first caudal segment, male 5.75 mm.; of fifth caudal segment, male 4.25 mm.; length of same measured along the side 10 mm.; breadth of vesicle, male 4.25 mm.; length of same 10 mm.

In respect to the shape of the hand and the granulation of the last abdominal sternite and of the infero-median keels of the first caudal segment in the male, this form is intermediate between typical *pugnax* and the form described by me from Keilands under the name of *O. latimanus* *Koch* var.

keilandsi.¹ It resembles that form also in the posterior position of the median eyes; it differs in that the tail of the male is much stouter in *natalensis*. The fifth caudal segment in an adult male of *keilandsi* measures 10·5 mm. in length and 3·75 mm. in width.

Dr. Purcell² points out in his important monograph on the genus *Opisthophthalmus* that the presence or absence of stridulatory lamellæ on the chelicerae is usually of no specific value. However, I am inclined to regard the character of some importance in the various forms which range around and between *pugnax* and *latimanus*. Such lamellæ are present in all our examples of *latimanus*, 132 specimens of all sizes, from Grahamstown, Highlands, Brakkloof, Fort Beaufort, Jansenville, Schurfteberg, Alicedale, Glen Lynden, Mimosa, Redhouse, Alexandria, and Queenstown; they are even present as a row of bristles on the newly hatched young. They are present in *latimanus* var. *austeroides mihi* and in every specimen of our series of typical *pugnax*; they are completely absent in *keilandsi*.

It is not improbable that intermediates between *keilandsi* and *natalensis* will be found, in which case it will no longer be possible to maintain *pugnax* as a species distinct from *latimanus*. With the discovery of new local forms in the genus *Opisthophthalmus* the differences between the so-called species are gradually breaking down and the genus is seen to be composed of numerous local forms which more or less completely grade into each other.

¹ 'Records, Albany Museum,' vol. iii, p. 7, 1914.

² 'Annals S. Afr. Museum,' vol. i, p. 134, 1899.

Observations on some South African Termites.

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With Plates XXV—XXXV and 16 Text-figures.

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I. INTRODUCTION.

THESE notes do not pretend to be more than fragmentary records which have been brought together for publication at the express wish of my friend, Dr. Ernest Warren. They include observations which have been made or collected only during the past two or three years; for most of them the writer is personally responsible; but, for some, which are duly acknowledged in the text, he is indebted to his colleagues and other friends. Unfortunately, owing to the difficulties

experienced in determining the material collected during the period mentioned, it has not been possible to include all the observations made; these it is hoped to deal with at some future date.

African termites having been described somewhat inadequately, as a whole, and for the most part in foreign languages, the opportunity has been taken to redescribe the soldier caste of some species discussed, and to furnish some comment upon the general characteristics of each.

As far as possible those speculations, which the study of termite-nature excites in every observer, have been avoided; here and there, however, the temptation to speculate has been too great to overcome.

For the sake of completeness, some observations made by others are repeated; these are chiefly derived from the Haviland notes (1) or Dr. Sjöstedt's monograph (2), and the context indicates whether or not they have been confirmed. The opportunity is also taken to correct some misapprehensions the author was under in writing his notes, "White Ants in Natal" (3).

II. THE ABUNDANCE OF TERMITES.

Owing to the fact that a number of South African species are to a great extent subterranean in their habits, little idea exists as to the great abundance of termites in general. This abundance may not be widespread, but it may be said of many parts of the country that the soil teems with termites. In some parts many species are found whose subways interlace without anastomosing, and all find sustenance in the same pastures. Where, in other parts, kinds are fewer, at least one sort tends to be particularly abundant. Again, upon the rock-strewn hills and mountain-sides a number of species, making their nests under stones, find a congenial environment.

As only a few points in the Union have been at all explored



for termites, and none very thoroughly, these generalities call for some verification.

In the south-west Cape, where termites are regarded as rare and where, as at Cape Town, white-ant attacks upon wooden structures are practically, if not wholly, unknown, *Hodotermes viator* exists abundantly, and a brief search in the neighbourhood of Stellenbosch, made for the writer by Mr. C. P. van der Merwe, revealed this and three other species.

In the Great Karroo *Hodotermes karrooensis* is almost ubiquitous and, in restricted areas, *Eutermes trinervius* also abounds; builders of large mounds, other than the last-mentioned insect, are seemingly non-existent, but there is little evidence on this point, and nothing is known of subterranean and rock-nesting forms.

Over the whole of the central area of the Orange Free State, the abundance of *Eutermes trinervius* is phenomenal; other forms are reported from various parts.

In Natal and the Transvaal it is no exaggeration to say that the soil is riddled from end to end of the country with termite tunnellings, through which an inconceivable host of insects constantly passes to and fro.

In two small areas at Pietermaritzburg (784 square yards each), the writer reported (3) finding fourteen and sixteen nests respectively, the homes of six different species. This, however, was an observation based solely upon surface indications. Latterly, a favourable opportunity presented itself to observe subterranean conditions at Pretoria in the case of extensive excavations which were being made for the foundations of certain large Government buildings. These works, covering two to three acres, were visited almost daily, and many of the observations detailed later were made during their progress. It was found that the soil was inhabited by eight species; to a depth of 4 to 5 ft. it was riddled with their galleries, and not a cubic yard existed which did not contain one or more cavities belonging to one species or another.

III. THE BEHAVIOUR OF WINGED TERMITES.

It may be taken as an axiom that every colony of the genus *Termes* is originally founded by the unaided efforts of a pair of winged insects. There is no acceptable evidence to the contrary; and the oft-quoted presumption that all adult termites are helpless and dependent upon adoption by a section of wandering workers is based upon the merest conjecture.

Again, the aerial flight is often regarded as having for its chief objective the prevention of inbreeding; that it may fail in this connection is indeed very obvious, although it must be admitted that the possibility of insects from different colonies mating is sometimes present. The real object of the production of sexual individuals in such vast numbers and their annual exodus seems only to be for the purpose of perpetuating the species; the countless swarm of emigrants which emerge, most of them to meet with speedy death, has its parallel in the phenomenal number of eggs or of young produced by many organisms.

In the case of two species many individuals have been seen to mate and at once to seek shelter in the earth within 6 to 8 ft. of the spot from which they had just emerged. Again, with these two species, and others, it has been noticed on occasion that an aerial flight takes place from one nest and not from others of a like kind adjoining it, and that insects mating far afield were of the same colony. At times, vast numbers of this species or that, or several kinds together, take to the wing simultaneously over a great area of country; it is on such occasions as these that sexes of different parentage meet. At other times vast numbers emerge in restricted localities only, or from one nest only.

The flying powers of winged termites do not appear great, and the majority do not fly far. At the same time, even in the case of those displaying the smallest powers of endurance, some few at least far outdistance the majority. Clumsily as they seem to fly many are well able to direct their movements

and rapidly avoid obstacles placed suddenly in their way. As might be expected, those which take to the wing after dark are readily attracted by light.

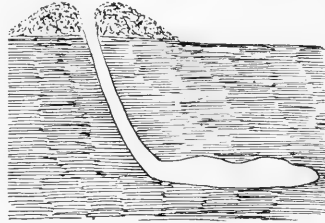
It seems almost certain that this phase in the history of a termite is a succession of events which follow upon one another in regular order, and, if the chain is broken at any point, it remains so. This may be illustrated by several specific cases. The night-flying *Eutermes trinervius*, if attracted by illuminating a white sheet, alights, and both sexes dealate after meeting. If some are captured at once before meeting and placed in a tube, they do not dealate. Some, so captured, have been kept over four days alive in confinement, and whilst a few dealated, or to be more correct lost their wings, no attempt at pairing was made. The same holds good for the dusk-flying *Termes incertus*, but to a modified extent only. Further, with these two species and three others (undetermined) no attempt is made at burrowing if the sexes are kept separate. In the case of two males confined together it was noticed that one would frequently follow the other as if it were a female. The stimulation induced them to burrow together, but they soon desisted from doing so, although stimulated thereto several times by one another; ultimately they died on the surface of the soil. Again, a number of pairs of *T. natalensis* were captured one evening and placed in a small box; in the morning it was found that the couples had lost all regard for one another; they were allowed to wander over a table, but none again mated voluntarily. When, however, the sexes were sorted out and the male placed in the position it had been in when captured, the sequence of events was re-established. In a further instance six pairs of *Hodotermes transvaalensis* were collected (December 30th, 1913) from burrows which they were making at the time, the couples were then placed in jars of soil, but were found to have lost the instinct to start burrowing again. They wandered aimlessly about, the males taking no notice of the females. When, however, artificial burrows were made, and the pairs placed in them side by side, the environment reacted upon them at once

and they burrowed to the bottom of the jar. In 1914, similar results attended the mating and re-mating of this species.

The act of pairing appears to differ in the details of its manifestation with each species, as the following accounts concerning several species will show.

Hodotermes transvaalensis *sp. n.*—This species was noticed upon the wing after nightfall in Pretoria on December 30th, 1913, and was again observed at 8 p.m. on December 7th, 1914. The actual meeting of the sexes was not seen.

Many gathered about the electric street lamps, and beneath these some were seen already paired off with the females leading, whilst other individuals, male and female, scurried rapidly about, as if in search of one another. As soon as a mated female began to dig, the male took his place by her side and seconded her efforts. Both insects are very expert excavators, and when once started soon construct a burrow. Much of the loosened soil is scattered by



Section of initial burrow and cell made by a pair of *H. transvaalensis*. $\times \frac{1}{2}$.

the feet, the action resembling a hen scratching. Pebbles of no mean magnitude are loosened, carried out in the jaws, and placed well to one side of the pit's mouth. The larger and grosser female displays just as much activity in this work as does the lither and less obese male. Their strength and their aptitude is best illustrated by the fact that they succeeded in burying themselves in the stones and grit of a macadamised roadway.

If interfered with the insects become most excited, and pairs placed on soil in captivity fled around like cockroaches, taking no notice of one another. When, however, artificial burrows were made, and the insects were dropped head first into them, they became normal at once, and just as instantaneously began burrowing.

Actual burrowing in open land has not been observed, but under the uniform conditions of a box of soil and observation cells, it was found that the insects did not close in their burrow behind them; instead they placed the loose particles regularly around the aperture so as to form a small perforated mound, which persisted for several weeks (text-fig. 1). Some females laid eggs within the first week, others only after the lapse of a fortnight. On May 25th, 1915, one pair with young were still alive.

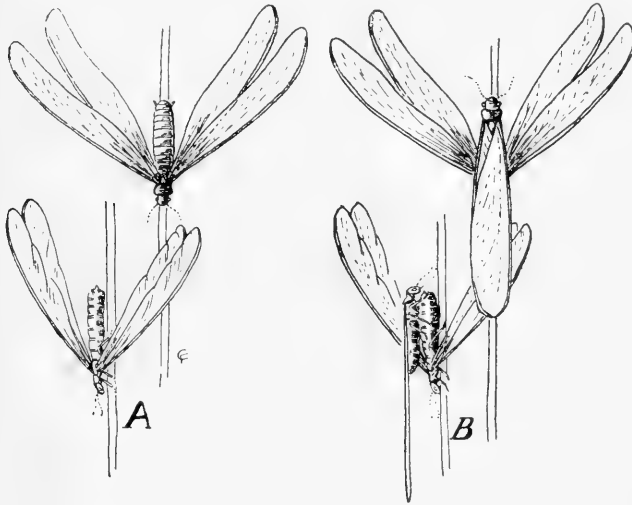
Termes natalensis Haviland.—The mating of this species has only been observed on one occasion (Pretoria, October 28th, 1913, 6-7 p.m.), when it took place in conjunction with a flight of *T. incertus*. The latter was, however, quite local, whilst the winged *natalensis* had come from far afield—probably a mile away. The insects flew high with well-sustained flight, and many passed overhead. The females, as appears usual, alighted first; selecting free and high-standing grass spears. Upon gaining a foothold (fifteen to twenty inches from the ground) they at once reversed their position and stood head downwards. Then all four wings were half opened and the apex of the abdomen became visibly swollen. Some males were flying low over the herbage when this act took place, and in a very short space of time the females were discovered by them. The male alights, as a rule, directly on the dorsum of the female, flying to her with much precision. He rapidly aligns himself, with wings closely folded and head upward, and combs across and across from one cercus to the other the dilated apex of the abdomen of the female. During this the female sits quite still, but presently she dealates and gives evidence of restlessness; when her movements sufficiently stimulate the male, he dealates and crawls from her back. The female then moves forwards down the stem, the male close behind, with mouth-organs always closely brushing the anal plates of the female.

There is no doubt in connection with this mating that, whilst the male is attracted to the female by the sense of

smell, as is the case with *T. vulgaris*, the directness with which he alights indicates further that, within a circumscribed radius, the female is visible to him; the play of the rays of the setting sun upon her half-spread wings rendering her quite a conspicuous object.

On this occasion a number of dealated pairs were collected and confined over-night in a small cardboard box. Several

TEXT-FIG. 2.



The mating of *Termes natalensis*. A. Two views of female in calling attitude on grass-stem. B. Two views of association of sexes. $\times \frac{3}{4}$.

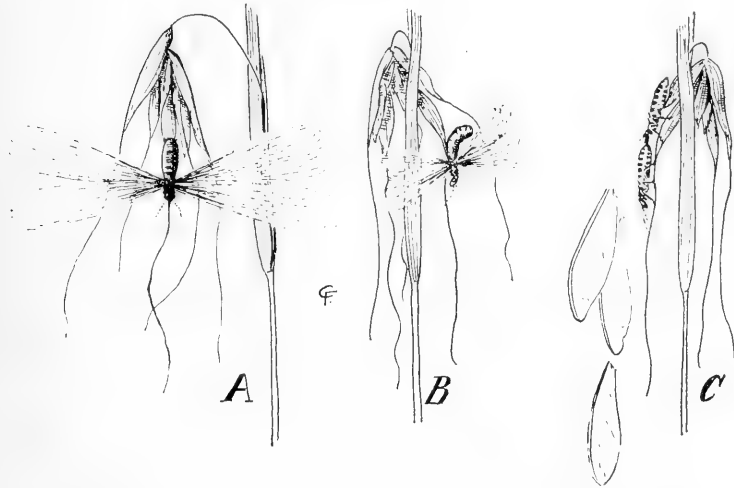
of these were successfully re-mated the following morning, three pairs burrowing into the soil contained in large glass jars. All burrowed to the bottom, to a depth of between four and five inches; and, unable to proceed further downwards, contented themselves by making a more or less globular cell about an inch and a quarter in horizontal diameter and three-quarters of an inch high. Owing to this fortunate circumstance it was possible, after removing the dark shield placed around the jar, to obtain some small view of the actions of the insects. The first pair soon died; the individual

which survived for a time buried its mate. On the fourteenth day one of the second pair died, and its mate was watched whilst it carefully encoffined the corpse in earthen paste. The third pair remained alive, displaying little if any anxiety when exposed to the light. On the sixteenth day (November 13th) a small bunch of yellowish eggs was noticed adhering to the glass side of the cell. On December 29th the first egg hatched, but whether one of those first laid (these appeared to become somewhat desiccated) could not be determined. Two days later fourteen young termites were counted, and many eggs were still unhatched. Before they hatched, the eggs were the object of frequent attention by both parents, and they often inspected them, feeling them over with their palpi. The young insects received constant attention from their parents, and apart from being fed by them they seemed to be constantly groomed. On the ninety-eighth day (February 2nd, 1914) some of the workers appeared to be adult, the heads showing yellow chitin. By this time the cell was a crowded mass of life and some eggs were also seen; at the same time no enlargement of the cell had been made and no galleries driven from it. Naturally, neither male nor female had taken any kind of nourishment, but they did not appear any the worse for their long fast nor emaciated by the feeding and raising of their young. This unfortunately is the last note made upon the colony. The writer left headquarters the next day, and during his absence the soil was kept too moist, and the whole colony succumbed and rotted before his return.

The burrowing of the pairs of this species resembles that of the smaller kinds; but, in common with other larger sorts, it is capable of greater exertions, and in beginning the operations the insects can be seen scratching the loose particles with their feet and throwing them behind them, as do most burrowing animals. When a pebble is met with, it is not avoided but picked up in the jaws and carried out and deposited where it cannot roll back into the excavation.

Termes latericius.—The mating of this species was observed in Pretoria at dusk on December 4th, 16th, and 18th, 1914. The females were seen to alight first, taking up an inverted position on pendulous parts of grasses and herbage. Immediately on assuming this attitude they begin to agitate their wings violently, and keep them in motion until a male becomes associated with them. How long a

TEXT-FIG. 3.



The mating of *Termes latericius*. A and B. The female in the calling attitude, violently agitating her wings. C. The sudden discarding of the wings when the sexes meet. $\times \frac{2}{3}$.

female may go on agitating the wings without a male finding her cannot be said, but one watched for twenty minutes never stopped, and after dark was still unmated.

The males seem to have great difficulty in finding the females; they fly low and incessantly over the tops of the grasses, and again and again approach quite near to a female, and even circle within a few inches around, only to fly off again far afield.

When mating was accomplished during twilight it was noticed that the male flew in narrowing circles around the

female and alighted near to her. Directly the male touches the female the wings of both drop with inexplicable suddenness, those of the female seeming to fall whilst still being agitated. After this the female leads the way to the earth, the male following close behind. Here they soon burrow into the soil, and there form a cell. Two pairs which burrowed into observation-cells on December 16th had both produced fifteen to twenty eggs eight days later. They were transferred to glass capsules, and on January 2nd had laid a further batch of ten to twelve eggs. Alive May 25th, 1915.

Termes vulgaris Haviland.—The mating of this species has only come under observation once (Pretoria, December 4th, 1914). The departure of the adults from the nest and their mating occurred between the hours of 8 and 10 a.m., immediately after a heavy and continuous downpour of rain which had lasted over three hours. The flight took place from a nest in the banks of a stream, and, but for this fact, the nest could not have been located.

The insects emerged from numerous apertures in the bank and in the surface overlying the site of the nest. Later in the day these were closed and covered with little mounds of soil. From the fungus-garden cavities to the apertures the insects travelled along specially excavated galleries, an inch and a half wide and a quarter of an inch high, driven upwards through the soil so as to form an inclined plane. These galleries are exactly similar to those made for the same purpose by *T. latericius*, and form another connecting link between these two similar but quite distinct species.

Upon leaving the nest the adults radiated out in all directions from it, and mating commenced within the first 100 yards. The full periphery of the flight was not actually determined, but in one direction it extended for more than half a mile. No wind was blowing at the time, and there was no evidence of an exodus from another nest. Along the radius of flight observed it must be conceded that all the mating was between insects of like parentage.

The females came to rest first, alighting here and there upon grass stems—both long and short—and immediately took up a position at the apex of the stem, with head downwards and wings closely folded. No particular inflation of the abdomen could be noticed, but it was obvious that some sense other than sight alone guided the male insects.

When a female alighted, a male was soon to be noticed fluttering low over the herbage. This flight was seen to be most erratic, although generally round and about the centre represented by the female. Often the male would fly close by and attempt to alight upon an adjacent stem—sometimes even doing so—but only to fly off, low across the grass tops for ten to twenty feet. Ultimately the male manages to locate the female, and settles below her upon the same stem. He at once crawls up beside her and rapidly passes the mouth-parts across the region between the cerci and touching the cerci themselves. Almost simultaneously with this action both insects dea-

late and the female begins to crawl downwards, the male following. In this attitude the insects progress until the female finds a site suitable for burrowing; the male never more than just keeps in touch with her. When burrowing commences the male takes his place beside the female, and in loose soil the pair soon become lost to sight. Pairs of this species did not thrive in the observation jars, but they constructed cells, and eggs were laid within a few days. One pair with a few young May 25th, 1915.

Termes incertus Hagen.—It would appear that shortly

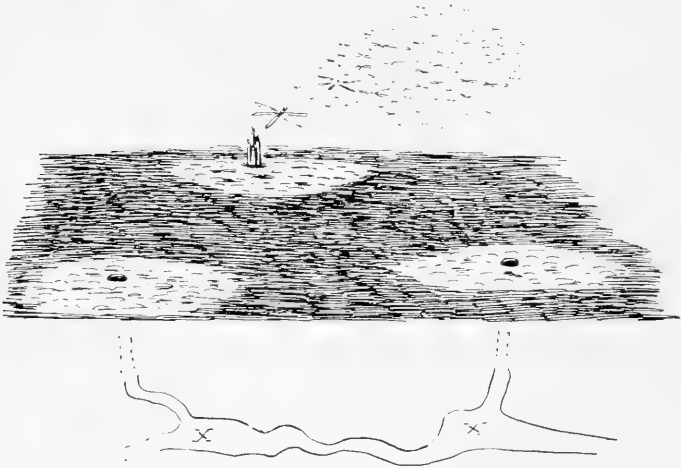
TEXT-FIG. 4.



The mating of *Termes vulgaris*. Female in calling attitude. $\times \frac{7}{8}$.

before the time arrives for the exodus of the winged individuals of this subterranean species, a number of wide galleries or chambers are excavated within two to three inches of the surface of the soil beneath some bare spot, and in these the winged forms are assembled, ready to depart at the chosen moment. When this arrives several (one to five) perforations are driven upwards through the surface. From each of these first of all adventure 2-300 workers, but never any soldiers ;

TEXT-FIG. 5.



The flight of *Termes incertus*. x x. Underground assembly-cavities shown in section. $\times \frac{1}{2}$.

these workers swarm around the individual openings out of which they have come, spreading out to form a circular mat four to six inches across. In this circumscribed area they keep constantly upon the move, and none ever wander away from the main body. Their egress is immediately followed by that of the winged.

Although the workers and the few soldiers that remain within the galleries hasten about among the imagos, perchance instilling into them "the spirit of the hive," those without pay no attention to them, their function seeming only to be the formation of a barrier—a living sacrifice—against

the ants which gather viciously around. By their action they secure to the winged a safe departure. Overcome with anxiety to seize upon the winged insects, the excited ants take no notice of the worker termites, and it is quite exceptional to see one of these carried off until after all the winged insects have dispersed. The barrier is effective, however, because when an ant steps in among the workers to reach its most prized prey, it is so discomfited by the nips of the little termites upon its feet that it is compelled to retire.

At Pretoria, both in 1913 and 1914, the imagos of this species emerged in great abundance on various dates throughout the month of November,¹ and always between the hours of 6 and 7 p.m. or during the brief twilight. The act took place almost invariably 10 to 24 hours after a fall of rain, the evenings selected being uniformly mild and quiet. Very many instances came under observation, but in none of these did one occur at any other time of the day, nor when windy, nor when rain was falling. On the other hand an emergence may often be followed within an hour or so by both strong wind and heavy rain.

The exodus commences almost suddenly and ceases quite abruptly. When darkness actually falls the insects are no longer on the wing, so that the period involved is never more than 30 to 45 minutes. Numerous cases came under observation in my garden, on the neighbouring kopjes and elsewhere. During one evening in 1913, and again in 1914, over a mile length of street was traversed, and along the whole length this species was emerging from countless places, in every garden, and at short intervals along the sidewalks. Such instances furnish some idea of how extensively this species inhabits the soil of Pretoria.

The winged *incertus* issue forth from the soil very rapidly and jostle and crowd upon one another, in the narrow confines of the apertures, to such an extent that very often they are so densely packed as to form small upright columns from the

¹ The actual period is the last week in October into the first week in December. Another emergence occurred in March, 1914.

apex of which those ahead take flight. As the insects all stream away in one direction, carried on some gentle air current, the emergence as a whole resembles a cloud of smoke issuing from a chimney.

If one of the holes from which they are emerging is covered by a glass tumbler the action at once ceases and the workers retire. If a series of holes are so covered the effect is the same, but, very rapidly, fresh openings are made near by and the exodus proceeds.

The females are the first to alight, and they do so directly on to the soil surface, always selecting a spot—large or small—which is bare of vegetation. On alighting they immediately dealate; occasionally they then run forward an inch or two, but more usually stand still and, puffing up the apex of the

TEXT-FIG. 6.



T. incertus. A female
in the calling attitude.
× 1.5.

abdomen, elevate it until one half of that region is at right angles to the rest of the body. Without doubt some perfume is wafted upwards, for males flying low overhead are immediately attracted and drop to the ground within 6 to 18 inches of the female. Usually only one alights, but sometimes several do so. The male at once dealates and hurries with, comparatively speaking, remarkable precision towards the female, even should he fall amidst the grass. In one instance where the females were alighting the ground was overrun with ants to such an extent that as each fell it was captured. Over this area males were seen flying low (20 to 30 inches) and, to all appearance, systematically searching the area for the expected scent. This they did until darkness fell.

The female does not remain in the calling attitude indefinitely, and the period is seldom more than a minute at the outside. She usually lowers her abdomen after a short while, runs a little way and then elevates it again. Directly she detects the immediate proximity of the male, and is certain that he is about to approach her, she hurries forward, and the male, catching up to her and placing his head upon the end

of her abdomen, hastens along wherever she may lead. Occasionally two or even three males will follow one and the same female, and later the whole party will proceed to burrow into the soil quite amicably. Once the male has taken up his position, the female's objective is some crack in the soil or some small pebble she can easily pass beneath. This reached she immediately begins to burrow, and the male, coming forward beside her, assists in the excavation. If a scratch is made in the soil, so as to surround an advancing couple, the female on reaching it will begin to dig; reacting at once to the stimulus of this suitable but artificial environment.

The burrow is begun by lifting out the earth particles and placing them around the spot. When it is sufficiently deep to accommodate the full length of the body—about three-quarters of an inch—the entrance is closed by a gradual process of building in the earth particles until a dome is made. The gallery is then extended slowly downwards, each particle as removed from the bottom being



T. incertus. A pair beginning their burrow, and the same insects after about an hour's burrowing. About natural size.

carried up and inserted and carefully compressed into the vault. In doing this the insects work to a very great extent in alternate positions, one excavating at the base whilst the other is placing its burden into the roof above. Hence it comes about that as the burrow is extended downwards it is filled in behind. The insects do not appear to moisten or cement the earth particles in place, the moisture in the soil itself being no doubt sufficient for the purpose.

Although operations proceed without intermission, and both sexes work rapidly, progress is very slow. This is not so much due to the difficulty of excavating as to the time taken in inserting the particles into the dome. A number of couples, whilst succeeding in burying themselves in ten to

fifteen minutes, had only reached a depth between 1 and 1½ in. in two hours, and 4 in. in eighteen hours.¹

On October 28th, 1913, a pair of *T. incertus* burrowed into the soil of a glass jar. They did not go to the bottom but to a depth of 5 in. The jar was left undisturbed until December 30th, when the soil was carefully removed and portion of the cavity they were occupying exposed. Both insects were then quite healthy and were surrounded by a brood of callows which they had obviously reared themselves. The cavity was closed and the jar refilled. They were not again disturbed until the middle of February, when, during the absence of the writer for a fortnight, too much moisture was added to the jar and the colony succumbed.

In November, 1914, attempts were again made to keep this species under observation in glass cells. At first, the insects took kindly to their artificial environment, and several pairs placed in the cells on November 5th had laid five to seven eggs on December 2nd and then succumbed; the dead bodies being covered with mould-growth which appeared to be rather of a parasitic nature than to be due to excess of moisture or other adverse conditions.

A few pairs remained alive in artificial cells, i. e. glass tubes plugged with earth; their eggs had not hatched on January 11th, 1915. All died early in February.

Eutermes bilobatus *Haviland* and an undetermined species.—The undetermined species is an insect which is related to *Eutermes bilobatus* but is not known to build a superficial mound. Structurally the soldiers of the two species are quite distinct; but for convenience the mating of the imagos of both species may be dealt with together. The *Haviland* notes (1) contain a good description of the mating of *bilobatus*, although it is curious that neither in the description of this species nor in that of its mating does *Haviland* remark upon the great disparity in size, as between male and female.

¹ The observations were made with couples placed in narrow vertical glass jars of moist soil.

According to the notes, the adults of *bilobatus* "fly around bushes and ultimately settle upon them. The male seizes the ventral surface of the abdomen of the female with his wings projecting in front of her head. The female flies away with him in the direction of the wind. On settling the male loosens his hold and both shed their wings. The female then proceeds to look for a place of shelter, the male following her."

No full opportunity to confirm these observations has yet presented itself. On several occasions the species was seen emerging before seven on sunny summer mornings; in one

TEXT-FIG. 8.



The mating of species allied to *Eutermes bilobatus*. *a*. Male attaching itself to female. *b*. Female dragging off dealated male. *c*. Female flying with male. *d*. Male and female seeking a spot to burrow. (About natural size.)

case a female was seen to alight on the ground beside a dealated male, when the small creature immediately seized her abdomen with all his feet, and then the female rose into the air and flew off with him.

The mating of the allied species was more fully noticed in Pretoria, November 14th, 1914, between 1 and 2 p.m. Before this, the species had been seen several times on the wing during light showers of rain and its habit of swarming around trees noted. During a shower of rain the writer happened to be standing under an open umbrella in a field where thousands of insects were emerging from the soil. The umbrella attracted them, and soon a cloud flew around, hundreds alighting upon the wet, upper surface, but none attempting to come beneath its shelter. In the wet film pairing proceeded rapidly. The females walked about con-

tinually, rapidly uplifting and lowering the whole of the abdomen, and raising the wings in unison. Presently a male would run in under the uplifted abdomen and, raising his head to its apex, seize it with all six feet; then, as the female pressed downward, he would dealate and tumble beneath her. This association achieved, the female walked with half-spread wings to the edge of the wet field, dragging the tightly clinging male with her. From here she took to flight, and, obviously burdened, soon settled down to earth. Immediately on touching the earth, the male-encumbered females dealated; during the action the male released his hold on the ventral surface and climbed upon the back of his mate, placing the head upon the fifth or sixth abdominal segment and clasping with both fore and mid-legs; only the hindmost pair was disengaged for walking. It appeared that upon some occasions the male did not dealate on clasping the female, as a winged pair was noticed on the wing; the male attached as Haviland describes in the case of *bilobatus*. This pair fell into a rain-pool, and on touching the water the female dealated. When lifted out the male relinquished his embrace and flew away.

The adults were noticed to emerge from small round apertures leading from cavities just below the soil. This they did in a manner very similar to that of *incertus*, except that never more than forty to fifty workers formed the surrounding mat. In the assembly-cavities many workers and a few soldiers were seen hastening in and out amongst the crowded winged forms.

It may be said, with no small degree of certainty, that all imago termites are at first positively hydrotaxic, and a captured pair of this species displayed the symptom to a remarkable degree. They were placed upon a tray of dry soil and wandered disconsolately over its surface. When a few drops of water were applied to one spot they soon found it; they wandered about for ten minutes, but returned to the small moist area and there buried themselves. They remained in the moistened area and burrowed about in it for twenty-four

hours—apparently refusing to enter the dry surrounding soil.

IV. OBSERVATIONS ON THE NESTING HABITS AND GENERAL ECONOMY OF CERTAIN SPECIES.

Hodotermes transvaalensis *sp. n.* Pl. XXV, figs. 2-7,
Pl. XXVI, figs. 1-5.

During the progress of the excavations, of which mention has been made, much care was taken to acquire some knowledge of the subterranean work of this species. The opportunity was excellent, as all of the ground involved was inhabited by it. Upon the whole, however, the results were meagre.

A great many hives were exposed, but only two of these were inhabited. The majority were in various stages of dilapidation and others appeared to have had their general contours destroyed by flooding. The evidence collected went to show that ordinarily the species voluntarily deserts its hives and later fills them up with excavated particles of earth; using them, in fact, as dumping grounds. It is quite possible that desertion is sometimes due to the collapse of the fragile interior structure.

The inhabited hives were both similar, and were in reality central granaries in which the hay harvested is finally deposited. They are doubtless also nurseries, but neither a queen, nor eggs, nor particularly small callows were found in either. The surrounding earth was explored in the hope of tracing some special compartment in which eggs were possibly incubated, but nothing of the sort was found, although many cubic yards of earth were removed.

There was ample evidence that during the excavation before the hives were reached the insects left them; one, in fact, was wholly deserted. In the other, which was broken into somewhat suddenly, numerous and quite white callows were found; none, however, were particularly small, the

smallest being 5 mm. long. It is suspected that the hives of this species intercommunicate, as do those of *Eutermes trinervius*, and that the economy of the two is more or less analogous.

The hive-cavities (Plate XXV, fig. 2, and Plate XXVI, fig. 1), with one exception, were all sub-spherical, having a horizontal diameter of 24 in. and a perpendicular height of 18 in. The cavities are partitioned by very numerous horizontal and close-set shelves (Plate XXV, figs. 4-6). These are constructed of a thin and very papery substance which does not dissolve in water or in alcohol. The shelves lie one above another with striking regularity, and are attached to a series of clay brackets projecting from the walls. The shelves are not equi-distant apart throughout the cavity, but range from 6 to 15 mm. Innumerable little cylindrical columns of wooden texture, spread over the field of each shelf, hold the whole fabric together (Pl. XXV, fig. 4). These little columns are not stairways; the insects pass up and down from storey to storey of the hive by short inclines. The hive is not like that of any other known termite structure in South Africa. Except that the shelving is as brittle as charred paper, whether moist or dry, the shelves might be described as being more like dark brown paper than anything else, as they are scarcely thicker than stout paper.

A most striking feature is found in a series of eight great shafts which, descending more or less perpendicularly from the sides and bottom of the cavity to a distance of 2 to 3 ft. into the soil, run forward in a horizontal coil and then end blindly. Whether these are for the purpose of permitting heavy gases developing in the hive to find a lower level, or are merely for drainage in the case of soil saturation, is purely a matter for speculation.

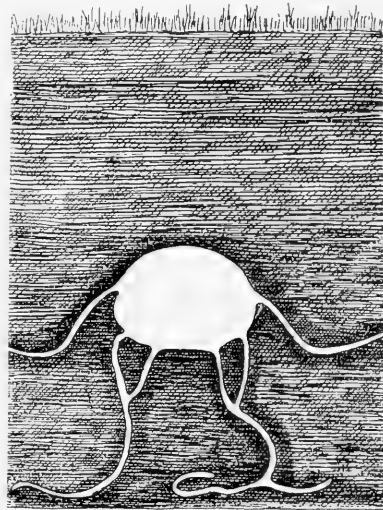
The hive is approached and entered by equally large galleries which perforate the sides of the cavity. They are comparatively few in number, only four being found in the nest examined fully. The galleries do not run off in a horizontal plane, but first descend to a level below that of the

nest and then rise again (text-fig. 9). Here they become greatly reduced in diameter (Pl. XXV, fig. 7) and then travel in a horizontal plane, but somewhat erratically, away from the nest. Owing to the labour involved and the indirect route taken, it was found impossible to trace a gallery the whole way either from the nest to its exit at the surface or from a surface burrow to the nest. The greatest length of straight gallery exposed was about 30 ft. This rose from a depth of 4 ft. to within 2 ft. of the surface, running in horizontal lengths of 6 to 8 ft. rising by short inclines from one level to the next. Because of the fewness of pouches in this particular gallery, and its relationship to one of the hives, it was regarded as a middle length in a main passageway.

Upon reaching to within a foot or so of the surface the galleries branch and interlace, some naturally connecting up with others; from here galleries are driven to the surface, and as many as

twenty-six openings were counted on one feeding ground 10 ft. by 5 ft. Near to the surface of the soil, cavities are made for the temporary storage of the material harvested. These are usually to one side of the gallery and in the form of wide, flat pockets. Deeper in and also where the tunnels approach the hive there are much larger cavities (6 to 8 in. in diameter). The floors of these gallery extensions are all broadly convex; they are quite shallow, however, and the

TEXT-FIG. 9.



Hodotermes transvaalensis.
Section of subterranean granary
showing entrance galleries and
descending blind shafts. $\times \frac{1}{30}$.

majority of them fall away on one side of the gallery to a lower level (Pl. XXVI, figs. 2 and 2a).

It was noticed in all the inhabited and uninhabited hives that no passage-way entered the dome of the hive, and where a tunnel was found about a foot below ground running over the site of one nest it showed no indication of approaching the cavity but kept straight and horizontal along all the distance (10 ft.) it was exposed.

Harvesting is conducted in the bright sunshine, and Mr. F. Thomsen, of the Division of Entomology, informs me that on several occasions when bivouacking on the veld he has observed *Hodotermes* *sp.* working 'at night, but only when the moon was bright and full. He also states that they quite commonly enter stables and feed on the hay litter therein at night.

Ordinarily, however, they work during the daylight, closing the entrances to the burrows at night-fall with short stoppers of clay. Harvesting is conducted all the year round with, as far as observations go, a break when winter merges into spring. From complaints reaching the writer *Hodotermes* *ssp.* seem to be most active, or are noticed to be most active, during the autumn and early winter months. In Pretoria, however, the activities of *transvaalensis* were noted all through the summer and until the end of June. Some time subsequently these ceased and remained in abeyance from August to the middle of October. Their activity in the latter part of the season may be put down to the then more favourable condition of the grass for storage, and the cessation later on to the fact that their granaries are full, rather than to the succulence of the young grass. There are several fictions regarding the activities of these termites. One is that they are more abundant during periods of drought, the other that they are most active just before a thunderstorm. Speaking on personal observation alone, they have never been seen more busy than on one winter's morning between 8 and 9 a.m. when frost lay thick near-by under the shade of a *Cupressus* hedge. They

appear more abundant during drought, first because they are then more apt to pillage cultivated crops, and secondly because the veld is barer and so they are more readily seen. The thunderstorm fiction seems wholly due to the fact that, in the stillness preceding the breaking of a storm, the noise they make in biting through dry stems of grass is distinctly heard and draws attention to them. The writer cannot say positively that they are not more active at such a time, as it is quite possible that they are more excited, responding, as do many insects, to storm influences; they seem to be making hurried efforts to get in the last piece of hay before the storm breaks.

The foraging is done by the workers, both large and small, callows also assisting in it. The lengths are carried upright, as described and figured for *H. havilandi* by Sharp, or are merely dragged along to the mouth of the burrow. Here the bulk is deposited, but some is always being carried in. When a sufficiently large quantity is collected, or towards nightfall, harvesting ceases, and such supplies as have not been broadcasted by the wind are removed below the ground. The soldiers do not accompany the workers, but as a general rule one or two are to be found on guard just within the mouth of the gallery.

Sometimes, when a very large collection of hay has been made, a loose mound of earth has been thrown over it. Such an accumulation may remain so weighted down for several days (Pl. XXVI, fig. 3).

As no mound of any sort overlies the site of the hive, and as no galleries are driven to the surface in its proximity, it is interesting to note the disposal of the considerable quantity of earth excavated in the making of cavities and galleries. As far as possible this soil is utilised for filling up disused galleries and deserted hives; cavities made by other termites are also filled. Curiously enough these fillings remain dry where they are placed, the soil particles not being easily wetted.

The following are a few specific instances coming under observation: (1) a deserted hive completely filled with earth

particles, the interior partitions being mostly intact; (2) a deserted hive, in which the interior had collapsed and fallen the bottom, was being filled *through openings in the dome* of the cavity, the earth particles and *fragments of dead Hodotermes* being dropped in; (3) the filling in of the small fungus-gardens of *T. incertus* from *holes in the dome* of the cavity. To these may be added many cases where cavities of all sorts and sizes were found completely filled up.

Besides acting in this manner, *Hodotermes transvaalensis* brings a great deal of earth to the surface, arranging the loose particles in mounds which, when of any size, strongly resemble small mole-hills (Pl. XXVI, fig. 4). These often occur over a fairly wide area, but they do not coincide with the nest-site nor are they necessarily adjacent to the openings from which the termites emerge when bent on gathering provender.

A hole is driven to the surface which is about a half or one-third of an inch in diameter. The first particles of moist earth are built together as a collar around this, and further particles are pushed up so as to fall outside it. As the mound rises in height so the collar grows into a chimney, the encircling pile of earth supporting it upon its weak foundations (Pl. XXVI, figs. 5 and 5*a*). Often these progress no further, the holes at the top are closed up, and the wind wearing on the hill leaves the apex of the chimney exposed.

Where large quantities of earth have been thrown out, the inner chimney is found enlarged and branched and of various grotesque forms. It is obvious from the arrangement of the branches that they are constructed so that the soil will fall away from the point on one side of the moundlet where it is discharged (Pl. XXVI, figs. 4 and 4*a*, 4*b*, 4*c*).

Curiously enough the insects do not expose themselves in doing this work. When the pellets are brought to the mouth of the chimney they are moist and cling together so as to cloak it; and all that one sees is grain after grain taking its place at the apex of the mound and then, on drying, rolling down the incline. If the mound of loose earth is gently removed, the chimney—however bizarre—stands upon its base; but if

touched falls over and crumbles readily to pieces. Rain and wind both rapidly distribute these heaps of soil.

A hive of *H. havilandi* was discovered under rather peculiar circumstances at Weenen in Natal. Unfortunately when inspected nothing but the cavity and some débris, from which dead termites were removed, was found. This occurred in the wall of an office in the village, and all the information obtainable was that one day a slab of plaster fell away, and a mass containing many termites and pieces of grass fell out on to the floor. The cavity was about 2 ft. 6 in. from the ground, and 15 in. in both diameters. The wall was built of burned brick; but since the bricks lining the cavity were only grooved, so as to form brackets for the shelving, one cannot help suspecting that the spot in the wall chosen by the termites was a part which had been filled with some sun-dried bricks. *Hodotermes havilandi* is a very familiar insect in and about the village of Weenen; because of this, it is interesting to add that the Chairman of the Village Board—in whose office the event here related happened—had never seen the insects feeding nearer to the hive than 100 yds. off. He had, however, been long familiar with the fact that they were tunnelling in the plaster of the walls of his office.

H. havilandi appears to have a very definite life-zone in Natal, being restricted to the warm and dry river valleys of the midlands.

The method of harvesting of all our *Hodotermes* is uniform with that of *Eutermes trinervius*. The accumulation of provender outside the burrow entrances has a double purpose—it prevents congestion of the tunnels and allows any green parts to dry. Doubtless also its storage in pockets before being carried into the main hive is to insure sufficient dryness so as to avoid the growth of mildew.

Under date of January 12th, 1915, my colleague, J. C. Faure, entomologist at Bloemfontein, sent to me specimens of *H. transvaalensis* with the following notes.

“ Bloemfontein, December 7th, 1914, 6 p.m. Heavy rains had fallen a few days previously. Near the Sewage Farm orchard I was attracted

to flying *Hodotermes* by a large number of dragon-flies that were hovering around one particular spot.

“Winged forms.—They were emerging in considerable numbers from ordinary foraging holes in the soil. There was a considerable number of small mole-hill-like workings near by. The males and females ran out of the holes, and took flight almost at once by jumping a little distance into the air and then bringing the wings into action. The distance flown could not be ascertained because the dragon-flies captured a very large percentage of all the termites that took to wing. Those that did escape did not fly more than, say, 30 ft. from the flight-holes. They got rid of their wings in the ordinary way. The meeting of the sexes was not observed. I think it likely, however, that the male and female meet on the ground after losing their wings. Only a few pairs could be found in the act of beginning to burrow. They were, however, entirely alone, no soldiers or workers being present.

“Workers.—Near the holes from which winged forms were emerging there were many workers engaged in their ordinary work of foraging. I did not actually see them carrying food into the flight-holes, but there were several other openings to galleries near by. There were no workers at the flight holes while the males and females were emerging.

“Soldiers.—A number of soldiers were found near the openings of the galleries from which earth-mounds had been thrown up. These were about 10 ft. from the flight-holes. I was unable to get soldiers from one or two flight-holes that I dug up. At any rate, it was easy to get soldiers under the little earth-mounds near by, much more so than when no flight is in progress. There were, however, no soldiers on the surface of the soil.

“It was remarkable how large a percentage of the flying termites were captured by dragon-flies. They were mercilessly captured, their abdomen was devoured in a very short time, and then the head, thorax and wings were dropped. Frequently these “de-abdomened” termites were seen frantically digging in the soil, obeying their instinct to fly, drop and dig. In these abnormal cases, however, they forgot to search for a mate first, and they did not drop their wings, probably because they had no abdomen. Needless to say, they soon died.

“Large black ants prowled around near the flight-holes and carried off injured termites or those that were unable to take flight soon enough.”

Hodotermes viator (*Latreille*). Pl. XXVI, figs. 6, 6a, 6b, and 7.

A number of imagos without wings which appear to be of this species were collected for me at Victoria West during

December, 1914, by Mr. F. Jansen, the Resident Magistrate. These were found issuing from holes in the ground in the streets and in the country surrounding the township.

Specimens of soldiers and workers have been collected in the Stellenbosch district by Mr. F. W. Petty, Lecturer in Entomology at Elsenburg Agricultural College, and by Mr. C. P. van der Merwe, of the Division of Entomology. The following observations have been communicated by these colleagues.

(a) C. P. van der Merwe. "Insects collected May 15th, 1914, in pine forest at Stellenbosch. These termites were observed to collect pine-needles into heaps varying from 1 to 3 ft. in diameter and from 6 to 18 in. in height, a few being quite $2\frac{1}{2}$ ft. high. The small heaps consisted only of whole pine-needles, and a fungus was growing through the heaps. The large heaps consisted of finely cut-up needles and numerous earthy pellets like fine seeds.

"The small heaps have a tube of earth running down the middle into the soil. In the large heaps there are more than one of these tubes, but they appear to run from the surface directly into the ground. Pieces of cut-up needles were found in the burrows."

(b) F. W. Petty. "The specimens sent were collected from two types of mounds, of which I send you sketches (Pl. XXVI, figs. 6, 6a, 6b, and 7) in the barley and oat fields. These mounds are about $2\frac{1}{2}$ in. high or less. They are made of small, loose, black pellets brought up from below ground, and the mound has a firm, hard core running up through the middle of it. This core never runs up straight, and often branches into two tubes, one being always shorter than the other. These tubes or cores are not made up of the black pellets, but consist of ordinary soil, and have the inner lining smooth and hard. Evidently the pellets are brought out of the opening, and, as they pile up, the tube is lengthened. The insects also make small mounds of gathered bits of grain, leaves, weeds, etc., the particles of vegetation being from $\frac{1}{4}$ in. to 3 in. in length. These collections of vegetable matter are simply grouped about a hole in the form of a low mound no more than 1 in. in height. I also found burrows which have been closed over by a hard roof of earth, forming an irregular low chamber into which the burrow opened. Surrounding the outside of the roof of this chamber were pieces of vegetable matter (Pl. XXVI, fig. 7).

"A striking fact which I noticed in the grain fields where these termites were doing much damage was that many colonies, or rather the termites of many exit holes, were dead, and usually the head had

been severed from the body. I thought this was due to the 'witgat spreuw,' because bird excrement was found near and amongst the dead termites. On one occasion a flock of these birds was seen in the field, and on reaching the spot where they were evidently feeding numerous dead and mangled termites were found and fresh bird excrement as well. I was, however, told by Dr. Peringuey that this destruction of termites was very likely due to a small beetle (*Monoplius inflatus*), as he had previously observed a similar state of affairs.¹ Upon investigation I found many beetles and larvæ in the affected colonies among the termite excreta. There are two kinds of beetles (identified as *Monoplius æmulator* and *M. segillatus*), and they are possibly attracted by the termite excreta. I have not yet succeeded in obtaining any proof that they destroy the termites. I have confined termites with *Monoplius*, but the one does not disturb the other; the termites die off with no evidence of death from bites.

"In those colonies where the termites are all healthy and busily gathering cut leaves, etc., none of the fine, black pellets mentioned above are to be found."

In a recent communication under date of January 11th, 1915, Mr. Petty adds the following.

"As regards *Monoplius* beetles, I may say that further observations led to finding them in small colonies among termite excreta where no dead termites were present. I have found dead termites among the excreta where no beetles were present. Without a doubt *H. viator* has the habit of removing dead termites from underground through burrows at the surface, since I have found dead ones brought out by living ones. The 'witgat spreuw' kills and eats this termite.

"You may be interested to know that along roadsides with sloping banks in this district, *H. viator* makes simple openings on the face of the bank, without projecting tubes, and discharges the fine, black particles (excreta) together with peculiar flat, black pellets. These roll down the bank and accumulate; in some places as much as a bushel may be seen. Evidently no projecting tube is made in these cases because it is not required."

Calotermes durbanensis Hav. Pl. XXV, fig. 1.

There is evidence to show that this species occurs very generally along the coast of Natal. According to the Havi-

¹ L. Peringuey, "Note on le Gen. *Monoplius*," 'Ann. de la Soc. Ent. France,' lxx, 1901.

land notes, burrows are made in the living wood, the invaded parts subsequently decaying. It is further recorded as attacking orange trees. The writer cannot help thinking that Haviland was under some misapprehension regarding the habit of this species, because those colonies which have come under his notice have always been at work in dead branches, either still attached to the tree or prone upon the ground. The opportunity has not been found to make any particular study of its habits. It may be interesting to add, however, that a piece of infested wood collected in March and left to dry out in a breeding cage, in Pretoria, contained live insects, soldiers and nymphs, when opened during the latter part of October. And further, nymphs and soldiers placed during March in a glass tube with fragments of the wood from which they were extracted were alive when last examined (January 11th, 1915). During the whole of this period there was no evidence to show that the insects had fed to any extent.

The workings of this species in the wood take the form of elongate, flattened chambers communicating with one another by tubes of a narrow diameter.

The following notes have been received from Dr. Warren on the observations of Dr. Conrad Akerman of the Natal Museum :

“ On March 1st, 1913, a piece of dead branch (about 10 in. long and 3 in. in diameter) containing *Calotermes* was broken off a living tree, at a height of about 5 ft., in the bush near Winkle Spruit on the Natal coast. The branch was brought to the Natal Museum and sawn through longitudinally. The wood had been considerably channelled, and the insects were numerous: nymphs with wing-pads, nymphs without obvious wing-pads acting as workers, soldiers and many small young could be seen, but no eggs were observed. The two halves of the branch were tied together with string and placed in an inclined position in a glass jar without a lid. About an inch of water was poured into the bottom of the jar, and the end of the branch was just in contact with the water. The termites flourished, and large quantities of fecal pellets continually dropped into the jar. In March and April forty, or more, winged imagos emerged. From April 23rd to August 23rd there was a pause in the emergence of winged forms.

"The two halves of the branch were occasionally separated for the purpose of inspecting the colony, and they were firmly glued together, apparently by means of the faecal pellets. The so-called workers were by far the most numerous of the different castes. No eggs were seen at any time. In 1913 emergences occurred on March 18th and 24th, April 3rd and 23rd, August 23rd, November 11th, 17th, and 21st (numerous), December 5th (numerous). In 1914, January 5th (numerous), February (several). In September, 1914, the colony was seen to consist of a few soldiers and of approximately 250 large nymphs with well-developed wing-pads. There were no individuals in the working stage, and no young of any kind. From these observations it would appear that the small young seen when the trunk was collected in March, 1913, had grown into nearly full-grown imagos by September, 1914, a period of eighteen months. The piece of wood had been reduced to little more than a shell, and the imagos which emerged amounted to about 300 in number. Thus the number of individuals in the original piece of wood, assuming that no reproductive female was present throughout the time, was 550, which, together with, say, 50 soldiers, gives a total of approximately 600. The piece of wood was subsequently sawn into small pieces, but no trace of young could be seen, and, since no eggs had been noticed at any time, it is doubtful if a reproductive female was present when the piece of trunk was removed from the tree."

Rhinotermes putorius Sjöst.

This species has only been observed in the Durban Botanic Gardens where the Haviland material came from.

No opportunity has yet presented itself for studying its nesting habits. On the assumption that its nest was in the dead timber of the trees up the trunks of which its galleries were noticed, the galleries were followed up to the topmost branches, and here it was found that the creatures entered and burrowed in the dead wood where *Calotermes durbanensis* Hav. was established. The soil around the base of the tree was examined by Mr. F. Thomsen, but he was, for want of time most probably, unable to locate a nest. This species builds long, narrow covered ways up the tree trunks. The coverings of these are well cemented together and obviously intended to be of a permanent nature. They differ from covered ways of other species in being of a carton-like

material mixed with sand, such as *E. parvus* has, in exceptional cases, been found building. As a rule only one gallery is built up the main stem, and a nearly perpendicular pathway is made from the level of the soil. If a branch is made in the gallery upon the trunk of the tree, it is only in the form of a loop. From these galleries major and minor workers, a few minor soldiers, and a rare major soldier may be recovered.

Termes waterbergi *sp. n.* Pl. XXVII, figs. 1-3.

My attention was first drawn to this insect by Mr. C. A. Simmonds, of the Division of Horticulture, who sent to me material from a mound found below some thorn trees at Warmbaths, in the Waterberg district, during October, 1911.

Mr. David Gunn, of the Division of Entomology, subsequently obtained for me a large series of major soldiers from a single gallery which he found in this mound. Time did not, however, permit him to make any particular examination of the nest.

More recently (March, 1915) I have been fortunate in finding this species at De Wilt on the northern side of the Magalies range. The country here is what is generally called middle veld. It is hot and somewhat dry and covered by various acacias and a large variety of other bush-veld trees. Throughout, at very short intervals, which are studded mostly with acacias, are more or less circular clumps of dense set trees. The trees in these clumps are of a number of kinds, and all are more umbrageous than those between the clumps. In a fair number of clumps stands a solitary and large *Euphorbia*, that characteristic feature of the park-formations of Zululand. Without exception the soil-level beneath the tree groups is higher by 2 to 4 ft. than that around them, and has obviously been raised around the stems of all the older plants. The better part of three days was spent in examining this particular aspect of park-formation, and, except in the case of some tree groups inhabited by *T. waterbergi*, there was ample evidence to show that all were the homes of

Termes badius. A week previously the country had been subjected to a torrential downpour of rain, and because of this all evidence of old Termite work had been washed away, and what was present was quite recent. Beneath one group of trees a colony of *badius* had in the intervening period covered its nest-site, to a depth of 4 to 6 in., with a fresh layer of earth over an area of 100 square feet. No evidence whatever of the presence of *Termes natalensis* was found, but *T. latericius* abounded. The nests of this species were only occasionally found in the tree-covered nest-sites, but in the intermediate spaces they were quite numerous, and almost invariably indicated by chimneys only, the absence of mounds being quite conspicuous.

The very general abundance of *T. badius* and *latericius* over the whole area examined made the restriction of the series of nests of *T. waterbergi* to a small area surrounding a natural spring quite remarkable. On account of the water the tree clumps in which they were found were larger and denser than those further afield. This series of nests being found somewhat late in the inspection, time and labour did not permit me to make a full investigation of the nesting habits of the species, and only one mound of medium size, which happened to lie conveniently to one side upon a smaller nest-site some 20 ft. in diameter, was explored. Here a nest-cavity was disclosed, which, from the absence of the queen-cell and eggs, I can only conclude was but a part of the whole nest. An adjacent nest-site was over 200 ft. in length and about 60 ft. across. It was overgrown with many large trees and a thicket of undergrowth into which one could scarcely penetrate. Throughout it, however, were many weathered mounds of earth which had been thrown up by this species. Nearly all were 2 to 4 ft. higher than the surrounding soil (itself elevated above the natural level), and the largest mound was 15 to 20 ft. across.

The mounds of *T. waterbergi* are not masonry mounds, although they have that appearance when beaten down by rain. They are simply deposits of loose earth particles which

are not cemented together in any way. All were entirely composed of subsoil, and presumably represent the soil removed by the insects in making large hive cavities and other low-level excavations. But very few galleries traverse the mounds, and such as do are purely temporary, being made only for the purpose of throwing out the excavated earth. This is discarded in a very similar manner to that adopted by *Hodotermes*, but there are no hardened tubes made through the centre of the earth piles. The pellets are brought up and pushed out loosely without the insects exposing themselves. In this way many perfectly conical heaps of soil are formed, and those seen were from 6 to 10 in. in height and 12 to 18 in. in diameter. They were found anywhere upon the surface of the larger weathered mounds and also round about them, some being even a little outside the fringe of the nest-site.

The mound examined was oval in outline, 5 to 6 ft. long, 4 ft. across, and 24 to 30 in. in height (Pl. XXVII, fig. 1). It was so recently made that no roots had as yet penetrated it (fig. 2). Immediately under the centre of this mound was found a large sub-globular cavity with a flattened floor and a somewhat conical dome (fig. 3). A layer of undisturbed soil of some 18 to 20 in. in thickness overlaid the apex of the dome. The height from the floor of the cavity to the roof of the dome was between 24 and 30 in. and the diameter at the floor 30 to 36 in. The walls of the cavity were smoothed, but not plastered over with a cemented clay lining, as is the case with most species, and in the somewhat similar cavities made by *T. badius*, *T. vulgaris*, *T. latericius*, and *T. incertus*. Access to this cavity was gained by the termites through a series of more or less triangular and fairly large openings to devious galleries leading away from it.

The cavity was completely filled by a large sponge-like formation of clay-laminae or shelving, remarkable for the fact that at no point was it attached to the walls of the cavity as in the case of *T. natalensis* and *T. latericius*, and also for its simulation of certain fungus-gardens, such as



the supplementary gardens of *T. badius*, *latericius*, and more particularly *vulgaris*. When sectioned it was found that all the shelves were close together—seldom more than an inch apart—those at the bottom were level, but from one-third of the height the shelving sloped upwards from the sides to the centre of the construction, the inclines becoming more acute towards its apex.

On one of the lower shelves fragments of dried grass were found. Dispersed about other parts were flattened separate fungus-gardens, none of which were more than four inches across. These fungus-gardens resemble those of *T. natalensis*; their upper surfaces are flattened and the lower coronetted like the surfaces of the gardens of *natalensis*, but the perforations are arranged more like the cells of a honey-comb. The lower surfaces of nearly every garden had been recently gnawed away by the termites, but the few places that had not been mutilated showed that this surface somewhat approached the coronetted surface of the garden of *natalensis*.

The hive was inhabited by major and minor soldiers, workers, and by young in many stages. The minor soldiers were not as numerous as majors, and were not at all aggressive; on the other hand, the major soldiers poured out and were aggressive, drawing blood with each bite they managed to inflict. The workers retired; but, if one ceased disturbing the nest for a minute, they came forward with pellets of soil in their jaws prepared to repair the breaches.

Termes natalensis, *Haviland*. Pl. XXVI, figs. 8-19;
Pl. XXVIII, figs. 1-12.

MOUNDS AND NEST-SITES.

The mounds of the *natalensis* series do not agree with the historic illustration given by Smeathman, nor are they begun and built up after the manner which he describes. In

fact, the only ones approaching Smeathman's picture have been seen at Winterton, Natal (Pl. XXVIII, fig. 1); these were not more than 5 ft. high and 6 to 8 ft. through at the base. Nests may be said to fall into two categories, being either of ancient or modern formation; the ancient types are represented both by isolated mounds and by "nest-sites," the modern by rounded, pinnacled, pyramidal or conical masonry mounds.

The modern mound, which occurs commonly in the grass veld (savannah) around Pretoria, is a wide, low, barren mound, regularly domed; it is built of fine earth particles, firmly cemented together, and presents an all but smooth surface. Such mounds are 3 to 4 ft. in diameter and 12 to 16 in. high, and occur within 50 to 100 paces of one another (Pl. XXVI, fig. 8). Among them are to be found solitary ancient mounds of a roughly conical form, of 3 to 4 ft. in height, which are clothed with small, rough, stunted herbage, the roots of which penetrate into the matrix of the mound and are not interfered with by the termites (Pl. XXVI, fig. 9).

Isolated modern mounds are not common along the Natal seaboard, where the species also abounds. Two, found in a wattle plantation at Mount Edgecombe in a light sandy soil, were regarded as less than seven years old. These (Pl. XXVI, figs. 10 and 11), although composed of sand particles, were extremely hard, but they showed weathering. One, roughly rounded, 2 ft. high and 3 ft. in diameter, was upon the edge of a slope and the lower base had extended 18 in. by weathering. The other, an acute regular cone, 4 ft. high and 4 ft. in diameter at the base, stood upon a flat area and was encircled by a small buttress of recently weathered-off particles, which extended 18 in. from its periphery.

Sheltered in the natural bush at Bellair a recent mound was examined which, upon certain information gathered on the spot, was estimated at under ten years. This nest was a regular dome 6 ft. in diameter and between 2 and 3 ft. high (Pl. XXVI, fig. 12). It was of extremely tough texture,

being formed from a clayey mould. Its surface was littered with dead foliage, and into its matrix the roots of the surrounding trees had penetrated, whilst from its summit grew a sapling 10 to 12 ft. high with a stem 2 to 3 in. in diameter. This mound was grossly invaded by *T. incertus*, whose fungus-gardens were in great abundance and seldom more than 6 in. apart. Pyramidal, pinnaced, and conical masonry mounds are to be met with on the highlands of Natal in great abundance; in favoured sites being seldom more than 100 paces apart and often less than 60 paces (Pl. XXVI, figs. 13 and 14).

The two Mount Edgecombe nests are described to indicate the genesis of those great termite ramparts which are preferably referred to as "nest-sites." These, it is thought, are of very ancient formation indeed, and owe their huge bulk to the work of generations of termites and the accumulations of organic matter from the plants which overgrow them.

The bush fringing the sea-front of Natal contains an extensive flora, but in many parts the so-called wild banana (*Strelitzia augusta*) predominates. As the bush extends back from the sea it becomes more and more sparse, until the glades cease in open country; this, however, is dotted over with circular patches of bush, standing oasis-like in the grass and giving the impression of an inland invasion of the coast bush; this is usually alluded to as the "park formation" (Pl. XXVI, fig. 15). These oases are nest-sites. As they stand, they are islands of trees, palms, and strelitzias girt about by a fringe of dense low-growing plants, all so thickly intergrown as to be nearly impenetrable. Cleaned of the encumbering scrub, they are found to be circular or oval ramparts of earth, 20 to 60 paces across and from 3 to 8 or 10 ft. in height. Very few present any superficial evidence of termite work, although in all there is ample evidence in the huge burrows of the aardvark (*Orycteropus capensis*) that they are or have been recently inhabited by a colony. Occasionally a typical mound is found on the rampart, and not infrequently a nest-site harbours a huge nest of *T. latericius*.

Such nest-sites are even more common in the thick fringe of bush bordering the sea-shore, and upon the whole they are so abundant up to six or eight miles inland as to alter the regular contour of every slope and ridge; a feature readily observed because of the vast sugar-cane fields now covering the country, once in part or wholly bush. Owing to the rapidly undulating nature of the country it follows that these nest-sites nearly always occur upon hill-sides, and for this reason they appear very much larger when approached from below than from above. It has, however, been noticed that the upper side of a ridge is more favoured than the crest or lower down the slope; hence, many a long ridge of gentle gradient when approached at right angles appears serrate, so rapidly does one nest-site succeed another down its length. The inhabited portion is usually at the front apex of the site, and, by passing up a slope along the line of nest-sites, one progresses over so many huge steps of an earthen ladder (Pl. XXVI, fig. 16).

The clearest cut example of a simple nest-site was found in front of a marine residence at Scottburgh. This was originally overgrown by *strelitzia* and *phœnix*, but had been cleared and surmounted by a garden-seat. This mound was regularly rounded, with a more or less flattened top 8 ft. in diameter. Approached from above, it was 5 ft. high but fell away in front 10 to 12 ft. The sides were fairly acute and the smallest diameter at the base 15 ft. The presence of a living community in this rampart was demonstrated.

The conclusion arrived at regarding the paucity of isolated modern nests of *T. natalensis* away from old nest-sites along the Natal coast is that such is due to the better and very ample opportunities for nest-making which these ancient sites afford.

The ordinary or modern mound is always perforated by almost vertical galleries which ramify upwards throughout it. The arrangement of these is complex and disorderly, they are large and either circular or elliptical in section, some of the latter presenting a long diameter of 4 to 6 in. All reach

nearly to the crust of the mound, and at times small tubes are driven from them into the crust. What the purpose of the mound is, is one question; what it is, is another. The mounds do not begin in a small way and gradually increase in size. No amount of field observation can discover the mounds of *T. natalensis* in stages of growth below a certain minimum size,¹ and there is every reason to believe that a mound of some magnitude is built up suddenly. This may synchronise with that moment when the colony has attained a certain strength, and an extensive addition to its domicile is called for. Even the minimum mound (a primary) contains more material than is represented by the nest-cavity below it. The material used for the building of a mound is, no doubt, obtained by increasing the diameter of existing galleries and extending them. Whatever it may be that leads to the formation of a fairly large primary mound, the subsequent growth of the mound is due to the fact that it is the dump for the soil removed in driving galleries through the soil; and the bulk of the soil in a mound, of almost any magnitude, is the material removed in mining far-reaching stopes. The purpose of the mound is primarily for the protection of the nest from subsidence. From the position of the queen-cell it is obvious that the extensions of the cavity are for the greater part around and above it. This is evidenced by the fact that in the high mounds the upper region of the cavity is above normal soil level (Pl. XXVIII, fig. 2). The ordinary mound, therefore, serves a double purpose, protecting the cavity from subsidence and submersion on the one hand, and permitting its upward extension on the other. Also the great shafts which perforate the mound are utilitarian, permitting a multitude of miners to reach the crust rapidly and superimpose an extra layer of cement whenever occasion demands. At the same time, they aid in aerating the whole nest-system.

¹ The smallest nest I know of was found by Dr. Warren. This, I am informed, had a diameter of about 18 in. and a height of about 15 in. The nest-cavity was considerably smaller than the mound. The queen-cell was found, but the nest was entirely deserted.

In this connection it is not urged that the mound-shafts are, in any sense, flues through which currents of air are always in circulation.

Strongly as the earth particles are cemented together, mounds are subject to weathering, and their surfaces have to be repaired. As colonies are subject to decimation, more particularly by aardvarks, it follows that the mounds of weakened communities, and those uninhabited, weather rapidly. In the weathered stage grass creeps over them, or seeds of large plants, which have no great opportunity to become established in the grass, find a suitable nidus and flourish. Then the mound becomes the home of a fresh colony which reconstructs to its own accommodation. It is a succession of such phases which brings about in the course of time the huge nest-sites and oases, or park formation.

The exploration of a large nest-site involves a considerable amount of labour. With a view to ascertaining whether such a nest-site bore evidence of successive habitation, one below the medium size was selected and thoroughly examined at Mt. Edgecombe, Natal (Pl. XXVI, fig. 17). This stood in a wattle plantation, the bush having been removed some seven years previously when the land was put under wattles.

The features of this nest-site were as follows. It was a large accumulation of soil, rising in the centre to a rough cone, and it presented, at two points on the circumference, aardvark burrows which penetrated inwards for 4 and 6 ft., going down to a depth of 2 and 3 ft. below the natural level of the ground. The whole mound, including the central cone, was perforated by galleries containing living termites, those of the cone resembling the typical ramifying galleries found in a normal mound. The whole of this mound was removed, and the nest of its occupants was found on the western slope well above ground level.

No other colonies or traces of cavities were found, but there can be no doubt that such previously existed and were destroyed by the aardvarks. The site of the nest of the existing colony indicated that it originated from a pair which

had penetrated the mound at that point. The mound on the whole displayed a weathered appearance, but the surface had been recently repaired immediately above the cavity, whilst parts of the cone had had some attention.

Inferentially we may assume that it is possible for nests of this species to exist without mounds; but as to whether there is any reason to suppose that under certain climatic conditions—such as along the Witwatersrand (5000 ft.)—the species never makes a mound, the writer is not yet prepared to make a statement. In this connection it may be mentioned that the species has been taken destroying young gum-trees (*Eucalyptus*) and feeding upon manure where no indication of a mound could be seen for a mile around. Again the species has been seen feeding upon grass in Pretoria where no mound could be found. This latter instance, however, rather indicated the existence of a colony that had not as yet built a mound than one that would never do so.

It is not yet possible to say for certain how a nest of *natalensis* as an architectural structure begins; but it is not difficult to see how it could originate by observing the behaviour of young pairs, and their peculiar adaptability to their environment in nests built under houses, or in the earth-matrix filled in beneath cemented, bricked, or stone-flagged floors. When nesting beneath such floors *natalensis* does not need to build a protecting mound. As a rule, however, there are dump-heaps; these may be either in free spaces beneath the house or even outside of it (Pl. XXVI, fig. 18).

A number of such cases have come under observation, and the nests arise out of the entrance of a pair through some interstice. In the case chosen for illustration, the queen-cell was just below the cement, and the hive extensions were below it; the nest arrangement is inverted, the cavity being extended downwards instead of upwards.

What appears to be the ordinary course of events is for the sexual couple to burrow into the soil to a certain depth; this is about 18 to 20 in. There they form their brood-cell. When

the brood matures, and as it increases, the nest is enlarged by the making of cavities around the original cell; and these increase in number and size with the growth of the colony, whilst the original brood-chamber becomes the queen-cell and is enlarged from time to time to accommodate her growth. Evidence of this latter contention is supplied in the case of a nest examined for me at Barberton. This was indicated by a low and comparatively small mound, and the queen-cell (Pl. XXVIII, figs. 3 and 4) taken from it is a quite small, thin-walled structure, with a long diameter of 60 mm. and a height of 10 mm.; it is exceptionally entire, having no shelves bracketed to it. The soldiers and workers of this colony were normal in size and plentiful, but the queen was only 40 mm. long.

The soil removed by a young colony in making the hive-chamber and driving tunnels is no doubt scattered loosely over the surface—this is usually what happens where this species is found feeding over the open veld on dry grass or the droppings of animals. The mound, it is thought, is only built when the hive-cavity has been enlarged upwards so much as to be threatened by subsidence; in short, when it becomes necessary; and it is because of this that really small and new mounds are never found. It is difficult to explain why in certain parts mounds are not built; but, as the parts of the country (the Witwatersrand) where there is some evidence of this are high in elevation (5 to 6000 feet) and bleak in winter, it may yet be shown that the species takes advantage of the naturally stony nature of the country to construct its hives beneath or amidst sheltering rocks, when the presence of a mound would become non-essential. In this connection it is to be noted that when the species nests under tiled, stone, or brick-flagged floors it extends its nest upwards to the floors. Where these are not laid upon a strong cement bed, subsidence frequently occurs; indeed it is no exaggeration to say that the characteristic unevenness of old brick floors to rooms and stoeps in Pietermaritzburg, where *natalensis* abounds, is entirely due to this termite.

THE HIVE.

When the nest of *Termes natalensis* is spoken of, the term necessarily includes the cavern in which the colony congregates and propagates, together with the mound and the great stopes and galleries. Some precise term is required to express the chamber in which the community has its headquarters, wherein resides its parents, and all matters pertaining to the propagation of the young take place. No word is more applicable than "hive"; but it must be remarked here that whilst the term signifies a part of a whole as applied to the nests of certain termites, it applies to the whole in others (*parvus*), and cannot be used at all in connection with some (*incertus*).

Upon these premises the hive of *natalensis* may be described as a single sub-globular (sometimes ellipsoidal) cavern, which lies as a rule immediately below the centre of the mound. It is like a many storied house, a series of flats rising tier upon tier from its concave floor to its arched ceiling. The shelves of clay are slightly arched and attached strongly all around to the walls, being systematically bracketed thereto. Besides this they are supported by vertical columns so fashioned as to serve this purpose, and at the same time form stairways from storey to storey.

In the lower hemisphere of the cavity the shelves are no more than thin laminae of clay, and but shortly removed from one another; then, as storey succeeds upon storey, the space between each is increased, and the most spacious are those in the dome. As the distances increase so does the thickness of the shelf until it may be as much as a quarter of an inch. Similarly the pillars or stairways are increased in their dimensions. The whole of the partitioning is soft and moist and of a friable nature, so that stability is due to the architectural features; the weight being so distributed and the curvature of the shelves such that the higher and more ponderous do not fall and crash through the more fragile structure below. This feature is perhaps illustrated at its

best in the case of the Pretoria nest (Pl. XXVIII, fig. 2) wherein the cavity was extended right into the dome, and the arching of the shelves quite exaggerated.¹

The royal chamber is externally a flattened, rounded mass of clay, the exterior form being occluded by the shelves bracketed to it and by the grooves which lead to the tunnels through its walls (Pl. XXVIII, figs. 5 to 8). It is suspended, as it were, at a central point in the lower hemisphere; but not infrequently it partly rests upon some intrusive stone or root, so excavated that it projects into the hive. When not upon such foundation it seems to be in a very precarious position, but the exact support to such royal cells has not yet been sufficiently traced.

The pillars which support or suspend each shelf are in reality stairways, excepting those which connect the top shelf with the dome of the cavity; these latter can only be regarded as suspenders.

Most of the stairways are canted slightly and twisted a little spirally. In section they are flattened, oval, and slightly grooved on the surface traversed by the termites. This groove causes the pillar to appear to be more spiral than it really is. The canting of the pillar and the pathway upon it are both factors in rendering the ascent easier.

Upon the upper shelves the individual fungus-gardens are arranged, placed like so many loaves of bread upon a larder shelf. The lower and more restricted shelves at the basement of the hive have so far always been found empty; and, if there is differential feeding of the young, it takes place in these compartments.

The gardens present a granular formation throughout, the matrix and the entire surface showing coarse granulations. They are of varying sizes and heights, being of greater height in accordance with the available perpendicular space above them. Irregular as they are in shape, differing in height and

¹ This nest was not examined by me, but the series of insects in the collection bearing the same accession number are typical *T. natalensis*.

in diameter—some being low and spreading, others more conical—they present a characteristic likeness one to another, and can only be likened to small, rough coronets. In their natural state they are soft and friable, but when dried they become hard and woody. Viewed from above nearly every garden presents a broad oval outline.

The royal cell is not so spacious an affair as is that of some other termites (*badius*). It is broadly oval in outline with a flat floor and shallow concave vault. The distance from floor to roof in four examples before me is 18 mm., a space which is just sufficient to accommodate the body of the queen; in fact, the queen may be said to be compressed between the roof and floor of her citadel. The short diameter is 80 to 100 mm., and the long diameter 127 mm.

This description of the hive is based entirely upon my own observations. Because of its incompleteness it is given with much reluctance; and, if adding little that is new, is presented with the intention of showing that the structure provides many architectural problems well worthy of investigation.

THE INHABITANTS.

(1) *The Queen*.—Smeathman's picturesque account of the live queen of *bellicosus* is indeed a good one for *natalensis*. The creature, when imprisoned in a box with attendants, doubtless behaves quite naturally for some time. She is very excitable and constantly changes her position, swinging her body from side to side, and progressing not forward, but somewhat around a small circle. To achieve this, the head and thorax are thrown right round to one side or the other until the head is brought in contact with the side of the abdomen. All the time the insect pulls forward with the full strength of her legs. The massive body soon reacts to the strain and pivots on its base. This continuous leverage of the body, only momentarily interrupted when a worker presents its quota of food, is varied but in direction, and is the result of enormous muscular effort. Indeed it may be said

that the characteristic of this queen is that it is, and looks like, a superanimated muscle. Doubtless the effort to move is lessened by the compression of the insect in its shallow cell. The flaccid and immobile queens of *T. badius* lie in high domed cells, and so the workers can approach the eggs from all directions. The movement of the *natalensis* queen is perhaps not without purpose, as it ensures the depositing of the eggs more or less regularly around the periphery of the cell.

Egg-laying has for its accompaniment an excessive muscular action, independent of the movement of the body as a whole, and as involuntary as the act of breathing with man. This muscular action is complex and represented by the bulging, or great lateral expansion, of various regions of the abdomen. The body is invariably very asymmetrical, and the bulging is quite erratic; it is not a regular undulation proceeding from the anterior to the posterior region, and any inflations upon one side do not correspond or alternate with any progressing on the other. The dorsal region—a median area wider than the sclerites—remains taut, as does the similar ventral region.

The eggs are produced spasmodically; they may form into a small packet, which clings for a while about the vulva, or they may be squirted out in a quantity of fluid. Even those which are laid separately are embedded to some extent in a white matter. Although laid spasmodically, the intervals of rest are very short, and upon the average the queen lays 140 eggs per hour. This is far short of Smeathman's 30,000 in twenty-four hours; but, upon the other hand, it is in agreement with observations made upon *T. badius*, of which fuller particulars are given.

It may be urged that the rate of egg-laying would be modified by the abnormal circumstances under which the observations were made. Whilst not prepared to concede this point, the figures may be doubled or even trebled for the purpose of showing how far short of 30,000 they still remain.

The queen is frequently grossly infested with small and

very active *Thysanura*, and at times mites are found fixed to her body.

(2) *The King*.—The queen is invariably accompanied by one male; more than one has never been noticed. This creature, under observation, displays an extraordinary devotion to his mate. He seldom wanders more than an inch away from her; constantly approaching her head and paying apparent court; then inspecting her flanks and eggs with preoccupied attention; behaving, in short, as most male termites seem in the habit of doing, but never revealing the purpose of his existence. The male is always somewhat inflated with body-fat; the conjunctiva of the sides of the abdomen being distended, but not that of the dorsal and ventral sclerites.

(3) *Soldiers*.—The main defence of the nest falls upon the minor soldiers, or at least appears to do so, because they are more numerous than the major soldiers. The major soldiers do certainly accompany the minors, whenever any breach of mound or inner citadel is made, but in small proportion. Upon the whole the bulk of the major soldiers retreat to the inner parts of the nest, the fungus-gardens and the neighbourhood of the royal cell. Both larger and smaller soldiers bite, and the jaws of the larger will meet and cut like a knife through the thick skin of the finger-tip. The principal enemy of this species being *aardvark*, it is extremely probable that the function of the greater soldiers is to lacerate the creature's nostrils and mouth parts, and by so doing guard the queen-cell from demolition. That the part played is effectual, in this regard, is doubtful.

(4) *Workers*.—The workers, on the whole, retire when the nest is molested, many crowding into the queen-cell. They gather in force for repairing the breach within a very short time after the attack upon the nest ceases. An opening (about 2 sq. ft.) made in a nest one day at 3 p.m., in exposing half a hive, was completely closed by 8 a.m. the next morning.

It is obvious, from the fact that this species permits plants

of any sort to grow upon and send their roots ramifying through the mounds, that it feeds naturally upon dead vegetable matter. It is only circumstances that render it a pestilential creature. Upon the whole it plays a beneficent rôle by soil improvement, and nowhere is this more evidenced than in sugar-cane fields, where the cane flourishes amazingly upon the nest-sites, giving a greater yield and withstanding drought conditions better. On the other hand, a zone of poor cane is often noticed about such a site, which may be due to the concentration of organic matter by the termites; or, in other words, the constant removal of all the dead parts of the grass formerly present.

Termes badius *Haviland*. Pl. XXX, figs. 1-6.

Termes badius is not in the strict sense of the term a masonry mound-builder; at the same time, under native conditions, nests are found in mounds which are so hardened that they might be described as masonry. If it were not possible to observe in and about Pretoria numerous nests without mounds, which are distinctly the work of one colony, it would be quite natural to describe the species as a mound-builder; at first, I found it possible to locate nests under nature conditions only when in mounds. Whilst no nests have been found in open lands which could, with certainty, be attributed to this species, still certain soil subsidences and deserted cavities which have been found cannot readily be credited to any other termite. Generally speaking, it may be conceded that any superficial indication of a nest would be obliterated almost as speedily as made in open country. This will be better understood from the description of the modern nests, of which six have been explored.

The modern nests are found beneath the shelter of ever-green trees, shade-belts, and hedgerows; they are very common at Pretoria in the Zoological Gardens, in the principal parks, and in the grounds surrounding many residences. Such nests are readily detected by the series of close-set hillocks

which overlie them (Pl. XXX, fig. 1). These hillocks persist not because of their inherent stability, but because of the undisturbed positions in which they are located, and the shelter provided against the violence of rain and wind. The trees beneath which they lie being of comparatively recent growth (twenty to thirty years) the nests are necessarily modern, and it is not difficult to decide that during recent times the site they hold has not been previously occupied by any mound-building termite. The hillocks are not masonry moundlets; they resemble mole-hills except for the fact that the earth-particles, of which they are built up, are loosely cemented together. They are, therefore, of a temporary nature, and weather away more or less slowly.

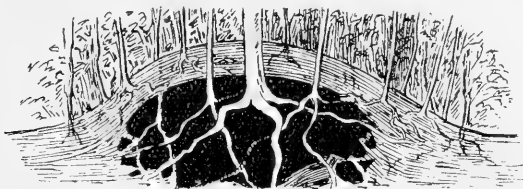
In the case of some nests, protected by hedges, mounds have already begun to form, and there is evidence that a large mound would ultimately accumulate, if the hedges were left neglected and plants allowed to grow in the mounds and so bind together the earth deposits.

Incidentally it may be mentioned here that *badius*, like *T. natalensis*, very frequently forms a nest in the soil below stone-flagged floors; in these cases there are large accumulations of earth in open spaces below the flooring of the house or abutting the outside of the building. The deposit below the floor remains as it is placed, and is much traversed by tunnellings through which the results of further excavations are carried. Outside deposits are scattered or weathered away unless placed among plants and creepers growing against the exterior walls (Pl. XXVI, fig. 18).

Under nature conditions some nests are found in large rounded mounds which form the core of isolated thickets of trees or park formations (text-fig. 10). Whether the colonies in these mounds are as ancient as the sites they occupy is a question which cannot be answered, but what is more than likely is that these tree-spots originated long ago upon mounds of *natalensis* or *latericius*, and the presence of the trees induced *badius* to colonise them. Further, it is evident that the mounds and thickets have only acquired their present

character after years of occupation by successive colonies of this and perhaps other termites. The thickets in Pretoria are composed of several varieties of acacias (*Acacia horrida*, *robusta*, and *caffra* predominating), associated with them are other thorny plants, the more usual kinds being *Gymnosporia buxifolia*, *Ehretia hottentottica*, and the spiny *Asparagus*. In these mounds, which may reach 2 ft. above ground-level and be 10 to 20 ft. across, the actual nest is above soil-level; but the whole is generally so involved by the intermingling and twisted root-systems as to render any account of the interior structure impossible.

TEXT-FIG. 10.



T. badius. Vertical section of nest in mound, involved in root-systems of many plants (diagrammatic). ($\times \frac{1}{40}$.)

In one instance, however, where a thicket had been burned over, the nest-cavity was found baked and preserved, the clay composing it being changed into a fairly hard red tile.

In the case of the modern nests the structure is readily observed, and, whilst erratic, keeps to a general plan. The external feature is the presence of the series of hillocks already referred to. In some cases these are superimposed upon the mat of leaf-débris under the trees; when this is the case they can be lifted bodily from the ground. They are not solid, but are perforated by small tubular, twisting galleries which lead from the centre at the base and allow the termites to dispose of excavated earth by placing it as a new crust to the moundlet.

The tenuous galleries all enter at ground level into a fairly large gallery or vertical shaft, which descends either by a

direct or indirect route into one of the extensions of the fungus-garden. As some of these shafts widen out considerably as they descend, it is extremely probable that they have much to do with the aerating of the nest, and are not solely roadways to the dump-heaps.

The nest proper takes the form of a very large globular cavity with supplementary fungus-gardens which imitate those of *Termes latericius*, except that they are in wide communication with the central nest, or it has many large irregular extensions around its periphery.

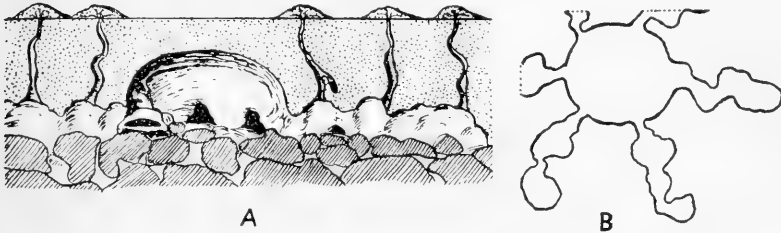
The dome of the great cavity is within 8 to 10 in. below the surface of the soil, and as its vertical diameter may be as much as 2 ft. and the horizontal diameter 3 ft., and as it contains no strong clay-supports, it is readily understood why the species displays such a marked predilection to establish itself at the base of a tree. Up to the present no nest has been examined in which at least one large root did not pass through the great cavity or sufficiently near to help in strengthening it. The interior walls of the cavity are always plastered about an inch thick with clay-cement, and a consistent feature is the strong cemented clay cupola roofing it. This is so strong that it can be completely exposed by removing the surface soil, and then, if cut around, it can be lifted off in a solid piece like the lid of a caldron. It is not necessarily perforated, but, in the case of the nest somewhat diagrammatically illustrated (Pl. XXX, fig. 1), one circular hole, three-quarters of an inch in diameter, gave access to a vertical shaft above it. The cavity is quite filled by a fungus-garden; this is like a giant sponge and obviously built in level layers, although its full arrangement is occluded by the reticulum of a clay frame irregularly disposed within it; a frame which is never attached to the cupola and which is not firmly joined to the walls. If the nest displays lateral extensions, as shown in text-fig 11, A and B, the fungus-garden branches, octopus-like, along the length of these. When supplementary cavities are present, they have broadly oval, flattened floors and are widely vaulted. The fungus-

gardens in them fill them completely, and if removed resemble irregular and more or less flattened loaves.

The queen-cell (Pl. XXX, figs. 2-5) is situated in the great cavity and, in those nests explored, in a peculiar position and always on small pedestals. The cell itself is within an irregular lump of clay, forming a rough column at or towards one side of the nest. Its site is indicated in both nests, of which diagrams and illustrations are given.

In one of the two nests illustrated the pedestals of the queen-cell rested upon the stones which formed the bottom

TEXT-FIG. 11.



T. badius. A. Vertical section of nest lying over boulders, showing lateral fungus-garden excavations. B. Ground plan of same. ($\times \frac{1}{36}$)

of the cavity, in another it was attached to a shelf which ran around the chamber at about half its height. In the three nests the joining of the upper part of the clay column to the cupola was perhaps more indefinite than as figured in the diagram, and the cell itself not quite so much a part of the wall.

Between the two diagrams a considerable difference appears, and the difference in the nest arrangement displayed is thought to be due to the different nature of the soil. In the case of the shallow nest it was found that underlying the site there was a layer of stone boulders. To some extent the soil between these had been removed and the spaces so made filled up with fungus-garden; it was assumed that as the termites had not been able to excavate deeper they had made the larger horizontal extensions shown in the diagrams.

The nest-cavity shown in Pl. XXX, fig. 1, is to be regarded as the more normal, being made in deeper soil, in which stones and boulders offered no obstacles to the architects. From the depth at which the queen-cell was found it is reasonable to assume that the original part of this nest was that which appears in the section as an upper storey, while the lower region was subsequently excavated. Here the central cavity seems to have reached its maximum proportion of safety, and it would appear that the supplementary cavities were constructed to meet the full demands of the great brood of termites being raised.

The striking feature of the nest of this species may be said to lie in the fact that the cavern is not developed around the queen-cell, but to one side of it. The fungus-garden is closely applied about the queen-cell, and eggs are scattered freely in the centre of the fungus-mass for incubation; there also young termites in all stages of growth abound.

The king and queen are found in a chamber hollowed in the clay-mass. This is of large proportions, and characterised by the high dome. In three examples the long diameters are 130-140 mm., the shorter 75-90 mm., and the heights 28-38 mm. It will be seen that the cells agree with that figured by Sjöstedt for *T. transvaalensis*. The cells are very different to those of *T. natalensis*, and the great space above the queen is peculiar, seeing she possesses so flattened and flaccid a body. The king is active, but never departs far from the queen, even when the two are confined in a wider space than that of the cell. The queen, on the other hand, cannot move, and her body is an almost inert mass. She pulls and tugs with her legs, and the head and thoracic parts are as lively as those of the queen of *natalensis*. The involuntary muscular movements of the abdomen proceed as in the case of *natalensis*, but more slowly. When opened the queen-cell contains a fair proportion of soldiers, a few major workers and a multitude of minor workers. If a queen is transferred to an observation box with workers, the process of egg-laying goes on uninterruptedly, whilst the workers, after making

tunnels in the soil, carry off the eggs and place them in these prepared recesses; they will also start enclosing the queen in a new cell. The rate of egg-laying is the same as that given for *T. natalensis*, and averages two to three per minute.

The following is the record of egg-laying for a queen immediately after removal from a cell into the observation box. It is complete except for one short break of 20 minutes, when the eggs were lost, and gives a reasonable figure of 4000 odd eggs for 24 hours.

Date.	Time.	Period.	Actual count.	Average per min.
Sept. 3rd, 1914	4 p.m.: queen placed in observation box			
Sept. 4th, 1914	9 a.m.: eggs removed	17 hrs.	2360	2.31
	9.20 a.m.: eggs lost	20 mins.	—	—
	9.20 a.m. to 9.35 a.m.	15 mins.	160	10.6
	9.35 a.m. to 3.45 p.m. 3.45 p.m. to	6 hrs. 10 mins.	1683	4.5
Sept. 5th, 1914	9 a.m.	17 hrs. 15 mins.	2611	2.5
	9 a.m. to 9.12 a.m.	12 mins.	0	0
	9.12 a.m. to 9.23 a.m.	11 mins.	72	6.5
Totals		41 hrs. 23 mins.	6886	2.4 per min.

The king is not inflated with body-fat as is the king of *natalensis*. The queen resembles that of *T. latericius*, but is not quite so flaccid. The general colour of the body is cream, stippled with reddish brown, except for the smooth wide bands down the middle of the dorsum and ventrum. The bands are partitioned by the sclerites and ornamented by an irregular broad brown strip. The stippings of the remainder of the integument take the form of elongate stars arranged along the long axis of the body. Length of largest queen (alive) 90 mm., width of abdomen 24 mm., height 9 mm.

In examining the supplementary gardens of this species it was noticed that the lower portion was concave and somewhat

old in appearance. There is no doubt that in the case of these gardens enlargement is effected by the application of additional layers. It is reasonably supposed that a cavity is first made of some minimum dimension and filled with a fungus-garden; when necessity arises, it is enlarged by the lateral extension of the floor and by a general heightening of the vault. At periods the core deteriorates and crumbles away, and so a concavity is formed. There is some evidence, however, that the worn-out part of the fungus-bed is renewed.

T. badius shows a decided preference for the bark of trees, but only the dead bark is removed. To accomplish this the termites swathe the tree trunks with a thin shell of clay, carrying the shell to a height of even 20 ft. It feeds upon dead grass and the droppings of animals, and it is also a pest to wooden structures, wherever it can work undisturbed. Unlike other species it does not tunnel into the wood, but removes the surface, layer by layer, working as on tree trunks under a shell of clay. In houses it may destroy the flooring boards, removing the wood-fibre piecemeal from beneath, working along the length of the boards, but always working under a canopy of clay.

One very unusual nest of this species was found in a dis-used stable. Here several sheets of corrugated iron had laid for some time upon some litter. On lifting the iron it was found that the concavities had been freed of débris and long, narrow fungus-gardens built within the spaces. In addition to this the colony had taken advantage of a space behind a sheet of iron leaning against the wall, and by building up clay partitions it had converted the space into a roomy cavity and filled it with a large fungus-garden.

Mr. J. B. Gordon has sent to me a queen-cell (Pl. XXX, figs. 4 and 5), with its living contents taken from a nest near Pretoria. This particular cell is not only remarkable for its size but also because it differs from any other in the collection in having a well-defined exterior. It can only be inferred that the cell was removed from an older nest than any

examined by the writer. The soldiers and workers were normal, and the queen smaller than others from very much smaller cells. Owing to the fact that the cell had been broken open at one end it was not possible to take its exact measurements; but for all practical purposes it was 200 mm. long, 110 mm. wide, and 32 mm. high.

Termes latericius Haviland. Pl. XXIX, figs. 1-8;
Pl. XXX, fig. 11; Pl. XXXI, fig. 6.

The juvenile nests of this species are moundless and do not present the characteristic funnels or air-pits of older ones; further, there is much reason to believe that colonies of some magnitude are established long before any surface indication marks the site of the nest. Surface indications first take the form of simple crusts composed of clay particles cemented together fairly strongly. Such crusts present the characteristic cobble-stone appearance of all new termite work of this nature (Pl. XXVI, fig. 19) and are spread more or less flat over the ground with but occasional and inconspicuous, conical elevations. Several of such were noticed in Pretoria and its environs during May and June (1914), and two occurred in a footpath; these latter did not develop, as the constant destruction of the crust seemed to disturb the makers. If the more elevated portions of the crust are removed, they will be found to cap shafts of $\frac{3}{4}$ to 1 in. in diameter; possibly the beginnings of the air-pits.

Large nests in Natal, the Transvaal and Orange Free State are always readily recognised either by the air-pits or by them and their chimneys (Pl. XXXI, fig. 6). *T. latericius* is a true mound-maker, but air-pits protected by large chimneys have been observed without the least elevation of the soil level, as described by Haviland. There can be no doubt that the mounds represent the soil removed from the pits as well as from the extensive caverns made to accommodate the main and supplementary fungus-gardens. Where mounds are absent the reason is not at all apparent.

The commonest type of mound is a wide, low elevation, usually from 10 to 20 or more ft. across, and of an elevation of less than 2 ft. At irregular intervals on this mound are the apertures of the air-pits, which may or may not be surrounded by an elevated rim. Occasionally a conical, non-perforated, super-mound also marks the nest-site; this may have a diameter at the base of 3 to 4 ft., and an elevation of 2 to 3 ft. (Pl. XXIX, fig. 1, *a*). Some of the air-pits are roofed over with a clay cupola, and, as far as observations go, remain permanently in this condition (Pl. XXIX, figs. 1, *d*, and 2). Then they appear as low conical protuberances on the mound surface. It is certainly not the case, as given by Haviland, that the air-pits are roofed over in winter and opened in summer; moreover one rarely finds less than three pits, and over eleven have been recorded (3).

The elevated rims around the mouths of the pit are usually flattened and rounded by weathering (Pl. XXIX, fig. 1, *b*), but in the first place are constructed by the insects as regular turrets or chimneys; the large super-mounds are, without doubt, the outcome of combined turret building and weathering. Equally, no doubt, the whole mound is the result of these two factors acting together over a long period of time.

There can be no doubt that the large nest-sites of *T. latericius* are of very old origin. This is often evidenced by the trees sometimes growing upon them, which must be by their nature of no mean age. There is also evidence that the hives progress within the large mounds; in other words, as a part becomes stale it is neglected and the main hive driven further afield through the soil. Very striking evidence of this was obtained in examining a large nest in Pretoria, the inhabited cavity being 12 ft. removed from the further extremity of the collapsed and deserted region it abutted upon.

Termes latericius may often be seen at work in broad daylight renewing or extending the rims of the air-pits; this they do by continuing the margin in the form of a thin

wall in a nearly regular manner all round. The building insects move up the walls of the air-pit in great numbers, like so many bricklayers, each adding its quota of material to the structure. Whilst this work is proceeding, the thickening of the rim is done by insects working within the chimney wall, and although the edge of the ring is quite thin whilst the work is in progress, yet, when the required height is reached, the wall of the chimney is thick throughout. Chimney building is not conducted all the year round, but is frequently to be seen in progress during spring and summer.

In most cases the chimney is seldom more than 6 to 8 in. high. The highest observed in Natal was 20 in., but in the Transvaal and Orange Free State some chimneys are carried up to between 2 and 3 ft. (Pl. XXXI, fig. 6).

It has yet to be shown by exact experiment that currents of air pass up the taller of these structures; but that the pits of which they are the chimneys are for the aeration of the nest there can be no doubt. Nor is there any doubt that the chimneys, or rims as the case may be, are for the purpose of preventing any inrush of water. It is seldom that the air-chambers are filled with soil by weather effects; but instances have been noted—the nests so affected being on footpaths worn in the veld by the natives—where torrents of water during rain storms have poured into them.

The air-chambers may be of great size and flask-shaped, or they may be but deep vertical shafts, in which case they have equally large branches (Pl. XXIX, fig. 1, *a*). They are associated with the large main hives made by this species and connect with them by only a very few small galleries, just sufficiently large for two insects to pass one another. It is a feature of the mound and super-mound of *latericius* that no galleries are driven through them, and this fact strongly suggests that the great shafts in the mounds of the *bellicosus* group act largely in aerating the hives, although they have no actual apertures. The main hives contain a vast extent of fungus-bed; but, as they are more than half

filled with a complex array of clay-girders, brackets, shelves and stairways in and amongst which the fungus-beds lie, they baffle concrete description. Flung out all around the main hive a foot to six feet away are many supplementary fungus-gardens in which young are also raised; a state of affairs almost suggesting differential feeding. These gardens are placed in typical high domed cavities (usually 6 in. in diameter and 4 to 5 high) with flattish and circular floors. The fungus-beds in these annexures are regularly built and always present an agreeable symmetry (Pl. XXX, fig. 11). Their general appearance may be likened to large rosettes, and they are noticeably built up tier upon tier; each tier, decreasing in diameter from the base upwards, is circular and emargined with triangular, slightly deflected, rigid flaps. The fungus-beds are quite distinct from the spongiform loaf made by *T. vulgaris* and do not at all resemble those of the other species here described.

Communication between the cavities containing the small supplementary fungus-gardens and the main hive is established by a single and simple, cylindrical tunnel, sufficiently large for a couple of insects to pass one another. There are no large main pathways leading out from the smaller cavities or even from the hive-cavity, and it is only with difficulty that the small tubes are displayed. These leave the hive at or near its base and, running almost horizontally throughout the greater part of their length, rise by short steps in the same manner as do the foraging galleries of *Hodotermes transvaalensis*.

Whilst there are no conspicuous galleries radiating directly out from the hive, somewhere near the periphery subterranean runways are to be found. These seem to be a distinct feature and to be for the purpose of giving the insects ready and rapid access to the neighbourhood of the nest on the one hand, and the surface soil on the other, as well as to connect up with the system of peculiar outlying granaries which this species builds. As far as could be ascertained, communication with the hive-cavity from a main runway is only through

a number of small tubes; and similar small tubes lead from the main runway to the granaries. These main runways, as far as followed, were perfectly uniform. They lay at a depth of 18 in., went quite straight and did not deviate in their level. They had a flat pathway about a third of an inch wide and a vaulted roof, never more than a quarter of an inch at its highest point above the floorway (Pl. XXIX, fig. 3). From the vault of these tunnels an inclined and slightly wider gallery occasionally leads upwards to within a few inches of the soil surface; from its terminus a number of small cylindrical galleries ramify through the grass roots (Pl. XXIX, fig. 4).

The granaries excavated by this species are very interesting structures. Those that are small are easily described as globular cavities divided into two parts by a horizontal shelf (Pl. XXIX, figs. 5 and 6). In the larger granaries the shelf is also present, but the cavity is so fantastically partitioned in other respects that it baffles description (Pl. XXIX, fig. 7). Except in one instance where a few short lengths of green grass were found in the upper storey of the cavity, all of those inspected were empty. Nevertheless, embedded in the soil all around the cavity (in some cases to a depth of 4 in.) were thousands of grass seeds perfectly preserved, as evidenced by the fact that they germinated readily when tested. It is more than likely that these granaries are destined to be filled with supplementary fungus-gardens, and the storing of the seed in the adjacent soil is perhaps to facilitate the rapid building of the nidus for the fungus. What the diaphragms are for one cannot even speculate.

The food of *latericius* may be described as very varied. The collection and storing up of grain does not appear to have been ever suggested for termites, although a feature in the economy of ants. *T. latericius* feeds commonly upon the droppings of animals and upon dead wood, bark, and dried grass. It has also been taken destroying acacia seedlings, and harvests green grass after its own fashion. In

harvesting grass it displays a remarkable predilection for a variety known as Florida Grass, a fine and tender variety of *Cynodon dactylon*. Consequently it is a frequent pest to lawns in Pretoria and Johannesburg, where this grass is favoured. If not interfered with, latericus will establish itself in a lawn, and not only will keep it constantly mown, but will disfigure it utterly with the clay canopies beneath which it works. The insects first form a small canopy not an inch in diameter and cut the grass off beneath it; as the herbage is removed the margin of the canopy is extended until it may be 6 to 10 in. in diameter. As soon as the canopy is fairly large, the insects lose their timidity and venture out two to three inches from beneath its protection, mowing the grass evenly all round as if with a scythe. If disturbed, the workers desist and hasten for shelter. A few lose their way. Long after the workers have disappeared, the soldiers (about 1 per cent. of the herd) remain, obviously on the defensive, and their movements and attitudes convey the impression that they are trying to shepherd the stragglers back to safety.

An interesting feature is found in connection with the departure of the winged insects in the early summer. For this purpose special exits from the nest are prepared, which take the form of inclined oval galleries radiating from the hive (Pl. XXIX, fig. 8, *a, b, c, d*). These have a wide diameter of 1 to 2 in. and a height of $\frac{1}{2}$ in., dimensions which are retained until the inclines approach the surface of the ground, where they narrow down sharply to an elongate oval (1 in. by $\frac{1}{4}$ in.), and then taper narrowly into the exit. Just above the soil-surface is built an oval and expanded rim of clay; this rests obliquely and forms a vantage from which the insects can take flight.

Before and after the imagos emerge the position of these shafts is indicated by very small moundlets of hardened clay.

Termes vulgaris Haviland. Pl. XXX, figs. 7-10.

Mounds.—In Natal the masonry mounds of this species are common, and more nearly approach mounds of the natalensis group than do those of any other, being formed of earth particles strongly cemented together, and presenting a hard exterior and an interior with more or less vertically placed channels. Often the mounds are very inconspicuous, and the abode of a fairly large community may be overlaid by quite a small mound which looks no more than a hard clod of earth inset in the soil. A rough idea of the form of these and the nests below them has already been given (3); they need, however, more thorough investigation when opportunity offers. Although nests of 3 ft. in elevation have been recorded (2), the highest met with at Pietermaritzburg was 18 in., and as this took the form of a low cone, it was first thought to be a small nest of *T. natalensis*. Ordinarily the large mounds of this species are circular, widely arched, with a diameter of 2 ft. 6 in. to 3 ft. 6 in. and an elevation of 4 to 6 in. No mounds of this species have been noticed in Pretoria, but, as mentioned elsewhere, a moundless nest has come under observation, and similar ones have been found at Platrand, Transvaal, and Tylden, Cape.

Nests.—Unlike the nests of the natalensis series, which can be considered under three headings—mound, hive, and galleries—the nest of vulgaris does not lend itself to such treatment. One has to consider the whole and the relationship of the various parts to one another. This is perhaps best revealed by the description of a nest explored at Bellair (Pl. XXX, figs. 8-10). In this case the whole nest arrangement may be said to centre upon the fungus-garden, which took the form of a large, flatly pyriform loaf, resting upon a broad base and crowned with pinnacles, the central being the highest. It measured 12 in. in height and 18 in. through its greatest diameter. In common with other fungus-beds of this species, it was more spongiform than any of the

fungus-gardens of the other species under discussion, and consisted of a series of layers $1\frac{1}{2}$ in. thick enwrapping a central core. Fragile as the garden is these layers separate readily. The chamber in which this mass lay conformed roughly to its outline; the floor was overlaid with a clay mesh-work, bone-like in structure, which formed a raised skeleton platform. From this platform arose upright columns of clay—most reminiscent of arm and leg bones—which converged and connected indirectly with the roof of the cavity. This peculiar frame-work of clay, both in horizontal and perpendicular directions, was the scaffolding or skeleton supporting the fungus-garden, although the latter was not in any way cemented to it.

Immediately above the fungus-garden there was a narrow conical dome, hollow except that from it depended numerous thin clay arms; these being the indirect connections of the thicker vertical columns which penetrate the fungus-garden. Some of these minor arms had living grass roots at their cores, the roots penetrating the matrix of the mound from its periphery. As many hang rigid, like stalactites, it was conjectured that either the grass root was preserved by the application of a layer of clay, when the dome was excavated and during an enlargement of the nest cavity, or the roots were encouraged, by applications of clay to their growing points, to descend through the hollow dome into the main upright and so strengthen them; a conjecture supported by the discovery of roots in some of these latter. From the dome itself several wide shafts ($1\frac{1}{2}$ in. in diameter) led upwards into the mound, there broadening out, an inch below its surface, into conspicuous cavities. Apart from these, other shafts led up from the base of the nest around the cavity to the crust of the mound there terminating in a similar manner. Means of access to the cavity and other galleries from these shafts were provided by apertures at their bases and along their length, the openings being both large and small.

The mound of *vulgaris* appears purely protective, and although repaired in the same manner as in *natalensis* it

represents but little more than the earth removed to form the cavity, and in many cases not as much.

Although in most nests, examined somewhat cursorily, no supplementary fungus-gardens were noticed, such were certainly present in the one discovered by accident in Pretoria.

Termes incertus *Hagen*. Pl. XXIX, figs. 9-10 ;
Pl. XXXI, figs. 4-5.

The Haviland notes give the following account of the nest of *T. incertus*.

“This species generally forms its nest in the nests of the large species of fungus-growers, but it is sometimes found independently. In the latter case the nest may occur at a variable depth below the surface, from a few inches to several feet. Owing to the freedom with which kings and queens wander about when the nest is opened, it is difficult to determine how many there are in a colony or what are the limits of a colony. Occasionally three or four queens are found not far apart; kings are less often found.”

This account rather tends to convey the impression that *T. incertus* prefers to nest in the matrix of the masonry mounds of fungus-growing termites and only occasionally to make nests independent of mounds. Far from this being the case it may be said, with a great deal of assurance, that wherever this species abounds it is just as common to the surrounding soil as to any mound present. The masonry mounds, however, undoubtedly provide congenial quarters, as very few indeed are not riddled by *incertus*. What is remarkable is that the larger termites tolerate their presence; that they do so can only be because the presence of the smaller species and its tunnellings make no difference to the actual purpose of the mound.

When *incertus* lives in the mound of another species, owing to the narrowness of the parts inhabited, its galleries are tortuous and no definite plan can be recognised. Nests in the field, however, although intricate, do present a general

plan which, whilst difficult to expose, has very constant features.

As Haviland states, it is not possible even in the field to define the limits of a colony. In the account given of the behaviour of the winged imagos it is indicated that at Pretoria the earth is thoroughly occupied by the species, and it is no exaggeration to say that to a depth of 4 ft. the soil is pregnant with its fungus-gardens.

In order to obtain some idea of the main features of the underground occupations of *T. incertus* numerous galleries were traced through the soil for considerable lengths, and it is upon the result of this examination that the foregoing conclusions have been arrived at.

Termes incertus feeds upon dead grass and will often attack plants which have died and may damage newly set out seedlings, especially when planted in virgin soil that has recently been broken up. It is also known to destroy fruit trees and rose bushes. In this work, however, it retains all its subterranean characters and is very rarely found above soil-level, unless in a dead post.

In grass lands it makes a network of thin tubular galleries through the soil amongst the roots, and secures its food under cover of inconspicuous clay canopies. From this upper network of galleries equally tenuous shafts are sunk deep into the soil. The tracing of these is very laborious owing to the difficulty of following so small a gallery, but many interesting features are presented every inch or so along the length followed. These features are illustrated in a sketch (Pl. XXIX, fig. 9) made of a portion of such a gallery whilst being examined. Before summarising these, however, it is necessary to say that the long lateral galleries subsequently referred to generally wander through the soil for several feet, and connect with other descending shafts without displaying any such features.

The descending shaft figured went downward at a fairly regular angle of 45° . Here and there, for an inch at most, it would fall almost perpendicularly, but this feature was

sufficiently rare to be conspicuous when it did occur. The chief feature to be noticed in the sketch is that, at every few inches, the gallery opens out into well-defined chambers (*a, a, a*). All of these chambers are elongated; and, being vaulted and having flat floors, they much resemble the queen-cells of other termites (*vulgaris*, *latericius*, etc.); ordinarily they are 1 to $1\frac{1}{4}$ in. long, one half inch wide and a quarter to a third of an inch high. Some of them, even those within a few inches of the surface, contained young insects which were attended by workers. Such young being far removed from the fungus-gardens may have been undergoing differential feeding; but no evidence on that point was secured. Some of these chambers are junctions from which lateral galleries, or galleries leading to the fungus-garden cavities, go out. The majority, however, have but one entrance and one exit—the main down-shaft entering above at one end and continuing its course through a hole in the floor at the opposite end of the cavity. These elongated cavities are orientated in various directions and occur in the compressed nests found in mounds. The second striking feature is the little pocket-caverns which subtend the descending gallery (*b, b, b*) and open directly into it; they are domed, have circular flat floors and seem to be rest-houses. These are the lenticular cells of Haviland. A further feature are slight fusiform enlargements (*c, c*) which occur wherever the short, radiating and always descending galleries to the fungus-cavities join the down-shaft, or where lateral galleries join it.

Among the irregular features are cavities such as *d, d*, and the cavities *e, e*; the latter are, however, regarded as the beginning of excavations for the accommodation of fungus-beds.

The fungus-garden cavities are placed around the down shaft (Pl. XXIX, fig. 9, *f*, and Pl. XXXI, fig. 4), usually two to three inches away from it, or even more. These cavities are, as a rule, globular, although the floors generally tend to be flattened. With them the whole system looks like nothing

else than the underground stems of a plant with many tubers hanging to them. There is only the one aperture to these fungus-garden cavities, and, whenever a tunnel leading to one is branched, the branch leads to the cavity of another fungus-garden. These galleries always slant downwards and fall acutely on reaching the vicinity of the cavity, entering it at the side. Fungus-garden cavities do not vary much in size; the largest have usually a perpendicular diameter of $1\frac{1}{4}$ to 2 in. and a horizontal diameter of 3 to 4 in.

The fungus-garden nearly fills the cavity (Pl. XXXI, figs. 4 and 5). It is distinctly granular and crumbles easily, the pellets of which it is composed separating. All are coral-like in appearance, and may be compared, as regards folds and involutions, to the kernel of a walnut. In the case of most termites when, in digging, a gallery is broken through, the aperture is speedily closed with pellets of moist clay. *T. incertus* does not do this, but endeavours to bridge the break by building out a pipe of clay from the disturbed surface, constructing the pipe in the direction the lost part took (Pl. XXIX, fig. 10). In trenches recently cut through soil inhabited by this species, thousands of these projecting pipes are to be seen. As a rule the structure is not continued more than an inch, but some pipes projecting 2 to 3 in. have been noticed, and some were even branched. They are quite tenuous, with the outer surface roughly granular and inside quite smooth.

Eutermes parvus (*Haviland*). Pl. XXIX, figs. 11, 12; Pl. XXXI, figs. 1-3.

According to the Haviland notes *E. parvus* is found in Natal "from the sea-coast to an altitude of 5000 ft., and the winged forms have been taken on the tops of hills of 6000 ft." The species is only known to me from nests collected in the bush-lands of the Natal coast, and from specimens kindly collected for me by Mr. F. W. FitzSimmons at Port Elizabeth, where the species appears to be abundant.

Haviland noted further that "the nests are sometimes built practically on the surface of the ground, but they are often some little distance below, occasionally several feet, the nest being an irregular cellular structure." Up to the present only the surface nests have been found, but somewhat similar nests of a closely allied species abound in the soil of the Pretoria district; these range from the size of a large egg to that of a large cocoanut, and may be either superficial, beneath stones, inset in the mounds of other termites, or buried to some little depth in the surface soil.

Without doubt sandy dunes, covered with scrub, are the sites in which *parvus* flourishes best of all. At Scottburgh, Natal, several nests were found amongst beach plants within 20 ft. of high-water mark, and one, but 15 ft. off, overhung the beach (Pl. XXIX, fig. 11). This was 11 in. in diameter and quite globular. Originally built in the loose sand and involving in its matrix several stems of beach plants, under the stress of wind and storm it had become quite exposed. The insects inhabiting it established communication with the sand dune, from which it depended, by means of covered ways along the supporting tangle of roots, as well as through the interior of those that were dead. All other nests were found loosely embedded in the soil; so loose that they were easily extracted whole. The top of these nests usually projects a little above the surrounding soil, and has the appearance of a weathered and rotten piece of black wood. Domed nests are sometimes to be found, and these are obviously of recent structure (Pl. XXIX, fig. 12, *b*). The domes may be 3 to 4 in. above soil-level and have a cobble-stone surface of an ashen grey colour (Pl. XXXI, fig. 1). The underground part of every nest found tended to become obconic, some being elongated and others quite squat. In one instance a domed nest when extracted resembled in shape a huge carrot, 18 in. long and 4 in. through at its widest diameter.

The nests of *parvus* contain no provisions of any sort, but the workers are animated food-reservoirs. The structure of the interior is cellular; the cells being for the most part

uniform in size and irregularly oblate. Each cell has, as a rule, two apertures. In the core of the nest is a large flattened and horizontal queen-cell (Pl. XXXI, fig. 2), and, almost invariably, above this is a series of large inclined cells, which can be seen in the vertical section illustrated in Pl. XXXI, fig. 3. These cells form a kind of stairway, up which the queen can and does progress. Whilst she has not been detected laying her eggs in these superior cells the quantities of eggs located there indicate that she migrated to them for ovipositing. If this is the case it may be assumed to overcome the difficulty which would arise from too great an accumulation of eggs in the queen-cell. The largest nests found had a surface diameter of 12 in. and extended 8 to 10 in. deep into the soil.

In the scrub-lands *parvus* feeds upon decaying wood; the allied species in the Transvaal feeds upon grass, and will also attack young trees, hollowing out the roots and other underground parts.

The first impression which the nests of *parvus* gives is that they are formed by the conversion of dead stumps, and whilst I am inclined to think that this sometimes occurs there is sufficient evidence to show that it is not necessarily the case.

Eutermes bilobatus (*Haviland*). Pl. XXXI, figs. 7-9.

This species normally inhabits a clay hive, portion of which is thrust above ground in the form of a low rounded mound 3 to 5 in. high and 5 to 7 in. in diameter; the whole interior is cellular; and there is no differentiation or partition between that portion in the confines of the mound and the subterranean region which it overlies. Its striking external feature is the resemblance borne by it to a water-worn boulder inset in the soil; a feature which is not only one of appearance but also of hardness as well (Pl. XXXI, fig. 7). The crust of the dome is nearly always one-half to three-quarters of an inch in thickness; under this the structure is cellular, and in this form the hive is continued into the soil

to a depth of 6 to 8 in., the diameter of the subterranean part being invariably greater than that of the base of the mound. All the cells are of about one dimension except for one, or perhaps two, central cells, which lie two inches below soil-level. These are wide and shallow, and are the headquarters of queen and king. The rest of the cells are very irregular, but tend to become flattened spheres; each forms a separate compartment communicating with adjoining compartments by two or three small perforations in the walls. The walls between the cells may be described as strong, and of a fairly uniform thickness. The perforations have a small diameter of 2 mm., and are counter-sunk into each wall. There is no series of large permanent galleries leaving the nest, and such galleries as do lead away are fine and not easily traced. In the large series of nests (both normal and abnormal) examined nothing in the nature of stored provisions has been met with. Upon the other hand, the multitude of workers, always present, invariably have their abdomens so grossly distended that they can only be looked upon as animated food-reservoirs.

When observations were first begun upon this species the frequent intermingling of its mounds with those of *E. trinervius*, and a general resemblance in the relation of the mound to the subterranean part together with other broad structural features, led to a suspicion that *bilobatus* invaded small deserted nests of *trinervius*, as indicated by Haviland, and converted them into a structure to their own liking. Then the discovery of a small mound inhabited in part by the two species, one half built to the *bilobatus* pattern, the other to that of *trinervius*, led to a series of observations which showed that *bilobatus* simply expels young *trinervius* colonies from their own mounds. The process is not, so far as can be seen, one of decimation: *bilobatus* simply gaining an access to one point of the *trinervius* mound, and then by gradually converting the more open *trinervius* galleries into cells, it slowly builds the original artificers out. This process often results in the building of a new mound some

little distance off by the *trinervius* community; in several instances this has been begun before the colony has been altogether dislodged.

It is not argued that *bilobatus* raids the nests of *trinervius*, although upon two separate occasions correspondents in Natal have sent to the writer specimens of *bilobatus*, which they had taken from columns of workers found migrating in daylight over the surface of the ground. It is rather thought that just as pairs of *trinervius* will burrow into a hive of *bilobatus* so couples of the latter will burrow next to a hive of *trinervius*, and when the latter is not exceptionally strong their progeny will evict it.

As nests of *bilobatus* are also found under stones it is concluded that they take equal advantage of the nest structures of a nasutu *Eutermes*, closely allied to *trinervius*, which nests in such situations.

One extraordinary and large nest with a globular mound found in a wattle plantation at Mt. Edgecombe cannot be accounted for unless it was originally a large clod of earth, left when the land was broken up for planting, which had been converted into a nest and enlarged. Probably the abnormal conical mound, of which form only two examples have been observed, shown in Pl. XXXI, figs. 8 and 9, is only abnormal because rare.

E. bilobatus nests have been found completely surrounding those of the undetermined species allied to *E. parvus*. These are similar in architecture to those of *bilobatus*, but being built of carton, and owing to their ligneous nature, *bilobatus* does not invade them. Moreover, the other species possesses passage-ways through the *bilobatus* nest; using the cells and communications of the latter but lining them with carton. Whether this inference is correct, or whether the undetermined species builds its nests in those of *bilobatus*, gradually replacing the clay by their own building material, it is impossible to say upon the evidence at hand.

Here it may be mentioned that the process of dislodging carried out by *bilobatus* upon *E. trinervius* has its

parallel in the attack of true ants upon them and other similarly nesting species. It is scarcely possible to find a normal mound of *bilobatus* about Pretoria which has not a nest of a true ant in part of it; the ants capture the nest in the course of time by taking possession of it cell by cell. The process is not, however, a rapid one, as the termite can build up quicker than the ant can break down, and the very art which enables this termite to supplant another of its kind is its most potent means of defence where the ant is concerned.

When a hive of *bilobatus* is broken into the ants excitedly swarm in at once and seize and carry off the termites; they will not attack an injured nest of *trinervius* with like avidity, and seldom make their own domiciles near to the mounds of this latter species. Indeed they evince great circumspection, and always endeavour to capture the *trinervius nasutus* from behind.

The queen of *bilobatus* has the abdominal region vastly enlarged, but it is somewhat vermiform, presenting a number of irregular bulges of the far-stretched connecting membrane. Although so much enlarged and cumbersome the queen is able to make rapid progress, and when exposed essays to escape deeper into the nest. The apertures in the cell-walls are far too small to allow her abdomen to pass through unimpeded, but it is drawn through by the strength of her exertions, being constricted in the process to half its diameter. The eggs are found in packets in different parts of the nest, to which they are carried by the workers.

The workers comprise the bulk of the colony except when the nymphs of winged adults are present. When the nest is broken some hide away, but the majority of those exposed make no attempt to escape, crawling aimlessly about. Later, if unmolested by ants, they will start and repair the structure with pellets of clay-cement voided from their bodies.

The soldiers are always very few in number—often no more than a dozen can be found in a nest, at times they are entirely absent. This is especially the case when the imagos

are present in the nest. Since after the nuptial flight has taken place callow soldiers are soon to be found, it is assumed that for some reason the soldiers are destroyed at this period. The soldiers are extremely cowardly, and always retreat rapidly when a nest is broken into. This, together with their scarcity, seems to indicate that *bilobatus*, as a species, is not in any way dependent upon the soldier caste, and the representatives which do occur are but relics of a former economy.

The winged insects are of two sizes, the male being very much smaller than the female. When the adults are present in the nest it has a fœtid and disgusting odour—a feature never to be noticed at any other time.

Eutermes trinervius (*Rambur*). Pl. XXIX, figs. 13–17;
Pl. XXXII, figs. 1–2.

Apart from South Africa, the species ranges far afield, and it is very widespread throughout the sub-continent, being the commonest and most prevalent kind.

It occurs all over Natal from within 100 yds. of high-water mark to altitudes of 5000 to 6000 ft. It is, however, much more abundant in the drier parts of the midlands (Klip River County) than elsewhere, and is least common on the higher altitudes.

It is very common in the Transvaal, and abounds on high altitudes (5500 ft.) under fairly severe winter conditions, with the difference that these altitudes receive less rain and mist than regions of the same altitude in Natal, and are not mountainous. In the Cape Colony it ranges from the Orange River to the southern coast, but does not seem particularly common in the extreme south-west. In the Karroo it is to be met with, but always more abundantly in areas where summer grasses grow.

In the Orange Free State the species abounds from east to west and north to south. Through the middle region of the plateau, which has a mean altitude of 4500 ft. (ranging from

4000 to 4900 ft.), it is incredibly abundant; so much is it so that one may travel by train for a whole day through country so thickly studded over with mounds as to look as if overrun by a multitude of grazing sheep. This extreme abundance on this wide plain, hot in summer and bleak in winter, indicates that the species flourishes best in a dry atmosphere. Here the denudation of grazing land caused by the presence of these numerous colonies, proceeding year by year, must impoverish the land, but the species works in so insidious a manner that it is extremely doubtful whether those most affected—the stock owners—have the slightest idea of the loss entailed.

The nest of *trinervius* is a "hive-nest" assuming the form of a globular mass, the lower quarter of which is embedded in the soil. In Natal the mounds are symmetrical half-spheres, whilst the base inset in the soil is a low inverted cone. Regularly rounded domed mounds may also be found in parts of the Transvaal and Orange Free State where moister conditions obtain, and this is the prevailing shape in the southern region of Cape Colony. Where conditions are drier and the summer rains come in fierce tropical showers, regular contours are uncommon, and the mounds are roughly shouldered and tend to become conical. This alteration of the contour is due to spasmodic additions to the nest, coupled with weathering; the colonies under these conditions adding humps to the nest and not making a crust which envelopes at least two-thirds of the surface, as they do under milder and more uniform climatic conditions. Along the high ridge (5000 ft.) of the Witwatersrand (Heidelberg to Germiston) about half the mounds have a somewhat bizarre appearance (Pl. XXIX, fig. 17), and on the summit of some of these small or quite large tapering cones are developed. There seems to be nothing to account for this local eccentricity. It may be said of this species that it does not make bricks without straw, as a considerable amount of grass is always incorporated into any new addition of the nest.

There are several classes of mounds. The first of these is the juvenile mound, obviously the domicile of a young colony. These nests appear as collections of clay amidst a tussock of grass. From this stage the nest develops into a small domed domicile with the soil about the periphery of the mound perforated in every direction by a mesh of galleries, much like those of the hive itself. From this second stage develop the larger mounds. Around the large and old mounds the network of galleries is absent, but replaced by radiating trunk routes to feeding grounds away from the nest. The remaining class is the mound built up by a colony after having been expelled by *bilobatus*, or by the destruction of the mound, when it is frequently erected on the same site or hard by. Under such circumstances a supplementary mound may be formed. These mounds are built quite rapidly; in one instance, where a series of small nests was exposed for queens, it was found that those colonies, in which the queen had escaped detection, had, a week later, built mounds equal in size to those which they were previously in occupation of.

Owing to the difficulty in detecting queens in large nests it was thought for some time that a queen did not inhabit every mound, but this point was kindly cleared up for me by Mr. Leonard Bagshawe-Smith, of Platrand, Transvaal, upon whose farm the investigation, to be detailed below, into the connections between the mounds was carried out. Writing to this point under date of August 25th, Mr. Bagshawe-Smith says: "Yesterday, I took out fourteen nests. In thirteen I found queens, and in the fourteenth, a fairly big mound, I found a king. In one I found both king and queen. If you dig the big mounds out very quickly you find the queen; if you take time you will not. The queen gets away very quickly; with a quick movement she slides and falls from gallery to gallery and gets below soil level. I had a good opportunity of watching one sliding and falling, with a crowd of workers after her." Again, under date of September 2nd, he writes: "I took queens from each of six nests

that were connected by runways. In the first series we examined I had great difficulty in recovering some of the queens; again and again I was about to give it up, but luck favoured and I found one queen over 12 in. below soil-level."

Haviland states that there is only one king and one queen to a nest, that they generally live near the centre, and when disturbed may escape into the surrounding soil. As a matter of fact, the king is very seldom detected, whilst the queen moves with such agility that even when one has seen her enter a lump of nest this often has to be broken to fragments to capture her, so quickly are her efforts at concealment manœuvred. Placed upon a level surface the queen cannot get along at all rapidly, but she can climb a wooden upright. From this and the foregoing observations it is clear that the insect is adapted to rapid progress in the peculiar and involved galleries of the nest. Two queens have been taken in one nest, but this is unusual.

If queens are removed directly from nests and placed with nest fragments and workers in a glass jar, egg-laying can be readily observed, and the workers attend to the queen as if nothing had happened. Feeding is continuous, and it is seldom that there are not more than two workers in attendance. The queen is fed with some reddish fluid of which but a minute quantity is passed from the mouth of the worker to that of the queen. An individual worker may give one, two or three sips before retiring, and the queen may take two or three sips from one attendant before turning to the other, or she may sip from them alternately. A succession of workers attend to the feeding, and when one retires another takes its place.

The eggs are extruded one by one and stick together in a little parcel about the vulva. Never more than ten to twenty seem to accumulate, as workers are constantly removing them. The eggs do not separate away from one another readily, and the workers endeavour to remove them with the maxillæ and not with the jaws; it is only when the maxillæ

fail that the jaws are used. When the egg is separated it is carried off in the mouth, projecting out between the jaws.

The cellular arrangement of the whole of the nest, whilst appearing in section (Pl. XXXII, fig. 1) as a series of layers, is so intricate that it baffles concise description. Such words as "honeycombed" or "spongiform" do not express it. It is better described as a labyrinth of galleries which cross and recross one another and go in all directions. It has been found that, starting from a given point, a termite can progress to any other given point by a multitude of routes. Thus a termite at one point can reach any other by an almost direct route straight through the nest, or it can take a curving or zig-zag route to right or left, restricted only by the outer confines of the hive; equally it can take either of such routes by a series of ascents and descents or *vice versâ*. There is, in fact, no limit to the possible ways of journeying from one part to another. In its arrangement the whole nest can be likened to the fungus-beds of such species as *T. badius* and *vulgaris*. The nest structure throughout is formed of gritty earth particles firmly cemented together, but the hardness of the nest is largely dependent upon the nature of the soil from which it is built, those in sandy loams being much the softer.

From the larger mounds numerous galleries are driven out through the soil at one inch below the surface; these are quite straight for some distance, and resemble the spokes of a wheel, with the mound for the hub. Their number is variable, but as many as twenty have been found radiating from a mound having a diameter of $3\frac{1}{2}$ ft. Many of them anastomose within a few feet of the mound. For great lengths these galleries and their branches are of a permanent nature, and form a succession of straight short lengths or very wide curves. They are uniformly an inch below the surface, and rise and fall most regularly with the details in the contour of the surface. They have a uniform width throughout, have hardened floors, and are vaulted above (Pl. XXIX, fig. 14). They connect either directly

with other mounds or lead to feeding grounds. At irregular intervals along their length, seldom at a distance of less than two inches apart, pouches are excavated on both sides (Pl. XXIX, figs. 15, 15a, 15b, 15c, 15d); these extend outwards

TEXT-FIG. 12.



Eutermes trinervius. Sketch plan of system of galleries showing nest connections and palmate termini. All the galleries in the triangle formed by nests B, K, and G are exposed. Only around nest B are all the radiating galleries exposed. Actual distances apart of nests—A to E, 120 ft.; A to K, 102 ft.; K to E, 102 ft.; B to C, 6 ft.

and downwards, and usually undercut the path. Where, by chance, two such pouches are opposite each other the pathway is often completely undercut, so that it forms a bridge across a small chasm. These pouches are all sub-globular, and, as a rule, measure 1 in. in the long diameter, and bulge out about three quarters of an inch from the edge of the pathway. The apertures into them, from the side-walls of

the tunnel, are always an elongate oval. Their purpose is for the temporary accommodation of the night's harvest.

A peculiar feature of the galleries is that at every minor branch the connection of the branch with the main gallery is an indirect one, and occurs between two and three inches deep in the soil; this connection can only be compared to a knot. Galleries which approach a feeding ground suddenly taper and branch in a palmate form, each branch running out to the surface. The surface exits are small round holes of a fairly permanent character which have been noticed to remain open for over a week. There is some evidence that feeding grounds are more or less permanent, and that continued feeding about one point results in barren or bare patches.

The accompanying sketch illustrates one of a series of observations upon galleries and nest-connections. It is drawn approximately to scale, and shows, as nearly as possible, the directions taken by the various galleries. The mounds A, B, C, D, F and K were inhabited by active colonies, and in each a queen was recovered. Unfortunately this series was rather near to the homestead, and some of the nests had been removed for chicken food. The sites of these are indicated at G and H; the galleries ran through them, descended below, and rose again on the other side of the site; from this it is concluded that the nests when standing formed part of the series. It will be obvious that only a few of the galleries have been exposed, but the galleries are not more abundant than indicated in the rough triangle formed by nests B, K, G, which were all exposed. If the evidence revealed is followed to its natural conclusion it would appear that all the nests except E formed a complete series. Nest E appears to belong to a different series. Point is given to this by the obvious avoidance of the galleries of the nest D by that from E. Again the partly exposed gallery x x, obviously leading to the gallery connecting nests C and D, was deliberately undermined by the second gallery from nest E.

It is to be noticed in the foregoing account that all the nests explored harboured colonies; this was fortunate, as it is

seldom there is not quite a large percentage of deserted mounds. Why so many mounds are deserted is very baffling. Dr. Warren tells me that, in the course of his study of the biology of this species, he endeavoured to sustain his colonies by watering the nests through the dry winter; but, notwithstanding this attention, many became deserted. Dr. Warren was fortunate enough to see the action of desertion, and by his express wish his account is incorporated here. It should be stated, however, that the observation was made prior to our full acquaintance with the radiating galleries.

One day during the winter of 1913, whilst visiting the ground where he had a series of nests under frequent observation, he noticed a series of small holes 4 to 6 in. apart and a quarter of an inch in diameter arranged in straight lines all radiating from the mound (Pl. XXIX, figs. 16, *a*, *b*). Upon looking into these holes it was seen that the termites were hurrying backwards and forwards in an agitated stream. Quite unexpectedly, the insects—nymphs, workers, and soldiers—poured out of the radiating channels, scattered over the surface, and before long died. Some that were taken and placed in test-tubes with moist earth lived a fortnight longer. In addition to this abnormal behaviour, small holes about a quarter of an inch in diameter were formed irregularly over the mound and more particularly on the sides. These holes might be plastered up again with moist pellets; when open they were always fringed by a border of soldiers within, whose closely placed heads, projecting beyond the edge of the hole, formed a conspicuous reddish border to the aperture, as viewed from the outside.

Subsequently at the sources of the Crocodile River, and again at Platrand and at Pretoria, the writer found, during the winter of 1914, many nests showing these radiating lines of holes. The natural inference was that they were simple perforations in the roof of the galleries; but upon investigation it was found that the galleries had been deliberately altered and the floor there raised towards the soil-level, the apertures being immediately over the raised part of the runway.

The reason for this extraordinary manifestation, limited as it is to some nests only in a series, is very elusive. It can scarcely be due to the queen going astray in the galleries or to her gaining access to another nest, although it is possible for her to do this. If it is due to her death, one would expect that the inhabitants of the one mound would simply augment the colonies of those with which it is in such intimate communication and not commit suicide. The circumstance cannot be credited to drought or cold, for many near-by colonies no better circumstanced continue to thrive; nor is it from shortage of food, as Dr. Warren found ample provender in the deserted nests, whilst a similar state of affairs obtained at Platrand and Crocodile River.

The speedy death of the insects on outpouring from the nest is equally remarkable; not alone because those captured and placed in a test-tube lived for so long, but also because, if a nest be broken and the insects exposed to the glaring sunlight, they do not die. The workers simply seek shelter under the broken fragments strewn around or in the recesses of the nest, whilst the soldiers expose themselves for hours unmindful of danger from foe and uninjured by the sunshine.

On the face of it, this extraordinary action and voluntary death seems to be the reflex of some unknown stimulus; and perhaps we may assume that the few insects set aside lived because their capture and removal to a fresh environment broke the influence of the stimulus.

The two agarics (*Podaxon pistillaris* and *P. carsinomalis*) which grow out of the mounds of *trinervius* have nothing to do apparently with the economy of the termites (Pl. XXXII, fig. 2). The mycelia from which these arise ramify throughout the earthen structure of the mound. Mycelial swellings form in cells just beneath the crust of the mound and the agaric breaks through the crust. It must be conceded that the mycelium subsists upon the organic matter in the matrix of the mound. It is to be remembered that there is a good deal of grass incorporated in the substance of

the mound, and a thin layer of black, and no doubt organic, matter on the walls of the galleries, for the fungus to subsist upon; this wall-deposit is more conspicuous when a red or grey coloured soil has been used to build the fabric. Although the termites will destroy the base of the agaric if the stalk is deep set in the mound, they never attack the superior portion; indeed, in the case of the larger agaric, the termites construct what appear to be protecting clay collars around it when in the sprouting stage. Whilst several (one to five) agarics may grow upon one mound, it is rather extraordinary that only a small percentage of mounds have the fungus associated with them.

The galleries of the mounds are throughout summer and winter choked to a great extent with short grass-lengths or hay. This is sometimes noticeably more abundant in the outer galleries of the nest, those under the crust, and the larger cells (or cellars) at the floor of the hive; but, as a rule, the provisions are distributed fairly evenly throughout the whole nest. It is only in the spring of the year (November) that there is a marked depletion in the hay contents of the hive.

According to Haviland's notes the workers cut the grass during the wet season (summer), working at night or in the early morning, and even in the middle of the day during dull weather. He further states that, "like *Hodotermes*, they stand head downwards¹ on a stem of grass, and with their mandibles gradually cut around the stem until it is sawn through." It has only been my good fortune to observe these insects foraging in the twilight, when their activities are difficult to follow. The workers seem to cut the grass blades through as best they can and stand in any attitude. They also gather green grass seed, and in the early evening this is piled on the surface of the ground ready for removal into the burrows before daylight.

It has been recorded that the imagos reach maturity during September and October in Natal, issuing after night-

¹ *Hodotermes* does not necessarily adopt this attitude.

fall from the nest during November. This is also the case for the Transvaal. It has also been noticed that such swarming takes place after rain has fallen, and that the full complement does not leave the nest at one and the same time. The crescent-shaped openings in the crusts of the mound through which the winged insects emerge, and the facts that these are closed up and subsequently persist for quite a long time afterwards, have also been repeatedly observed.

When a nest is broken open suddenly numerous representatives of all four castes are exposed; but shortly such workers as can get out of sight do so. The soldiers, however, swarm over the broken surface, the smaller predominating, all lifting their heads aggressively and discharging viscid fluid. So eager are these little creatures that, where a perpendicular break is made, hundreds of them fall and form a mass at the base. After nightfall the breach is repaired by the workers, and in a little time the mound may be built up to its full proportion again. When a calamity like this befalls the nest, the bulk of the workers attended by some soldiers, and, if present, all the nymphs, retreat into the radiating galleries; hastening away from the zone of danger.

Upon the whole this species is very immune from attack, and it is extremely rare to see nests much despoiled. In some, small holes are burrowed, 3 or 4 in. in diameter, most probably by meerkats; but whether as a foe of the termite, or simply for the sake of making a lair, has not been determined. Haviland's notes state that jackals appear to feed largely on the species. This seems merely a conjecture. It has also been said that the aardvark destroys the nest, but if this is really so it is extraordinary that I have seen absolutely no evidence of it.

The species to some extent escapes the attack of true ants. In certain parts of the Pretoria district where many nests of *E. bilobatus* are intermingled with those of *trinervius*, whilst every nest of the former species has one ants' nest associated with it, and presents ample evidence of the constant siege going on, nothing of the sort obtains with the

latter. If by chance an ants' nest is somewhere near to a *trinervius* mound and the mound is broken the ants will swarm around; they do not, however, display that delirious blood-lust exhibited, under like circumstances, against *bilobatus*, but behave with the greatest circumspection, never facing the soldier termite, but awaiting an opportunity to seize it from behind, in the region of the nape.

As the viscid fluid ejected by the soldier of this species, considered as a missile of defence, can only be most ineffectual against a large marauder of the nest, it must be regarded as their chief form of defence against true ants.

In the foregoing account it is assumed that each *trinervius* colony inhabiting a mound is a separate colony, despite the fact that its mound may be connected by underground galleries with another mound or series of mounds. No experiments have been made to ascertain how far the insects of adjoining mounds are antagonistic or friendly, but Mr. Bagshawe-Smith assures me that whenever he introduces a foreign queen to a mound the soldiers attack her, sliming her over with their viscid secretions.

V. CLASSIFICATION.

I. INTRODUCTION.

This contribution is designed to fix the identity of the species whose habits have formed the subject of the preceding discussion and that of several allied species. That some species are presented as new is incidental.

For the purpose in view the soldier caste has received chief consideration, but worker characters, essential for their determination or for the qualification of those of the soldiers, are also given. The imagos have not been described. Particular attention has been given to the full characters of the soldier mandibles and more especially to the basal regions which are ordinarily hidden by the labrum; these characters are as

important as those that are more in evidence. The various antennæ of the different adult castes have much specific value provided the limitations of the caste variation and their mode of growth are known. The colour effect of the chitin as overlying muscular tissue is given without attempting differentiation; this seems to be the usual practice. Unless otherwise stated, they are taken from material preserved in 75 per cent. alcohol. In certain species the colour tones and the colour patterns of the head are fairly constant, in other species they are not. Whilst of assistance in diagnosis neither should be regarded as of great specific value. In general the length of the head with the mandibles and its greatest breadth are secondary aids to diagnosis, whilst the total length of the insect is a very deceptive measurement, as illustrated in the subsequent discussion of *Termes natalensis*. Here it may be mentioned that the various measurements given in the description are only to be regarded as approximate, whether given in mm. or μ . They have one value inasmuch as all have been taken by the same means. Total length, head with mandibles and head-width have been determined by placing insects which have died in a more or less extended position upon a plane surface cross-ruled to half a millimetre and then reading off the length with a magnifying glass of low power. This method permits the taking of long series of approximate measurements rapidly; by various checks I have found the results quite as reliable as measurements taken by more laborious and elaborate methods. Whilst the lengths of the soldiers are for fully extended insects, or those in which the long axis of the head is continuous with that of the body, the lengths of the workers are for insects with the head in the natural position at right angles to the long axis of the body.

The lengths for the antennal segments are approximately the length of the chitinised portion of the joint and are taken along the middle line of the joint. This omits the conjunctiva, and it does not give the full length of such joints as have a soft telescopic apex—all but two or three of the basal joints

and the apical joint. However, it is a far more satisfactory method than endeavouring to trace elusive apical margins.

Terms.—With regard to the descriptive terms these will be found to follow very closely those of Comstock and Kellog (5). The general terminology also follows these authors, Comstock and Chujiro Kochi (6) and J. B. Smith's 'Glossary of Entomology' (7). Perhaps the only term used at variance with these authorities is "frons," which is given preference to "front." Not unnaturally some descriptive terms have been used in a restricted sense, a few terms have been borrowed from allied natural sciences, and some at least have been invented. To avoid any confusion a short glossary is given (see Appendix) so that it will be only necessary to indicate here the application of the terms "frontal area," "frontal folds" and "ventral genæ."

"Frontal area" is an inclusive term embracing the areas of the frons and the clypeus in those cases where the Y-shaped suture of the epicranium and the clypeo-frontal suture are both obsolete. Thus "frons" is only used when the area is demarcated by a decided Y-suture or by some intra-chitinous trace of it.

The suture (clypeo-frontal) dividing the frons from the clypeus is present in workers, other than those of *Hodotermes*, and in all imagos; but in all the soldiers it is to be regarded as obsolete, except in the case of *Rhinotermes putorius*, where it is fully expressed. Its probable position is indicated to one degree or another in all soldiers by the features to which I have applied the term "frontal folds." These folds arise at the point of articulation of the mandible and usually extend obliquely backwards more or less into the median region of the frontal area. They are striking features in the soldiers and workers of *Hodotermes*, and in all cases it appears as if the lateral portions of the original suture were overgrown by a fold of the frons. The folds are actually the points of attachment of the props of the tentorium, and they are heavily marked owing to the thickness of the chitin, and a greater depth of colour occurs in the form of paired oblique

bands. To define these the term "frontal folds" has been introduced.

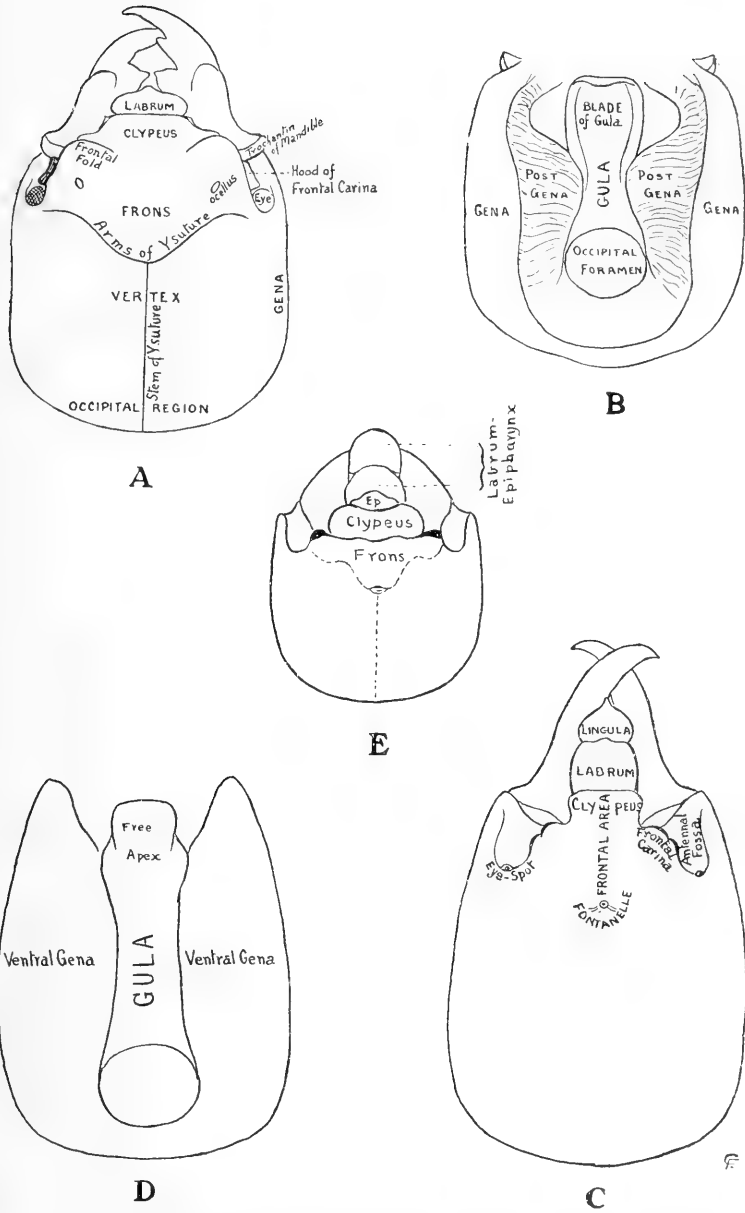
In certain species, especially in *Hodotermes*, the post-genæ are very large and profoundly differentiated from the genæ. In most other species, however, all trace of differentiation is either lost or but slight indications are present; as in the transverse wrinkles exhibited by *Termes swaziæ* and the colour differentiation in *Termes waterbergi*. Owing to the flatness of the head it is very desirable to describe the ventral aspect, and, as an aid towards this end, the term "ventral-genæ" has been improvised to indicate the whole of the cheeks lateral to the gula.

The Head.—In the soldier caste it may be said that the head is a simple cylindrical capsule composed of two pieces—the epi-cranium and the gula—with a supporting tentorium. As a consequence, the regions to which the names of sclerites are apportioned must be regarded as indefinite and merging into those adjoining them.

The accompanying diagrams of heads of *Hodotermes* and *Termes* will suffice to illustrate the approximate areas to which sclerite names have been applied. As a matter of convenience, the term "epistome" has been retained and applied in the restricted sense of a separate piece behind the labrum attached to the front margin of the clypeus. In the soldiers this is but a thin plate-like extension of the clypeus and is included as a part of the clypeus in the descriptions. In most of the workers discussed (and in the imagos) it is, however, a large and well-defined region calling for a special and particular definition.

The labrum of the soldiers and workers of *Hodotermes* appears to be always simple. There are, however, many instances in which the labrum of common acceptance is in part the epipharynx. Thus in the soldiers of *Termes swaziæ*, *waterbergi* and *natalensis* the labrum terminates in a fleshy cordiform tip to which I have applied the term "lingula." This is simply a prolongation of the epipharynx. Again in *Eutermes bilobatus*, the labrum of

TEXT-FIG. 13.



Termite head. A. Dorsal aspect of the head of *Hodotermes* soldier. B. Ventral view of the same. C. Dorsal aspect of the head of *Termes* soldier. D. Ventral view of the same. E. Dorsal aspect of the head of *Termes* worker. Ep. Epistome.

which is said to be a forked structure, I can only think that the true labrum is a very atrophied sclerite, and that the so-called labrum is a chitinised extension of the epipharynx. In nearly all the workers of the *Termes* species the labrum is distinctly bi-articulate and can only be considered as the labrum-epipharynx. In the *Eutermes* species there is a pseudo-articulation near to the apex of this sclerite which indicates that its structure is the same but simpler.

Because it seems the proper thing to do, I have endeavoured to the best of my ability to describe the impressions, grooves, keels, mounds, etc., of the frons. But it is a wearying matter in most cases, as, with every shifting illumination and every alteration of the point of vision, the aspect changes. Hence my introduction of "kaleidoscopic" into some of the descriptions of the frons and my appreciation of Haviland's remark: "I have not attempted to outdo Nature in distinctness; indeed, in this respect I am conscious of shortcomings."

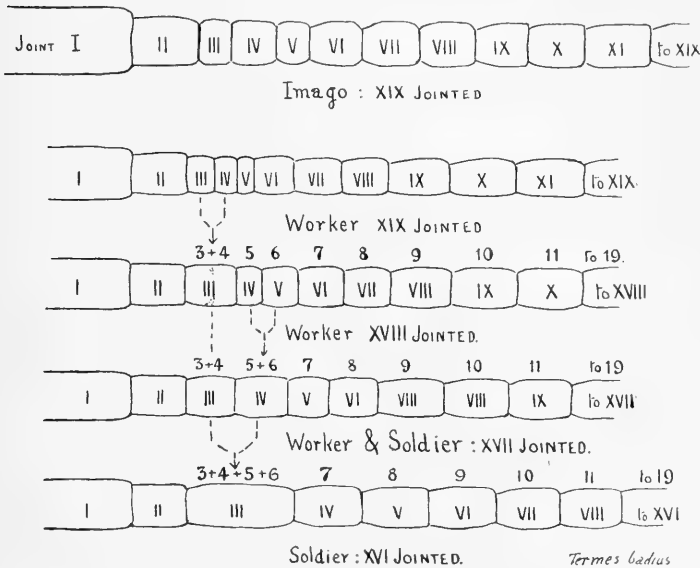
Upon the whole the frons when impressed and embossed is very variable in the degree of its sculpturing, and the details are so minute, so variable, so indescribable and of so little specific value that no more than a loose reference to the nature of this area is really necessary. Indeed, I have found by experiment on my colleagues that no two of us could agree upon the exact nature of the frons-sculpture of either *Termes natalensis* or *T. badius*.

Legs.—In certain species the tibia of each leg appears to be two-segmented; the differentiation being more or less distinct in different species. This arachnoid feature may possibly be looked upon as indicating a primitive character.

Antennæ.—The growth of the termite antenna after the hatching of the young termite may be said to be due to the production of a series of intercalated joints in a vegetative manner. This development has not been actually traced, but it may be deduced with some confidence. If, for example, *T. badius* is examined it is found that the imagos have antennæ of 19 joints whilst the adults of other castes may have less; the major workers presenting 19, 18, and 17

segments; major soldiers 17 and 16 segments, and the minor soldiers 17 segments. The XIX-jointed worker is rare, and the XVIII-jointed is more common than the XVII-jointed form, a circumstance which, in combination with other features, illustrates that the worker-caste is due to arrested development.

TEXT-FIG. 14.



Diagrams of different antennæ of various castes of *Termes badius* to illustrate how the variations exhibited arise through the more or less complete failure to separate of the segments immediately distal to joint II.

If the several forms of the worker antennæ are compared, it is seen that the rare XIX-jointed form is very similar in its pattern to the adult imago form; the chief difference being in the generally smaller size of the joints. This is illustrated in the antennal curves to which reference will presently be made. It is further illustrated in the accompanying diagrams. Starting from the XIX-jointed form it is not difficult to show how the XVIII-jointed form arises out of fusion (or, more

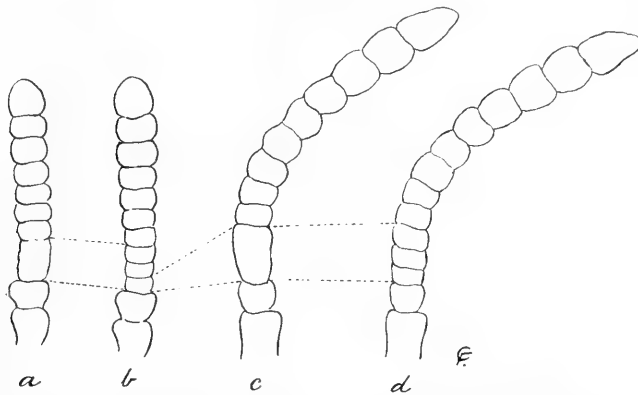
correctly speaking, the failure to separate) of joints III and IV; because, if a series is searched for, every degree of non-separation can be found from joints with two whorls of bristles and distinct pseudo-articulations through joints with two whorls of bristles and no trace of articulation to simple uni-whorled segments giving no direct evidence of how they originated. That the XVII-jointed antenna is formed by the non-separation of joints V and VI of the XIX-jointed form can be demonstrated just as readily.

Turning to the soldier caste ample evidence can be found to show that the XVII-jointed form originates as does the XVII-jointed major and minor worker form; that is, by finding pseudo-articulations and double whorls of bristles on joint IV (or 5 + 6 of the XIX-jointed antenna). In certain nest-series there are soldiers which present XVI segments to the antenna and all joints are complete and uni-whorled. However, amongst them can be found (*a*) normal soldiers with XVII-jointed antenna, (*b*) sometimes an abnormal soldier with both a XVI- and a XVII-jointed antenna, and (*c*) an abnormal soldier with both antennæ XVI-jointed, in some of which III shows an intermediate articulation; in other words the joint III of the XVI-jointed antenna has arisen through the non-separation of joints III, IV, V, and VI of the XIX-jointed form.

In this connection the segmentation can be deduced from the larval forms of *T. badius*. The youngest condition observed is the larval stage (1 to 1.3 mm. long) having ten joints clearly expressed (Text-fig. 15, *a*). Joints I and II have already acquired their fixed expression, and seven apical joints are distinctly separate and joint III is elongate. Joint III then subdivides into three segments and gives a XII-jointed antenna (*b*). It then elongates (*c*) and later subdivides to give the XIV-jointed antenna (*d*). This shows that the XIX-jointed antenna arises out of the growth and sub-division of joint III. If there is no check in development, the extra joints appear between III and IV of the X-jointed antenna until the XIX-jointed form is fully expressed, and this, at

one stage, involves the separation of III into two instead of three segments. Consequently the final condition of III varies according to whether the final IV is completely articulated or not. If no complete fissure occurs the XVI-jointed antenna results. On occasion, too, the most recently formed segments, i. e. V and VI, appear to fuse instead of becoming definitely separated, and this circumstance, together with the compound nature of III, results in the XVII-jointed

TEXT-FIG. 15.



T. badius; antennæ of larvæ. *a.* X-jointed expression with a long joint III. *b.* The X-jointed changed to a XII-jointed expression by the subdivision of III. *c.* The XII-jointed expression prior to the subdivision of the long joint III to give the XIV-jointed expression. *d.* The XIV-jointed expression before the enlargement of III.

form. The XVI-segmented type is obtained by an arrest of development which must be considered to involve III as comprising what would really have been III, IV, V, and VI of the XIX-jointed type.

In short, the XIX-jointed antenna is produced from a form with fourteen segments by a process of proliferation or fission in joint III.

Apart from this process other factors seem to come into play to influence the form of certain joints. In badius joint V is a relatively small joint in the XIX-jointed antenna



of both the imago and worker castes ; and, as joint IV of the XVIII-jointed form, it is also small. In the XVII-jointed form the fifth joint is practically the smallest of the series ; and, as this represents the relative large joint VII of the XIX-jointed form, it gives evidence that the shape and size of the joint is influenced by the distance it is removed from the head.

A somewhat similar state of affairs prevails in the antennal pattern of *T. natalensis*, where in the XIX-jointed imago antenna V is narrower and smaller than IV and VI. It is reproduced as joint IV in the XVIII-jointed ; but, in the XVII-jointed expression, it is again V that is smaller than IV or VI. In the XVIII-jointed antennæ, III and IV are small and about equal, whilst V is always larger than VI ; from this it is inferred that the XVIII-jointed worker antenna is due to the failure of V and VI of the full expression of XIX to separate, and that the XVII-jointed form of both major and minor soldier is due to the fusion of III with IV of the XVIII-jointed form ; by this means the small joint VII of the imago becomes the small joint V of the soldier. A pseudo XVII-jointed worker-major antenna is due to the fusion of the joints V and VI of the XVIII-jointed form. Upon the other hand, the XVII-jointed antenna of the worker-minor is not due to the failure of joints to separate after being produced, but rather due to the fact that joints have not been produced.

As it was thought that a series of antennal formulæ, such as have been used by workers with coccids, might be useful in fixing species, a number of exact measurements of many antennæ of *T. natalensis* and *T. badius* were made. Although of a constant general pattern, the variability in the actual length of the joints was such that it was rare that more than two formulæ in ten coincided. My colleague, Mr. C. K. Brain, of the Union Division of Entomology, having met with similar difficulties with the formulæ for coccid antennæ, had some time ago devised a means of reflecting the antennal patterns by charts. This he has improved to show the range in the lengths of the individual segments. By

applying his method to the antennæ of termites some very satisfactory results promise to follow, as is indicated in the provisional antennal charts now submitted for *T. natalensis*, *T. badius*, and *Eutermes trinervius* (Pl. XXXIII). I do not anticipate equally satisfactory results from its application to the genus *Hodotermes*, although I do for most genera.

Mr. Brain has been kind enough to permit me to include here a note by him on his use of antennal charts.

"The most useful arrangement of antennal data seems to be arrived at by giving the range of variation in measurements of the different segments with the addition perhaps of the mode of each. After working over a large series of slides one is impressed with the characteristic appearance of different coccid antennæ; but this difference is difficult to express. The nearest approach is obtained by charting a polygon showing both the mode and the range of variation in the segment lengths. This supplies a most useful aid for the preliminary location of coccids from slide specimens.

"Whenever possible, the range of measurement should represent at least ten measurements, twenty to thirty being made where material is sufficiently plentiful to allow such to be done. The measurements are then plotted in the centre of each antennal column and the polygon completed. Thus it appears that where any segment is constant the charted area approaches a simple line, while a wide band represents a wide range of variation.

"Similarity of antennal chart, whilst indicating similarity of antennal formula, does not of necessity indicate identity of coccid species; but it does give a clue to work upon, and possibly at times indicates relationship."

2. SYSTEMATIC ACCOUNT.

HODOTERMES.

I have ventured to split into four species a certain group of specimens in the collection which, in part, has been identified

as *Hodotermes mossambicus* Hagen. In this I think I am right, although it must be admitted that the characters are elusive. I have considered it safer to regard them, for the time being, as different species, because the terms subspecies, variety, and race are either quite opinionative, and therefore involve the personal equation, or they imply a biological knowledge, and are only correctly used when founded upon a comprehensive study of an extensive series with full details of range, local conditions, and life-history. In the case of each, however, I have been able to examine one or more good series from separate colonies and localities, and have found that, when compared side by side, the soldier caste of each would seem to represent different species.

The insect which I have specified as *H. mossambicus* is that to which the descriptions of Hagen's species, which are available to me, apply best. Further, it is that which, in the collections of the Division of Entomology and the Natal Museum, has been obtained from localities approximating the range of *mossambicus*. It is represented by material from the moist coast region of Zululand and the dry table-lands of the interior (Kimberley, Marico). In dealing with the series the description of the soldier of *H. transvaalensis* *sp. n.* is given as a standard for comparison. Photo-micrographs (Pl. XXXV) are given of the labrum of each species recorded, and, in order to fix the elusive variations of mandibles of similar dentation, a series of camera-lucida outlines of these is also furnished (Pl. XXXIV). This series shows the mandibles selected from the largest soldiers equally magnified. In the illustrations it is seen that the different sets have been variously orientated, but all are arranged so that the basal processes are level. Further to this the appearance is largely due to the fact that mandibles are articulated in different species in slightly different attitudes.

I have not regarded any of the *Hodotermes* as having major and minor castes, either among the soldiers or workers, because in any extensive series of South African forms all grades are to be met with between two extremes—the smallest

and the largest. In the species specified as *Termes badius Hav.* the same course has been followed with the soldier caste for similar reasons; but *badius* does possess well-defined major and minor workers.

The worker caste of several species has been described in detail, but these descriptions, as far as they go at present, can be applied for all practical purposes to the largest workers of any species except *viator* and, perhaps, *karrooensis*. Certain peculiarly obese and bright yellow, worker-like insects, taken foraging in company with adult and callow workers of *H. karrooensis sp. n.* and *H. warreni sp. n.*, have not been described because it has not been possible to decide whether these are aberrant workers or juvenile imagos.

Hodotermes transvaalensis sp. n. Pl. XXXIV, figs. 1, 1a; Pl. XXXV, fig. 1.

SOLDIER.

Measurements.¹—Total length 15 to 20 mm.; head with mandibles 6 to 8 mm., head-width 4·5 to 5·5 mm., head-length 4·5 to 5·2 mm.

Head.—Vertex pale brown, or reddish- or yellowish-brown; frons conspicuously mottled with light whitish yellow; of this colour three triangular pennant stripes extend backwards, their narrow wavy apices reaching well over the vertex; clypeus wholly dark, or dark red-brown or purple, with two faint patches of paler hue. Surface polished; vertex quite smooth; frons wrinkled; clypeus strongly chitinised; the whole with short scattered hairs, those on the frons being the stronger. Dorsal outline broadly U-shaped, not wider behind than in front; Y-suture distinct; vertex flatly arched;

¹ The figures given in this and the following descriptions are with a few exceptions based on the measurement of at least ten insects, but in some cases many more were measured. The range is not that of a nest series, but represents the difference between the largest and smallest of the measured insects.

sides convex, parallel and straight; genæ faintly concave; trochantin of mandible strong and prominent.

Frons deflected and twice depressed; depressions separated by a short, distinct, transverse ridge which forks at both ends, the caudal prongs merging into the vertex and the anterior prongs passing within the ocelli and terminating at the mandible; caudal depression shallowing into vertex; cephalic merging into clypeus and with a low pale-coloured median mound which appears triangular and tapers backwards, the apex merging into the ridge separating the two depressions.

Eyes black, sub-reniform, facing more outward than forward.

Ocelli distinct, white, surrounded by a reddish aureole; viewed from the side they appear inset in the top of low mound.

Clypeus actually oblong but with corners so obliquely deflected as to give the cephalic margin (the epistome) a three-sided appearance, swollen behind cephalic margin so as to form a transverse, rounded ridge; a distinct furrow or wrinkle connecting frontal folds (= the clypeo-frontal suture).

Labrum pale brownish-yellow; somewhat polished; with yellow bristles; short and broad; arched and very broadly cordiform; distal margin flatly brace-shaped or roundly acute.

Mandibles black; dorsal mounds very dark reddish-brown; broad and flattened; with wide bases and teeth; lateral margins shouldered near the base and then broadly curvate; the dorsal surface of each with an elevated ridge which is high at the basal knob and extends forward to the second tooth as a flattened punctate mound having a rounded margin. Apical points broad, much incurved and deflected; the inner margin sinuate, at first incurvate then curvate and tapering into acute incision above the first tooth; the left point longer than the right, but not quite as wide and more deflected. The left mandible longer and wider than the

right; with three teeth, of which the first is acute and the largest, the third the smallest with a faintly sinuate, tri-curved edge; also with a strong basal process, below which the margin tapers and is incurvate and then curvate. The right jaw with two teeth, both of which are larger than the first two of the left jaw, the cutting edge of the second long and wavy; margin below the second tooth with three incisions and two well-defined scallops; margin extending obliquely outwards.

Antennæ pale yellow-brown throughout; whip-like; joints I and II forming the handle, the rest a fusiform thong; joint I inset below the hood of the frontal carina; of about XXVIII, XXIX, or XXX joints; III, IV, and V usually sub-equal and the narrowest and shortest of the series; VI to apical increasing and then decreasing in length; from VII or VIII to the fourth to sixth apical joint the width is generally constant, the apical series tapering slightly; from VI the lengths gradually increase to a maximum which may be reached between XIII and XVI; apical joint always shorter than the penultimate and often decidedly narrower; maximum length of longest joints about equal to that of II.

I, strong, cylindrical, apex with a distinct whorl of bristles; more than twice the length of II (range 400 to 500 μ).

II, strong, cylindrical, nearly as wide as long, wider than any succeeding joint; with an apical whorl of bristles and scattered bristles on apical half (range 200 to 300 μ).

III, IV, V annular; less than half the length of II; III anchylosed to II; each with an apical whorl of bristles (range 70 to 100 μ).

VI annular; longer than V; with an apical whorl of bristles (range 100 to 130 μ).

VII longer than VI (100 to 150 μ); often with two whorls of bristles.

VIII and onwards, the first few joints globose, the middle series obconic, the apical series elongated with almost parallel sides and two whorls of bristles.

Apical with convex-truncate apex and with two whorls of bristles.

Post-genæ differentiated from the genæ by a sharp carina; sloping down to the gula; transversely and regularly rugose.

Gula scoop-shaped; free blade broad, with sides bent up and parallel, distal margin curvate; inserted stem much constricted behind blade, and widening gradually into blade; one third as long as blade.

Thorax.—Median area of each shield bright yellow, broadly and sharply bordered with smoky brown; meso- and metanotum with paired and very distinct dark brown dots.

Pronotum sellate; narrower than the head; partitioned before half its length by an open transverse furrow which debouches on either side into cup-like hollows; quartered by a faint median line; cephalic area arched, but with its median field hardly raised above level of caudal field; cephalic margin arched, arch rising almost perpendicularly from the lateral processes and bending in a flat curve to its apex where there is a shallow and small notch; caudal area with the median field arched, the side-plates sloping gently outwards; sides curvate, tapering slightly, margins not upbent; lateral processes salient, spout-like (like gargoyles), large, projecting outwards and forwards as well as pointing downwards, incised at base before and behind, much hollowed, hollows shallowing into transverse furrow; caudal margin broadly incurvate, almost straight.

Mesonotum with median field convex; sides broadly curvate and with edges a little bent up in front; caudal margin faintly bilobed, nearly straight; as broad as pronotum less the processes.

Metanotum a little narrower than that of mesonotum; arched; sides curvate, diverging sufficiently to form distinct caudo-lateral angles with hind margin, edges as with mesonotum; caudal margin bilobed, median portion prolonged, laterad of lobes very incurvate.

Legs brown; apex of tibia of I with 2 to 4 spurs, of II

with 3 to 5, of III with 2 to 4; in any insect there is always a greater number on II than on I and III. The tarsus of III is the longest, of II a little longer than that of I, the ratio is 7 : 5 : 4; in all, joint IV has a length which is constantly equal to the length of 1 + 2 + 3.

Abdomen.—Pale brown. Styli with rather long but not numerous bristles.

This soldier is closely allied to that of *pretoriensis*, but differs chiefly (*a*) in its comparatively broader mandibles, (*b*) its less acute labrum, (*c*) in the basal scallops of the right mandible, (*d*) in the styli both species are entirely different from *karrooensis*.

WORKER.

Measurements.—Total length 7·5 to 12 mm.; head-width 2·5 to 4 mm.

There is no great difference between the worker of this species and that of *pretoriensis* except that it seems to show a lower length range, and the yellow spot is not so prominent on the frons.

Hab.—Transvaal; Pretoria.

Hodotermes pretoriensis *sp. n.* Pl. XXXIV, figs. 2, 2*a*;
Pl. XXXV, fig. 2.

SOLDIER.

Measurements.—Total length 16 to 20·2 mm.; head with mandibles, 7 to 8 mm.; head-width 4·7 to 5·5 mm.

Head.—Vertex pale brownish-yellow; frons a little more yellow, but not conspicuously so, with short pennant stripes running a little backwards over the vertex, and with two conspicuous copper-brown bands extending inwards obliquely from the bases of the mandibles and indicating the frontal folds; clypeus reddish or pale brown-yellow, except that the lateral processes behind mandibles are black. Surface dulled; vertex sparsely punctate; frons finely wrinkled; whole with conspicuous scattered hairs, which appear stouter on the

frons. Dorsal outline broadly U-shaped; almost as long as wide, not broader behind than in front; Y-suture distinct; vertex roundly arched, more arched than *transvaalensis*, and occipital region inflated; sides nearly straight, slightly curvate; trochantin of mandible strong and prominent.

Frons deflected; without transverse ridge or brow; almost flat with paired median impressions between ocelli; merging into depressed region of clypeus; frontal folds very distinct.

Eyes black, sub-reniform, facing more forwards than outwards.

Ocelli represented by distinct, irregular-fusiform pits.

Clypeus with epistome: margin truncate, sides more or less obliquely rounded.

Labrum broad, longer, and with a more acute apex than in *transvaalensis*, and longer and a little less tapering sides.

Mandibles light red with teeth and apical points black. Dentation and form very similar to that in *transvaalensis* but more highly polished; longer and narrower; margin below second tooth of left with two incisions and one distinct scallop. Apical point and distal tooth of both mandibles sometimes duplicated.

Antennæ yellow; whip-like; as with *transvaalensis*; joints III to V very variable, sometimes III, IV, and V equal and small, sometimes III larger than IV, or IV than III, in which case the larger joint usually presents a pseudo-articulation and two whorls of bristles; number of joints ranging from about twenty-seven to thirty.

Post-genæ and gula much as with *transvaalensis*, but inserted stem of gula longer and widening more sharply into blade; blade more rectangular with sides faintly incurvate.

Thorax.—Almost uniformly dull yellow ochre, with quite inconspicuous paired dots on shields of meso- and metanotum. Agrees in structural details with *transvaalensis*, except (1) the lateral processes do not project so much, and, as a consequence, the mesonotum appears as wide as the pronotum;

(2) there is only one basal scallop on the right mandible. Much like that of *mossambicus*, except that (1) the cephalic margin of the pronotum is distinctly notched, (2) the caudal margins of all three shields are more retuse, (3) the basal scallop of *mossambicus* is not curvate.

Legs pale brown; in the majority of cases I with 3, II with 4, and III with 3 spurs; occasionally I with 2, II with 5 to 6, and III with 4.

Abdomen.—Whitish brown, sordid, paler than that of *mossambicus*.

WORKER.

Measurements.—Head-width 2·7 to 4·2 mm.; total length 8·5 to 13 mm.

Head.—Vertex a dark chocolate-brown or paler, dark colour extending forward over median area of frons; mediad and laterad of antennal fossæ pale sordid brown; incised portion of clypeo-frontal suture indicated by well-defined dark brown bands; epistome translucent; clypeus usually pale or basal area darker, when pale the ridge brown; labrum translucent, a sordid yellow brown; trochantin of mandible pallid; there is always a small white median dot in the apex of a pale V line in the caudal darkened area of the frons. Dorsal outline open U-shaped; cephalic extremity broadened; sides convex, tapering sharply and merging into caudal margin, not bending in markedly to trochantin of mandible; Y-suture distinct; vertex flatly arched.

Frons with cephalic area very flatly depressed, with a very faint median carina in depression.

Eyes black, sub-reniform.

Ocelli quite obsolete, represented by faint shallow punctures.

Clypeus with median length of clypeo-frontal suture obsolete; with a transverse cephalic ridge; epistome plate-like, broad, sides tapering; cephalic margin straight with a small median lobe.

Antennæ pale or dark brown; apical joints tapering.

Joints III, IV, V sub-equal in the largest insects; IV the largest; in the smallest, III, IV, V, VI sub-equal.

THORAX.—Constricted; each shield with a well-defined dark brown area bordered with a sordid white. Pronotum with cephalic margin white; arched, with a small median notch.

Mesonotum longer and narrower than metanotum; both with faintly curvate, almost straight, diverging sides, then rounded and tapering incurvately to narrow straight caudal margins.

Meta- more prolonged than mesonotum.

Legs with tibia and tarsus pallid, rest brown.

ABDOMEN.—Convex above; dorsal sclerites with dark chocolate-brown bands which diffuse to pale brown towards both margins; anal appendages long, tipped with brown; cerci translucent.

HAB.—Transvaal; Pretoria.

This species is closely allied to *transvaalensis*, and has similar habits, and occurs in one and the same locality. The most striking differences are mostly those of colour, and the thorax of *transvaalensis* is ornate in comparison with the dull mono-tint of that of *pretoriensis*. The styli of the two insects are essentially different, those of *pretoriensis* being more bristly—the proportion being apparently four bristles to every three of *transvaalensis*. The styli of the workers differ in the same respect, but the difference is not so striking and can only be seen when a series of these organs from the two species are microscopically compared. On two occasions it has been taken mining in the plaster of inner walls of houses in Pretoria, and is reported to have destroyed books and starched lace curtains. The more serious complaint against it was the noises made by the rappings of the soldiers at night. In one series the majority of the soldiers have the apical point and distal tooth duplicated, so that, when viewed from the inner side, the apical points and the teeth below them are furcate.

Hodotermes karrooensis *sp. n.* Pl. XXXIV, figs. 3, 3a;
Pl. XXXV, fig. 3.

SOLDIER.

Measurements.—Total length 15 to 19 mm.; head with mandibles 7·5 to 8·5 mm.; head-width 5·2 to 5·5 mm.

Head.—Vertex bright yellow or reddish-yellow, broadly striped with diffuse copper-brown; frons pale yellow-brown with a conspicuous yellow triangular patch in the fork of the Y-suture; mediad of antennal fossæ large diffuse patches of yellow, and a triangular yellow patch caudad of base of clypeus; clypeus copper-brown. Surface polished; vertex and frons equally faintly wrinkled and equally clothed with very scattered short hairs. Dorsal outline broadly oval and noticeably wider than long; Y-suture distinct; sides broadly curvate, in part almost straight and parallel; trochantin of mandible well expressed.

Frons deflected and twice depressed; depressions not separated by a distinct ridge; caudal depression very faint, level, merging into deflected cephalic depression; presenting two pits, and between them a median elevation which has the form of a low triangular pyramid.

Eyes black, sub-reniform, facing obliquely upwards.

Ocelli obsolete, indicated by shallow depressions centring a small diffuse reddish spot.

Clypeus oblong; cephalic margin (epistome) faintly incurvate, thin and deflected anterior to a distinct transverse ridge; clypeo-frontal suture indicated by wrinkles connecting frontal folds.

Labrum bearing a strong resemblance to that of *pretoriensis*, but less acute, and sides less tapering; more acute than in *transvaalensis*.

Mandibles reddish-yellow, apical points and teeth black; much coarser than in *transvaalensis* or *pretoriensis*; lateral margins irregularly curvate (wavy), more incurved than in either *transvaalensis* or *pretoriensis*, especially

the apical point of right; dentation as with *transvaalensis*, but teeth more separated; basal margin of process of left acute; margin below second tooth of right with two shallow obtuse incisions and no distinct scallop between them.

Antennæ yellow; whip-like; much as with *transvaalensis*, but joint III usually the smallest, with IV larger than III, V larger than IV, and VI larger than V; sometimes with IV and V equal; sometimes with III larger than IV, and when so presenting a double whorl of bristles; number of joints about twenty-eight to thirty-one.

Post-genæ concolorous with genæ or brighter yellow.

Gula scoop-like; edges of free blade tapering towards the apex; distal margin faintly incurvate; inserted stem short and wide.

Thorax.—Median area of each shield bright golden yellow bordered by pale brown; with paired and distinct pale brown dots on meso- and metanotum; agreeing in structural details with *transvaalensis*, except that (1) the segments are proportionately broader, (2) the processes not so incised behind, and (3) the metanotum is as wide or wider than the mesonotum. Much like that of *mossambicus*, except that (1) the shields are relatively broader, (2) the pronotum presents a faint notch on the cephalic margin, and the lateral processes project more outwards, (3) the mesonotum is more angled behind.

Variation in Number of Spurs.

Specimen.	1			2			3		
	I	II	III	I	II	III	I	II	III
Tibia.									
On the right . . .	4	4	*	3	1	*	2	4	4
On the left . . .	2	3	3	2	4	2	2	4	2

* Spurs broken off.

Legs yellow brown; in the majority of insects tibia I with 3, II with 4, and III with 3 strong spurs.

Abdomen.—Bright golden yellow.

WORKER.

Measurements.—Head-widths 2·5 to 4·5 mm.; total length 9·5 to 14 mm.

Head.—Vertex intensely black, colour extending over median frontal area towards base of clypeus; frontal folds chestnut brown; yellow patches median and lateral to antennal fossæ on cephalic margin of head; clypeus with epistome translucent, with a broad dark median stripe bordered with white patches; labrum yellowish; trochantin of mandible white. Dorsal outline open U-shaped; cephalic extremity broadened; sides convex, slightly curvate, tapering, tapering more decidedly in small workers than large, bending in to trochantin of mandible; Y-suture distinct, especially in small workers where it is pale in colour; vertex flatly arched.

Frons with cephalic area presenting a small median mound and lateral to this two depressions; separated from clypeus by a groove connecting two lateral incisions (an incomplete clypeus-frontal suture).

Ocelli represented by pale spots.

Eyes black and sub-reniform.

Clypeus large, broad; epistome plate-like and prolonged with a narrow straight margin and incurvate oblique sides; apex of clypeus elevated and forming a distinct transverse ridge reaching almost from side to side.

Labrum large; cephalic margin broadly rounded; anterior lateral corners lobed; sides incurvate and tapering.

Mandibles reddish-yellow or chestnut with black points.

Antennæ a pale sordid brown; III, IV, V annular, sub-equal, IV generally the largest of the three in the largest workers and the smallest in the smallest workers.

Thorax.—Constricted, narrower than head; dark black-brown, except that the cephalic margin of the pronotum is a paler sordid brown; pro-, meso- and metanotum with a pale median line.

Pronotum with cephalic margin rounded, entire, arched,

and somewhat prolonged over head; processes deflected and prominent; caudal margin straight, sides curvate, tapering acutely.

Mesonotum long and broad; sides diverging; caudal margin broadly curvate or faintly bilobed.

Metanotum shorter and wider than mesonotum; caudal margin with three edges, laterals straight and converging, median faintly incurvate.

Legs with coxa dark brown, femur pale brown, tibia and tarsus pallid.

Abdomen.—Broad and flat; colour always pale; dorsal sclerites pale, sordid brown; colour not contrasting sharply with conjunctiva; ventral plates a sordid white; styli long white and black tipped; cerci pallid. This species can always be separated from the others by the characteristic colour of the worker abdomen.

Hab.—Cape Colony; Middelburg, Steynsburg, Victoria East (The Karroo).

The habits of this species agree very well with those of *H. transvaalensis*. Field collections made in August, 1913, contained many large bright yellow insects. These were quite as large and as brightly coloured as the soldiers and somewhat obese. They have the worker form, except that the heads are less flattened, and they forage with the workers and immature imagos. The imagos which I consider to be of this species are of a bright yellow. These were collected on the same date with soldiers and in the same place as this species abounds in. This species is known to be very destructive to growing crops and to tunnel through the clay plaster of inside walls.

It was regarding this species that Mr. Albert Rubidge, farm Emerald, Middelburg, wrote to me the accompanying letter under date October 3rd, 1912. As no large species of the genus *Termes* have been noticed at Middelburg, it is extremely probable that Mr. Rubidge's reminiscences refer to a *Hodotermes*.

"I note that you say the nest of the marching termites has not been discovered. The following may, therefore, be of interest to you. As far back as forty years ago, a couple of Bushmen arrived at my father's place in Graaff Reinet and asked to be employed in taking out the nests of the 'rijsmier.' As these little insects were then troublesome in a cottage my father set them to work near it. As a child I was much interested and watched the process; it consisted of putting a wheat straw (or several in different passages in a small area) down the passage from the surface, then excavating to near the end of the straw; then again inserting the straw as far as it would go; and so on. As the passages frequently have short curves it is easy to lose the run of them. Thus these Bushmen dug several large holes to the depth of 6 to 8 ft. without success; but ultimately they succeeded in reaching the nest at about 8 ft. down. This consisted of a circular hole or well from 18 to 24 in. in depth by about 10 to 12 in. in diameter—beautifully smoothed and cemented. From this was taken about a bucket to a bucket and a half full of insects together with the queen—about $2\frac{1}{2}$ in. in length and about $1\frac{3}{4}$ in. to 2 in. in circumference, in appearance very similar to your illustrations (3) and of a dirty white colour.

"The entrances to the passages were to be found over an area of about 50 yards square, and the actual nest was found about 15 yards away from the building.

"The unsuccessful holes dug by the Bushmen were 8 to 10 yards from the successful one. You will note that I am not very definite in my figures, but must bear in mind that I am speaking from impressions on the mind of a child forty years back.

"These termites were very troublesome in my house at one time, so I mixed some white arsenic with bran, filled the round of a magnum bonum pen, and blew the mixture into the entrances to their passages. This proved effectual; as they eat their dead the poisoning continued, and they came out to die, so we removed them by plates full (as they died in the old-fashioned wall cupboards)."

(As *Hodotermes* discard their dead, it is more probable that those which died were thrown out by the insects from the outlets in the cupboards.—C.F.)

In a further letter Mr. Rubidge writes :

"The damage done in my house referred to was not to the wood work, but rather to the plaster and paper. They tunnelled along under the paper in all directions and ate the paper from the walls. Moreover they destroyed books and other papers, and carved out extra patterns in the window-curtains, even eating linen clothing."

Hodotermes mossambicus (*Hagen*). Pl. XXXIV, figs. 4, 4a; Pl. XXXV, fig. 4.

Termes mossambicus *Hagen*. *Monatl. Bericht. d. K. Akad. der Wiss.*, Berlin, p. 480, 1853.

SOLDIER.

Measurements.—Total length, 14 to 15·5 mm.; head with mandibles, 5·7 to 6·5 mm.; head-width, 4 to 4·5 mm.; head-length, 4 to 4·5 mm.

Head.—Vertex reddish-yellow; clypeus reddish, darker in the middle; frons yellow, mottled as with *transvaalensis*, but not so conspicuously. Surface polished; vertex not quite smooth; with few and inconspicuous scattered hairs; frons faintly wrinkled; clypeus not strongly chitinised. Dorsal outline broadly or roundly oval, a little longer than wide; Y-suture distinct; vertex flatly arched; sides convex and curvate; trochantin of mandible not so prominent as in *transvaalensis*.

Frons deflected and once depressed; depression cephalic; fairly deep, merging into clypeus, bordered behind by a low transverse brow, the median region of which projects a little forward.

Eyes black, sub-reniform, facing obliquely upwards.

Ocelli in the form of two minute, oval, white spots.

Clypeus as with *transvaalensis*.

Labrum with flatly brace-shaped cephalic margin; distal corners somewhat lobed, then tapering somewhat acutely; like that of *transvaalensis* but distal margin more flattened, very different from that of *havilandi*.

Mandibles at base dark red, the rest black; dentation and form as with *transvaalensis*, but with apical points much incurved, and more slender and both about equally coarse; not so highly coloured as in *havilandi* and coarser; with margin below basal process of left irregular and not incurvate; with margin below second tooth of right with two short incisions and only a suppressed scallop between them; cephalic edge of second tooth of right distinctly bi-curved.

Antennæ yellow; whip-like; distal series not tapering as conspicuously as in *transvaalensis*; composed of 27, 28, 29, or 30 joints; III, IV, V subequal, annular, and the three narrowest and smallest; VI and onwards increasing in length and width; width from VII or VIII constant up to the last 4 to 6 apical joints which taper very little; lengths reaching maximum at the twelfth to fourteenth joint from apex, apical joint always shorter than penultimate and often decidedly narrower.

I strong, cylindrical, furnished at apex with distinct whorl of spines; more than twice the length of II and one third wider (length range 400 to 500 μ).

II strong, cylindrical, nearly as wide as long; wider than any succeeding joint; furnished with a whorl of bristles at apex and with scattered bristles over apical half (200 to 230 μ).

III short, annular, less than half the length of II; with a single apical row of bristles; anchylosed to II (70 to 100 μ).

IV and V similar to III and

VI annular; longer than V; with apical bristles (100 to 130 μ).

VII larger than VI; with apical bristles and often with a second whorl (110 to 150 μ); first few succeeding segments globose; rest obconic; apical series more elongate, with almost parallel sides (130 to 210 μ); VIII onwards, with two whorls of bristles and scattered bristles.

Apical joint shorter than penultimate, sides parallel, apex convexly truncate (175 to 200 μ).

Post-genæ as with *transvaalensis*.

Gula scoop-shaped; as with *transvaalensis*, but free blade with noticeably chitinised and much up-turned sides; concolorous with post-genæ.

Thorax.—Almost uniformly reddish-brown, paler than head; with dark paired brown spots upon meso- and metanotum; agreeing in structural details with *transvaalensis* except that (1) the processes tend to be more rounded apically and more lateral in direction of cephalic edge, and (2) that the anterior margin of the pronotum is entire.

Legs brown; spurs of tibia very variable, I with 1 to 3, II with 2 to 5, III with 3 to 4; an analysis of four insects gives:

Specimen.	1.			2.			3.			4.		
Tibia . . .	I	II	III	I	II	III	I	II	III	I	II	III
On the right	2	4	3	2	4	3	1	4	4	2	3	3
On the left	3	4	3	3	4	3	2	2	4	2	5	3

It will be observed that out of eight cases for four insects recorded the same sequence only occurs twice.

Abdomen.—Whitish brown, sordid, darker than in pretoriensis.

WORKER.

Measurements.—Head-width 2.2 to 4 mm.; total length 8.0 to 13 mm. Antennæ 31 to 34 joints.

Head.—Vertex black-brown; the greater part of the frons yellow or white, sometimes with median area dark- or black-brown; clypeus pale yellow at sides, dark in the middle; epistome white; labrum yellowish with a greenish tinge. Trochantin not projecting beyond margin.

Ocelli, each surrounded by a diffuse ring of yellow.

Antennæ pale-brown; whip-like; joints I and II large and strong; III to V short, annular and sub-equal; III usually the smallest; remainder increasing in length to about one-third the distance from base to apex; apical series elongate and narrowing; apical joint shorter than penultimate and elongate oval; of 31, 33 and 34 joints.

Thorax.—Shields in the middle black-brown with a pale median stripe; side-plates pale brown; cephalic margin of pronotum with a mottled white or pale yellow band.

Pronotum much narrower than the head. Mesonotum as broad as pronotum with processes; metanotum broader than mesonotum.

Legs tarsi and tibia pallid, femur dark brown; I with 3, II with 4, III with 3 spurs to tibia.

Upon the whole agreeing with the worker of *pretoriensis*.

Abdomen.—Dorsal sclerites each with dark and pale brown bands, paler caudad; conjunctiva forming white transverse bars between sclerites; frequently the caudal half of the abdomen much paler than towards thorax; ventral sclerites paler than dorsal.

Hab.—Zululand; Somekele. Transvaal; Marico. Cape Colony; Kimberley.

The habits of this species seem to agree generally with those of the others. Mr. David Gunn, of the Division of Entomology, collected the species at Marico and states that it seemed to be confined to the irrigated lands there.

Hodotermes havilandi Sharp. Pl. XXXIV, figs. 5, 5a;
Pl. XXXV, fig. 5.

Hodotermes havilandi Sharp, The Cambridge Nat. Hist., vol. v, p. 384, 1895; Haviland, Journ. Linn. Soc., vol. xxvi, p. 372, 1898.

SOLDIER.

Measurements.—Total length 11·5 to 14·5 mm.; head with mandibles 5·5 to 7 mm.; head-width 4 to 4·5 mm.; head-length 3·5 to 4 mm.

Head.—Vertex bright yellow, with three broad bands of a warm mahogany-red, one median and two lateral; the genæ yellow; clypeus pale reddish; frons light yellow. Surface polished; vertex not quite smooth; frons as smooth as vertex and without conspicuous hairs. Dorsal outline, round-oval, a little longer than wide; sometimes almost circular; Y-suture distinct; vertex flatly arched; sides convex and curvate; trochantin of mandible not very prominent and not projecting outwards.

Frons deflected and twice depressed, depressions very shallow and separated by a simple but distinct transverse

ridge which is interrupted in the middle and has a faint elevation anterior to the break.

Eyes black, sub-reniform, facing obliquely outwards.

Ocelli obscurely represented by pale spots.

Clypeus with a triple edged cephalic margin (the epistome); median edge extending over labrum as a thin pale plate; without a transverse ridge, but with a faint median elevation.

Labrum with lobed sides as in *mossambicus*, but with a flatly convex and not brace-shaped or acute distal margin, as with the other allied species.

Mandibles yellow-red over greater area; apical points and teeth black. Much lighter in colour and with a greater coloured area than in *mossambicus*. Dentation and form as in *transvaalensis* but with outer margins more curvate; apical points sub-lunate, fine, long, slender and much incurved; that of left but a little more slender than of right; incisions above first tooth very acute. Both mandibles distinctly narrower and more incurved than those of *mossambicus*; the third tooth of the left more suppressed than in either *mossambicus* or *transvaalensis*, the process below it more acute; the margin below process bicurvate, less oblique than in *transvaalensis*. Right mandible with cutting edge like that of *transvaalensis* and with three incisions and two scallops below second tooth.

Antennæ whip-like; joints III, IV, and V sub-equal; III the smallest, or IV sometimes smaller than III and V, or IV longer than III and wider than V. Number of joints 31.

Post-genæ as with *transvaalensis*.

Gula much paler than post-genæ; scoop-shaped; free blade sub-oblong with straight sides and straight distal margin; sides not conspicuously chitinised; inserted stem short.

Thorax.—Pale yellow suffused with mahogany-red, cephalic border of pronotum pale and almost white. Structural details in general agreement with those of *trans-*

vaalensis except that (1) the anterior margin of the pronotum is almost semi-circular and entire, (2) the processes more like sessile bat's ears, (3) the mesonotum distinctly broader than the pronotum and processes, (4) the metanotum is broader than the mesonotum, (5) the colour is different.

Legs pale reddish-yellow; having 2 or 3 spurs to tibia of I; 2 or 4 to that of II; and always 3 to that of III. Analysis of 14 gives: six with 2-4-3, two with 2-3-3, three with 3-3-3, three with 3-4-3.

Abdomen.—Bright yellow.

The soldier of *havilandi* is distinctly different from that here described as *mossambicus*; the chief points of difference being (*a*) the more circular head outline, (*b*) in colour, (*c*) in size-range, (*d*) in the character of the mandible.

WORKER.

Measurements.—Head-widths 2 to 3.5 mm.; total length 7 to 10.5 mm.

Antennæ about 29 to 33 joints.

Except that (1) the prevailing colour of the workers of this species is chestnut brown and not black-brown, and (2) the largest workers do not reach the maximum size of those of *mossambicus*, and the smallest are much smaller, there appears to be little difference between the workers of the two species. The description for the worker of *preto-riensis* applies in general, but the V mark of the frons is absent.

Hab.—Natal; Weenen, Colenso (the valley of the Tugela River).

The habits of this species agree with those of *H. transvaalensis*. It is often very destructive to lucerne crops. When infested lands are irrigated the insects suspend operations.

The species is very local and not found far from alluvial soil.

Hodotermes warreni *sp. n.* Pl. XXXIV, figs. 6, 6a;
Pl. XXXV, fig. 6.

SOLDIER.

Measurements.—Total length 8 to 14 mm.; head with mandibles 3·5 to 6·5 mm.; head-width 2 to 3·7 mm.

Head.—Resembling dully polished tortoise-shell; sometimes a rich reddish-brown with colour bands ill-defined. Vertex with a bright orange-yellow ground and three deep red-brown furcate-lanceolate stripes; median stripe fusiform, extending along stem of Y-suture; sub-median stripes extending from caudad of eyes over occipital region, then forming a median line on the ventral slopes of the genæ; clypeus reddish in the middle, bright yellow at sides; small lateral prolongation behind mandibles black. Surface polished; the whole finely wrinkled; cephalic depression of frontal area distinctly wrinkled; without conspicuous hairs. Dorsal outline broadly U-shaped; longer than wide; sides parallel, nearly straight or flatly curvate; Y-suture distinct; vertex broadly arched; trochantin of mandible not very conspicuous.

Frons not conspicuously impressed.

Eyes black, sub-reniform.

Ocelli small, indistinct, and not bordered by a darker colour.

Clypeus with the cephalic edge (epistome) rounded and deflected anterior to a transverse ridge; frontal folds distinct, oblique, extending well backwards.

Labrum pale yellow, very broadly cordate, as in *transvaalensis*, but a little more roundly acute and proportionately longer.

Mandibles in form and dentation as with *transvaalensis*; apical points acute and narrow, but not as slender as in *havilandi*; first tooth of left elongate, acute, and directed somewhat towards apical point; basal process acute and very prominent; second tooth of right comparatively large, margin below wavy and not incised.

Antennæ yellow; whip-like; much as with *transvaalensis*; about 25 to 29 joints; joint III larger or smaller than IV.

Post-genæ as with *transvaalensis*, but mottled with brown.

Gula scoop-shaped; with sides of free blade much upturned, straight; distal margin straight, anterior lateral corners oblique.

Thorax.—Pale yellow or yellow with median patches of red-brown on each shield.

Pronotum arched; cephalic margin entire; processes deflected, projecting forward and not outward, not incised behind; sides straight; tapering; caudal margin slightly incurvate, nearly straight.

Mesonotum broadly oval, narrower than pro- and metanotum; caudal margin slightly truncate.

Metanotum short and broad; broader than pronotum; widest behind; sides nearly straight, oblique and diverging; caudal margin three-sided, all three edges straight or broadly incurvate.

Legs pale brown-yellow. Tibia of I with 2 to 3, II with 3 to 4, and III with 3 spurs.

Abdomen.—Yellow.

WORKER.

Measurements.—Head-width 2 to 3.5 mm.; total length 6 to 10 mm.

The worker of these species is much like that of *pretoriensis*, but presents a lower length-range, and the frontal depression of the frons is very shallow.

Hab.—Orange Free State; Lovat, Tha'banchu.

Reported as very destructive to veld grass during the drought of 1914. The field series collected at Tha'banchu in August, 1914, contains an obese worker-like creature, larger than the soldiers with a rounded yellow head and pale yellow body. This is probably an immature imago.

Hodotermes braini *sp. n.* Pl. XXXIV, figs. 7, 7a;
Pl. XXXV, fig. 7.

SOLDIER.

Measurements.—Total length 12 mm.; head with mandibles 5 mm.; head-width 3 mm.

Head.—Vertex marked by a broad median, parallel-sided stripe of pale brown which seems to extend from the clypeus to the occiput, and is about half the breadth of the head; lateral to this the field is dark brown to the sides. Clypeus reddish-yellow. Frons yellow with a dark, ill-defined median area. Surface dulled; frons and clypeus faintly wrinkled. Dorsal outline distinctly oblong, U-shaped and flatly rounded behind; Y-suture distinct; vertex flatly arched and not depressed; sides parallel and straight, somewhat constricted, tapering from laterad of eyes to trochantin of mandible; trochantin well defined, concolorous with adjacent parts.

Frons deflected slightly and but faintly impressed.

Eyes black, sub-reniform.

Ocelli small, but distinct, oval, white, surrounded by a narrow ring of dark red-brown and a diffuse band of pale yellow.

Clypeus oblong; with cephalic corners of epistome rounded and much deflected, giving it a three-sided appearance; with a median, cephalic, flat, pyramidal elevation; frontal folds indistinct.

Labrum much like that of *transvaalensis*, but more elongate and front margin more acute.

Mandibles black, bases suffused with dark red; dentation as with *transvaalensis*; comparatively slender and straight; apical points long and not conspicuously incurved, that of left nearly straight; on the dorsal surface, at the base of each, a small punctate area; process of left acute and deflected; margin below second tooth of right, twice incised and bicrenulate between the incisions.

Antennæ with basal half yellow, rest smoky; apical segments not decidedly tapering; last segment short, very little longer than wide; joints of one complete specimen 23.

Post-genæ and gula much as with *transvaalensis*, but gula more elongate and much paler than post-genæ.

Thorax.—Pale yellow-brown with pale red-brown patches in median field of each segment.

Pronotum much like that of *haviglandi*; cephalic margin arched and entire; processes acute.

Mesonotum large, as wide, if not wider, than pronotum and as long; sides diverging with curvate margins; caudal margin broadly and distinctly bilobed.

Metanotum as wide as mesonotum, but shorter; caudal margin three-sided, lateral edges curvate, posterior straight.

Legs yellow; tarsi of I with 2 to 3 spurs, II with 3 to 4, III with 3.

Abdomen.—Golden yellow.

WORKER.

Measurements.—Total length 7 to 8 mm.; head-widths 1·8 to 3 mm.

The salient features agree with those of the workers of *pretoriensis* but without V mark or spot on frons. The size of the workers is consistently small and presents the smallest range of measurements for our *Hodotermes*.

Hab.—Transvaal; Pretoria district.

This species is erected upon a good series of workers, but unfortunately only one soldier has been found; it is, however, sufficiently characteristic, especially as regards the alignment of the mandibles, to warrant this description. The opportunity of investigating its habits has not yet presented itself, but it may be stated that numerous workers and callows were found in small mole-hill-like deposits of earth particles.

Hodotermes viator (*Latrielle*). Pl. XXXIV, figs. 8, 8a ;
Pl. XXXV, fig. 8.

Termes viator *Latrielle*, Hist. Nat. des Crust. et des Ins., xiii, p.
51, 1805.

SOLDIER.

Measurements.—Total length 7 to 13 mm. ; head with mandibles 3 to 6 mm. ; head-width 2·3 to 3 mm.

Head.—The whole dark red-brown, cephalic half very dark in the larger and paler in the smaller soldiers. Surface polished. Dorsal outline **U**-shaped, as broad as long, widest at cephalic edge; **Y**-suture faint or distinct; vertex flatly arched; sides straight, parallel, tapering in lateral to eyes, often asymmetrical, often flatly curvate or incurvate; trochantin of mandible strong and distinct.

Frons deflected and twice depressed; depressions separated by a wide, rounded transverse ridge running between the ocelli; caudal depression shallowing into vertex.

Eyes black, facing forward and outward.

Ocelli white and defined in small soldiers; in large masked by chitin; represented by pale aureolate spots which under a low magnification appear as dark raised points.

Clypeus with anterior margin straight and usually bordered with a pale yellow, somewhat inflated, brace-shaped strap (the epistome).

Labrum bright but opaque, its orange yellow colour in strong contrast to surroundings; large, spatulate and arched; distal edge convex with a broad convex median prolongation quite different from that in the foregoing species of *Hodotermes*.

Mandibles black, except for a small reddish patch at inner bases; this is covered by the lateral lobes of the labrum, both comparatively straight; dentation as with other species, but teeth sharp and more on a median alignment, so that the lower margin forms a cutting edge; lower margin of each tooth on left distinctly lobed; first and second tooth on both attenuated and sharply pointed; basal process of left having

a strong, blunt, conical tooth ; margin below second tooth on left once incised.

Antennæ opaque yellow-brown throughout ; not conspicuously haired ; much like that of *transvaalensis* ; about 26 to 27 joints ; I particularly long, wider at the apex than the base and with concave sides ; II strong, cylindrical, about one-third the length of I ; III very small ; IV (in some) much larger than III and larger than V ; V larger than III, a little shorter and narrower than IV ; VI, VII, VIII equal and the same as VI ; basal joints from III onwards are first annular, then moniliform or globose, then short obconic ; the apical joint is elongate oval and the three preceding it elongate obconic. (This pattern is also present in some of the smallest soldiers, but occasionally joint III is quite large, larger than IV.)

Post-genæ as in *transvaalensis*.

Gula much darker than the post-genæ ; scoop-shaped ; free blade with up-curved, parallel sides and convex median region ; distal apex soft incurvate, normally white ; inserted stem half cylindrical, narrower than the blade ; very short and constricted.

Thorax.—Brownish or reddish-yellow or concolorous with abdomen.

Pronotum narrower than the head, in general resembling that of *transvaalensis* ; cephalic margin acutely elevated (45°), almost semicircular, entire ; sides upbent, margins curvate and tapering behind, hind margin broadly incurvate ; lateral processes somewhat deflected, projecting outwards from bases of cephalic arch at right angles to median line of body ; front margin straight, hind margin curvate, curve continuous with that of sides.

Mesonotum narrower than pronotum ; almost oblong ; caudal margin almost straight, but slightly concave at middle ; sides bent, curving inwards in front, outer edges straight and parallel, behind bent inwards at an obtuse angle.

Metanotum narrower than mesonotum, caudal margin straight.

Legs concolorous with abdomen; last joint always longer than the remaining three taken together. Tibia of I with 3, II with 4, and III with 2 spurs. For a series this 3, 4, 3 feature is fairly constant.

Abdomen.—A bright golden yellow and always in sharp contrast with head.

WORKER.

Measurements.—Total length 6 to 8.5 mm.; head-width 1.6 to 3 mm.

Head.—Reddish-yellow or chestnut-red; when pale, colour uniform, Y-suture paler, eyes black and in strong contrast, aerolate yellow patches at ocelli; when dark, colour uniform but Y-suture not pale, ocelli areas pale, clypeus pale. Surface highly polished. Dorsal outline broadly U-shaped; cephalic extremity broadened; sides nearly straight and parallel, bent in sharply to trochantin of mandible; vertex rather roundly arched.

Frons twice depressed; caudal depression very shallow; cephalic depression merging into clypeus and with a median elevation; cephalic and caudal depressions separated by a low transverse ridge.

Eyes dark chestnut brown, sub-reniform.

Ocelli obsolete, represented by pale spots.

Clypeus differentiated from frons by a transverse furrow; cephalic margin straight and elevated, forming with the epistome a transverse ridge; epistome translucent, cephalic margin narrow, faintly curvate, sides oblique.

Labrum a bright orange-yellow.

Antennæ pale yellow throughout; joints annular to half the length, then broad and short, then elongate. Apical portion tapering very faintly.

Thorax.—Concolorous with abdomen; cephalic margin of pronotum arched, acutely curvate and entire; processes deeply incised at junction with arch of cephalic margin; caudal margin widely bilobed.

Mesonotum long and broad; caudal margin broader than

pronotum; sides straight, diverging outwards; caudal margin faintly bilobed.

Metanotum nearly as long as mesonotum and wider; sides similar; caudal margin flatly curved.

Legs uniformly concolorous with abdomen.

Abdomen.—Bright red-gold; somewhat wide towards extremity; not banded.

Hab.—Cape Colony; Stellenbosch, Elseuberg, Victoria East.

This is a well-known and destructive insect in the older settled regions of the Cape, and is that to which the term "hout-kapper" was first applied. It is strikingly different from any of the other species mentioned in this paper, but much like *aurivellii*, another distinct species, a description of which is deferred.

CALOTERMES.

Calotermes durbanensis *Haviland*. Pl. XXXIV, fig. 9.

Calotermes durbanensis *Haviland*, Journ. Linn. Soc. Lond., xxvi, p. 377, 1898.

SOLDIER.

Measurements.—Total length 7 to 10 mm.; head with mandibles 3·5 to 3·7 mm.; head-width 1·5 to 1·7 mm.

Head.—Vertex dark brown, clypeus black, labrum reddish. Surface polished, cylindrical. Viewed dorsally, elongate, sub-oblong; sides straight and parallel; vertex with a distinct shallow median depression which extends backward from the frons over half the length of the head; Y-suture absent; occipital region not indented; trochantin of mandible projecting conspicuously.

Frons precipitous, depressed, wrinkled; cephalic margin straight; parted from the clypeus by a transverse ridge which generally presents paired median points.

Eyes almost obsolete, pale. Ocelli absent.

Clypeus pale, sub-oblong, with a straight cephalic margin and oblique sides.

Labrum short, almost circular.

Mandibles black, faintly tinged with mahogany-red, bases reddish; straight, comparatively slender, right the stouter, both equally long, with incurved points and with very conspicuous, short, caudo-lateral shoulders. Left mandible with two teeth upon distal half and two proximal to these, the pairs being separated by an acute incision; below the lower pair an acute basal process; the distal tooth is lobe-like and constricted at its base, the second formed like a cleaver, with a bicurvate blade, the third convex, the fourth blunt, conical and more salient than any; fourth separated from the third by a shallow concave incision; margin below fourth incurvate and deeply incised distal to the process. Right with two teeth on proximal half; below the second tooth a sharp incision, the base then broadening; the distal tooth is cleaver-shaped with a blunt conical apex and bi-curvate blade; the second cleaver-shaped and with both margins bi-curvate.

Antennæ 12 to 13 joints; arising from below a conspicuous hood; short; IV and onwards moniliform; characterised by the long highly chitinised clavate joint III and the erratic fusion of more distal joints; II a little longer than wide; III twice the length of II and clavate; apical joint oval.

Gula with free apex very much broader and shorter than inserted portion, with a rounded apex and tri-curvate, sub-parallel sides. Inserted portion elongate narrow; caudal extremity narrow; sides at first parallel and then diverging outward; not constricted as in *Hodotermes*.

Thorax.—Sordid yellow-brown; much arched, with margins of pro-, meso-, and metanotum much deflected and introse.

Pronotum large; broader than head; cephalic margin incurvate with a very faint median notch; sides curvate, caudal margin broadly curvate; with paired elongate pyriform dark brown spots in cephalo-lateral corners, which are connected by a wavy transverse furrow immediately posterior to cephalic margin.

Meso- and metanotum much narrower than, and about half the length of, the pronotum.

Legs pale and dark brown; short and stout; more or less highly chitinised; femur broad.

Abdomen.—Sordid yellow-brown; concolorous with thorax.

Hab.—Natal; Durban, Bellair, Winklespruit.

The species here discussed agrees with the Haviland material, and some specimens were obtained from the same source. If *durbanensis* is synonymous with *C. madagascarensis* *Wasm.*, as stated (2 and 4), the description of the mandibles of the latter is as incomplete as was Haviland's description of those of *durbanensis*.

RHINOTERMES.

Rhinotermes putorius (*Sjöstedt*). Pl. XXXIV, fig. 10.

Termes putorius *Sjöstedt*, Ent. Tidskr., xvii, p. 298, 1896.

MAJOR SOLDIER.

Measurements.—Total length 7·5 to 8·5 mm.; head with mandibles 2·5 mm.; head-width 2 mm.

Head.—Reddish or golden red; bases of frontal folds chocolate brown. Dorsal outline short-ovate, somewhat cordate; sides tapering and constricted lateral to antennal fossæ; Y-suture absent; frontal folds clearly expressed in the form of a V with curved sides; vertex faintly wrinkled; area of front indicated by several strong wrinkles which run parallel with suture and are V-shaped.

Eyes minute and pale. Ocelli and fontanelle obsolete.

Clypeus with cephalic margin straight with a thin plate (epistome); sides diverging to margin of head; limited caudally by the two frontal margins of the frons, which converge to a large white foramen; the foramen seems to be placed in the clypeo-frontal suture and lies in the fork of the frontal folds, well in the middle of the anterior region of the

head; from the foramen a distinct, grooved ridge slopes down to the cephalic margin.

Labrum short and broad, distinctly divided into two convex regions by a median groove, which forms a continuation of the clypeus groove and permits any secretion from the clypeo-frontal foramen to flow to the apex of the labrum; cephalic margin of chitinised portion distinctly bilobed, and with a distal plate-like extension whose curvate margin is fimbriate; on the disc behind the fringe are several (six to eight) stout, spine-like bristles; sides bicurvate, at first diverging then converging.

Mandibles deep red-brown in sharp contrast with head colour; short and stout with long incurved apical points; left with two acute teeth; right with one; neither with a basal process; incisions above teeth very acute.

Antennæ with I stout and cylindrical; II cylindrical, shorter than I; III elongate, sub-obconic, much narrower at base and longer than II; IV and onwards moniliform; IV large and broader than III and longer and broader than V; V-XVI sub-equal; XVII not longer than XVI, tapering a little, and roundly truncate, XV to XVI-jointed; IV and V fused in XV-jointed.

Gula with free apex short; distal margin incurvate; nearly straight; sides diverging and incurvate. Inserted stem narrow, long, sides slightly incurvate; concolorous with ventral genæ, with dark stripes in lateral sutures.

Thorax.—Concolorous with head; polished.

Pronotum broadly sub-oval; median region convex; cephalic margin broadly curvate; sides tapering and merging into caudal margin which is faintly bilobed.

Mesonotum large; sides broadly curvate, diverging widely; caudo-lateral corners rounded; caudal margin as wide or faintly wider than pronotum, curvate and faintly bilobed.

Metanotum with oblique, slightly curvate sides; caudal margin not as wide as that of pronotum, curvate, nearly straight; caudo-lateral corners rounded, but more acute than those of mesonotum.

Legs pale yellow.

Abdomen.—Concolorous with thorax; styli and cerci prominent.

MINOR SOLDIER.

Measurements.—Total length 4 to 5 mm.; head and mandibles 1·5 mm.; head-width 1 mm.

Resembling major soldier, but having a more elongate subpyriform head and proportionately longer jaws and labrum. The labrum tapers from its base to apex, and the sides are bicurvate, curvate at the base and incurvate towards the apex, so forming with the cephalic margin small lobed corners.

Antennæ short, 15 or 16 joints.

WORKER.

Measurements.—Total length 4·5 mm.; head-width 1·2 to 1·5 mm.

Head.—Pallid, yellow; smooth; Y-suture distinct with triangular splash of white in fork; two small pennant strips extending caudad from arms of suture at half their length; at lateral extremities, behind antennal fossæ, large blotches of white; cephalic part of frons with two square patches of yellow just lateral to median line, lateral to these and medial to frontal carinæ two irregular yellow patches; frontal carinæ with fine brown lines which merge into two concolorous spots at superior attachments of mandibles; clypeus, epistome and labrum concolorous with head; mandibles yellowish with white spots; teeth of mandibles dark brown.

Antennæ pallid, moniliform, XVI or XVII-jointed.

Hab.—Natal; Durban.

This is the insect which Haviland noted in the Botanic Gardens, Durban, and hesitated to describe in the absence of imagos.

TERMES.

A study of a long series of soldiers and workers from separate nest-series and different localities seems to indicate that the various insects known as *Termes monodon* Gerstaecker (1891), *badius Haviland* (1898), *terricola Sjöstedt* (1904) and *transvaalensis Sjöstedt* (1904) are all one and the same insect; if so, the last three fall as synonyms to *monodon*. The reasons for this supposition are as follows :

(a) The soldier of *T. monodon* is said to differ from *badius* (1) in being larger (*monodon*, total length 7 to 11 mm., head with mandibles 4 to 5.2 mm.; *badius*, total length 7 to 10 mm., head with mandibles 4 to 4.5 mm.); (2) in that the eyespots appear to be sometimes absent; (3) in the presence of a rounded median (?) keel upon the frons. But (1) in a nest-series of *badius* before me the full length range of spirit material is 9 to 12 mm., with head and mandibles measuring 4.5 to 5 mm., (2) when killed in spirit many soldiers of *badius* have the muscles of the head densely stained by the red-staining fluid they eject when attacked and then the eyespots are always seemingly absent; (3) *badius* presents a low-rounded transverse keel, and in certain lights and on certain insects even a low median keel can be detected; (4) I have before me workers of *T. badius* which have been determined through Dr. Sjöstedt as those of *T. monodon*.

(b) The description of *T. terricola* is the best given in the monograph for the series under review, and, as far as it goes, it applies wholly to *badius*. It is said to differ (1) in point of size, and (2) in certain impressions or markings on the frons. But (1) it is well within the *badius* range, and (2) these markings (more or less obsolete ocelli) are always present and, with the minute fontanelle, are quite distinct features in any cleared preparations of the heads of *T. badius*.

(c) The soldier of *T. transvaalensis* is said to differ from *badius* (1) in being smaller and (2) in having XVI-jointed antennæ. But (1) the size of *transvaalensis* comes within the *badius* range; (2) I have nest-series of *badius* from Natal, the soldiers of which are less (7 to 8 mm.) than the *transvaalensis* range, but unmistakably *badius*; in another nest collection of *badius* from Pretoria this range is, total length 7 to 11 mm., head with mandibles 3.6 to 4.9 mm.; (3) the autotype material shows both XVII and XVI-jointed antennæ (in one instance a soldier having the typical XVII-jointed antennæ on the left and a pseudo XVI-jointed on the right); further, the XVI-jointed antennæ are all obviously due to the non-separation of joints III and IV; in a field collection made in Pretoria the several soldiers present have perfect XVI-jointed antennæ and conform in size to that given for *transvaalensis*, but some show the pseudo-articulation and moreover the workers display the several antennal patterns of *badius* and agree in all other features; further, in a nest collection from the same locality, soldiers possessing XVI, XVII, and pseudo XVI-jointed antennæ are present whilst the worker characters conform to those of *badius*; (4) the *transvaalensis* autotypes have the same peculiar inverted rose-thorn-like tooth near the base of the right mandible; (5) the imagos of *T. badius* conform in every particular with the description of the imagos of *T. transvaalensis*.

Apart from Haviland's material of *badius* and Sjöstedt's autotypes of *transvaalensis*, the series examined comprises twenty-two collections of soldiers and workers; of these ten were obtained from separate nests and four are field collections from in and around Pretoria; five are field collections and one a nest collection from various other points in the Transvaal; one is a field collection from the Orange Free State, another from Pietermaritzburg, Natal. With few exceptions the collections comprise a long series of soldiers and workers; in five, kings and queens are represented. There are also three nest collections and two field collections

of winged adults made in Pretoria, and one nest collection from Alberton, Transvaal.

With regard to *T. natalensis Haviland*, it is necessary to point out that the Haviland material¹ contains major (and minor) soldiers of several forms. One series (a) possessing large and thick heads and flattened frons, and of which certain members of a nest-series display a very aberrant meso-thorax; another (b) having a rather flattened frons, the sides of the meso-thorax rounded and the heads large and thick,² and (c) a third series in which the frons is deeply impressed and grooved. The prevalent South African form is *T. natalensis Haviland*, and it seems to be *T. bellicosus Smeathman*; but, being unable to decide this point, I have grouped, for the present purpose, the whole collection of nest-series studied as *T. natalensis Hav.*

I have relied upon the constant features of the mandibles and the antennæ of the Haviland material.

I have come to the conclusion that the aberrant forms which happen to predominate in the portion of Haviland's material before me represent a locality variation. The prevailing form, in my collection, comes from the coast, from the thorn country at Kimberley, and from the thorn country of the tablelands of the Transvaal. The several nest-series from the midlands of Natal illustrate both the typical and aberrant forms of *T. natalensis*. The latter form is at once recognisable by the presence of certain soldiers (major or minor, or both), of which the meso-thorax presents caudo-lateral lobes, and the sides, instead of being rounded, are oblique and divergent. That Haviland regarded this as only an aberration is obvious from the fact that he does not mention it in his description. As to whether *natalensis* is synonymous

¹ The Haviland material in the Natal Museum comprises a number of insects from different nest-series collected and labelled by Haviland himself; some of those before me were actually measured by him and, no doubt, for the purpose of his original description.

² Like the types, as far as one can judge from Professor Sjöstedt's discussion.

with *bellicosus*, or whether under the circumstances one can select a portion of the Haviland series as a variety, I am not in a position to say; but it can be said that the differences cited for the two species in the Monograph (2) are not of specific value.

Some particulars regarding my examinations of *T. natalensis* may not be out of place here.

Forty series examined composed as follows:

Fourteen nest collections represented by soldiers, workers, and imagos (kings and queens). From Natal, three (Mount Edgecombe, Bellair, Winterton). From the Transvaal, eleven (Pretoria, Pietersburg, Barberton).

Seven nest collections represented by soldiers and workers only. From Natal, four (Pietermaritzburg, New Hanover, Weenen). From the Transvaal, three (Pretoria, Tzaneen).

Twelve nest collections represented by two or more soldiers from each (Haviland material from the district of Estcourt, Natal).

Seven field collections represented by soldiers and workers. From Natal, two (Bellair, Pietermaritzburg). From the Transvaal, five (Pretoria and district).

An examination of the series of major soldiers before me brings out one or two peculiar features. The first is that, as regards colour, markings, and general appearance, the longer material has been in alcohol the more do the specimens harmonise. Thus whilst Haviland's insects, which have been in spirit since 1898, are all agreeably alike; colour notes, made from certain material, when freshly preserved twelve months ago, do not wholly apply at the present moment. Again, many colour markings and features are more readily seen upon submerged specimens than dry ones. On the other hand certain other features may be obscured, more particularly the sculpturing of the frons. The appearance of the insects is changed in alcohol as regards shape as well as colour; the whole insect becomes clarified, and the inflation of the abdomen, so marked in living material, disappears, probably by the slow dissolving of certain body-contents and the escape of gases and air.

A study of both major and minor soldiers shows that the length of the insect has but little relation to the length of the head.

With regard to the total length of major and minor soldiers, the major soldiers in my collection have a range of from 13 to 18 mm. and the minors of from 8 to 12 mm. A purely miscellaneous series of measurements of 155 major and 63 minor soldiers gives the following analysis:

Major soldiers.		Minor soldiers.	
Total length.	Number.	Total length.	Number.
Mm.		Mm.	
18.4 - 18.0	1	11.9 - 11.5	1
17.9 - 17.5	0	11.4 - 11.0	4
17.4 - 17.0	5	10.9 - 10.5	4
16.9 - 16.5	6	10.4 - 10.0	12
16.4 - 16.0	32	9.9 - 9.5	13
15.9 - 15.5	14	9.4 - 9.0	23
15.4 - 15.0	51	8.9 - 8.5	3
14.9 - 14.5	12	8.4 - 8.0	3
14.4 - 14.0	23		
13.9 - 13.5	7		
13.4 - 13.0	4		
Total . .	155	Total . .	63

The following tables, showing the range of variation, are based upon the measurements of 10 major soldiers and 10 minor soldiers, or 100 insects in all, from five widely separated nests in regions having very different climatic conditions (comprising at least four of the floral regions proposed by the late Dr. Bolus).

No. 1 nest: Mount Edgecombe, Natal, at an elevation of 201 ft. and in coast bush country.

No. 2 nest: Winterton, Natal, elevation 3354 ft., in grass veld.

No. 3 nest: Pretoria, Transvaal, elevation 4471 ft., located below a house.

No. 4 nest: Barberton, Transvaal, elevation 2877 ft., in middle veld bush country.

No. 5 nest: Kimberley, Griqualand West, elevation 4012 ft. arid Karroo veld.

Major soldiers.					
Nest.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Mm.	Mm.	Mm.	Mm.	Mm.
Total length	14 to 16	14 to 15	14·2 to 17·5	14·2 to 16	14·5 to 15·2
Head with mandibles	6·5 to 8	7·5 to 8	7·2 to 8	7 to 8	7 to 8·4
Head-width	3·8 to 4·2	4·2 to 4·5	4 to 4·5	4 to 4·5	4 to 4·8
Minor soldiers.					
Total length	8 to 9·7	8·2 to 10	9 to 12	9 to 10	9 to 10
Head with mandibles	4 to 4·5	4 to 5	4·7 to 5	4·2 to 5	4·2 to 5
Head-width	2·1 to 2·5	2 to 2·5	2·5 to 3	2·1 to 2·7	2·2 to 2·5

Of the major soldiers enumerated in the first table the length of the head with the mandibles was taken from 97 individuals, and it showed a range of from 6·5 to 8 mm. Of the whole, only 3 measured less than 7 mm., 32 measured between 7·0–7·4 mm., 38 between 7·5–7·9 mm. and 25 measured 8·0–8·4 mm.

In these cases it was found that the ratio of the length of the head with the mandibles to the length of the thorax + abdomen varied widely. The distribution of these ratios is given in the accompanying table:

$\frac{\text{Head + mandibles}}{\text{Thorax + abdomen}} \times 100$	133	125	114	111	107	100	98	94	90	87	82	79	68
No.	1	1	19	1	4	24	6	2	3	14	19	1	2

The curvature of the head varies within certain limits sufficiently to give that organ quite different appearances; this occurs in the case of both major and minor soldiers. The dorsal outline is always horse-shoe shaped, but may be attenuated, in which case the length exceeds the width; or it may be more clumsy, in which case the length more nearly approaches the width, and the thickness of the head is increased. In the major soldiers the usual proportion of length to width is 5 to 4, and this may vary to 4 to 4. The shortening of the head adds to its thickness and the alteration of its outline, and the measurements taken appear to indicate that the head of the major soldier tends to reach a certain capacity, and the shortening of one dimension is compensated for by an increase of another dimension.

It should be added that the greatest deviation from the normal, e. g. from the attenuated and more or less flattened head, was found in the case of certain Pietermaritzburg and Weenen material, the soldiers presenting a strikingly angled mesonotum.

Termes swaziæ, *sp. n.* Pl. XXXIV, fig. 11.

MAJOR SOLDIER.

Measurements.—Total length, 20 to 22·2 mm.; head with mandibles, 9 to 9·5 mm.; head-width 5·6 to 6 mm.

Head.—Massive; rich dark chestnut-brown with a long median and dark stripe; generally paler on genæ and ventral genæ; distal margin of clypeus obscurely yellow (the colour of the head of the major soldier in sharp contrast with that of the minor). Vertex broadly arched and somewhat flat; dully polished, with scattered, fairly stout reddish bristles, a prominent group on the frontal area. Dorsal outline somewhat jar-shaped; caudal margin very flatly curvate with rounded corners; sides sub-parallel or tapering and flatly curvate, constricted and incurvate a little posterior to antennal fossæ.

Fontanelle very distinct, black, with a few radiating wrinkles; Y-suture absent.

Frontal area much depressed with a median, elongate, triangular and transversely wrinkled mound; mound with its apex a little anterior to the fontanelle and its base upon the cephalic margin of the clypeus; lateral to this mound are fairly deep converging grooves; lateral to its apex and in the depression paired suppressed mounds.

Eyespots pale and insignificant.

Ocelli represented by a mark which has the appearance of a closed eye.

Clypeus with a cephalic margin (epistome) three-sided, distal margin straight or a little incurvate; distal corners oblique and straight; sides of clypeus incurvate and parallel.

Labrum concolorous with head; sides curvate, tapering, but almost parallel, apex with a large white cordate lingua (epipharyngeal).

Mandibles black throughout; powerful; simple; long and tapering; incurved and upcurved; with tapering bases which penetrate deeply into epicranium. Left broader than right, larger and longer (L. 3.5 mm.; R. 3.2 mm.); distal half of inner margin of left faintly crenulate, proximal half with a large produced piece having two rounded points at either end and the margin between these incurvate; proximal to this a small process. Right with inner margin entire and distinctly elbowed at one-third its length.

Antennæ XVII-jointed; I and II reddish, the rest dark brown; each with a distal ring of pale colour and with yellow-brown bristles; length about 6 mm.; joint I cylindrical, about twice the length of II (8:4), with a whorl of small spines; II ankylosed to I, cylindrical, short, nearly wide as long, with minute almost obsolete spines; III clavate and long, as long as II \times 2.5 (9:4) and longer than I, bristled; IV as long as I, bristled; V to XII about equal and a little shorter than IV (7:6); XIII to XVI tapering and becoming shorter; XVII longer than XVI (6:5); IV to XVI elongate, obconic, about half as wide as long, bristled. XVII elongate, oval; apex convex, truncate; bristled. Joints III and IV of the worker XVIII-jointed antenna fusing to form III of the XVII-jointed.

Gula darker than and about half the width of ventral genæ; sides parallel, incurvate; free apex narrowed, distal margin straight, sides oblique with distinct caudo-lateral lobes.

Ventral genæ exhibit transverse wrinkles on that portion which would be delimited as the post-genæ of *Hodotermes* spp. There is no indication of the suture.

Thorax.—A very dark brown, shields outlined with black.

Pronotum sellate, comparatively short and wide, not as wide as head but nearly so; with cephalic and caudal margins distinctly bilobed, the incisions between lobes rather acute; sides curvate, tapering roundly to hind margin.

Mesonotum as wide as pronotum, about half its length; caudal margin broadly bilobed; sides irregularly rounded, frequently asymmetrical, often angled and edges a little bent up.

Metanotum a little wider and shorter than mesonotum; caudal margin broadly incurvate; sides acutely curvate, diverging and edges a little bent up.

Legs yellow-brown.

Abdomen.—Somewhat polished; with reddish bristles; dorsal sclerites with caudal margins black-brown diffusing to a dark yellowish-brown; ventral sclerites paler.

MINOR SOLDIER.

Measurements.—Total length 12 to 13 mm.; head with mandibles 6 mm.; head-width 3.2 mm.

The minor soldier displays most of the characteristics of the major soldier, but the head is pale-ochraceous in both living and spirit material; the dorsal outline more rounded ovate, and not constricted lateral to antennal fossæ; the fontanelle is equally well expressed but not black; the epistome is pale and larger; the frons not so deeply impressed and with a very faint median carina; the abdomen is dark and banded as in the major but is not so highly chitinised; the mandibles are more incurved and more slender, left 2.7 mm.,

right 2.2 mm.; the left mandible is almost acicular; the antennæ are XVII-jointed, joints III and IV of the worker XVIII-jointed fusing to form III of the XVII-jointed form.

WORKER.

Measurements.—Total length 7 to 11 mm.; head-width 3.1 mm.

There appears to be only one caste, but the workers may be graded into three series upon the lengths of their abdomens.

Head.—Dark brown or dark reddish-brown, with clypeo-frontal suture black, clypeus pale brown, epistome white, labrum-epipharynx yellow-brown. Dorsal outline U-shaped. Vertex flatly arched, median region quite flat; Y-suture almost obsolete with paired elongate ocellus-like spots immediately posterior to suture and towards apices of arms (caudo-mediad of antennal fossæ).

Frons with caudal area flat, with a round pit in fork of Y-suture in which is a bright yellow spot; cephalic area much depressed posterior to clypeus; this depression with a faint median carina and a few transverse wrinkles. (If a submerged specimen is examined, the face of a fox is distinctly presented on the frontal area, the pale spot in the pit in the fork of the suture representing the nose.)

Clypeus transversely elliptical, oval and bombous.

Epistome plate-like, large with distal margin widely rounded and with a large median lobe.

Mandibles diffuse yellow-brown, teeth black.

Antennæ XVIII-jointed; joints II and III sub-equal.

Thorax and abdomen brownish-black.

Hab.—Transvaal; Tzaneen, Barberton.

A nest of this species was examined for the writer at Tzaneen by Messrs. A. O. D. Mogg and W. F. Behrens of the Division of Botany. The king and queen together with fungus-gardens were collected. The ♂ measures 13 mm. in length, and has a head-width of 3 mm.; the female is 100 mm. long, and both are characterised by crimson-brown heads; the

antennæ of both have been shortened to (king) 13, (queen) 13 and 10 joints respectively.

The nest-site was indicated by a bare patch about which were disposed several rough hillocks about 1 ft. high and of 1 to 2 cubic ft. in bulk.

Later a second nest was found and examined for me at Barberton by Mr. Kenneth Munro, of the Division of Entomology. The following note is by Mr. Munro.

"This nest was found in a private garden in town. The surface indications were as follows. There was a cleared oval space some 15 ft. long and 6 ft. wide. This was divided into two raised portions. On the one half was a low flat mound about 2 ft. high, on the other a more conical mound, 3 ft. high, and beside it a smaller subsidiary mound.

"I dug down beside the higher mound and found the nest-cavity 3 ft. down. The mound was very solid, having only two or three galleries one quarter of an inch in diameter which widened to about one inch lower down.

"As soon as I broke into the cavity, large and small soldiers poured out; the smaller in the majority and no workers were to be seen.

"The nest was arranged in layers, with the fungus-gardens like those of *natalensis*. The fungus-gardens were much larger and looser than those of *natalensis*.

"I dug underneath and downward as far as I could, but did not find the queen-cell nor any trace of it. The nest seemed to extend a good way in all directions with a radius of quite 5 ft. around the hole I made.

"In the upper part of this mound I found *T. incertus*.

"The cavity has a very nauseating smell, very much like the aroma of *E. trinervius*; I did not notice this with the *natalensis* nests I exposed.

"This insect is well known to the inhabitants of Barberton and feeds upon any wood or dead timber it can obtain. It is said of it that the workers and soldiers emerge in droves after dark and forage freely on the surface as do *Hodotermes*."

Termes waterbergi, *sp. n.* Pl. XXXIV, fig. 12.

MAJOR SOLDIER.

Measurements.—Total length 15.5 to 18 mm.; head with mandibles 8.5 to 9 mm.; head-width 4.5 to 5 mm.

Head.—Pale reddish-brown, ventral genæ ochraceous, broadly arched; dully polished; with short inconspicuous

scattered hairs. Dorsal outline very evenly horseshoe-shaped; cephalic region much narrowed.

Fontanelle minute (diameter $11\ \mu$), generally in the apex of minute V groove and with a parallel series of short curved wrinkles immediately posterior to it.

Frontal area not deeply depressed; with a medium triangular mound, the base of which may extend to the cephalic margin of the clypeus or may be interrupted at a wrinkle which represents the clypeo-frontal suture; in the apex of this mound, a little anterior to the fontanelle, a black, imperforate, chitinised spot, like an obsolete foramen.

Eye-spots large, oval, pale, vaguely faceted; diameters $170 \times 153\ \mu$; surrounded by concentric wrinkles.

Ocelli quite obsolete.

Clypeus somewhat convex with a pale plate-like extension (the epistome); cephalic margin curvate; sides straight.

Labrum concolorous with head and with a large white cordate lingula.

Mandibles black throughout; large ($3\cdot3$ to $3\cdot4$ mm. long); simple; both incurved and upcurved. Left the more upcurved; straighter and broader than right, proximal third with a produced piece, the distal end of which very short, incurved and pointed; proximal to this a small conical process. Right mandible attenuated; more incurved than left; distinctly elbowed at half its length and presenting a small protuberance on the inner margin a little below the elbow.

Antennæ XVII-, XVIII- or XIX-jointed; the XVIII-jointed antennæ formed by the failure of either III and IV or V and VI to separate. The XVII-jointed through the failure of III-VI to separate. The following is an analysis of 26 antennæ from 13 insects:

- | | | | |
|----|------|----|---|
| 7 | with | 19 | joints. |
| 11 | „ | 19 | „ V and VI fused but showing pseudo-articulation. |
| 1 | „ | 18 | „ III and IV fused but showing pseudo-articulation. |

5 with 18 joints, V and VI fused and showing no pseudo-articulation.

2 ,, 17 ,, III, IV, V, VI fused with a pseudo-articulation between III and IV.

Length ranges of joints, when not fused, of four antennæ :

I 400 μ constant.	VI 250-290 μ .	XI 320-350 μ .	XVI 280-290 μ
II 180-220 μ .	VII 310-340 μ .	XII 310-330 μ .	XVII 270-280 μ
III 260-280 μ .	VIII 330-360 μ .	XIII 310-320 μ .	XVIII 260-270 μ
IV 230-270 μ .	IX 340-360 μ .	XIV 310-320 μ .	XIX 270-280 μ
V 220-250 μ .	X 340-360 μ .	XV 290-300 μ .	

Colour chestnut-red, banded; I stout, cylindrical and the longest, with a few short, stout spines; II stout, cylindrical and the shortest, with a few quite inconspicuous spines; III-XVIII attenuated obconic; III with one whorl of bristles, rest with two; joint XIX oval and comparatively small, as a rule as long as III. In the XIX-jointed antennæ, III is longer than II or IV, V shorter and narrower than IV and much shorter than VI.

Gula a little darker than ventral genæ; lateral sutures brown; less than one-quarter the width of the head; sides parallel, slightly incurvate. Free apex narrowed with distal margin straight and oblique incurved sides.

Ventral genæ with post-genæ represented by pale ochraceous areas.

Thorax.—Diffuse ochraceous-brown, each shield with a black outline; sides of shields somewhat up-bent.

Pronotum sellate, narrower than head; median cephalic margin bilobed and acutely elevated; cephalo-lateral processes rather acutely rounded; sides straight converging; caudal margin broadly bilobed; caudo-lateral corners broadly rounded.

Mesonotum not quite as wide as pronotum; sides angled, at first curvate and diverging, then converging and straight or faintly incurvate and merging broadly into caudal margin; caudal margin incurvate, nearly straight.

Metanotum shorter and wider than mesonotum; sides

extended, curvate; sharply angled at caudo-lateral corners; caudal margin straight or faintly incurvate.

Abdomen.—Polished, diffuse ochraceous-brown.

Legs ochraceous.

MINOR SOLDIER.

Measurements.—Total length 8 to 9 mm.; head with mandibles 4 to 4.5 mm.; head-width 2.3 mm.

Compared to major soldier very small; head ochraceous; mandibles slender, 2 mm. long; antennæ XVII-jointed; agreeing in other features.

MAJOR WORKER.

Measurements.—Total length 8 to 9 mm.; head-width 2.7 mm.

Head.—Reddish-ochraceous, rather pale with a white spot in fork of Y-suture and paired ocellus-like spots on caudal side of arms of suture as in *T. swaziæ*; mandible reddish; abdomen a dark sordid brown.

This worker is characterised by its distinct, convex, pale yellow eye-spots and the peculiar pattern of the antennæ.

Antennæ XIX-jointed; joint VI broader than V or VII and very conspicuous; II elongate, cylindrical, constricted at half its length and swollen at apex; joints III and VI are both striking; III is elongate cylindrical, constricted at half its length and swollen at its apex, it is either nude or with short spines; VI is obconic and very broad, much broader than any joint other than I; V is a narrow joint compared to IV and VI.

I the longest (260 μ) broad cylindrical with a whorl of short spines.

II cylindrical, with a whorl of bristles a little shorter than I (200 μ). III (as above) as long as II.

IV short obconic, broad, somewhat globose; as broad as II or broader, not as broad as VI, nearly half the length of III (120 μ).

V conspicuously narrow, longer than IV and shorter than VI (150 μ).

VI as above and of the same length as II, III and VII (200 μ).

VII–XIV elongate, sub-obconic ; about equally wide.

VIII–XIV sub-equal (250 μ).

XV–XIX shortening faintly and tapering slightly.

XIX elongate oval.

MINOR WORKER.

Measurements.—Total length 7 mm. ; head-width 1.7 mm.

Head.—Pallid yellow and body generally paler than that of major.

Antennæ XVII-jointed ; joints I, II, III as with major worker ; IV a long joint constricted at half its length with two whorls of bristles and a well-defined pseudo-articulation, into this joint is compressed the characteristic IV and VII series of the XIX-jointed major worker antennæ.

Hab.—Transvaal ; Warmbaths (district of the Waterberg), De Wildt (district of the Magaliesberg).

In the material from Warmbaths, collected in October, 1913, are several large and obese white nymphs measuring 20 mm. long, also one imago. The imago is somewhat like that of *T. natalensis* but longer, the measurements are a little below those of *T. goliath* *Sjöst.* Total length of body 20 mm. ; head-width 4.5 mm. ; ocelli with a diameter of 40 μ ; length of insect and wings, wings folded, 42 mm. ; fore-wing 36.5 mm. long and 9 mm. wide ; hind wing 34 mm. long and 9.5 mm. wide.

Termes natalensis *Haviland.* Pl. XXXIV, fig. 13 ;

Pl. XXXIII, fig. 3.

Termes natalensis *Hav.*, Journ. Linn. Soc. Lond., xxvi, 1898.

? *Termes bellicosus* *Smeathman*, Phil. Trans. Lond., vol. 71, 1781.

MAJOR SOLDIER.

Measurements.—Total length 13 to 18 mm. ; head with mandibles 6.5 to 8 mm. ; head-length without mandibles 4.5 to 6 mm. ; head-width 3 to 5 mm.

Head.—Above pale yellow, or pale reddish-yellow, or pale reddish-brown; cephalic extremity always the darker, paler beneath except gula. Vertex with three parallel brown stripes below chitin, one median and two sub-median; median stripe often shortly bifurcate at fontanelle and sometimes extending over occiput to occipital foramen; submedian stripes sometimes confluent in frontal area from which they diverge and running parallel to the median stripe pass over occipital region and traverse the middle line of each ventral gena (indicating the obsolete demarcation of the post-genæ from the genæ); all three stripes strongly or faintly indicated, or only partly indicated; the median frequently faint and often abbreviated, only extending from fontanelle towards occipital region; submedian stripes frequently abbreviated and then only expressed upon occipital region; submedian stripes infrequently branched, forming a veined pattern and then upon both dorsal and ventral surfaces.

Elongate and somewhat flattened; surface smooth, polished, with scattered hairs, dorsal outline horseshoe-shaped, broadest in caudal region; caudal margin broadly curvate; cephalic width a little more than half greatest width (but variable); sometimes faintly compressed at the level of the antennal fossæ.

The range of the measurements made on ten insects from three nests is given in the following table:

Dimensions.	Nest 1.	Nest 2.	Nest 3.
Greatest widths.	4 to 4.4 mm.	4.3 to 4.5 mm.	4 to 4.4 mm.
Cephalic widths.	2.3 to 2.8 mm.	2.4 to 2.8 mm.	2.8 to 3 mm.

Fontanelle always present, often black, often indistinct.

Frontal area depressed and sloping, features kaleidoscopic. Depression bordered by frontal grooves, these grooves originate at the caudo-lateral corners of the clypeus, they converge shortly and then diverge and shallow-out at the level of the antennal fossæ (or recurve and embrace paired, low,

oval mounds which lie lateral to the caudal apex of a raised median area of the frontal area). Median area of depression generally more or less elevated; elevation more or less triangular with its apex a little anterior to the fontanelle and its base demarcating the caudal extremity of the clypeus; at the base of the triangle, and between the superior articulations of the mandible, there are several transverse wrinkles which represent the obsolete clypeo-frontal suture (triangular median area often suppressed). Frontal carinæ black, chitinous, widely diverging, crenulate; forming the lateral margins of paired, well-defined, diverging ridges; these ridges originate at the superior articulation of the mandibles where they are narrow, mediad of the antennal fossæ they widen and laterad of the fontanelle merge into the vertex; median slopes of ridges falling more or less abruptly into frontal grooves.

Eye-spots inconspicuous, pale. Ocelli absent.

Clypeus oblong, wider than long, slightly arched, sides straight and parallel; cephalic margin with a thin plate (the epistome); faintly curvate or straight with slightly oblique, cephalo-lateral corners.

Labrum elongate, tapering, slightly arched; sides curvate; distal margin of chitinised region more or less incurvate, bearing a white cordate epipharyngeal lingua.

Mandibles black, strong, forcipiform, more or less simple, incurved; apices upbent. Left mandible stouter than right; distal half of cutting margin finely wavy; proximal half produced into a series of irregular processes, one of which is particularly prominent and like the blade of a small scalpel. Right mandible with cutting margin entire; base faintly wavy with two insignificant sub-conical protuberances.

Antennæ XVII-jointed, dark brown-red, ringed. Joint I always the longest, II nearly always the shortest, III always the second longest joint, V always narrower and shorter than IV and VI, generally longer than II. VI-XVI sub-equal, or gradually increasing in length from VI to X and decreasing from XII-XVI; XVII always slightly longer and

narrower than XVI. Joint I cylindrical, with an apical whorl of small bristles; II coarse, sub-clavate, with a whorl of almost obsolete bristles; III elongate clavate, with an intermediate and distal whorl of bristles; IV onwards with one whorl of bristles; V sub-obconic; VI–XVI elongate, sub-obconic; XVII short-oval; apex convex, truncate.

Gula elongate, less than half the width of ventral gena; sides parallel and faintly incurvate. Free apex short, narrowed; distal margin incurvate, sides straight, oblique.

Thorax.—Yellowish or yellowish-red; shields frequently deeply bordered with smoky brown; margins slightly up-bent.

Pronotum sellate, narrower than head, about half as long as wide; median part of cephalic margin more or less elevated and distinctly bilobed, incision notched; cephalo-lateral corners broadly rounded; sides curvate, tapering roundly into caudal margin; caudal margin broadly bilobed.

Mesonotum about half as long as pronotum and slightly narrower; caudal margin nearly straight, broadly incurvate; sides parallel, curvate, or with sides angled variously, or straight, diverging widely and forming with caudal margin distinct caudo-lateral lobes.

Metanotum a little shorter than pronotum and a little wider; sides more or less acutely curvate; caudal margin sinuate.

Legs pale brownish-yellow, generally paler than body.

Abdomen.—Bright yellow and pallid yellowish-brown, flattened or arched.

MINOR SOLDIER.

Measurements.—Total length 8 to 11·5 mm.; head with mandibles 4 to 5 mm.; head-length less mandible 2·4 to 3·3 mm.; head-width 2 to 2·5 mm.

The minor soldier agrees very generally with the major soldier, but the head is usually paler, the frontal area less depressed and the mandibles proportionately more slender.

The antennæ of the minor soldier, presenting the same

number of joints and a similar pattern to those of the major soldier. Joints II and XVII often as long as these joints of the major soldier antenna. Joint III often sub-equal to II, but generally longer. Joint V generally shorter than II.

MAJOR WORKER.

Measurements.—Total length 7 to 9.5 mm. ; head-width 2.1 to 2.6 mm.

Head.—Dark brown or dark red-brown, somewhat marmorate; occipital region and genæ paler, stem of Y-suture pale, with a bright white or bright pale yellow spot in fork of suture; eye-spots pale, translucent yellow; clypeo-frontal suture darkened; clypeus paler than frons with a median brown stripe; epistome white with brown diffuse stripes. Labrum-epipharynx translucent, brown or tinged with green.

Mandibles at base pale yellow-brown merging through diffuse brown to the black teeth.

Dorsal outline U-shaped; vertex polished. Frons with a small circular pit in fork of Y-suture and with an oblong transverse depression posterior to clypeus. Clypeus elliptical oval; epistome with distal edge brace-shaped.

Antennæ dark brown to smoky-black, ringed with white; XVII or XVIII-jointed; in XVIII-jointed form III and IV sub-equal and V always larger than VI; in XVII-jointed form III is longer than IV and V smaller than VI.

Thorax.—Sordid, yellow-brown. Pronotum narrower than head; quartered by a median and a transverse pale line. Mesonotum half the length of pronotum and narrower. Metanotum wider than mesonotum, but not longer.

Legs pallid; apex of tibia and claws pale red-brown.

Abdomen.—White, transparent contents visible.

MINOR WORKER.

Measurements.—Total length, 5 to 6 mm. ; head-width, 1.5 mm.

Like major worker but paler; with ocellus-like, pale, oval spots near cephalo-lateral extremities of arms of Y-suture.

Antennæ 17 joints; dark brown ringed with white. III and V smaller than IV.

Hab.—Natal; Bellair, Mt. Edgecombe, Pietermaritzburg, New Hanover, Weenen, Estcourt, Winterton. Transvaal; Pretoria, Barberton, Tzaneen. Cape; Kimberley.

The imago is not being here described, but as a point of interest it may be mentioned that in examining the kings it was found that in nearly every case the antennæ had been reduced to XIII joints and never more than XIV were present.

Termes badius Haviland. Pl. XXXIV, fig. 14;
Pl. XXXIII, figs. 1, 2.

? *Termes monodon Gerstücker*, Jahrb. Hamb. Wiss. Anst., ix, p. 185, 1891.

Termes badius Hav., Journ. Linn. Soc. Lond., xxvi, p. 385, 1898.

SOLDIER SERIES.

Measurements.—Total length 7 to 12 mm.; head with mandibles 3·5 to 4·5 mm. Soldiers of one caste only but in three or four grades.

Head.—Pale, translucent, honey- or reddish-yellow, darker towards mandibles; (spirit material often yellow-brown, or reddish-brown or intense black-brown); without stripes showing through chitin (or with 4 or 5 short dark lines extending over occipital region, 1 median, 4 sub-median, median frequently absent); smooth; shining; somewhat thick; broad-ovate; sides curvate, tapering to mandibles, also tapering a little towards and merging into caudal margin; broadest at about three-quarters the full length of the epicranium.

Fontanelle indicated by a minute dot, or apparently absent; actually always present and always perforate.

Frontal area faintly impressed, sloping a little and then precipitous to cephalic margin of clypeus; divided into two regions which are separated by a low more or less arched transverse ridge; appearance otherwise variable and elusive,

varying with illumination, sometimes appearing as with a median keel. Frontal carinae not strongly elevated.

Eye-spots very distinct in living insects (distinct in pale spirit specimens); white or pale yellow with a black centre in the form of a tear-drop; paleness of colour due to thinness of chitin; pigmentation apparently upon muscular tissue.

Clypeus very short, precipitous, with pale, nearly straight margin (epistome), overhanging labrum like a pent-house, with several projecting bristles.

Labrum deflected, triangular, acute; covering one-third the length of the mandibles; apex thin and without a lingula, with three superior groups of large bristles, a distal group of six and two sub-marginal rows of four each.

Mandibles black over greater part, bases red or reddish-yellow; strong; about equal; elevated, but not up-bent; apices incurved; each with a strong salient tooth intermediate between base and apex, tooth on the left being a little more distal, larger, and more acute than that on the right; the distal half of the cutting margin of each minutely and bluntly serrulate. Left mandible with a sinuate, produced cutting-margin or blade below tooth, and below that a large conical basal protuberance. Right mandible with a minute, very acute, persistent, characteristic, and delicate tooth which resembles a reversed rose-thorn; this tooth is placed intermediate to the large tooth and the base.

Antennae pale reddish-brown, distal half darker; 2.5 mm. long; XVII-jointed (normal) or pseudo XVI-jointed and (rarely) with sixteen entire articles. When XVII-jointed, I is the longest and XVII nearly as long; III and V are short joints placed between the longer joints II, IV, and VI; III is slightly shorter and narrower than V; IV is always shorter than either II or VI, but it is wider than III or V; VI, and often VII, about equal to II; VIII-XVI sub-equal. Joint I cylindrical, robust; II stout, wider than long, narrower than I; III-VI annular, sub-globose; VII-XVI globose, sub-obconic; XVII fusiform or elongate-oval. Joints III-XVII with conspicuous apical whorls of bristles; I and II with incon-

spicuous almost obsolete whorls. When pseudo XVI-jointed, joints III and IV fused, with a pseudo-articulation. When XVI-jointed, joints III and IV of XVII form completely fused.

Gula much darker than ventral genæ; broad, elongate, wider than ventral genæ; sides parallel, curvate, faintly sinuate. Free apex short, narrowed, distal margin straight, sides diverging and incurvate; usually with a wide, shallow concave depression immediately posterior to the distal margin.

Thorax.—Tinged with yellow, semi-transparent; pronotum paler than head but more coloured than the meso- and metanotum; meso- and metanotum concolorous with abdomen.

Pronotum sellate; cephalic margin bilobed, somewhat convex and prolonged over head; cephalo-lateral corners broadly rounded; sides tapering, faintly incurved, merging roundly into the incurvate caudal margin, with a distinct incurvate transverse furrow debouching into two depressions; in each depression a low rounded mound; posterior to furrow are paired, convex humps.

Mesonotum sub-elliptical, more than half the length of pronotum and not as wide; sides parallel, curvate; caudal margin incurvate.

Metanotum sub-elliptical, shorter and wider than mesonotum; sides parallel, curvate; caudal margin straight or flatly incurvate.

Legs pallid.

Abdomen.—Oval, arched, transparent, slightly tinged with yellow; clothed with yellow-brown bristles. Contents of abdomen visible; contents opaque white and black, arranged in a pattern so as to show a black median stripe, which is always interrupted on the fifth dorsal sclerite and always at its fullest expression on the sixth sclerite.

MAJOR WORKER.

Measurements.—Total length 4·5 to 7 mm.; head-width 1·5 to 1·8 mm.

Head.—Pale straw-yellow or pale yellow tinged with brown; Y-suture with a white spot in fork; superior

articulation of mandibles forming two dark spots; lateral edges and teeth of mandible dark brown; cephalo-frontal suture a little darker; eyes distinct, with black centres, as with soldiers.

Antennæ smoky black, ringed with white; 19, 18 or 17 joints; the XVIII-jointed antennæ the most frequently met with, the XIX-jointed appears to be due to the sub-division of III of XVIII, the XVII-jointed to the fusing of III and IV of XVIII. In the XIX-jointed form, III, IV and V are the smallest, V being a little shorter than III or IV. In the XVIII-jointed form IV is the smallest and represents the unaltered V of the XIX-jointed form. In the XVII-jointed form IV is a large joint between two smaller joints. The following approximate measurements (in μ) of the three forms of antennæ from insects of the one nest-series will illustrate the reduction in the number of joints.¹

Joints.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
XIX-jointed .	220	135	60	60	55	85	95	115	125	150
XVIII-jointed .	220	140	95		50	85	95	115	125	150
XVII-jointed .	210	135	90		115		75	105	115	135
Joints—(continued).	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	
XIX-jointed .	150	150	150	150	150	140	140	140	175	} Measurements in μ .
XVIII-jointed .	150	150	150	150	150	140	140	140	175	
XVII-jointed .	150	150	150	150	140	140	130	130	175	

MINOR WORKER.

Measurements.—Total length 3 to 4.5 mm.; head-width 1.1 to 1.3 mm. Very much like the major worker; generally with XVII-jointed antennæ; antennæ simulating the XVII-jointed form of the major worker.

¹ See also introduction to Section V, p. 419.

Hab.—Natal; Pietermaritzburg. Transvaal; Pretoria, Alberton, Krugersdorp, Johannesburg, Pietersburg, Pyramids. Orange Free State; Dealesville.

Termes latericius Haviland. Pl. XXXIV, fig. 15.

Termes latericius Hav., Journ. Linn. Soc. Lond., xxvi, p. 386, 1898.

SOLDIER.

Measurements.—Total length 5 to 6 mm.; head with mandibles 2.5 to 2.6 mm.; head-width 1.4 mm.; mandibles 1 mm.

Head.—Pale reddish-yellow or dark red-brown. Ovate tapering markedly to mandibles, somewhat roundly arched. Fontanelle absent. Frontal area scarcely or not impressed; with an obscured Y-shaped mark indicating the Y-suture. Eye-spots absent.

Clypeus continuous with frons; distal margin (epistome) pale and straight or slightly curvate; sides straight and parallel or slightly diverging.

Labrum elongate-linguiform; with three groups of superior bristles, apical of 8, sub-marginals of 5 to 6.

Mandibles with distal two-thirds black, bases reddish; apical points sharp and incurved; cutting margins remarkably fine, entire and blade-like. Left a little broader than right, with a sharp tooth below an acute incision and placed two-thirds towards the apex; margin below tooth produced as a faintly sinuate, entire blade; at the base a strong, rounded, conical protuberance; directed forwards. Right with an almost obsolete tooth, protuberance salient and opposite to that on the left and a minute, acute, conical salient, tooth, placed a little distal to the base.

Antennæ, with 16 or 17 joints, usually with 16; bases pallid, distal two-thirds smoky; joints globose or sub-obconic, except I and II which are cylindrical. In the XVI-jointed form III is usually proportionately large and IV is the smallest joint; in the XVII-jointed form III is the smallest and

V next. In the XVI-jointed form III frequently shows a pseudo-articulation, and its comparatively large size is due to the fact that it represents III, IV and V in the XVIII-jointed expression found in the worker castes; the proportion of III to IV is not constant because the proliferation of the joint is arrested to varying degrees.

Gula much darker than ventral genæ; very broad, nearly half the breadth of the head; sides straight parallel. Free apex short, narrowed; distal margin straight, sides diverging and faintly incurvate.

Thorax.—Transparent, concolorous with abdomen.

Pronotum sellate; cephalic margin bilobed; sides curvate, tapering roundly into incurvate hind margin; cephalo-lateral corners rounded.

Mesonotum sub-elliptical; shorter and narrower than pronotum; sides curvate, more or less parallel; caudal margin incurvate.

Metanotum shorter and wider than mesonotum; sides curvate, diverging; caudal margin straight or slightly incurvate.

Legs pallid or pale brown-yellow.

MAJOR WORKER.

Measurements.—Total length 5·5 to 7·5 mm.; head-width 1·7 to 1·9 mm.

Head.—Pale red-brown; Y-suture darker, with an insignificant pale spot in fork; clypeus paler than epicranium, with a fine median brown line; epistome pale yellow-brown; clypeo-frontal suture dark; labrum-epipharynx pale brown; eye-spots insignificant.

Antennæ XVII- or XVIII-jointed, more frequently XVII-jointed. In the XVIII-jointed antenna, IV is the smallest joint; in the XVII-jointed, III is the smallest and V next because IV and V of the XVIII-jointed form have failed to separate; this failure is often indicated by pseudo-articulation in IV of the XVII-jointed form.

Legs pallid.

Abdomen.—Transparent.

MINOR WORKER.

Measurements.—Total length 4 to 4·75 mm. ; head-width 1·2 mm.

Similar to major worker, antennæ XVII- or XVIII-jointed.

Hab.—Transvaal ; Pretoria, Barberton. Natal ; Pietermaritzburg, Durban, Scottburgh, Mt. Edgecombe.

Termes vulgaris Haviland. Pl. XXXIV, fig. 16.

Termes vulgaris Hav., Journ. Linn. Soc. Lond., vol. xxvi, p. 387, 1898.

SOLDIER.

Measurements.—Total length 6 to 7 mm. ; head with mandibles 2·5 to 3 mm. ; head-width, 1·5 mm.

Head.—Reddish-yellow ; Y-suture faintly delineated ; vertex with paired but very faint sub-median stripes. Dorsal outline somewhat elongate, broadly oval ; roundly arched ; frontal area sloping and somewhat precipitous at clypeus ; with faint transverse wrinkles. Fontanelle and eye-spots absent.

Clypeus short, insignificant ; cephalic margin pale.

Labrum linguiform, reaching to half the length of the mandibles (more obtuse than that of latericius).

Mandibles yellow-brown to dark chestnut-brown or black, paler at the bases ; apical points sharp, incurved. Left mandible a little broader than the right, with a salient tooth two-thirds towards the apex ; cutting margin above and below tooth with a moniliform edge, the beads being more prominent below the tooth ; at the base a strong, blunt, triangular and salient protuberance. Right mandible with a distinct tooth, more intermediate than that on the left and less pronounced ; the cutting margin above and below the tooth is minutely irregular ; below the tooth towards the base there is a distinct curved excision, the proximal end of the excision

being produced as a small, salient, thorn-like tooth; at the base a rounded, strong protuberance.

Antennæ XVII-jointed or pseudo XVI, usually pseudo XVI-jointed; pale, bases pallid, distal two-thirds reddish. Joints I and II cylindrical, III and IV irregular, always more or less fused, V annular and narrower than IV or VI, VI and VII tending to become obconic, VIII to penultimate, short-obconic and only faintly wider than VI and VII, apical joint elongate oval. Joint I is the longest (160 μ) but only a little longer than the apical joint, II is two-thirds the length of I (100 μ), III when separate or fused to IV (30 μ); IV when separated (40 to 50 μ), when fused always appearing a little longer than III, always wider than III (III and IV when fused 70 to 90 μ). V equal in length to IV (40 to 50 μ) but always narrower; VI and VII sub-equal (60 to 70 μ); VIII longer than VII and shorter than IX (90 μ); IX to penultimate, equal (100 μ); apical joint always half as long again as penultimate and equal to II (150 μ).

On antennal features *T. vulgaris* differs from the closely allied *T. latericius* inasmuch as the worker of the latter has XVIII-jointed antennæ and those of *vulgaris* XVII-jointed.

Gula a shade darker than the ventral genæ and as wide or faintly wider; sides parallel. Free apex short, tapering.

Thorax.—Slightly paler than head. Pronotum sellate. Mesonotum more or less elliptical, sides and caudal margin curvate, narrower than pronotum. Metanotum short and wide, more or less oblong, wider than mesonotum.

Legs very pale yellow.

Abdomen.—Polished; pale yellow (in life the transparent, milky-white contents visible); ovoid.

WORKER.

Measurements.—Total length 4.5 to 5 mm.; head-width 1.5 mm.

Head.—Pale yellow-brown. Y-suture a little paler, with an obscure pale spot in fork; clypeo-frontal suture dark,

almost black; clypeus with a faint median line; superior articulations of the mandibles appearing as dark red-brown spots. Mandibles narrowly outlined and tipped with black. Antennæ pale reddish. Dorsal outline of head sub-circular; front with a shallow impression at fork of Y-suture.

Antennæ XVII-jointed, characterised by the insertion of the broad joint IV between the small III and V, otherwise as with soldier.

Thorax.—Pale yellow. Pronotum with two small dark spots sub-marginal to cephalo-lateral corners.

Legs pale yellow.

Abdomen.—Pallid; translucent.

Hab.—Natal; Mt. Edgecombe, Bellair, Pietermaritzburg. Transvaal; Pretoria.

Termes incertus Hagen, Pl. XXXIV, fig. 17.

Termes incertus Hagen, Bericht d. Königl. Preuss. Akad. d. Wiss., Berlin, p. 481, 1853; *Haviland*, Journ. Linn. Soc., xxvi, p. 388, 1898.

SOLDIER.

Measurements.—Total length 3·6 to 5 mm.; head with mandibles 1·4 to 5 mm.; head-width 0·7 to 0·8 mm.

Head.—Vertex pale brownish-yellow, frontal area with a whitish-yellow sub-quadrate blotch which is usually more or less divided by a darker median line and with its caudal boundary irregularly **W**-shaped, the dark colour of the apical points of the mandibles and the superior articulations in sharp contrast with head. Sub-ovate, tapering to mandibles; somewhat hairy. Frontal area not impressed, somewhat precipitous. Fontanelle absent. Eye-spots absent.

Clypeus broad, front margin incurvate, sides curvate, diverging, more or less lobed.

Labrum linguiform, elongate, almost lanceolate; extending over two-thirds to three-quarters the length of the mandibles; with an apical group of six conspicuous bristles and paired sub-marginal groups of inconspicuous bristles.

Mandibles like calipers; more or less slender with broad bases; apical points up bent and strongly incurved; cutting margins simple, entire or with a faint wire-edge. Left mandible not larger than right, but with a conspicuous basal projection, the distal margin of which is at a right angle to the cutting margin and has a small salient tooth above it.

Antennæ moniliform; pallid, translucent; XIV-jointed, characterised by the narrowness and often incomplete separation of joints III, IV, and V. Joints I and XIV sub-equal (100 to 120 μ); II usually the second longest joint (60 to 70 μ) sometimes nearly as long as III + IV + V, sometimes half or less than half as long as III + IV + V (III + IV + V 70 to 130 μ); VI and VII sub-equal (50 to 60 μ) generally a little shorter than II; VIII–XIII sub-equal (60 to 90 μ) generally longer than VI and VII. (When possible to measure III, IV, V separately: III (20 to 40 μ), IV (20 to 30 μ), V (40 to 50 μ)). Joints I and II cylindrical, II tending to be obconic; III–IX more or less globose; IX–XIII globose sub-conical (moniliform); XIV oval, wider than penultimate; IV the narrowest joint, always the shortest; V–VIII gradually increasing in width.

Gula broad, as wide as ventral genæ. Free apex proportionately long, narrowed, distal margin straight; sides straight and oblique.

Thorax.—Concolorous with abdomen, transparent, with white and brown body-contents visible.

Pronotum sellate. Mesonotum much narrower than pronotum. Metanotum broader than pronotum.

Legs pallid; somewhat compressed; tibia appearing two-segmented and with a patella.

Abdomen.—Haired; cerci with conspicuous bristles.

MAJOR WORKER.

Measurements.—Total length 3.5 to 5 mm.; head-width 1.0 mm.

Head.—Pale yellow-brown; haired; dorsal outline elongate

U-shaped; Y-suture distinct; frontal area whitish yellow with a pale stripe on genæ; clypeo-frontal suture brown; superior articulations of mandibles dark brown; clypeus yellow; labrum-epipharynx yellow or tinged with green; mandibles yellowish.

Antennæ XIV-jointed, moniliform; joints III, IV, V more distinctly separated than in soldiers; apical joint elongate-ovate.

MINOR WORKER.

Measurements.—Total length 3·5 to 4·5 mm.; head-width 0·7 to 0·8 mm.

The minor workers are much like the major workers and have a length-range nearly as great.

Hab.—Natal; Pietermaritzburg, Mt. Edgecombe, Bellair, Winterton, Weenen. Transvaal; Pretoria, Tzaneen, Warmbaths, Barberton.

EUTERMES.

Eutermes parvus (*Haviland*). Pl. XXXIV, fig. 18.

Termes parvus *Hav.*, Journ. Linn. Soc., xxvi, p. 404, 1898.

SOLDIER.

Measurements.—Total length 4 to 5·5 mm.; head with mandibles 2·0 to 2·6 mm.; head-width 0·8 mm.; head less mandibles 1·6 mm.; mandibles 0·5 to 0·6 mm.

Head.—Vertex pale yellow-brown, faintly smoky, outlines dark; frontal area diffuse smoky brown, somewhat maculate. Elongate, cylindrical; apex truncate; sides parallel; caudal margin rounded and convex; surface hairy. Fontanelle absent. Frontal area sloping and then precipitous; cephalic margin between bases of mandibles curvate. Frons convex, distinctly bilobed.

Clypeus produced, tricuspidate, insignificant.

Labrum short ovate, obtuse-linguiform, extending to one-third the length of the mandibles.

Mandibles very long and narrow like shear blades; equal;

somewhat straight; points incurved; taken together much narrower than head; with bases diverging widely to side margins of head; cutting margin very minutely jagged, not toothed or serrulate but resembling the "wire-edge" of a razor; left mandible with a delicate, rounded, salient tooth at base.

Antennæ pallid; almost moniliform; XIII-jointed; characterised by the smallness of III and its incomplete separation from IV. I and II cylindrical; III-VII globose; VIII-XII more or less obconic; XIII elongate-ovate; joints widening from III onwards. XIII the longest joint and I the second longest; VII to XII longer than II; VI sub-equal or shorter than II; IV longer than III and a little more than half the length of II; III half the length of II; III + IV = II.

Gula, free apex short, narrowed; distal margin straight, sides oblique. Inserted region elongate; widest at cephalic end; sides incurvate and tapering almost to occipital foramen, then diverging widely.

Thorax.—Pronotum sellate; meso- and metanotum distinctly bilobed.

Legs pallid; tibia appearing 2-segmented and with a patella.

Abdomen.—Elongate, oval, transparent.

WORKER.

Measurements.—Total length 3.5 to 5 mm.; head-width 0.7 to 1.0 mm.

Head.—Vertex and clypeus yellowish-white. Frons milky-white. Mandibles yellowish-white, finely outlined with dark reddish-brown; superior articulations of mandibles forming two dark brown spots.

Legs transparent; tibia appearing 2-segmented and with a patella.

Abdomen.—Transparent, contents visible.

Hab.—Natal; Durban, Bellair, Scottburgh. Cape Colony; Port Elizabeth.

A closely allied but distinct species, making similar but quite subterranean nests, is common to the Pretoria district, Transvaal.

Eutermes bilobatus (*Haviland*). Pl. XXXIV, fig. 19.

Termes bilobatus *Hav.*, Journ. Linn. Soc., Lond., xxvi, p. 411, 1898.

SOLDIER.

Measurements.—Total length 6·5 to 7·5 mm.; head with mandibles 3 to 3·5 mm.; head-width 1·3 to 1·5 mm.

Head.—Vertex pale, translucent, brownish-yellow; frons paler. Viewed from above short U-shaped, somewhat longer than wide; Y-suture distinct; sides almost parallel; tapering very faintly to mandibles; cephalo-dorsal margin curvate. Viewed from the side the head is seen to be short and thick, the caudal end convex, the frontal area swollen and capistrate; below the capistrum the cephalic face is hollowed; a little beneath the hood is a thick group of short spines which surround the aperture of a gland. Eye-spots and ocelli absent.

Clypeus short.

Labrum (so-called) pallid; strongly forked; stem of fork flattened; arms pointed somewhat acutely, sloping upwards; extending to nearly half the length of the mandibles. The true labrum is probably atrophied, represented by a thin plate superior to a forked, chitinised epipharynx.

Mandibles long, flat, equal, straight, slender, tapering, points slightly incurved; lateral margins not widening greatly at base; inner margins boldly shouldered at base; cutting margins minutely serratulate. Left mandible with a blade-like jagged process on proximal third, which is broadest towards its base; basal process large, salient, conical; distal margin of basal process at right angles to cutting margin and lower margin parallel with long axis of mandible. Right mandible with an acute process like a reversed rose thorn on proximal third; base like that of left but without process.

Antennæ pallid, slightly suffused with red; 15 joints, or with joints III and IV fused, 14 joints. Joint I longest (200 μ); II half as long as I (100 μ); III, IV, V smallest and about equal (50 μ); VI-IX increasing in length; VI (80 μ); VII (100 μ); VIII (110 μ); IX (140 μ); IX-XI about equal (140 μ); XII-XIV a little shorter (130 μ); XV longer than XIV (150 μ). Joint III narrowest; IV-VII increasing in width; VII-XIV equally wide. Joints III, IV, V sub-annular; VI-XIV elongate obconic; XV elongate oval.

Gula slightly darker than ventral genæ; sutures brown; elongate; sides sinuate; widest towards apex; constricted towards foramen. Free apex very short; distal margin straight; sides oblique, continuous with sides of inserted portion.

Thorax.—White, semi-transparent. Pronotum sellate, short, narrow, anterior part elevated. Mesonotum a little shorter and wider than pronotum; sides diverging; caudal margin broadly curvate. Metanotum shorter than mesonotum and wider; sides diverging; caudal margin lightly incurvate.

Legs pallid; tibia appearing 2-segmented and with a patella.

Abdomen.—Transparent, gritty contents visible; ovoid.

WORKER.

Measurements.—Total length 4.5 to 5 mm.; head-width 0.8 mm.

Head.—Vertex creamy-white; frons milk-white; clypeus, epistome and labrum creamy-white; superior articulations of mandibles showing as two distinct deep brown spots; mandibles white with dark brown teeth. Dorsal outline of head short U-shaped; with scattered long pale hairs.

Clypeus salient, bombous.

Antennæ 14 joints; as with soldier, but III somewhat large, clavate, with a pseudo-articulation and IV the smallest joint.

Thorax.—White, transparent; much as with soldier.

Legs transparent; tibia appearing 2-segmented and with a patella.

Abdomen.—Transparent, with contents and convolutions of viscera visible (when alive a greasy slate-blue); elongate-ovoid.

Hab.—Natal; Mt. Edgecombe, Bellair, Pietermaritzburg, Frere. Transvaal; Pretoria.

Eutermes hastatus (*Haviland*). Pl. XXXIV, fig. 20.

Termes hastatus *Hav.*, Journ. Linn. Soc., Lond., xxvi, p. 410. 1898.

SOLDIER.

Measurements.—Total length 4 to 5 mm.; head with mandibles 1·7 mm.; head-width 1·0 to 1·1 mm.

Head.—Pale creamy-white with a median pearly-white stripe which is about one-third the width of the head; colour of mandibles in strong contrast. Viewed from above, elongate oval; sides nearly parallel, tapering to mandibles. Viewed from the side; thick; roundly arched; caudal extremity convex; frontal area sloping, then precipitous. With scattered, long, translucent bristles.

Labrum obtuse-triangular; apex with long bristles.

Mandibles yellowish-red; falcate; very much incurved; equal; similar; apical points very sharp both with acute prominent barbs at half their length. Left mandible with a somewhat salient protuberance at base.

Antennæ pseudo XIII- or pseudo XIV-jointed, occasionally appearing XV-jointed. Usually pseudo XIV-jointed when III is as long as II and nearly twice the length of IV; III composed of III and IV of XV-jointed expression, always with a pseudo-articulation and two whorls of hairs. When pseudo XIII-jointed, III as in the XIV-jointed expression, with IV longer and larger; IV composed of IV and V of XV-jointed expression with a pseudo-articulation and two whorls of hairs. I cylindrical, longer and wider than II; proximal series cylindrical and the same width as II. Distal

series obconic, increasing in length and width to penultimate joint; penultimate longer than ante-penultimate. Apical joint narrow, elongate-fusiform.

Gula concolorous with ventral genæ; with very short free apex. Sides parallel, straight but tapering to apex; not as wide as post-genæ.

Thorax.—Concolorous with head. Pronotum sellate. Mesonotum wider than pronotum. Metanotum wider than mesonotum.

Legs pallid, tibia appearing 2-segmented and with a patella.

Abdomen.—Transparent, contents visible; broad oval.

WORKER.

Measurements.—Total length 3.5 to 5 mm.; head-width 1 mm.

Head.—Vertex pale creamy-white; frons milk-white; superior articulations of mandibles forming dark brown spots; clypeus and labrum creamy-white, mandibles pallid, teeth red-brown.

Antennæ pallid, translucent; 15 joints, III and V small; III very small; otherwise much as with soldier.

Legs pallid, tibia appearing 2-segmented and with a patella.

Abdomen.—Broadly ovate; transparent, contents visible.

Hab.—Cape Colony; Port Elizabeth, Stellenbosch district.

Nest-series of this species have been collected for me by several of my colleagues, amongst whom Mr. C. P. van der Merwe has sent the largest. In several series there are soldiers of an undetermined kind, probably a social species. Mr. van der Merwe informs me that a great many of the nests of *E. hastatus* are occupied in part or wholly by the Argentine ant (*Iridomyrmex humilis* *Mayr.*). This ant has been introduced comparatively recently into the Cape, and has now acquired a strong foot-hold in the Stellenbosch district. It will be interesting to note, as time proceeds, whether

I. humilis spreads far afield and, as it progresses, annihilates the termite colonies in the country it invades.

The nest of *E. hastatus* is very much like that of *E. trinervius*, and is constructed of earth particles; the cellular spaces are, however, smaller, and no provisions are stored in the nest. The queen is active and deposits her eggs in various parts of the nest.

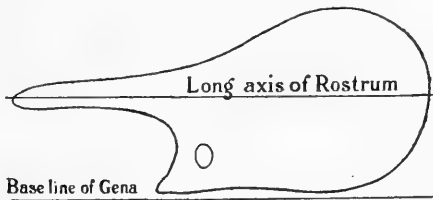
Eutermes trinervius (*Rambur*). Pl. XXXIII, fig. 4.

Termes trinervius *Rambur*, Hist. Nat. Néuropt., p. 308, 1842.

MAJOR NASUTU.

Measurements.—Total length 5 to 5·5 mm.; head with rostrum, 2·3 to 2·5 mm.; head-width 1·5 mm.

TEXT-FIG. 16.



Head.—Mahogany-red or aurantiaceous; very highly polished; rostrum dark brown to black from base or from half its length to its apex. Occipital view balloon-like, outline almost circular. Dorsal view turbinate, vertex sometimes with a shallow median depression. Ventral surface flat. Viewed in profile the epicranium is bombous, short, thick; the genæ faintly incurvate, almost straight; the cephalic margin below the rostrum oblique; the rostrum is attenuated, cylindrical, its apex perforated, and with its long axis parallel to the base-line of the genæ; from the apex of the rostrum to its oblique base (e. g. a point above the antennal foveolæ) it is shorter than the rest of the head-length, sometimes as much as 5 to 6. The superior margin of the apex of the rostrum

is slightly deflected. The rostrum has the appearance of being elevated above the vertex of the epicranium, but this is not actually the case. Y-suture, fontanelle, eyes, ocelli absent.

Clypeus, labrum, mandibles, insignificant.

Mandibles rudimentary; plate-like and triangular with broad bases; length to breadth 5:4.

Antennæ yellowish-red; 14 joints; I the longest joint; cylindrical; length constant (200 μ); II about half the length of I; cylindrical; the shortest joint (100 to 110 μ); III always longer than IV (140 to 180 μ); IV equal to or shorter than V (120 to 150 μ); V shorter than VI (120 to 150 μ); VI and VII sub-equal (150 to 170 μ); VIII, IX sub-equal, generally a little longer than VII (160 to 170 μ); X generally a little shorter than VIII and IX (150 to 170 μ); XI, XII, XIII, XIV, decreasing; XII and XIII (130 to 160 μ); XIV (130 to 140 μ).

Gula minute, quadrate.

Thorax.—Small, much narrowed; yellow or red-brown.

Pronotum very short; with deep transverse incision; cephalic and caudal margins elevated; caudal margin broadly rounded and notched. Mesonotum sub-elliptical, narrower than pronotum. Metanotum broader than pronotum, very short; sides very oblique, diverging.

Legs ample; pale red-yellow; tibia appearing 2-segmented and with a patella.

Abdomen.—Elongate-oval; dorsum very arched; sclerites diffuse yellow and brown; conjunctiva forming marked white bands.

MINOR NASUTU.

Measurements.—Total length 4 to 4.7 mm.; head with rostrum 1.7 to 2.1 mm.; head-width 0.7 to 1.0 mm.

Similar to major nasutu, but more slender; head less bombous; rostrum proportionately longer; antennæ as with major nasutu.

MAJOR WORKER.

Measurements.—Total length 4·5 to 5 mm.; head-width 1·5 to 1·7 mm.

Head.—With a bright, white, cruciform symbol, involving the Y-suture and having its median line extended to the clypeus; at the intersection a brighter white, fusiform flare radiating over the frons. On the vertex immediately lateral to the stem of the cross two sub-quadrate brown patches bordered by the very pale yellow genæ; mediad of each patch a pale sinuate line. Clypeus and epistome pale yellow or translucent and tinged with green. Mandibles very pale yellow, outlined with dark brown; teeth dark brown to black. Dorsal outline of head short, open U-shaped, widest across cephalic margin; genæ flattened and extended lateral to antennal fossæ; vertex quite flat; clypeus bombous. Labrum almost, if not quite complete.

Antennæ XV-jointed; the extra joint due to proliferation of III in the XIV-jointed fixed soldier pattern; the length of III in the XV-jointed worker antennæ is variable in accordance with how much it has enlarged after proliferation; it is either a very long almost clavate joint nearly twice as long as II or IV, or it is equal to II and IV or a trifle longer.

Thorax.—Pallid.

Legs pallid; tarsi appearing 2-segmented and with a patella.

Abdomen.—Very arched; translucent with almost characteristic brown and white convolutions of viscera visible.

MINOR WORKER.

Measurements.—Total length 3·8 to 4·5 mm.; head-width 1·0 mm.

Resembling major worker, but head markings generally paler.

Hab.—Cape Colony; Elsenberg, Mossel Bay, Port Elizabeth, Middelburg, Kimberley. Orange Free State, Transvaal and Natal—general.

VI. APPENDIX.

SIGNIFICANCE OF TERMS GENERALLY USED IN DESCRIPTIONS.

Anchylosed.—Grown together at a joint.

Antennal carinæ.—The ridges or brows superior to the antennal fossæ.

Antennal foveolæ.—The pits in which the antennæ are inserted, as a feature apart from the antennal fossæ.

Apical points.—The piercing tips of the mandibles of soldier termites.


Arched.—Applied to a curvate margin which rises more or less perpendicular to the plane of the body.

Aureole.—A ring of colour which is usually diffuse outwardly.

Barb.—(Restricted). As the barb of a fish-hook.

Bi-curvate.—With an in-and-out curve (sinuate).

Bi-lobed.—(As applied to margins). With two rounded processes, not necessarily thickened.

Brace-shaped.—Shaped like the brace or bracket () of printers. (Ornithological.)

Capistrate.—Hooded or cowed.

Capistrum.—A hood or cowl, like that of certain birds.

Caudal, Caudad, Caudo.—Pertaining to the anal extremity and more generally the direction (see Cephalic).

Cephalic, Cephalad, Cephalo.—Belonging or attached to the head and more generally the direction indicated by a line drawn from the centre of the animal to the head, but at an indefinite distance in that direction. Used in referring to both head and tail (Comstock and Kellogg).

Clypeo-frontal suture.—The suture separating the clypeus from the frons.

Concave.—Hollowed out, as opposed to convex.

Cordate.—Heart-shaped in outline.

Cordiform.—Heart-shaped in outline and convex above.

Convex.—The outer curved surface of a segment of a sphere.

Curvate.—Curved.

Deflected.—Bent downward, sloping.

Diffuse.—Spreading out, without distinct edge or margin.

Distal, Distad.—Toward or at the extremity used in reference to appendages or more or less free parts to indicate the end or nearness to the end which is free; opposites; proximal; proximad.

Epistome.—(Restricted). A distinct piece behind or above the labrum or a plate-like extension of the clypeus. In the latter sense always bracketed thus (epistome).

Fimbriate.—Set with a fringe of hair closely placed.

Foramen.—Applied to gland orifices of the head of certain soldier termites which are situated elsewhere than where the fontanelle is.

Fontanelle.—Particularly applied to a small gland orifice of the epicranium of certain soldier termites in which the γ -suture is absent and found at a spot which coincides with the fork of the suture in other soldier termites. (The fenestra of Haviland.) See Foramen.

Frons.—= Front; the anterior portion of the head cephalic of the γ -suture (see Frontal area).

Frontal area.—Used as an inclusive term to describe the front region of the head (frons and clypeus) when the γ -shaped suture and the clypeo-frontal suture are absent.

Furcate.—Forked.

Genæ.—The whole of the sides of the head from the cephalic extremity to the occipital region.

Incurvate.—Bowed, or curved inwards.

Insignificant.—(Restricted). Not essential to the diagnosis.

Intermediate.—(Restricted). To indicate the point or region at or about half way between apex and base of an appendage, or generally the second member of a series of three similar parts.

Introse.—Directed inward toward the body.

Labrum.—Used in the proper sense for the unsegmented flap-like sclerite articulated to the cephalic margin of the clypeus (see Labrum-epipharynx), or loosely for the labrum-epipharynx or labrum + lingula.

Labrum-epipharynx.—The long articulated labrum of the workers of many species.

Lingula.—A cordate prolongation of the epipharynx which is white and not chitinised, and the dorsal surface of which is continuous with that of the labrum (found in the soldier termites of the group represented by *T. natalensis*).

Obsolete.—Inconspicuous or apparently absent.

Occipital region.—An indefinite area forming the convex caudal extremity of the head.

Patella.—An apparent segmentation of the tibia of certain species, resembling the patella of the legs of spiders.

Pennant stripes.—Narrow, tapering, and somewhat long stripes like the pennant of a war-vessel.

Proximal, Proximad.—Used in reference to appendages (mandibles, antennæ, legs, etc.) and more or less free parts (clypeus, gula) to indicate nearness to the end which is attached to or inserted into the body.

Salient.—(Restricted). Jutting out more or less conspicuously.

Scallop.—(Restricted). A small, obtuse, and rather roundly curved tooth.

Scoop-shaped.—In the form of a shovel with a short, broad handle and with upturned sides to its blade.

Sellate.—Saddle-shaped, used in the restricted sense of the peculiar broad and convex shape of the pronotum of termites.

Serratulate.—With little teeth or serrations.

Side-plates.—Thin lateral extensions of the pro-, meso-, and meta-notum.

Sinuate.—Applied to lines and margins with an in-and-out curve.

Sub-reniform.—Almost reniform or irregularly oval.

Tricurved.—A line or margin with two out and one in curve or two in and one out curve.

Trochantin of mandible.—A narrow, and often salient, sclerite between mandible and gena.

Turbinate.—Top-shaped, or napiform (Botanical).

U-shaped.—Having the outline of the letter U, applied to the heads of many termites, although the arms are always a little in-bent at their apices.

Ventral genæ.—The two cheeks lateral to the gula composed of the genæ and post-genæ, but with the line of demarcation quite obsolete.

Wavy.—Sinuate, with several in-and-out curves.

Whorl.—A ring of long hair, or hair-like bristles, arranged around a centre like the spokes around the hub of a wheel.

Y-suture.—The Y-shaped suture or the epicranial suture which divides the vertex into two sclerites, the arms separating the vertex from the frons.

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EXPLANATION OF PLATES XXV-XXXV,

Illustrating Mr. Claude Fuller's paper, "Observations on Some South African Termites."

PLATE XXV.

Calotermes durbanensis Hav.

FIG. 1.— $\times \frac{1}{2}$. Tunnellings and chambers in dead wood, in vertical sections at right angles to each other.

Hodotermes transvaalensis sp. n.

FIG. 2.— $\times \frac{1}{10}$. Hive-cavity with shelving removed.

FIG. 3.— $\times \frac{2}{5}$. Fragment of wall of hive-cavity.

FIG. 4.— $\times 2$. A separated carton column for supporting shelving.

FIGS. 5 and 6.—Nat. size. Fragments of shelving showing inclines and columns.

FIG. 7.—Nat. size. Soil fragment perforated by a foraging gallery.

Termes swaziæ sp. n.

FIG. 8.— $\times \frac{1}{2}$. Large fungus-garden (120 mm. across) viewed from the side.

PLATE XXVI.

Hodotermes transvaalensis sp. n.

FIG. 1.— $\times \frac{1}{15}$. Vertical section of hive-cavity with two vertical shafts.

FIGS. 2, 2a.— $\times \frac{1}{15}$. Long and cross vertical sections of a large gallery-pocket.

FIG. 3.— $\times \frac{1}{10}$. Vertical section of pile of grass-lengths weighted down with soil, covering mouth of gallery.

FIG. 4.— $\times \frac{1}{7}$. Moundlet of earth particles.

FIGS. 4a, 4b, 4c.— $\times \frac{1}{7}$. Cores or tubes of moundlets like fig. 4.

FIG. 5.— $\times \frac{1}{10}$. Moundlet with simple core partly exposed by wind.

FIG. 5a.— $\times \frac{1}{10}$. Core of moundlet shown in fig. 5.

Hodotermes viator (Latreille).

FIGS. 6, 6a, 6b.— $\times \frac{1}{5}$. Vertical sections of moundlets of excreta particles with tubular extensions of gallery (F. W. Petty).

FIG. 7.— $\times \frac{1}{5}$. Vertical section of chambered moundlet covered with pieces of vegetation (F. W. Petty).

Termes natalensis Haviland.

FIG. 8.— $\times \frac{1}{80}$. Low, rounded, recent mound; Pretoria.

FIG. 9.—Rough, conical mound, with herbage; Pretoria (compare with figs. 3 and 4, Pl. XXXII).

FIG. 10.—Acutely conical and recent mound, showing recent and uniform extension of base from weathering; Mount Edgecombe.

FIG. 11.—Rounded and recent mound on hillside, showing recent extension of lower base from weathering; Mount Edgecombe.

FIG. 12.—Vertical section of domed and recent mound showing relative position of hive-cavity and galleries; in dense scrub; Mount Edgecombe.

FIGS. 13 and 14.—Vertical sections of mounds showing shouldered sides; higher altitudes in Natal.

FIG. 15.—Nest-sites or oases with fringe of coast bush in background; sketched at Mount Edgecombe, Natal.

FIG. 16.—A series of nest-sites on gentle slope and to one side of ridge; sketched at Mount Edgecombe, Natal.

FIG. 17.—Vertical section of large nest-site (marked α fig. 16); showing position of hive-cavity.

FIG. 18.—In vertical section, a stone-flagged, earth-filled veranda with nest-cavity immediately below cement reinforcement; with exterior dump-heap and one beneath flooring of interior of house (T. badius nests under similar conditions).

FIG. 19.— $\times \frac{1}{2}$. A break in the weather-worn surface of a mound in course of repair, showing the apertures through which the earth-pellets are placed outside; these apertures are subsequently closed. Sketched from nature.

PLATE XXVII.

Termes waterbergi sp. n.

FIG. 1.— $\times \frac{1}{30}$. Mound on periphery of nest-site (oasis of park formation).

FIG. 2.— $\times \frac{1}{30}$. Section of mound shown in fig. 1 to illustrate the absence of vertical permanent shafts and showing roots in undisturbed soil, but not in mound.

FIG. 3.— $\times \frac{1}{30}$. View of large cavity in half-section underlying site of mound. Photograph obtained by directing camera downwards at an angle of 45° .

PLATE XXVIII.

Termes natalensis Hav.

FIG. 1.— $\times \frac{3}{10}$. Large mound, lateral galleries cut through by trench.

FIG. 2.— $\times \frac{1}{12}$. Vertical section of large and unusually hollowed mound, Pretoria. (Photo by F. Thomsen.)

FIGS. 3 and 4.—Nat. size. Small queen-cell, without brackets, and with large entrances.

FIGS. 5 and 6.— $\times \frac{1}{3}$. Large queen-cell; fig. 5, exterior view; fig. 6, vertical long-section. Cavity 125 mm. long and 18 mm. high.

FIGS. 7 and 8.— $\times \frac{1}{3}$. A large queen-cell; fig. 7, exterior view; fig. 8, vertical cross-section. Cavity 90 mm. broad and 18 mm. high.

FIGS. 9–12.— $\times \frac{3}{4}$. Coronetted fungus-gardens; fig. 9, tall form (50 mm. high, 80 mm. across); fig. 10, short form (25 mm. high, 95 mm. across); fig. 11 short form from above; fig. 12, short form from below.

PLATE XXIX.

Termes latericius Haviland.

FIG. 1.—Vertical section of nest-site (diagrammatic) showing (*a, b, c, d*) various types of air-pits, (*e, e*) supplementary fungus-garden cavities; and general relation of hive-cavity to air-pits.

FIG. 2.— $\times \frac{1}{3}$. Vertical section of roofed air-pit (sketched from nature, Pretoria).

FIG. 3.— $\times \frac{3}{4}$. Vertical cross-section of a main-runway.

FIG. 4.— $\times \frac{3}{4}$. Vertical section of a main-runway, showing inclined vertical shaft to soil-surface.

FIG. 5.— $\times \frac{1}{5}$. Vertical section of small granary-cavity, with simple horizontal diaphragm.

FIG. 6.— $\times \frac{1}{5}$. Vertical section of small granary-cavity, with simple sub-horizontal diaphragm, showing: *a*, single entrance; *b*, a very small fungus-garden; *c*, a small collection of fresh grass-lengths deposited on floor of upper chamber.

FIG. 7.— $\times \frac{1}{3}$. Vertical section of medium large granary-cavity, showing conspicuous upper cavity, complex interior of lower region, and grass seeds embedded in surrounding earth (from nature, Pretoria).

FIG. 8.— $\times \frac{1}{4}$. Exit galleries made for imagos; *a*, front view of vantage; *b*, vertical longitudinal section; *c*, vertical section showing condition preceding and following flight; *d*, cross-section of gallery two inches from surface.

Termes incertus Hagen.

FIG. 9.—A twelve inch length of a down-gallery. For explanation see letter-press, p. 394.

FIG. 10.— $\times \frac{1}{3}$. The extensions made when galleries are severed.

Eutermes parvus (Haviland).

FIG. 11.— $\times \frac{1}{50}$. Globular nest overhanging sea-beach at Scottburgh, Natal.

FIG. 12.—*a, b, c.* Various types of nests.

Eutermes trinervius (Rambur).

FIG. 13.— $\times \frac{1}{80}$. Vertical section of mound with a lateral gallery passing under wheel track, showing how gallery follows contour of surface.

FIG. 14.— $\times \frac{1}{3}$. Vertical cross-section of lateral gallery.

FIG. 15.— $\times \frac{1}{3}$. Vertical section of a gallery and side-pouch.

FIG. 15*a*.— $\times \frac{1}{3}$. Vertical cross-section of gallery, with opposite side-pouches not anastomosing.

FIG. 15*b*.— $\times \frac{1}{3}$. Vertical cross-section of gallery, with opposite side-pouches anastomosing.

FIG. 15*c*.— $\times \frac{1}{2}$. A side view of 15*b*.

FIG. 15*d*.— $\times \frac{1}{2}$. Apertures of side-pouches on opposite sides of pathway, viewed from above.

FIG. 16.— $\times \frac{1}{40}$. Deserted mound showing apertures on surface and radiating series in soil-surface.

FIG. 16*a*.— $\times \frac{1}{2}$. Vertical section of lateral gallery showing how pathway is elevated towards aperture in soil-surface.

FIG. 16*b*.— $\times \frac{1}{2}$. Aperture as seen when looked into from above.

FIG. 17.— $\times \frac{1}{10}$. Bizarre type of mounds; Benoni, Transvaal.

PLATE XXX.

Termes badius Haviland.

FIG. 1.— $\times \frac{1}{30}$. Modern nest, in vertical section and perspective, showing trees crusted by termites with clay; small surface moundlets and descending shafts; great cavity and supplementary cavities filled with fungus-garden; queen-cell attached to wall of cavity (left side) and great radiating galleries. (Somewhat diagrammatic.)

FIG. 2.— $\times \frac{1}{3}$. A queen-cell from modern nest showing pedestals on which it stands; its rough outer surface with stones attached. Total length 170–180 mm.

FIG. 3.— $\times \frac{1}{3}$. A queen-cell from a modern nest showing in cross-section highly arched cavity, characteristic thin floor and pedestal. Width of cavity 85 mm., height 32 mm.

FIG. 4.— $\times \frac{1}{4}$. A very large cell, with more or less regular exterior, showing where clay arms were attached, and entrance holes. Total length about 260 mm.

FIG. 5.— $\times \frac{1}{4}$. A three-quarter view of fig. 4, showing cavity and pedestals.

FIG. 6.—Nat. size. Portion of upper surface of great fungus-garden.

Termes vulgaris Haviland.

FIG. 7.—Nat. size. Portion of outer surface of great fungus-garden.

FIG. 8.— $\times \frac{1}{20}$. Vertical section of nest described in text, p. 391.

FIG. 9.— $\times \frac{1}{3}$. Great loaf-like fungus-garden from nest illustrated in fig. 8.

FIG. 10.— $\times \frac{1}{3}$. Fungus-garden, in section, showing layer formation.

Termes latericius Haviland.

FIG. 11.— $\times \frac{1}{2}$.—A typical supplementary fungus-garden. Length 110 mm., height 50 mm.

PLATE XXXI.

Eutermes parvus (Haviland).

FIG. 1.— $\times \frac{1}{3}$. Nest viewed from above; the margin represents ground level. Diameter 160 mm.

FIG. 2.— $\times \frac{1}{2}$. Horizontal section of lower apex of nest, exposing queen-cell. (Photo. by Dr. Conrad Akerman.)

FIG. 3.— $\times \frac{1}{2}$. Vertical section of nest showing the queen-cell in base; the ground level is represented by a dotted line. (Photo. by Dr. Conrad Akerman.)

Termes incertus Haviland.

FIG. 4.—Nat. size. Earth fragment showing a very small fungus-garden cavity and the young fungus-garden.

FIG. 5.— $\times \frac{6}{7}$. A large fungus-garden viewed from above, 70 mm. across.

Termes latericius Haviland.

FIG. 6.— $\times \frac{1}{70}$. Nest site with one particularly high chimney at Pienaar's River, Transvaal. Chimney 2-3 ft. (Photo by F. Thomsen.)

Eutermes bilobatus (Haviland).

FIG. 7.— $\times \frac{1}{3}$. Common type of weather-worn mound associated with *Eutermes trinervius* mounds (140 mm. broad).

FIG. 8.— $\times \frac{1}{3}$. Abnormal and recent conical mound, not weather-worn. (Photo by F. Thomsen.)

FIG. 9.— $\times \frac{1}{3}$. Vertical section of fig. 8, showing typical cellular structure. (Photo by F. Thomsen.)

PLATE XXXII.

Eutermes trinervius (Rambur).

FIG. 1.— $\times \frac{1}{10}$. Vertical section of mound. (Photo by F. Thomsen.)

FIG. 2.— $\times \frac{1}{10}$. Mound bearing *Podaxon* sp. (Photo by F. Thomsen.)

FIG. 3.— $\times \frac{1}{30}$. *Termes* sp. Mound with *Cocculus villosus* ♂ growing on apex. Koodoos River, Zoutpansberg, Transvaal. (Photo by A. O. D. Mogg.)

FIG. 4.— $\times \frac{1}{30}$. *Termes natalensis* Haviland. Mound in low-veld overgrown by bush. (Photo by F. Thomsen.)

PLATE XXXIII.

FIG. 1.—*Termes badius*. Antennal chart (solid black) showing the range of variation for each joint of the XIX-jointed imago in ten individuals, and chart (double line) of one XIX-jointed worker antenna.

FIG. 2.—*Termes badius*. Antennal charts for the XIX-jointed soldier, worker major and worker minor.

FIG. 3.—*Termes natalensis*. Antennal charts of the major and minor soldiers.

FIG. 4.—*Eutermes trinervius*. Antennal chart of the major nasutu.

FIG. 5.—*Hodotermes* spp. Diagram to illustrate the ranges of the measurements given for the described species of *Hodotermes*. *a*. Total length ranges for soldiers. *a*¹. Head with mandible ranges for soldiers. *a*². Head-width ranges for soldiers. *b*. Total length-ranges for workers. *b*¹. Head-width ranges for workers.

Note.—In the case of all five diagrams the figures are based on the measurement of at least ten individuals except when otherwise stated.

PLATE XXXIV.

Hodotermes transvaalensis sp. n.

FIG. 1.—× 9. Mandibles of soldier. 1a.—× 6. Gula and ventral aspect of head.

Hodotermes pretoriensis sp. n.

FIG. 2.—× 9. Mandibles of soldier. 2a.—× 6. Gula and ventral aspect of head.

Hodotermes karrooensis sp. n.

FIG. 3.—× 9. Mandibles of soldier. 3a.—× 6. Gula and ventral aspect of head.

Hodotermes mossambicus (*Hagen*).

FIG. 4.—× 9. Mandibles of soldier. 4a.—× 6. Gula and ventral aspect of head.

Hodotermes havilandi *Sharp*.

FIG. 5.—× 9. Mandibles of soldier. 5a.—× 6. Gula and ventral aspect of head.

Hodotermes warreni sp. n.

FIG. 6.—× 9. Mandibles of soldier. 6a.—× 6. Gula and ventral aspect of head.

Hodotermes braini sp. n.

FIG. 7.—× 9. Mandibles of soldier. 7a.—× 6. Gula and ventral aspect of head.

Hodotermes viator (*Latrielle*).

FIG. 8.—× 9. Mandibles of soldier. 8a.—× 6. Gula and ventral aspect of head.

Calotermes durbanensis *Haviland*.

FIG. 9.—× 33. Mandibles of soldier.

Rhinotermes putorius *Sjöstedt*.

FIG. 10.—× 33. Mandibles of major soldier.

Termes swaziæ sp. n.

FIG. 11.—× 9. Mandibles of major and minor soldier.

Termes waterbergi sp. n.

FIG. 12.—× 9. Mandibles of major and minor soldier.

Termes natalensis Haviland.

FIG. 13.—× 9. Mandibles of major and minor soldier. 13a. Thorax and body showing rounded mesothorax. 13b. Thorax and body showing lobed or skirted mesothorax. 13a and 13b × 3·5.

Termes badius Haviland.

FIG. 14.—× 33. Mandibles of soldier.

Termes latericius Haviland.

FIG. 15.—× 33. Mandibles of soldier.

Termes vulgaris Haviland.

FIG. 16.—× 33. Mandibles of soldier.

Termes incertus Hagen.

FIG. 17.—× 33. Mandibles of soldier.

Eutermes parvus (Haviland).

FIG. 18.—× 33. Mandibles of soldier.

Eutermes bilobatus (Haviland).

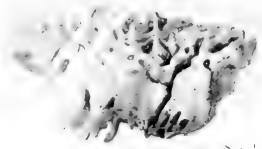
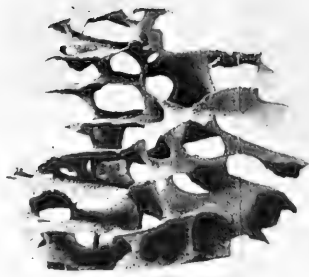
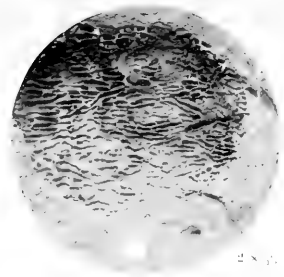
FIG. 19.—× 33. Mandibles of soldier.

Eutermes hastatus (Haviland).

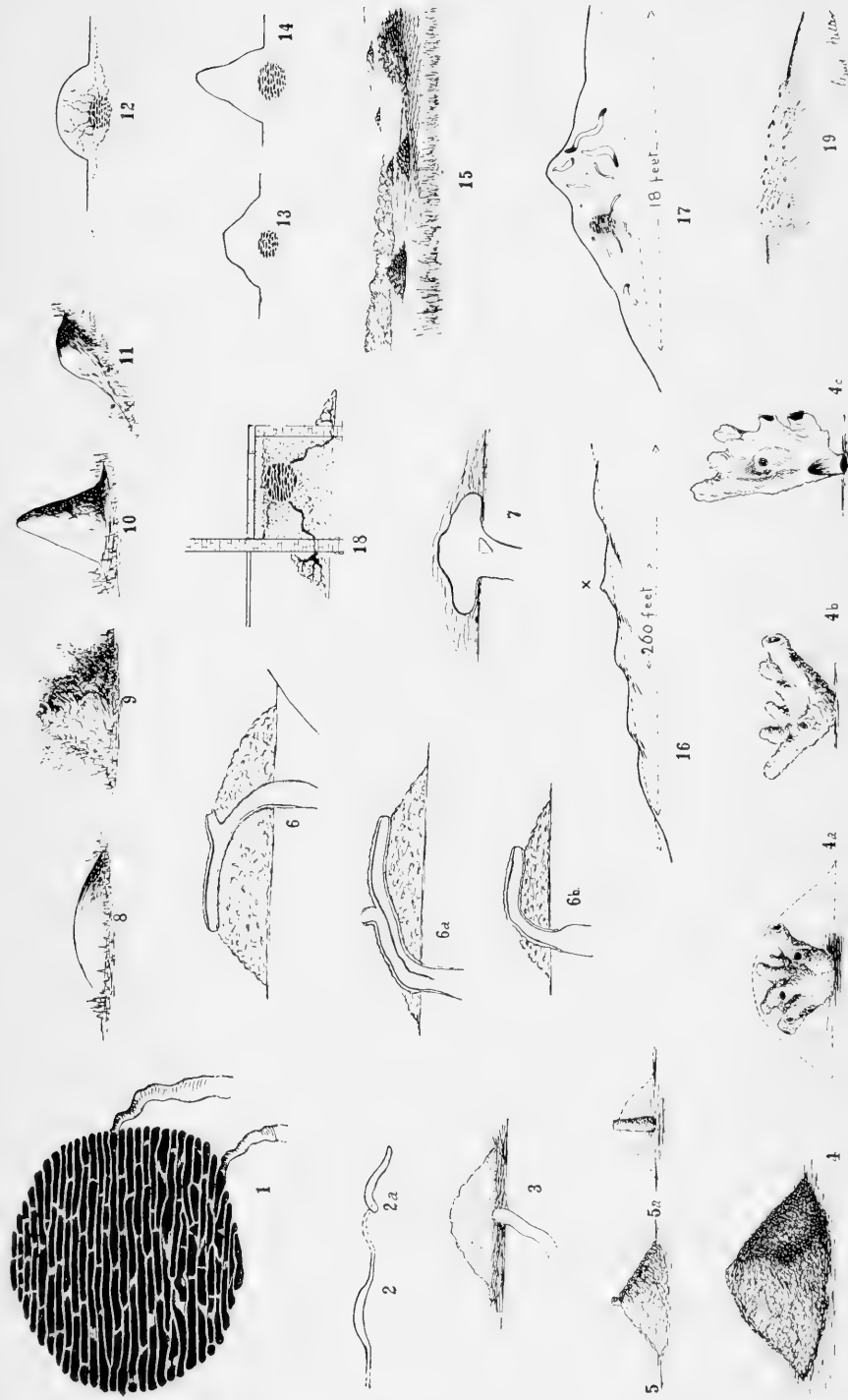
FIG. 20.—× 33. Mandibles of soldier.

PLATE XXXV.

Labrum of soldier of (1) *Hodotermes transvaalensis sp. n.*, (2) *pretoriensis sp. n.*, (3) *karrooensis sp. n.*, (4) *mossambicus (Hagen)*, (5) *havigandi Sharp*, (6) *warreni sp. n.*, (7) *braini sp. n.*, (8) *viator (Latreille)*. 1 to 8—× 28.



CALOTERMES DURBANENSIS, FIG. 1. HODOTERMES TRANSVAALENSIS, FIGS. 2-7. TERMES SWAZIE, FIG. 8



HODOTERMES TRANSVAALENSIS, FIGS. 1-5. H. VIATOR, FIGS. 6, 7. TERMES NATALENSIS, FIGS. 8-19.



1



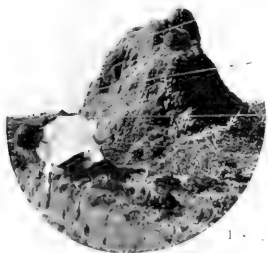
2



3

TERMES WATERBERGI *sp. n.* $\times \frac{1}{30}$

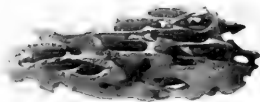




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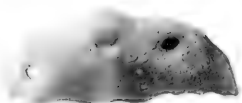
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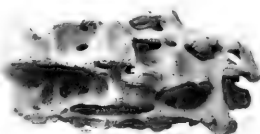
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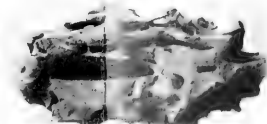
5 × 1



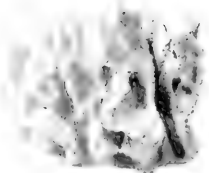
6 × 1



7 × 1



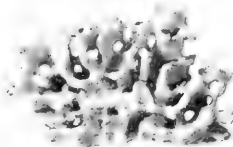
8 × 1



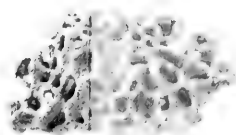
9 × 1



10 × 1



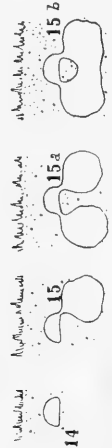
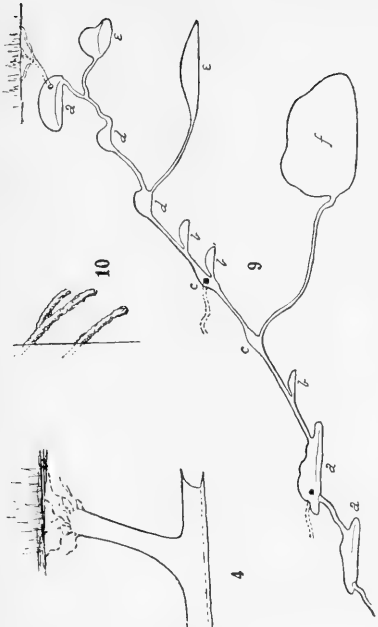
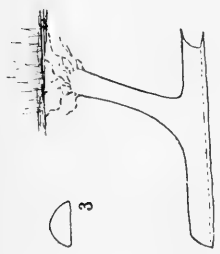
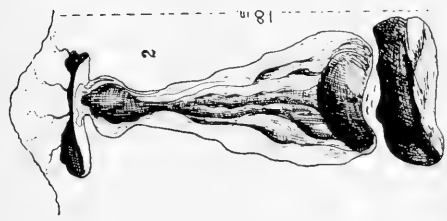
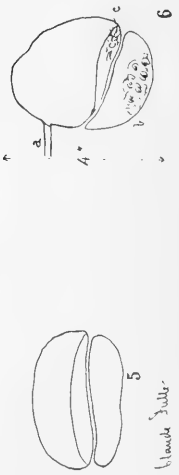
11 × 1



12 × 1

TERMES NATALENSIS. FIGS. 1-12.





TERMES LATERICIUS, FIGS. 1-8.

T. INCERTUS, FIGS. 9, 10.

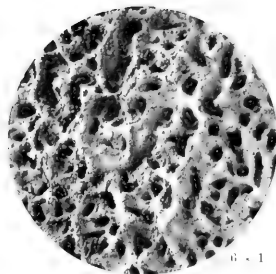
EUTERMES PARVUS, FIGS. 11, 12.

E. TRINERVIUS, FIGS. 13-17.

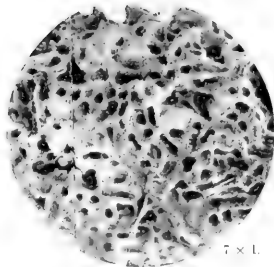




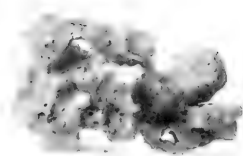
18



6 x 1



7 x 1



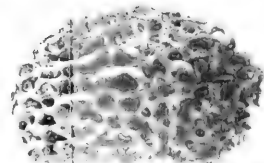
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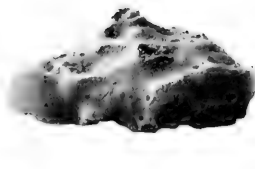
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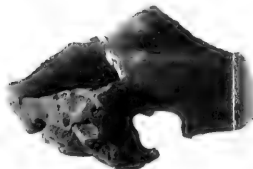
4 x 1



11 x 1



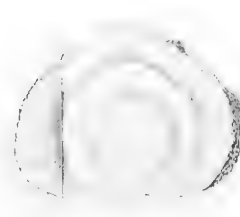
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5 x 1



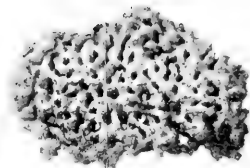
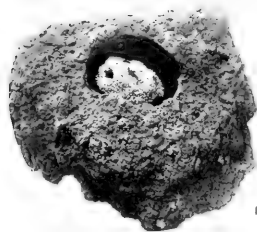
9 x 1



10 x 1

TERMES RADIX, FIGS. 1-6. T. VULGARIS, FIGS. 7-10. T. LATERICUS, FIG. 11.





1 x 1

3 x 1



4 x 1

5 x 1

5 x 1



1 x 1

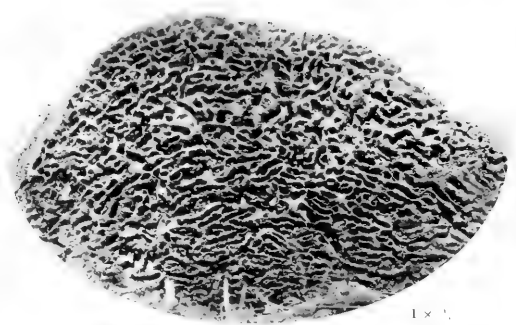
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9 x 1

ECTERMES PARVUS, FIGS. 1, 3. TERMES INCERTUS, FIGS. 4, 5. T. LATERICIUS, FIG. 6. E. BILOBATUS, FIGS. 7, 9.





1 x 1/2



1/2 x



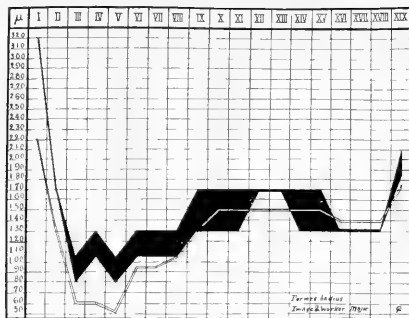
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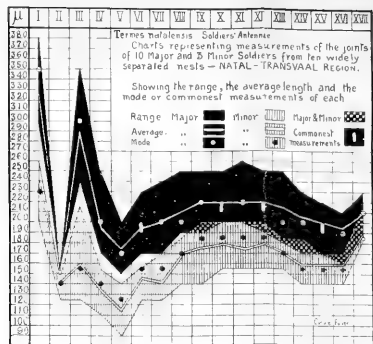
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EUTERMES TRINERVIUS, FIGS 1-2 TERMES SP., FIG 3 T. NATALENSIS, FIG. 4.

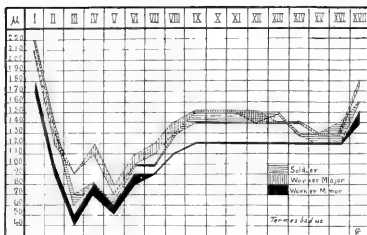




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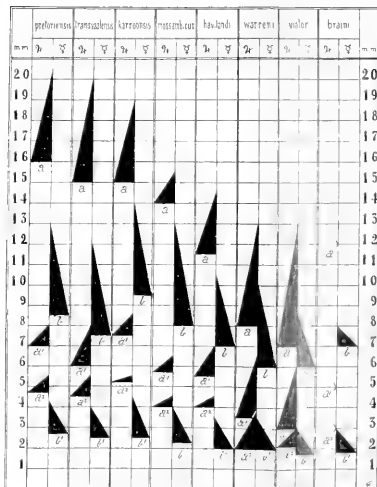


2



5

ANTENNA CHARTS
OF
TERMES (FIGS. 1-3) AND
EUTERMES (FIG. 4),
AND
VARIATION DIAGRAM OF
HODOTERMES (FIG. 5)



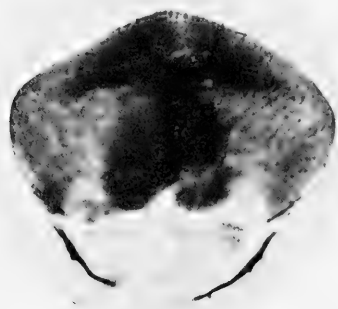
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MANDIBLES AND VENTRAL VIEW OF HEADS OF VARIOUS TERMITES

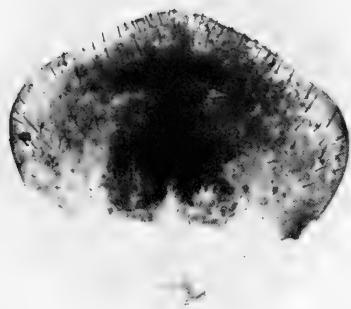




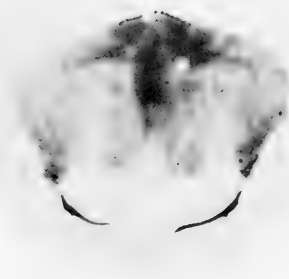
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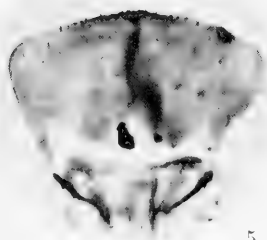
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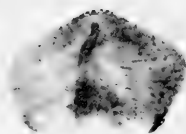
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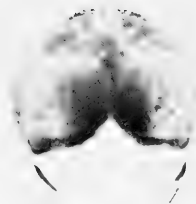
5



6



7



8

LABRUM OF VARIOUS SPECIES OF HODOTERMES. 1-8 \times 28.



A Further Note on Hybrid Cockatoos.

By

Ernest Warren, D.Sc.Lond.

IN 1914 I described in this journal¹ a case of hybridism between the male of *Cacatua galerita* (*Lath.*) and the female of *Licmetis nasica* (*Temm.*) There are now a few additional particulars to be given.

During the last season three eggs were laid; of these one duly hatched, while one was addled, and one was broken. The young bird appeared quite healthy and grew rapidly, but unfortunately it died when about three months old. Subsequent examination suggested that the cause of death was peritonitis. Mrs. Brown, who owns the cockatoos, very kindly presented the bird to the Natal Museum, and it has now been mounted. The growth of the bird appeared to be exceptionally rapid, since at the time of death the standing length was not less than in the two living hybrids.

The time between the laying of the first egg and the commencement of sitting varied from five to six days. In the former account it was stated that probably the period of incubation was about twenty-one days; but Mrs. Brown informs me that a special note had been taken of the dates of

Hybrid.	Date of commencement of sitting.	Date of hatching.	Period.	Approximate age at Dec. 31st, 1914.
1	Sept. 23rd, 1910	Oct. 20th, 1910	27 days	50 months
2	Aug. 15th, 1913	Sept. 11th, 1913	27 "	15 "
3	Sept. 8th, 1914	Oct. 4th, 1914	26 "	3 "

¹ 'Annals of the Natal Museum,' vol. iii, pt. 1, p. 7, 1914.

the commencement of sitting and of hatching in the case of all three hybrids. These dates are now given, and it will be seen that the period of incubation varied from twenty-seven to twenty-six days.

As I am unaware of the normal incubation periods of *Cacatua galerita* and *Licmetis nasica* it is not possible to make an interesting comparison as to whether hybridisation affects this period. It may be noticed that there is a difference of only about twenty-four hours in the incubation period of the three hybrids. It also must be noted that out of the two eggs (omitting the broken one) only one hatched, and in conjunction with the results on the former occasions we must regard the large percentage of failure in incubation as being due to the hybridisation.

At the time of writing the account of the first hybrid, the second hybrid was only three months old, and it did not seem to be fully grown. Owing to these circumstances details of the measurements were not given.

The second hybrid is now fifteen months old, and the bird which died was three months old. It is interesting to ascertain how far the brother hybrids resemble one another, and for this purpose comparative tables are given for the non-measurable and for the measured characters.

From these two tables it will be at once clear that although the hybrids bear a strong resemblance to one another yet they exhibit certain differences.

By reference to Table I it will be seen that the second hybrid on the whole does not come so near to the male-parent in its non-measurable characters as do the first and third hybrids.

In hybrids 1 and 3, five of the characters are nearer to those of *Cacatua*, four are more or less intermediate between those of the two parents, and one is closer to that of *Licmetis*.

The various characters, however, are not all similar to each other in the two hybrids. The colour of the naked skin around the eye is very pale blue in hybrid 1, and almost,

TABLE I.—Characters not Measured.

Character.	Hybrid 1 (50 months).			Hybrid 2 (15 months).			Hybrid 3 (3 months).		
	Nearer Cacatua.	Inter-mediate.	Nearer Lichmetis.	Nearer Cacatua	Inter-mediate.	Nearer Lichmetis.	Nearer Cacatua.	Inter-mediate.	Nearer Lichmetis.
Colour of crest	Dull yellowish orange	—	—	Dull yellowish orange	—	—	Dull yellowish orange	—	—
Colour of base of head and neck feathers	Brilliant gold	—	—	Brilliant gold	—	—	Brilliant gold	—	—
Colour of naked area around eye	—	Very pale blue	—	—	—	Distinct blue	Almost white	—	—
Shape of naked area around eye	—	Roughly circular	—	—	—	Roughly circular	Roughly circular	—	—
Feathering of cere	—	Partly feathered	—	—	Partly feathered	—	—	Partly feathered	—
Prominence of forehead	—	Medium	—	—	Medium	—	—	Medium	—
Granulation of eyelid	Less well-marked and regular	—	—	Less well-marked and regular	—	—	—	Much less well-marked and regular	—
Shape of the upper and lower mandibles and condition of hook	Shape less massive, and hook less straight	—	—	Shape less massive, and hook less straight	—	—	Shape less massive, and hook less straight	—	—
Colour of bill	Dark, but less black	—	—	Dark, but less black	—	—	—	Grey	—
Possession of coloured toes	—	—	Coloured orange and area smaller than in ♀	—	—	Coloured orange and area smaller than in ♀	—	—	Coloured orange and area smaller than in ♀
Addition of columns—10	5	4	1	5	2	3	5	4	1

TABLE II.—Characters measured.

Dimension.	<i>Cacatua gularita</i> ♂.	Diff. from ♀ × 100.	Hybrid 1, 50 mths.	Diff. from ♂ × 100.	Hybrid 2, 15 mths.	Diff. from ♀ × 100.	Hybrid 3, 3 mths.	Diff. from ♂ × 100.	<i>Licmetis nasica</i> ♀.
Standing length	Mm. 445	17	Mm. 381	10	Mm. 360	6	Mm. 385	11	Mm. 343
Length of longest hinder crest feather	114	56	73	48	78	51	79	52	38
Area of eye when eye-lids open	Sq. mm. 31	9	Sq. mm. 34	26	Sq. mm. 51	51	Sq. mm. 32	22	Sq. mm. 25
Area of naked skin around eye	144	31	208	65	260	32	193	78	343
Length of tail	Mm. 203	14	Mm. 178	32	Mm. 169	29	Mm. 167	28	Mm. 120
Length of upper mandible from forehead to tip	42	2	43	9	45	4	42	12	47
Depth from forehead to inner angle	27	13	24	21	22	14	21	14	19
Slope of lower edge of upper mandible with horizontal	8°	58	19°	42	15°	80	17°	59	27°
Mean of percentages		25		32	29	33	23	35	

although not quite, white in hybrid 3. In hybrid 1 the naked area around the eye is roughly circular in shape, and is about intermediate in size; while in hybrid 3 it is nearer to that in *Cacatua*. In the granulation of the eyelids hybrid 1 approaches *Cacatua*, and hybrid 3 is more or less intermediate. In the colour of the bill hybrid 3 is more distinctly intermediate than is hybrid 1.

Hybrid 2 is less like the male-parent than is the case in the other two hybrids; the naked area around the eye is distinctly blue and its shape approaches that in *Licmetis*. The prominence of the forehead is medium, but it is less marked than in the first hybrid. Thus in five characters the second hybrid approaches *Cacatua*, in two characters it is intermediate, and in three characters it is nearer to *Licmetis*. There is still prepotency on the part of the male-parent, but it is less pronounced than in the first and third hybrids.

The greater divergence of the second hybrid from the male-parent is confirmed by an examination of Table II showing the characters which were measured. Here the mean of the percentage divergences of the second hybrid from the father, expressed in terms of the characters in the former, is 29 per cent., as compared with 25 per cent. in the case of the first hybrid and 23 per cent. in the case of the young bird.

The means of the percentage divergences from the male-parent (*Cacatua*) and the female-parent (*Licmetis*) are respectively for the first hybrid 25 per cent. and 32 per cent., for the second hybrid 29 per cent. and 33 per cent., for the third hybrid 23 per cent. and 35 per cent., and the averages for the three hybrids are 26 per cent. and 33 per cent. In all the hybrids there is a general average prepotency of the male-parent, but it is least obvious in the second hybrid.

Thus on the whole the same order of magnitude is maintained in all three hybrids, although there is considerable variation in the expression of the different characters.

With only three individuals to deal with it is not possible to draw any very definite conclusions, but the differences

between the brother hybrids would seem to be greater than might be expected to occur between three pure-bred brethren.

Another point of interest may be mentioned. The eyes of the hybrids, as represented by the area of the eyeball exposed when the eyelids are wide open, are distinctly larger than in either the male- or female-parent, and this condition is especially marked in the second hybrid where the area is equal to 51 sq. mm., while in the male *Cacatua* it is 31 sq. mm., and in the female *Licmetis* 25 sq. mm. The appearance in a hybrid of a new character not clearly connected with either parent would seem to be especially worthy of investigation, but the data at present to hand are too scanty for any detailed examination.

The Plant Ecology of the Drakensberg Range

By

J. W. Bews, M.A., D.Sc.,

Professor of Botany, Natal University College.

With Plates XXXVI-XXXIX, and 3 text-figures.

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INTRODUCTION.

THE study of the vegetation of Natal from the ecological standpoint was commenced by the writer in 1911, and three papers¹ on the subject have already appeared. Important

¹ Bews, J. W., "The Vegetation of Natal," 'Annals of Natal Museum,' vol. ii, pt. 3, 1912. "An Ecological Survey of the Midlands of Natal," *ibid.*, vol. ii, pt. 4, 1913. "The Growth Forms of Natal Plants," 'Trans. of Roy. Soc. of S.A.,' 1916.

problems continue to present themselves, and the ecology of the Drakensberg Range has proved as interesting as its scenery is magnificent.

While increasing knowledge of the flora of Natal and its ecology has helped to lighten the task in some respects; yet the immense distances and general inaccessibility of most parts of the Drakensberg presented fresh difficulties.

A month (January, 1914) was spent by the writer at Van Reenen's Pass, which is a convenient centre for investigating the lower portion of the range and the character and relationships of the main plant formations, the bush and veld. Subsequently shorter visits were paid to the Newcastle district, and the Goodoo Pass and Mont aux Sources region.

The last mentioned will doubtless in time become much better known, since it is being set aside as a National Park. It is certainly worthy of the distinction.

The writer desires to acknowledge generous assistance from the following: Mrs. R. Pott, Botanist to the Transvaal Museum, who sent a list of plants which she had named for Mr. R. E. Symons from Giant's Castle; Mr. T. R. Sim for identifying the mosses and hepatics and other valuable assistance; Dr. E. P. Phillips, of the South African Museum, who undertook the naming of various collections made by the writer, and who also supplied other lists; Mr. J. S. Henkel, Conservator of Forests for Natal, for obtaining specimens through his forest officer stationed at Olivier's Hoek; and Senator F. F. Churchill, who was visiting the Goodoo and Mont aux Sources at the same time as the writer.

I. GEOLOGY, TOPOGRAPHY, AND SOIL CONDITIONS.

The Drakensberg range of mountains forms the western boundary of Natal. It is, properly speaking, the elevated escarpment of the great inland plateau. It is only when viewed from the Natal side that it appears as a lofty range of mountains, the ascent from the other side being much more

gradual. On the borders of Basutoland it reaches its highest altitude, the Mont aux Sources being given on the maps as 11,170 ft. (3405 m.), Cathkin Peak (Champagne Castle) as 10,357 ft. (3157 m.); and Giant's Castle as 9657 ft. (2944 m.), but probably these heights are exaggerated. The general altitude reached by this part of the range may be taken as approximately 3000 m. At the point where Basutoland joins Griqualand E., the main range bends south-westward, but a lower range passes along the boundary between Griqualand E. and Natal, terminating in the Ingeli Mountains.

From the Mont aux Sources northwards along the boundary of the Free State, the altitude gradually decreases to Van Reenen's Pass, this portion forming a range nearly at right angles to the higher part, which continues in line to form the boundary between Basutoland and the Orange Free State.

From Van Reenen the portion bordering Natal rises again slightly and forms a long escarpment facing Newcastle, which has an altitude of 6500 to 7500 ft. (1981 to 2286 m.).

This northern portion is much more accessible than the part bordering Basutoland.

The geology of the Drakensberg is fairly simple, owing to the absence of folding. The rocks lie more or less horizontally and may be classified in descending order as follows:

Upper Karroo	{ Amygdaloidal, basaltic, and rhyolitic lavas. Cave Sandstones. Red Beds.	
Lower Karroo		Molteno Beds.
		Beaufort Series.
	Ecca Series (not including the glacial conglomerate).	

The amygdaloidal lavas in some parts form practically sheer cliffs, but there are numerous buttress-slopes covered with a shallow layer of soil, in which tussock veld is formed, and in places this reaches almost to the top even of the

highest portions. The two sections given in text-figs. 2 and 3 (pp. 516, 517) illustrate the two types.

Immediately below the amygdaloids, a conspicuous sheet of dolerite or basalt (it is difficult to say which it is), varying from 50 to 300 or more feet in thickness, occurs; and this hard bed forms a protective cap for many of the upper foothills (text-fig. 1, p. 515). The lavas have been totally denuded from every part except the highest portion, which extends from the Mont aux Sources to the southernmost boundary of Natal.

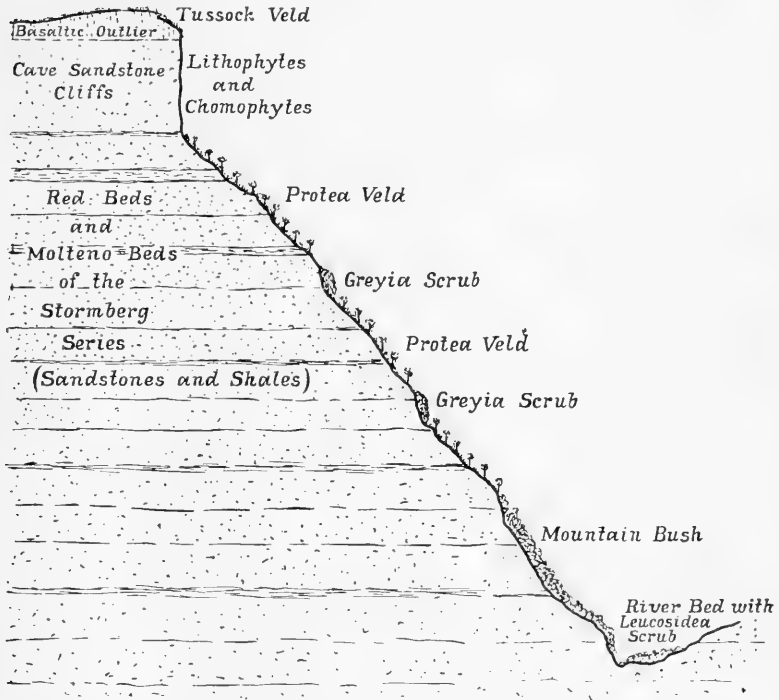
The Cave Sandstones, Red Beds and Molteno Beds, the downward succession of the Stormberg Series, form the northern portion and are exposed in the same order on the slopes facing Natal, below the amygdaloids. Sandstones alternate with thin beds of shale. The Cave Sandstones usually form conspicuous cliffs, covered with algæ and lichens.

The lower foothills which extend about thirty miles from the main range consist of reptilian sandstones and mudstones of the Beaufort Series. Below these again are the Natal Coal Measures, which are usually considered to belong to the upper Ecca Series. There is complete conformity between all the divisions from the Cave Sandstones downwards—and only a slight unconformity between the Cave Sandstones and the overlying lavas.

From the main range of mountains the chief rivers of Natal have their source, and they have cut through the outcrops of the various geological formations nearly at right angles. The result is that Natal, as a whole, rises from the sea to the Drakensberg in a series of terrace-plateaux. The Drakensberg range forms the highest plateau. The vegetation on the steep edge of this plateau, which faces Natal, differs considerably from the vegetation on the plateau itself, i. e. in the interior (cf. the differences between the edges and the surfaces of the lower terraces in Natal, as described by the writer in the previously cited papers). Between the rivers or between their main tributaries we have a system of

ridges, spurs, and foothills, projecting more or less at right angles to the main escarpment. The rivers and their tributaries have cut their way down very steeply, leaving usually sheer walls of rock at their upper ends and steep slopes

TEXT-FIG. 1.



Section through a typical foothill of the Drakensberg escarpment, showing the relationship of plant formation to the geological strata.

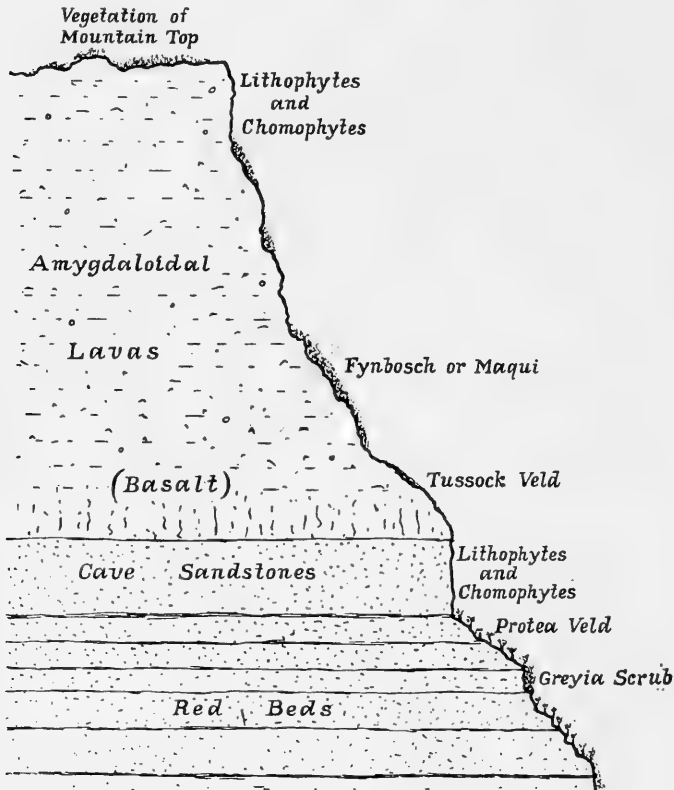
where the valleys begin to broaden. In spite of the fact, therefore, that the greatest portion of the main range faces south-east, the exposures vary exceedingly and the climate, soil conditions, and plant formations vary accordingly.

This fact is well illustrated as one passes from Bergville towards the Mont aux Sources up the great valley of the Tugela.



On the left the Drakensberg faces north-east, and the tributaries of the Tugela flow down between foothills in valleys which also open to the north-east. A good example is the valley of the Sanyati River, a grassy type devoid of

TEXT-FIG. 2.



Section through the steep part of the main Drakensberg escarpment.

bush and shrub. On the right the range faces south-east, and here there are several fairly large patches of the mountain type of bush.

The rate of denudation is everywhere at a maximum. After the winter dry season the Tugela (like the other main

rivers) often rises in flood and comes down in the form of a wall of water several feet high, which sweeps before it the accumulated débris of the river-bed and rolls along large stones, leaving the river-channel clean.

TEXT-FIG. 3.



Section through a butterslope of the main Drakensberg escarpment.

Where soil is able to accumulate it is quickly leached and is usually very poor in chemical salts. The shales are of a very friable character and are easily eroded. The sandstones among which they occur are more resistant. Frequently, therefore, the shale beds are hollowed out under-

neath overlying sandstones. In many places the process has doubtless been assisted by the Bushmen, who used the caves thus formed for shelter. These caves occur not only in the Cave Sandstones but in the other beds as well. Their chief interest to most people lies in the Bushman paintings, which they often contain, but they also afford shelter for many interesting shade-loving plants. In such caves, large and small, soil is able to accumulate, and if, as often happens, the type of plant formation is bush or scrub, a rich leaf-mould gathers and the undergrowth is relatively a rich and varied one, ferns and bryophytes in particular being abundant.

At the top of the lower portion of the range (Van Reenen's Pass, etc.) we find conditions of greater stability than on the Natal face.

Here there are vleis of considerable size, with a varied and interesting flora, and comparatively stable veld. The soil, however, even in such places, is a poor one, the soluble salts being quickly dissolved out of it. The following is an analysis of a sample of soil from Botha's Pass, and for purposes of comparison there is added the average of twenty-seven analyses (already published) for different parts of Natal:

Locality.	Percentages of constituents.							
	Moisture.	Organic and volatile.	Insoluble.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Iron and alumina.
Botha's Pass	1.77	5.22	86.89	0.04	0.18	0.04	0.05	5.34
Average of 27 analyses for lowlands of Natal	4.82	7.63	70.09	0.09	0.19	0.23	0.20	11.64

All Natal soils show extreme poverty in soluble salts, there being great scarcity particularly of lime and phosphates. The soil of the Drakensberg, however, is still poorer, having a high proportion of insoluble minerals. The water of the

mountain streams, which is clear as crystal, is very soft, showing absence of lime.

On the top of the upper portion, from the Mont aux Sources southwards, a distinct type of soil and plant formation occurs—the mountain-top detritus. This will be described in detail later, when the vegetation is dealt with.

II. CLIMATE.

A. ATMOSPHERIC PRESSURE AND INSOLATION.

The feature of mountain climate which shows the greatest regularity is the decrease of pressure with increasing altitude. It must naturally come first in our consideration, since so many of the other features depend on it. It varies with temperature and therefore with latitude, and consequently the decrease is not quite so great in Natal as in colder regions. The irregular changes in barometric pressure decrease with altitude in the same ratio as the pressure itself decreases. On the summit of the Drakensberg the pressure is from 150–250 mm. less than at sea-level, where it may be assumed to be 762 mm. (30 in.).

As a result of the decrease of pressure there is increased intensity of insolation, since the thickness of absorbing atmosphere is less. Water-vapour, which is a better absorber of solar radiation than dry air, decreases with altitude more rapidly than pressure decreases (*vide infra*). Atmospheric dust, which affects chiefly the shorter wave-lengths, is comparatively small in amount, consequently there is a marked increase in the more chemically active rays. The great intensity of the ultra-violet rays at high altitudes has been demonstrated by many observers. Bunsen and Roscoe many years ago gave the following figures regarding the chemical intensity of sunlight at different altitudes, expressed in percentages of the intensity just outside the earth's atmosphere, which they computed to be equal to 35·3 "light units."

Chemical Intensity of Sunlight (in percentages of the maximum).¹

Pressure (mm.).	Altitude above sea level (m.).	Sun's altitude.				
		90 degrees.	70 degrees.	50 degrees.	30 degrees.	10 degrees.
750	130	44	42	34	19	1
650	1270	49	47	39	24	2
550	2600	55	53	46	30	3
450	4200	61	59	53	37	6
350	6200	68	67	61	46	10

According to this table, when the sun is low, the chemical intensity of sunlight on the Drakensberg is three or four times greater than on the coast-belt, but the difference decreases as the sun rises to the zenith, when it is only 11 or 12 per cent. greater.

The remarkable colour changes in the flowers of species which extend from the coast to the higher altitudes is one of the many physiological effects of this factor. *Helichrysum adenocarpum* has flower-heads white or pale pinkish on the coast, but brilliant crimson in upper districts. *Dierama pendula* has pure white flowers on the coast, pink in the midlands, and deep purple on the mountains. *Moræa spathacea* shows similar variations.

A relatively high surface temperature of the soil is a direct result of the increased insolation. The temperature of the soil to a depth of several centimetres is often much higher during the daytime than that of the atmosphere. On the other hand, owing to the rarity of the air and the decrease in the amount of water-vapour, radiation of heat at night is increased, the temperature of the surface falls, and there is thus a much larger range of surface temperatures on the Drakensberg than on the lower terraces. The exposure is of

¹ Hann, J., 'Handbook of Climatology,' Trans. by D. C. Ward, New York, 1903.

great importance in connection with insolation. A large portion of the main Drakensberg faces the rising sun, but it will be seen from the description given of the topography that there are minor slopes and innumerable steep descents into the deep valleys, that are shaded much longer, sometimes throughout the greater part of the day. This fact, taken in conjunction with the distribution of water-vapour and precipitation, has an important effect on the vegetation.

B. TEMPERATURE.

Next in point of regularity to the decrease of pressure is the decrease of air temperature with rise of altitude. This has been taken¹ to average 0.57°C . for every 100 m. There are slight seasonal variations, of course, but here again the effect of the topography is most marked. At night, owing to radiation, which, as we have seen, increases greatly with altitude, the ground cools rapidly and the lower atmosphere is also cooled. The cold air, being heavier, settles to the lowest point; it flows from the hillsides down into the valleys, and it follows the course of the main valleys downward, exactly like the rivers. We thus have an inversion of temperature, higher altitudes being warmer than lower. This is seen regularly during the winter anticyclone, when calm weather prevails, when also the general temperature is lower. The water-vapour of this colder air is condensed into a fog, which settles into the valleys. In the early morning the mountain-tops rise above the dense white mist-cloud like islands in a sea. The rising sun gradually disperses the fog, and here again the exposure determines whether the sun's influence will soon make itself felt, or whether the cold air and fog will linger. The effect of the cold air drainage at night is seen most clearly at points where the current is more rapid, as where a narrow "nek" opens into a broader valley. At such a point the vegetation suffers severely from frosts.

¹ Hann, J., loc. cit.

The cold air, which thus flows down to lower altitudes, has to be replaced by air from above, which has not been cooled by radiation and is further warmed by compression as it descends. Consequently, the air on the mountain sides and even at the top may be relatively warm in winter. At the same time it is very dry. The valleys, therefore, are damp and cold at nights, the mountains dry and warm.

On the other hand, during the day-time, and particularly during summer, the temperature of valleys is relatively high, owing to the heat resulting from insolation being reflected and radiated from the sides of the valleys. The foot of the main escarpment, for the same reason, is relatively warm. The valleys and lower altitudes generally, therefore, show a much greater range of temperature than the enclosing mountains. A decrease of the annual and diurnal range of temperatures is a general feature of high altitudes, but it depends to a large extent on the topography. A valley at high altitude will show a much greater range than a hill of the same altitude.

A common feature of mountain ranges in higher latitudes, where there is a covering of snow, is the retardation of the time of occurrence of maxima and minima temperatures and of the seasons generally. This does not apply to the Drakensberg. It is true that snow may lie on the summit for several weeks, but its melting does not require a very large amount of insolation, and so it does not lead to any postponing of the advent of summer. On the contrary, the melting snow supplies the necessary moisture to give the vegetation an early start, and as a matter of fact the mountain regions of Natal have an earlier spring than the Midlands. It must be remembered that in Natal the rest during the winter season is due to drought rather than cold.

No exact meteorological figures have ever been taken for the higher parts of the Drakensberg, but the following table gives the average for three years, 1902-1904, for Qudeni, 5686 feet (1734 m.), and Weenen, the valley type, alt. 2841 feet (866 m.):

THE PLANT ECOLOGY OF DRAKENSBERG RANGE. 523

Locality.	Temperature (Centigrade)	Jan.	Feb.	Mar.	Apr	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Weenen (866 m.)	Mean max.	33·05	33·0	30·05	28·6	26·1	23·1	23·05	25·75	28·0	30·8	32·45	33·6
	Mean min.	16·3	16·3	13·9	10·1	4·05	-0·5	0·15	3·5	7·3	11·3	13·9	14·8
	Absol. max.	40·6	39·5	37·3	35·6	31·7	29·5	29·5	33·9	38·4	38·9	41·2	41·2
	Absol. min.	12·3	11·7	6·2	2·3	-1·6	-5·0	-4·4	-2·2	-1·1	2·3	6·7	6·7
Qudeni (1734 m.)	Mean max.	23·3	23·25	21·3	20·0	18·1	15·9	15·8	18·3	19·2	21·3	22·3	22·4
	Mean min.	12·1	11·5	10·0	8·3	5·7	3·2	3·9	5·0	6·6	8·5	10·0	10·8
	Absol. max.	32·2	30·6	28·4	26·7	23·9	21·7	20·6	26·7	30·6	31·7	31·7	31·7
	Absol. min.	4·4	2·2	1·7	2·8	-1·1	-5·5	-1·1	-0·5	-1·6	1·1	1·7	3·9

The range for Weenen is seen to be much greater, both for maxima and minima. The average of the absolute maxima for the period 1897-1908 for Weenen was 41·7° C.; for the period 1901-1905 (the only period for which records are available) for Qudeni it was 31·7° C. only: the corresponding averages for mean maxima being 29·1° and 20·0° C. The average of the absolute minima for the same period for Weenen was -5° and for Qudeni -1·7° C., the average of mean minima for Weenen being 11·6° and for Qudeni 8·0° C.

It is clear, therefore, that so far as temperature in general is concerned, two antagonistic phenomena have to be taken into consideration in dealing with mountain vegetation. The temperature of the soil, owing to the great increase in insolation, is relatively high during the daytime, and at night the soil cools rapidly owing to the increased radiation, so that the range of soil temperature is greater at high altitudes. The temperature of the air, on the other hand, decreases with rise in altitude (0·57° C. for every 100 m.), so that it is less during the daytime at high altitudes than in the valleys and lowlands, but again, owing to radiation and cold air drainage, we get an inversion of temperature at night, the valleys being colder. As regards the temperature of the air, therefore, it is the valleys that show a greater range than the mountains.

C. HUMIDITY AND PRECIPITATION.

The absolute humidity decreases rapidly with lessened pressure, and therefore with increased altitude. At a height of 2000-3000 m. (6561-9842 ft.) it is 49-35 per cent. of what it is at sea-level.¹

Cloudiness and precipitation, however, depend not on absolute but on relative humidity, i. e. the percentage of saturation of the air, and this does not as a rule necessarily vary with altitude. Very rapid variations and great extremes of atmospheric humidity are characteristic of mountain climate. The ascending currents of air bring up moisture which condenses; descending currents of air bring dryness, and these conditions often rapidly alternate. The moisture-laden winds in Natal come in from the sea, and are forced to ascend by the rising land.

Deposition takes place wherever the land rises steeply—the edge of each successive terrace first of all, and finally the Drakensberg range. The south-eastern exposures which face the rain-clouds receive the maximum amount of deposition.

During the winter dry season, when anticyclonic conditions prevail over Natal, the mountains remain for the most part clear of fog. Cold mists deposit a certain amount of moisture in the valleys, owing to the inversion of temperatures already described. In the summer rainy season, mists prevail on the mountains. The mist-belt of each mountain varies somewhat in position, the amount of mist usually, however, increasing with altitude, the base of the mountain being comparatively free from it. The rainfall behaves similarly. The zone of maximum deposition is somewhat difficult to determine, no exact observations having been made, but the vegetation itself may be safely used as an indicator.

The larger valleys remain comparatively dry during the

¹ Hann, J., *loc. cit.*

summer rainy season. The rain-clouds are carried across them without depositing moisture, and the conditions which produce valley mists in winter (calm air, clear sky, intense radiation) are not present.

As regards the diurnal variation in deposition, the forenoons commonly remain clear. Clouds begin to gather in the early afternoon, ending in a violent thunderstorm, which afterwards leaves the sky clear towards night. In connection with the humidity of mountain regions, certain other factors must be considered. Evaporation at high altitudes, owing to the diminished pressure, is greatly increased. This factor in itself has an important effect on the vegetation. The abundance of xerophytic characters seen in the vegetation is one result. During the spells of fine weather the air is not only rarefied, but also very dry.

The zones of maximum deposition naturally bear the densest vegetation. If the soil conditions are suitable, the type of plant formation is usually bush or dense scrub.

By the greater amount of transpiration thus induced, a local increase in humidity is caused as well as a cooling of the surrounding air. The water thus evaporated cannot ascend over the mountains, so it is again deposited. Mountains thus tend to keep their own moist atmosphere.

None of the mountain peaks of the Drakensberg rises above the climatic snow-line, which, in the latitude of Natal, would be about 4000 m. (13,000 ft.) or probably higher. In winter, however, the main range of mountains is frequently covered with snow for longer or shorter intervals. At exceptional times, all the foothills and the isolated peaks of the Midlands also have snow. Such snowstorms follow on atmospheric disturbances, the cause of which it is unnecessary to enter into here. They occur only rarely, at intervals of several years. The reasons for the general absence of much snow are to be found in the dryness of the atmosphere and the lack of precipitation during the cold season.

The Drakensberg, therefore, as already mentioned, shows none of the retarding effects of the melting snow

absorbing heat during spring, but when snow does fall, its melting supplies moisture to the soil and gives an earlier spring.

D. MOVEMENTS OF THE AIR.

Certain general movements of the air have already been dealt with in connection with their effect on temperature and deposition.

The moisture-laden winds blow in from the Indian Ocean during summer. There are also local winds, due to the rising of the heated air from valleys during the day-time, which blow up the valleys. Cold air drainage leads to a downward flow at night. During the winter, when there is snow on the Drakensberg, a cold wind blows down from it even during the daytime. This cold wind, however, becomes warmer by compression as it descends, so that its effect rarely extends to the coast-belt. The descent of air carries water-vapour down and leaves the mountains drier. The ascent of air leads to condensation and deposition. Since the former takes place regularly at night, the mornings are clear at the mountain tops, and the latter leads to the afternoon rains and thunderstorms, already noted.

These general movements of the air are further modified at somewhat irregular intervals by dry, hot winds, which have been variously named in different countries. Their characteristics have been fully studied in Switzerland,¹ and they are now commonly known as FOEHN winds. They are very hot and very dry, and they descend the valleys with extreme violence. Their high temperature is due to the fact that a mass of air, descending to levels where the pressure is greater, becomes heated by compression. Observations in Switzerland show that the increase is 1.0° C. for every 100 m. (cf. the average decrease of temperature with rise in altitude, which is 0.57° C. for every 100 m.). Their relative dryness follows as a result of their increased temperature. The conditions

¹ Hann, J., *loc. cit.*

which have been shown to give rise to them are as follows: A barometric depression exists at the time somewhere off the coast. The air at lower levels is drawn out towards this region, and the air from above has to descend to replace it. Their local variations depend on the complex topography which interferes with the movement of the air.

The south-eastern slopes are not affected by them to the same extent as the opposite sides of the hills, which meet their full force. Shelter and protection from the Foehn winds is a most important point in connection with the distribution of bush. The hot winds begin often from north, gradually shift to north-west and west, and then the wind veers round to the south and rain comes. Probably this is due to a gradual shifting northwards of the main barometric depression (cyclone). Hot winds are fairly general over Natal, although sometimes they are more local in their nature, caused by local barometric depressions. Though the Foehn winds may occur at any time of the year, they are most frequent and regular in their occurrence during the early spring, August and September. The ascending and descending winds are of importance also in connection with the distribution of seeds.

III. THE PLANT FORMATIONS AND ASSOCIATIONS.

The mountain region in Natal is of surpassing interest from the ecological standpoint, because here we are able to observe the birth and growth of the types of plant formation,¹ which have become more fixed and definite at the lower altitudes. It is all carried out on a magnificent scale, and the distances to be traversed in studying the different types are very great; but the succession and inter-relationships of the different plant formations is, on the whole, simple. At first it was thought advisable to divide the region into two

¹ The term "formation" is here used in the sense indicated by Warming, e.g. the "bush" (forest) of Natal is one formation, the associations, such as yellow-wood bush, being local.



zones—a lower and an upper—the upper limits of the lower zone to be taken as corresponding to the upper limits of bush and scrub, i. e. of tree-growth. The lower zone would include all the lower portion of the range from the Goodoo Pass northwards as well as the upper foothills; the upper zone would extend roughly from about 7000 ft. to the summit and include the portion of the Drakensberg from the Mont aux Sources southwards along the borders of Basutoland. However, it was found that on certain of the buttress-slopes the tussock veld extended practically to the top, even of the higher portions, so that as far as the most extensive of the plant formations (the veld) is concerned no such zonation is possible. Further, the cliff vegetation at altitudes of about 6000 ft. does not differ essentially or ecologically from that of the cliffs at the higher altitudes. Mere altitude is always an unsatisfactory basis for classification; for, as explained above, the climatic conditions at a lower altitude may be more rigorous than at a higher, and, as far as edaphic factors are concerned, more stable conditions sometimes exist at higher altitudes than at lower. It appears, therefore, that nothing would be gained, except a wrong impression, by attempting to adhere rigidly to any system of zonation. The floristic differences which one notices as one ascends will be brought out sufficiently clearly by defining as accurately as possible the limits reached by the different plant communities.

The plant formations of the mountain region include the same types, with a few exceptions, as those found in the Midlands. Each of those formations, however, are different in their composition, and ecologically, from the Midland types, and may for purposes of comparison be referred to simply as mountain types, though the prefix "mountain" will not be constantly repeated in the following descriptions. The mountain or tussock veld grades into the ordinary veld of lower altitudes and is represented on the higher hills of the Midlands as well as on the slopes and foothills of the Drakensberg. It is the most extensive type in the mountains as it is elsewhere in Natal. The Protea Veld is an interesting mountain type

not developed to any extent in the Midlands. The Mountain Bush occurs in isolated patches and ecologically contrasts somewhat sharply with the Midland Bush, though most of the species composing it—at least as far as the trees are concerned—are also found in Midland Bush. Mountain Scrub, Rocky Scrub, and the Fynbosch or Mâquis Formation are distinctive, but Vleis do not differ very much at different altitudes.

The dry valley-types of the Midlands, dominated by thorn-trees (*Acacia* spp.) and euphorbias, are not represented. On the other hand, nowhere in the Midlands do we find the magnificent cliffs such as those seen in the Drakensberg. The photographs reproduced will give some idea—though, it must be confessed, a very inadequate one—of what they are like. Many of them rise sheer for several thousand feet. True talus-slopes, such as those that occur in the Alps, are not common. What looks somewhat like them in the photographs are really buttress-slopes with a shallow layer of soil and covered with tussock-veld.

The plant formations and associations will be dealt with in the following order:

1. THE VELD FORMATION.

- (1) The veld grasses.
- (2) Associated plants and transitional types.
 - (a) Plants growing intermingled with the grasses.
 - (b) Plants occupying bare patches and rocky ground.
 - (c) Plants occupying moist places.

2. THE PROTEA VELD FORMATION.

3. ROCKY SCRUB FORMATION.

4. SCRUB FORMATION.

5. BUSH FORMATION.

6. STREAM BANK VEGETATION.

7. VLEI FORMATION.

8. VEGETATION OF THE MOUNTAIN TOP.

9. CLIFF VEGETATION.

- (1) Lithophytes.
- (2) Chomophytes.
 - (a) Exposed Chomophytes.
 - (b) Sheltered Chomophytes.
 - (c) Shade Chomophytes.
 - (d) Hydrophile Chomophytes.

10. FYNBOSCH OR MÂQUIS FORMATION.

1. THE VELD FORMATION.

The composition of the veld at high altitudes in Natal differs considerably from that of the Midlands, though most of the mountain species occur at lower altitudes also. The veld, as a whole, occupies the ground where the climatic factors are adverse to the growth of bush. Since the veld formation is the most extensive in Natal, the climate may be described as grassland climate, with local forest climate in places. The amount and distribution of the rainfall has usually been considered the climatic factor of greatest importance in determining the relationship between bush and grassland, but there are other factors as well, such as cold air drainage, protection from desiccating winds, which must be taken into consideration. These will be referred to again in the section dealing with bush.

The geological conditions of the mountain veld are the most stable of those occurring in the Drakensberg; but, of course, all mountain grassland is of a comparatively unstable type. The veld occupies the rounded foothills and outspurs, the more sloping sides of the valleys, and the flat summit of the lower portions of the main range. It extends up the buttress-slopes to an altitude of over 8000 ft. Its relationship to the underlying rock is illustrated in the sections on pages 515-517. It is the most extensive of the plant formations in the Drakensberg as well as in the rest of Natal. The soil conditions are exceedingly variable—much more so than at lower altitudes.

As a combined result of the edaphic and climatic factors,

we have certain striking differences in the general appearance and ecology, as well as in the composition of this mountain veld. Nowhere do we find the large associations dominated by a single species, which are common in the Midlands. The *Anthistiria* association, which covers so much of Natal, is not extensive. The *Andropogon* associations are fairly common, but not so characteristic of every hillside as at lower altitudes.

The Tambootie association (*Andropogon nardus* var. *marginatus*) is well developed in certain places, e.g. in the valley of the Tugela around Goodoo. Certain of the species characteristic of the Zwart Kop mountain, near Pietermaritzburg,—a type already described by the writer—assume a much greater importance on the Drakensberg.

The task of determining the exact requirements of each species represented would require a long and careful study in the field, and, consequently, a prolonged residence on the Drakensberg.

Though stress should be laid on the soil conditions in determining the relationship of the species composing the Alpine veld to one another, and in determining further the relationship of the veld to the other plant formations of the area, yet probably the explanation of the difference between this veld and that of lower altitudes is to be found rather in the climatic factors—the stronger insolation and its effect on soil temperatures; the rarefaction of the air and its greater dryness and the increased evaporation at certain seasons; the lowering of the temperature and increased radiation, etc.

In reaction to these conditions, we find the following features of Alpine veld:

(a) The grasses grow more in tufts and tussocks, the different culms thus affording one another greater mutual protection. There are bare spaces between the tufts. This gives the veld a characteristic appearance, very different from that of the *Anthistiria* veld of lower altitudes, which has a uniform, even appearance in late summer, like a cultivated field of rye-grass.

The description given by Cockayne and Laing of Tussock Steppe in New Zealand would apply fairly accurately to the mountain veld of Natal: "Seen from a distance, Tussock Steppe appears as a smooth brown carpet on the dimpled hillside. A closer view dispels the illusion, and reveals the bunched-up grass culms and leaves close together at the round base of the tussock, but spreading above and mostly dead at the apices, growing side by side, each some 40 cm. tall, in some places their leaves intermingling and in others distant, and with partially covered and more or less eroded ground between the clumps." Cf. also Volkens' description of the Alpine steppe formation on Kilimanjaro as quoted by Schimper.¹

(b) The growth-forms of the Alpine grasses are usually of a more xerophytic type. The lowest leaf-sheaths are very firm, rigid, and persistent. The character and position of the innovation shoots are of importance in this connection also. If these are intravaginal, they are protected by the close sheathing, firm and persistent nature of the leaf-bases. If they are extravaginal, they are protected by being buried in the upper layers of soil. The more protected species have the advantage, under the more unfavourable climatic conditions. In the Midlands, however, the less protected species have the advantage of quicker growth, greater vigour, and quicker assimilation, and under natural conditions gain dominance.

It is only through the artificial influence of fire—particularly too early burning—that this is turned to their disadvantage, their development being too much hastened so as to take place even in winter, when they suffer from frosts. Thus the more protected, tufted, wiry *Aristida* is ousting the *Anthistiria* even at lower altitudes. Burning the grass, therefore, seems to have an ecological effect similar to that of the adverse factors at high altitudes.

¹ Schimper, A. F. W., 'Plant Geography,' English translation, p. 738, Oxford, 1903.

(1) THE VELD GRASSES.

The following are the characteristic Alpine species found in the veld of the Drakensberg: *Harpechloa capensis*, *Microchloa caffra*, *M. altera* var. *nelsoni*, *Tristachya leucothrix*, *Trachypogon polymorphus*, *Axonopus semialatus*, *Eragrostis chalcantha*, *E. brizoides*, *E. curvula*, *Andropogon appendiculatus*, *A. schœnanthus* var. *versicolor*, *A. schirensis* var. *angustifolia*, *Trichopterix simplex*, *Kœleria cristata*, *Brachypodium flexum*, *Aristida angustata*, *Trichopterix flavida*.

These are all much more abundant at the higher altitudes, and they all show the features in their growth-forms, described above as characteristic. In addition to these, many other species occur, of which the following is a fairly complete list:

Elionurus argenteus, *Andropogon ceresiæformis*, *A. filifolius*, *A. plurinodis*, *A. hirtus*, *A. auctus*, *A. cymbarius*, *Anthistiria imberbis* (*Themeda forskalii*), *Digitaria monodactyla*, *D. diagonalis*, *D. tricholænoides*, *Panicum serratum*, *P. isachne*, *P. natalense*, *P. ecklonii*, *Setaria imberbis*, *Pennisetum sphacelatum*, *Tricholæna setifolia*, *T. rosea*, *Avenastrum turgidulum*, *A. caffrum*, *Pentaschistes natalensis*, *Agrostis lachnantha*, *A. eriantha*, *Aristida junciformis*, *A. bipartita*, *A. barbicollis*, *Perotis latifolia*, *Stipa dregeana*, *Eragrostis cæsia*, *E. chloromelas*, *E. nebulosa*, *E. superba*, *Chloris virgata*, *Ehrharta erecta*, *E. natalensis*, *Phalaris arundinacea*, *P. minor*, *Festuca scabra*, *F. costata*, *Bromus leptocladus*, *B. natalensis*.

The plant succession which culminates in the veld formation may be observed on the buttress-slopes. The talus type of plant formation, which, though not extensive, occurs on some of the steeper and less stable slopes, changes gradually by the invasion of grasses into tussock veld. The fellfield type referred to later is also transitional, and there are many

“oases” where the grasses are not dominant. On the buttress-slopes the soil, which is the direct product of the underlying lavas, is a comparatively thin layer, rarely more than a foot in depth. The slope is often very steep, yet the soil does not get washed away, though it often slips, leaving lenticular bare patches on the hillside, or a large boulder from the cliffs may become loosened and tear away a longitudinal strip of soil right down the mountain-side. On the whole, however, one is surprised at the fact that soil accumulates at all, and that the whole slope is not washed bare, as would happen in temperate or sub-arctic regions. There is no heavy covering of snow to cause landslips when it melts, and the heavy thunderstorms affect mostly the mountain-top, the water being rapidly drained off, through the numerous ravines, without disturbing the intervening buttress-slopes. The tussock grasses themselves of course help to bind the soil.

Tussock veld may also be observed invading the river-beds. In the upper parts of the river-bed, where the slope is steep, it has to compete with scrub; but lower down, as the valleys widen and the river-bed is flatter, soil accumulates, and usually the veld gains the upper hand, probably because the climatic factors, especially the valley frosts, are unfavourable to tree growth. The pioneer grasses are usually the wiry species of *Aristida* and *Koeleria cristata*. These grow in isolated tufts among the boulders, and fix a certain amount of soil. This gradually accumulates until the boulders get almost buried, and then taller and coarser species invade, e. g. species of *Andropogon*. Still lower down, the rivers form alluvial plains, and the veld is of the Low Veld type, described in former papers, with *Anthistiria* dominant.

(2) ASSOCIATED VELD PLANTS AND TRANSITIONAL TYPES.

In previous papers the writer has given somewhat extensive lists of plants which occur associated with the grasses in the veld. At the same time, it was remarked that, in typical veld consisting of pure *Anthistiria* association, they were

not so common. They were found to be more characteristic of the unstable slopes, where *Andropogon* associations marked a transitional type of veld. In the Drakensberg, where the veld is all of a semi-unstable type, the associated plants are very abundant. In spring, after the first rains, the ground is carpeted with innumerable brightly coloured flowers, especially of the herbaceous and bulbous species, while in autumn the taller suffruticose and shrubby forms meet the eye everywhere.

These associated plants increase in importance where the veld becomes more and more broken and ultimately passes into rocky scrub. In such rocky situations the grasses are often subordinate to the other plants.

On the other hand, on uniform or flat stretches which, seen from a distance, appear to be ordinary veld, a closer view shows that there are many bare patches, or moist patches, or places where there is a local variation in the soil conditions, such as small iron-pans, etc. Such small areas—they may be only a yard or two in diameter—are not occupied by grasses, but by various other species, e. g. woolly *Helichrysums* or other Composites, or in the case of the bare gravelly patches by leguminous plants, *Crassula* spp. etc. It will be seen, therefore, that species occupying such situations—broken, rocky ground or patches on the flats and slopes, which have soil conditions unsuitable for the grasses, though they occur in the area occupied by the veld formation—do not grow intermingled or intimately associated with the grasses. In many cases it is doubtful whether they should be included in the veld formation. They should rather be considered as so many oases of a distinct and transitional type.

Many of them also occur in the rocky scrub or around the margin of scrub and bush, and in such cases their transitional nature is easily seen. In the same way, those that occupy the moister patches are transitional to the vleis, and at higher altitudes the patches are transitional to the talus-slopes.

Apart, however, from the plants of these transitional types, there are a fairly large number of others that do grow more

or less isolated and intermingled with the grasses. In general it is evident that direct competition between the grasses and them is avoided by their occupying a different stratum of soil. The bulbous Monocotyledons—a characteristic South African type of growth-form—are usually veld plants of this class, and there are numerous tuberous or deep-rooted Dicotyledons included also, e. g. species of *Asclepiadaceæ*.

(A) ASSOCIATED VELD PLANTS GROWING INTERMINGLED WITH THE GRASSES.

Polygala hottentota, *Silene burchellii*, *Cerastium capense*, *Hypericum æthiopicum*, *Mahernia malvæfolium*, *Mönsonia attenuata*, *Geranium ornithopodium*, *Pelargonium aconitifolium*, *P. pulverulentum*, *P. schlechteri*, *P. flabellifolium*, *P. dispar*, *Oxalis convexula*, *Rhus discolor*, *Argyrobolium tuberosum*, *Indigofera hilaris*, *I. hirsuta*, *I. spp.*, *Buchenrœdera lotononoides*, *Melolobium cernuum*, *M. decumbens*, *Rhynchosia gibba*, *R. sp.*, *Crassula vaginata*, *Alepidea amatymbica*, *A. setifera*, *A. longifolia* var. *angusta*, *A. jacobsziæ*, *A. ciliaris*, *A. natalensis*, *A. concinna*, *Anthospermum sp.*, *Pentanisia variabilis*, *Galium rotundifolium* var. *hirsutum*, *Scabiosa columbaria* var. *dissecta*, *S. africana*, *Cephalaria attenuata*, *Nidorella depauperata*, *Helichrysum* cir. 12 spp., *Berkheya* cir. 6 spp., *Senecio* 3 or 4 spp., *Haplocarpha scaposa*, *Dicoma anomala*, *Hypochæris radicata*, *Gerbera parva*, *G. piloselloides* and other *Compositæ*, *Lobelia vanreenensis*, *Wahlenbergia zeyheri*, *Erica cerinthoides*, *Xysmalobium involucratum*, *X. parviflorum*, *X. stockenstromense*, *Schizoglossum* cir. 8 spp., *Asclepias humilis*, *A. cucullata*, *Pachycarpus* 3 or 4 spp., *Raphionacme divaricata* var. β and other *Asclepiadaceæ*, *Sebæa* cir. 5 spp., *Nemesia floribunda*, *N. melissæfolia*, *Diascia purpurea*, *D.*

cordata, *D. rigescens*, *Sutera* 3 or 4 spp., *Zaluzianskya* cir. 5 spp., *Cynium racemosum*, *Harveya coccinea*, *H. speciosa*, *Striga elegans*, *Thunbergia atriplicifolia*, *Ipomœa crassipes* var. *hirsuta*, *Selago* cir. 3 spp., *Salvia* cir. 7 spp., *Euphorbia striata*, *Acalypha punctata* var. *radula*, *Rumex ecklonianus*, *Dierama pendula*, *Morœa tricuspis*, *Aristea* cir. 3 spp., *Gladiolus* 4 or 5 spp., *Watsonia densiflora*, *Hypoxis* cir. 6 spp., *Brunsvigia cooperi*, *Cyrtanthus angustifolius*, *Buphane disticha*, *Anthericum capitatum*, *Eriospermum cooperi*, *Albuca affinis*, *A. pachychlamys*, *Eucomis undulata*, *Scilla rigidifolia* var. *nervosa*, *S. natalensis*, *Ornithogalum zeyheri* and other bulbous monocotyledons. Many of these, however, e. g. species of *Morœa* and *Aristea*, prefer the moister spots and are included in the list of those transitional to the vleis.

The *Compositæ* hold the chief place in this class, especially amongst those flowering in autumn. The bulbous *Monocotyledons* are also very abundant, their growth-forms being well adapted to the habitat. *Hemi-parasitic Scrophulariaceæ* belonging to the genera *Cynium*, *Harveya*, and *Striga* are common, their mode of nutrition making it necessary for them to grow intermingled with the grasses, which are their hosts.

(B) ASSOCIATED VELD PLANTS OCCUPYING BARE PATCHES AND ROCKY GROUND.

These are transitional to rocky scrub and also to the talus-slopes, marginal to scrub and bush. The various species may grow gregariously or may be individually somewhat rare.

Polygala virgata var. *decora*, *P. rarifolia*, *P. tenuifolia*, *Muraltia saxicola*, *M. ecornuta*, *Malva parviflora*, *Sphæralcea pannosa*, *Hibiscus leiopspermus*, *H. saxatilis*, *H. æthiopicus*, *Mahernia* sp., *Tribulus terrestris*, *Pelargonium bowkeri*,

Lotononis 6 spp., *Argyrolobium* cir. 5 spp., *Indigofera* cir. 3 spp., *Tephrosia* 2 or 3 spp., *Sutherlandia frutescens*, *Rhynchosia* spp., *Eriosema* 2 spp., *Buchenrœdera glabrifolia*, *B. sparsiflora*, *Cliffortia* 2 spp., *Crassula* cir. 12 spp., *Kalanchoe thyrsoiflora*, *Mesembryanthemum* 12 spp., *Psammotropha* 2 spp., *Oldenlandia amatymbica*, *Anthospermum* 2 spp., *Galium subvillosum*, *Vernonia* 4 spp., *Aster* 3 spp., *Heteromma* 2 spp., *Helichrysum* cir. 15 spp., *Metalsia muricata*, *Stœbe cinerea*, *Athrixia* 4 spp., *Printzia* 2 spp., *Athanasia* 2 spp., *Senecio* 11 or 12 spp., *Osteospermum moniliferum*, *Ursinea brevicaulis*, *Venidium arctotoides*, *Lobelia* 2 or 3 spp., *Cyphia* sp., *Wahlenbergia* 3 spp., *Erica alopecurus*, *E. aspalathifolia*, *E. caffrorum*, *E. drakensbergensis*, *E. lasiocarpa*, *E. natalitia*, *Royena cordata*, *Cynoglossum micranthum*, *Schizoglossum* spp., *Nemesia* spp., *Sutera* cir. 4 spp., *Zalusianskya* spp., *Buchnera dura*, *Orthosiphon macranthus*, *Syncolostemon macrophyllus*, *Plectranthus* sp., *Salvia* spp., *Achyranthes aspera*, *Arthrosolen gymnostachys*, *Herschellia baurii*, *Lasiosiphon meisnerianus*, *L. kraussii*, *Thesium* spp., *Antholyza paniculata*, *Asparagus* spp., *Aloe kraussii*, *A. minima*, *Urginea tenella*, *Eucomis humilis*, *Ornithogalum natalense*, *Commelina africana*, *Cyanotis nodiflora*, *Richardia rehmanni*.

In this transitional type, the tuberous and bulbous (geophytic) growth-form is poorly represented. The Leguminosæ play a more important part than in the veld proper, but they are not so abundant as at lower altitudes. Species of *Crassula* are numerous. The Compositæ are again very well represented and Ericaceæ also occur, especially at the higher altitudes. The type of growth-form is usually chamaephytic, the species remaining above ground during winter. Here and there, in small depressions with

fairly deep soil, the bracken fern *Pteridium aquilinum* is dominant.

In certain places, particularly at the higher altitudes, this type might be classified as FELLFIELD. Warming's description applies: "The soil is never completely covered by plants. One individual stands here and another there; between them we see bare, pebbly, stony, sandy, or clayey soil, which is devoid of humus and determines the prevailing colour of the landscape." The latter part of the description is particularly true of the type during the dry season. In the rainy season the growth is naturally somewhat more luxuriant, but the fellfield formation is never a close one. The tufted grasses which occur here and there among the other plants are more xerophytic even than in the tussock veld proper. Cushion growth-forms are more abundant here than in any of the other plant formations, especially the species of *Muraltia* and some of the *Helichrysums* and other *Compositæ*. The writer has not been able to discover any very large development of fellfield, so it is here included as subordinate to the veld formation and representing a transitional type.

(C) ASSOCIATED VELD PLANTS OCCUPYING MOIST PLACES.

These are transitional to vlei plants. Though the *Cyperaceæ*, as a whole, are found mostly in the vleis, the following prefer moist parts of the veld:

Ascolepis capensis, *Mariscus capensis*, *Bulbostylis cinnamome*, *Cyperus compactus* var. *flavissimus*, *Carex dregeana*, *Ficinia stolonifera*, *Fimbriostylis* sp.

In addition to these, the following plants belong to this class: *Hypericum lalandii*, *Trifolium africanum*, *Alchemilla woodii*, *Galium wittenbergense* var. *glabrum*, *Valeriana capensis*, *Denekia capensis*, *Senecio viscidus*, *Sebæa* spp., *Chironia krebsii*, *Wahlenbergia undulata*, *Mimulus gracilis*, *Melasma scabrum*, *M. capensis*, *Sopubia cana*, *S.*

simplex, *Bopusia scabra*, *Disa macowani*, *D. oreophila*, *D. pulchra*, *D. crassicornis*, *D. cephalotes*, *D. chrysostachya*, *Huttonæa grandiflora*, *Satyrium parviflorum*, *S. longicauda*, *S. cordifolium*, *Disparis cardiophora*, *Corycium nigrescens*, *Corycium magnum*, *Brownleea galpini*, *Habenaria bonatea* and other *Orchidaceæ*, *Moræa natalensis*, *M. spathacea*, *Aristea paniculata*, *A. montana*, *A. majubensi*, *A. sp.* near *torulosa*, *Hesperantha radiata*, *Ixia sp.*, *Geissorhiza sp.*, *Tritonia kraussii*, *Tritonia lineata*, *Acidanthera platypetala*, *Galtonia candicans*, *Antholyza paniculata*.

2. PROTEA VELD.

The Thorn Veld, where *Acacia* species grow isolated among the low-veld grasses, is absent from the Drakensberg. It reaches a fair altitude (about 4000 ft.) at the heads of the great main river-valleys, but it is not a mountain type. The thorn-trees are adapted rather to the dry, hot valley climate. Instead of the Thorn Veld we have another type on the Drakensberg, somewhat like it in certain features, but, in other respects, differing considerably, viz. the Protea Veld.

The species of *Proteaceæ* in it are not numerous. One of them, *Protea hirta*, is found at lower altitudes also, though not abundantly. The others are *Protea abyssinica*, *P. lanceolata*, *P. roupelliæ*, *P. flanagani*, *P. multibracteata*, *P. simplex*, *P. subvestita*, *Leucospermum gerrardi*. These are all small trees which, when in flower, are very handsome and the *Protea* associations may be considered the most ornamental occurring in Natal. The trees grow isolated like the thorn-trees, dotted over large areas of the veld. They are all xerophytic forms and grow fully exposed to the various adverse factors of the mountain climate. The veld in which they grow is of the tussock type, already described, with very unstable soil conditions. In this

respect the habitat differs markedly from that of the thorn veld.

The tree-fern, *Cyathea dregei*, is often fairly abundant among the Proteas, but it occurs at lower altitudes also. It requires protection when young, so it favours sheltered spots. It also demands plenty of water, so it is usually found near the streams. The dwarf *Encephalartos* (*E. ghellinchii*), a xerophytic form, is also associated. It favours rocky places, and reaches an altitude of about 8000 ft. Protea veld is most characteristic of the slopes below the Cave Sandstones, where the soil is a loose, well-aerated one, derived from the sandstones. The general distribution of the Proteas with respect to the geological formations is indicated in the figs. on pp. 515, 516, 517.

This association of tree-growth with grass land is ecologically of great interest. It shows that the factors which determine the grassland type on the one hand, and those which determine the forest type on the other, are, in the case of Natal, fairly delicately balanced. The thorn-trees of the thorn veld which covers so much of Natal, occupying as it does all the main river-valleys, represent a more progressive type than the Proteas. The tendency in that case is for the trees to close in and form thorn-thickets—a tendency which is counteracted by the grass-fires. These exercise a similar influence on the Proteas, though they are not, apart from this, such a progressive type as the Acacias. They make good firewood, and for this reason are rapidly disappearing from certain large districts.

The Proteas in Natal are not altogether confined to the Drakensberg. They occur on the Natal Table Mountain, on Murchison Flats, and at Pinetown on the Table Mountain Sandstone. The species *Faurea saligna* is common at the last-mentioned locality. Probably the explanation of their somewhat peculiar distribution is to be found in the edaphic factors. They prefer a loose, well-aerated soil, derived from sandstone which is poor in lime; and very probably the differences apparent between thorn veld and Protea veld is

largely to be explained on these grounds. Though most soils in Natal are fairly poor in lime, the low-veld soil where the *Acacia* species occur is much richer in that element than the others. It is, to a large extent, alluvial in its origin, and the lime, which has been dissolved out of the soils at higher altitudes in the dry river-valleys, is reprecipitated, often in the form of small nodules. The absence of the thorn-trees from the high veld of the Midland region may also be explained in the same way.

3. ROCKY SCRUB.

Very commonly the dominant tree in the Rocky Scrub is *Greyia sutherlandi* (Baakhout). This *Greyia* association occurs in small clumps, which are often quite isolated and surrounded on all sides by typical veld or Protea veld.

The ground is very broken, the geological conditions being of the most unstable type. There are often huge boulders and projecting masses of bare rock, around which the soil accumulates.

Typical rocky scrub has the following composition: *Greyia sutherlandi*, *Aloe natalensis*, *Royena lucida*, *R. cordata*, *Euclea undulata*, *Cliffortia linearifolia*, *Celastrus* spp., *Passerina ericoides*, *Buddleia salviaefolia*, *Phygelius capensis*, *Osteospermum moniliferum*, *Sparmannia palmata*, *Cussonia spicata*, *C. paniculata*, *Osyridocarpus natalensis*, *Hippobromus alatus*, occasional members of the Oudehout scrub described below, and a greater or less admixture of the herbaceous and shrubby species named above as occurring on the barer or rocky patches of the veld (Class B of associated veld plants, p. 537) and being transitional to Rocky Scrub.

The Proteas are often immediately adjoining in the veld, but they do not mix with the *Greyia* association (text-fig. 1). The Rocky Scrub of the lower zone has many points of similarity with the talus and ravine vegetation of the upper

zone, but with this important difference, that the larger trees are absent from the latter, being replaced by "elfin" growth-forms and shrubs.

4. SCRUB.

This is usually an association in which *Leucosidea sericea* (Oudehout) is the dominant tree, and may therefore be referred to as Oudehout Scrub. It is denser than the rocky *Greyia* type, and the separate examples of it are usually much more extensive, sometimes occupying the whole of a ravine system and extending over the hillsides.

The bed of the Tugela below the Mont aux Sources is occupied by open *Leucosidea* scrub to an altitude of about 7000 ft. It is well developed around Van Reenen's Pass (Pl. XXXVI) and other parts of the Drakensberg visited by the writer; in fact, it may be looked upon as the most extensive of the tree associations in the mountain region. In many cases the association is remarkably pure, differing in this respect from the Bush formation.

In such cases it consists of *Leucosidea sericea* dominant, with sometimes *Buddleia salviæfolia* (Sagewood or Saliehout) sub-dominant. Often, however, the association is much more mixed; the following list of species being characteristic of it: *Leucosidea sericea*, *Buddleia salviæfolia*, *Cussonia spicata*, *Heteromorpha arborescens*, *Royena lucida*, *Rhus dentata*, and several other species; *Pavetta caffra*, *Euclea undulata*, *Schmidelia africana*, *Rhamnus prinoides*, *Plectronia mundtiana*, *P. ventosa*, *Celastrus buxifolius*, *C. albatus*, *C. undatus*, *Burchellia capensis*, *Halleria lucida*, *Vangueria caffra*, *Clausena inæqualis*, *Scutia commersonii*, *Grewia occidentalis*, *Cluytia* sp., *Cliffortia linearifolia*, *C. natalensis*, *C. prostrata*, *Elæodendron* sp., *Cassinopsis capensis*, *Osyris abyssinica*, and other species.

The following lianes: *Scutia commersonii* (which some-



times also grows upright as a tree), *Rubus pinnatus*, *R. rigidus*, *Clematis brachyiata*, several species of *Vitis*, *Senecio deltoideus*, *S. macroglossus*, species of *Ipomœa*, *Dioscorea*, and *Asparagus*, *Riocreuxia torulosa* (Asclepiad).

As will be seen later, many of the species in scrub are also marginal to the bush. They are resistant to grass-fires, and certain of them regularly appear after a bush-fire, not only in the Drakensberg, but also in the Midlands of Natal, e. g. *Buddleia salviæfolia* and *Rubus pinnatus*.

The trees grow usually not more than about 6–15 ft. tall, but their spreading branches interlace, and thus it is difficult or often impossible to make one's way through the scrub. At the same time, a considerable amount of light is able to penetrate and the undergrowth is fairly rich. Underneath the boulders and in the damp krantzies and caves (the origin of which has already been described, p. 518) soil gathers and supports an assemblage of shade-loving herbs, and particularly of ferns: *Impatiens capensis*, *Begonia natalensis*; numerous species of *Streptocarpus*, Acanthaceous herbs, *Plectranthus* spp., *Stenoglottis fimbriata*, *Agapanthus umbellatus*, *Doryopteris elongata*, *D. athamantica*, *Asplenium lunulatum*, *A. protensum*, *A. monanthes*, *A. bipinnatum*, *Adiantum æthiopicum*, *A. capillus-veneris*, *Polypodium vulgare*, *P. lineare*, *P. lanceolatum*, *P. polypodioides*, *Ceterach cordatum*, *Mohria caffrorum*, *Pellæa viridis*.

5. BUSH.

The climax type of tree vegetation—the Bush—occupies the most favourable situations, where there is (a) maximum deposition of moisture, (b) rapid cold-air drainage and therefore absence of frosts, (c) shelter from desiccating winds, (d) suitable soil conditions and exposure. The situations which fulfil all these conditions are the south-eastern slopes and shallow depressions with a sufficient gradient. Bush is

absent from the part of the range which faces north-east from Cathkin Peak to the Mont aux Sources. This is relatively a stable type. As is the case elsewhere in Natal, resulting from man's interference and reckless destruction as well as from grass-fires, this bush is often rapidly disappearing, yet the natural ecological succession is rocky scrub—scrub—bush.

The following may be taken as the typical composition of the Drakensberg bush. The trees composing it are named in the order of their ecological importance :

- Podocarpus thunbergii*, *Podocarpus elongata*,
Podocarpus falcata (Yellow-woods).
- Celtis kraussiana* (Camdeboo Stinkwood).
- Kiggelaria dregeana* (Natal Mahogany).
- Toddalia lanceolata* (White Ironwood).
- Scelopia ecklonii* (Red Pear).
- Myrsine melanophleos* (Beukenhout).
- Ptæroxylon utile* (Sneezewood).

Of less importance :

- Calodendron capense* (Wild Chestnut).
- Xanthoxylon capense* (Knobwood).
- Pygeum africanum* (Red Stinkwood).
- Olea laurifolia* (Ironwood).
- Olinia cymosa* (Hard Pear).

O. cymosa is quite abundant, but usually somewhat outside the bush : it often reaches fairly high altitudes. The trees mentioned above are all important timber trees.

The following are of less economic importance :

Pleurostyliia capensis, *Elæodendron* spp., *Cryptocarya acuminata*, *Schmidelia monophylla*, *Trimeria alnifolia*, *Apodytes dimidiata*. The presence of such species as *Calodendron capense*, which is easily killed by frost, shows how important it is to have a sufficient gradient to secure rapid cold-air drainage. Frosts regularly occur below the bush. *Calodendron*, *Celtis*, and *Ptæroxylon* are deciduous forms.

Around the margin of the bush we have the following *Buddleia salviæfolia*, *Halleria lucida*, *Rhus* dis-

color and *Rhus* spp., *Schmidelia africana*, *Cluytia* sp., *Heteromorpha arborescens*, *Euclea undulata*, *Celastrus buxifolius*, *C. acuminatus*, *C. undatus*, *Pterocelastrus* sp., *Plectronia mundtiana*, *P. ventosa*, *Hippobromus alata*, *Cryptocarya acuminata*, *Royena lucida*, *Clausena inequalis*, *Rhamnus prinoides*, *Burchellia capensis*, *Grewia occidentalis*, *Leucosidea sericea*, *Cliffortia* spp., *Arundinaria tessellata*, and various lianes, *Scutia commersonii*, *Rubus pinnatus*, *R. rigidus*, *Clematis brachchiata*, *Senecio* spp., *Ipomœa* spp., *Dioscorea* spp., *Vitis capensis*, *Strophanthus capensis*.

In its floristic composition and ecology the marginal belt is very similar to the scrub—a fact which indicates the succession mentioned above. The undergrowth of herbs is not so abundant in point of numbers as that of the scrub, but it contains more or less the same species with such additions as: *Disperis fanninæ*, *Oxyanthus* sp., *Asparagus* sp., *Pteris cretica*, *P. dentata*, *P. biauriata*, *Cystopteris fragilis*, *Asplenium theciferum*, *A. præmorsum*, *A. cuneatum*, *Cyrtomium falcatum*, *Polystichum aristatum*, *P. aculeatum*, *Trichomanes pyxidiferum*, *Lycopodium verticillatum*, *L. gnidioides*, *Selaginella kraussiana*.

Comparing this Drakensberg bush with that of the Midlands, we note the following facts. The trees are gnarled and weather-beaten and often covered with bearded lichens; the deciduous tendency is increased; there is less undergrowth of shrubs; lianes are confined to the margin for the most part; the composition of the marginal belt differs considerably; epiphytes are not abundant, but species of *Angræcum* and *Polystachya* occur.

The need for greater protection is seen in a general decrease in size of the species. The Yellow-wood is often much dwarfed as compared with that in the Midland Bush. In most of the bush the lower portion is evergreen and denser, the upper portion is more deciduous, and the grasses tend to invade it.

Where streams, as they usually do, flow through the bush, the evergreen growth is denser near them, while the deciduous type favours the ridges in the bush. It must not be supposed that the composition given above applies to each separate patch of bush on the Drakensberg. It is meant to represent a composite type, with the species named in the order of their importance.

The actual and relative abundance of the different species varies at different places, and in some bushes certain important species may not be represented. The ecological nature varies in the same way. The Yellow-woods are most constant and most frequently dominant. Being an evergreen type, the canopy remains a close one and there is little undergrowth.

In bushes where the deciduous types become dominant, the canopy is more open, and the undergrowth, including grasses, more abundant. Such bushes, therefore, are similar to the upper portion and higher ridges of the larger bush areas. The following series of examples gives a fairly complete picture of the actual distribution of the Drakensberg forests:

(1) Overwood Bush, Polela, 4000–5000 ft. (1218–1524 m.).

Podocarpus thunbergii, *Podocarpus elongata*, *Celtis kraussiana*, *Ptaeroxylon utile*, *Xanthoxylon capense*, *Kiggelaria dregeana*, *Pygeum africanum*, *Calodendron capense*, with *Oudehout* and *Cliffortia* around the margins.

(2) From Tugela Falls to Olivier's Hoek Pass, several scattered patches of bush, cir. 5000 ft. (1524 m.).

Olinia cymosa, *Toddalia lanceolata*, *Royena lucida*, *Myrsine melanophleos*, *Ilex capensis*, *Elæodendron* sp. (um Nai), Yellow-wood (dwarfed), *Odina caffra*, *Bersama abyssinica*, *Cryptocarya acuminata*, *Scolopia mundtii*, *Euclea* sp., *Schmidelia* sp., *Grewia* sp., *Carissa arduina*, *Trimeria*

¹ In the other forests of the Polela district the Falcate Yellow-wood (*Podocarpus falcata*) is dominant.

alnifolia, *Rhamnus prinoides*. One of the poorer types. The Protea veld is particularly well developed in this portion of the range.

(3) North of Van Reenen's Pass, 5000-5500 ft. (1524-1677 m.).

Podocarpus thunbergii, *Podocarpus elongata*, *Myrsine melanophleos*, *Apodytes dimidiata*, *Scolopia ecklonii*, *Olinia cymosa*, *Olea laurifolia*, *Celtis kraussiana*, *Calodendron capense*, *Toddalia lanceolata*, *Kiggelaria dregeana*, *Chilianthus arborea*, *Plectronia spinosa*, *Halleria lucida*, with *Leucosidea* and *Buddleia* abundant around the margins.

(4) In the kloofs and south-east slopes of the Drakensberg facing Newcastle, 5000-6000 ft. (1524-1829 m.).

Podocarpus, both species. *Calodendron capense*, *Celtis kraussiana*, *Olinia cymosa*, *Scolopia ecklonii*, *Kiggelaria dregeana*, *Toddalia lanceolata*, *Celastrus* spp., *Elæodendron* spp., *Myrsine melanophleos*, *Cryptocarya acuminata*, *Xanthoxylon capense*, *Plectronia mundtiana*, *P. spinosa*, *Schmidelia africana*. *S. sp.*, and most of the other marginal species given above. Below the bush here, *Acacia horrida* and other *Acacia* species appear. *Protea* species (*Protea lanceolata* and *P. hirta*), on the other hand, form *Protea veld* above the bush.

(5) Near the Transvaal border at Majuba a forest of similar composition, but of still more stunted growth. Below this bush there is *Acacia veld* again—the beginning of the Thorn veld—which continues down the valley of the Buffalo River.

6. STREAM BANK VEGETATION.

Along the streams at fairly high altitudes (up to about 7000 ft.) *Ilex capensis* (Waterboom), *Ficus capensis*, *Myrsine melanophleos*, *Myrica æthiopica*, *Panax gerrardi*, *Erica caffra*, *E. cooperi*, *E. schlechteri*, *Arundinaria tessellata*, *Rhus* spp., *Aberia tristis*,

Vangueria lasiantha, with dwarfed Yellow-woods and occasional other trees of bush and scrub, form a distinct type.

In places, the interesting *Widdringtonia cupressoides* (the Berg cypress) occurs in similar situations. The stream bank type also includes the following associated plants: *Argyrobium marginatum*, *Psoralea pinnata*, *Bowkeria gerrardiana*, *Athanasia punctata*, *Schizostylis coccinea*, *Artemisia afra*, *Melianthus* sp., *Phygelius æqualis*, *Indigofera hedyantha*, *Geranium ornithopodum*, *Gomphostigma scoparioides*.

In the stream-bed itself, growing among the boulders, we have such species as the following: *Indigofera schlechteri*, *Hibiscus* sp., *Aster filifolius*, *Stœbe cinerea*, *Senecio tanasetoides*, *Osmites* sp., *Helichrysum splendidum*, *H. tenuifolium*, *H. reflexum*, *Gerbera* sp., *Valeriana capensis*, *Sutera* sp., *Zalusianskya goseloides*, *Ajuga ophrydis*, *Lessertia perennans*, *Selago flanagani*, *Scilla concinna*, *Ornithogalum* sp., *Juncus dregeanus*, *Carex petitiana*, and other Cyperaceæ, with grasses such as *Aristida* species, *Kœleria cristata*, *Agrostis lachnantha*, *Elionurus argenteus*, *Tricholœna setifolia*, *Andropogon nardus* var. *prolixus* and other species, *Imperata arundinacea*, *Pennisetum thunbergii*, *Arundinella ecklonii*, *Eragrostis nebulosa*, *Stiburus alopecuroides*, and the ferns *Elaphoglossum spathulatum*, *Dryopteris bergiana*, *Blechnum attenuatum*, *B. punctulatum*, *Cyclophorus africanus*.

The *Leucosidea* scrub and the veld occupy the habitat in many places in the manner described above.

7. VLEIS.

Seeing that drainage is so good, vleis are nowhere of great extent, and where they do occur the water is rarely stagnant. Marshy spots along the stream-banks have the same types of

vegetation. The Cyperaceæ are usually dominant, so that most of the vleis at high altitudes may be classed as *Cyperus* vleis. The associated plants include a large number of orchids and other monocotyledons.

The following is a list of Cyperaceæ that occur:

Pycreus umbrosus, *P. flavescens*, *P. macranthus*, *P. ferrugineus*, *P. angulatus*, *P. rehmannianus*, *Kyllinga melanosperma*, *Cyperus fastigiatus*, *C. marginatus*, *C. natalensis*, *C. schlechteri*, *Mariscus congestus*, *M. deciduus*, *Eleocharis limosa*, *Fimbristylis* sp., *Scirpus fluitans*, *S. hystrix*, *Ficinia stolonifera*, *Rhynchospora glauca*, *Ascolepis capensis*, *Scleria woodii*, *Carex esenbeckiana*, *C. spicataniculata*, *C. drakensbergensis*, *C. phacota*, *Bulbostylis* sp.

The following are also vlei plants:

Ranunculus cooperi, *R. baurii*, *R. meyeri*, *Nasturtium fluviatile*, *Geranium pulchrum*, *Epilobium flavescens*, *Agrimonia eupatoria* var. *capensis*, *Gunnera perpensa*, *Lythrum* sp., *Sium thunbergii*, *Alchemilla capensis*, *Sopubia cana*, *Veronica anagallis*, *Limosella aquatica*, *L. major*, *L. longiflora*, *Myosotis afropalustris*, *Mentha aquatica*, *Callitriche bolusii*, *Polygonum serrulatum*, *Rumex ecklonianus*, *Satyrium atherstonei*, *S. neglectum*, *S. macrophyllum*, *S. parviflorum*, *S. cristatum*, *S. ocellatum*, *S. sphærocarpum*, *Disa frigida*, *Disperis wealii*, *D. venusta*, *D. tysoni*, *Pterygodium hastatum*, *P. magnum*, *P. sp.*, *Brownleea cærulea*, *Brachycorythis pubescens*, *Huttonæa oreophila*, *Kniphofia* (several species), *Eucomis* sp., *Anoiganthus brevifloris*, *Comelina* sp., *Luzula africana*, *Juncus effusus*, *J. glaucus*, *J. exsertus*, *Eriocaulon baurii*, *Aponogeton natalense*, *Xyris* sp., and the grasses, *Stiburus alopecuroides*, *Setaria imberbis*, *Pennisetum thunbergii*, *Eragrostis nebulosa* (sometimes dominant).

8. VEGETATION OF THE MOUNTAIN TOP.

At high altitudes we have a type of soil and plant formation which differs from the tussock veld found on the tops of the lower foothills. The top of the main Drakensberg escarpment is, on the whole, flat, but there are fairly large depressions and bare portions which are higher. The detritus occurring on the mountain top recalls that which is formed on the mountains of Scotland, described by Crampton¹ in his memoir on the vegetation of Caithness. It is formed in situ, and in Scotland, according to Crampton, is due chiefly to the action of frost and wind. On the Drakensberg these factors are in action also, and, in addition, probably the intense insolation, which, as has been already pointed out, leads, through the rarity of the air, to great heating of the surface, and the sudden cooling by thunderstorms must be taken into consideration as an important factor, the heated rock-surface being shattered by the sudden cooling. The alternate freezing and thawing during the colder season and the percolation of water continue the process of disintegration.

The débris consists of rather small, angular fragments of the underlying rock (amygdaloidal lavas), and forms a spongy, porous layer from about 4 in. to a foot or two in thickness in the depressions. On the higher, bare portions it continues to be formed. After a rainstorm it appears as a wet, oozing mass with innumerable rivulets; but the water runs off, and it dries very quickly. Some of the deeper hollows, however, remain permanently wet, and in winter the water becomes frozen into a mass of ice.

The vegetation is partly of an extremely xerophytic character, the growth-forms being designed to give the greatest possible protection. The rhizomes and shoots intertwine to form low mats, and in places a certain amount of black humous soil is formed among the heathers. On the bare rocks we get lithophytes and chomophytes, as described

¹ Crampton, C. B., "Vegetation of Caithness considered in relation to the Geology," 'Brit. Veg. Comm.', 1911.

for the cliffs. In the wet spots, Cyperaceæ and other marsh plants occur. There is, therefore, considerable variation in the type of vegetation. On the whole it may be described as a mixture of heathers and Compositæ, with tufted grasses and a variety of other associated plants. The Ericaceæ include *Erica algida*, *E. woodii*, *E. frigida*, *E. caffrorum*, *E. oatesii*, *E. alopecurus*, *E. thodei*. Among the Compositæ, the genus *Helichrysum* is again much in evidence, the following species being recorded: *H. trilineatum*, *H. chionosphærum*, *H. elegantissimum*, *H. subglomeratum*, *H. fulgidum*, *H. cymosum*, *H. album*, *H. alticolum* var. *montanum*, *H. calocephalum*, *H. cooperi*, *H. flanagani*, *H. randii*, *H. setigerum*, *H. aureo-nitens* (in wet places), *H. re-tortoides* (rocky places).

Other Compositæ: *Aster uliginosus*, *Vernonia natalensis*, *Felicia drakensbergensis*, *F. pinnatifida*, *Athrixia fontana*, *Eumorphia sericea*, *Senecio barbatus*, *S. gramineus*, *S. seminivea*, *S. tugelensis*, *S. reptans*, *Euryops montanus*, *Dimorphotheca caulescens*, *Ursinia montana*, *Berkheya* (*Stobœa multi-juga*), *Macowania glandulosa*.

Other orders: *Heliophila subulata*, *Lessertia flanagani*, *Geum capense*, *Guthriea capensis*, *Mesembryanthemum nubigenum* (rock fissures), *Crassula rubescens*, *Alepidea thodei*, *Psammotropha myrianthus*, *Wahlenbergia depressa* (wet rocks), *Sebœa marlothii*, *S. procumbens*, *S. spathulata*, *S. thomasii*, *Sutera crassicaulis* var. *purpurea*, *Zaluzianskya montana*, *Z. flanagani*, *Ornithogalum flanagani*, *Androcymbium natalense*, *Wurmbea kraussii*, *W. pusillus*, *Hypoxis rubella*, *Syringodea flanagani*, *Romulea thodei*, *Commelina africana*, and in the marshy spots, *Aponogeton spathaceum*, *Luzula africana*, *Cyperus flava*, *Scirpus falsus*, *Carex drakensbergensis*.

9. CLIFF VEGETATION.

Following Oettli,¹ we divide this type into Lithophytes and Chomophytes, the former being exclusively cryptogamic and consisting of algæ, lichens, and bryophytes, which colonise the bare rock faces, and the latter being the plants of the rock ledges and crevices. Much further collecting and naming of species must be done before the ecology of this type can be adequately dealt with. Collections have been made by the writer and sent to various specialists, but some time must elapse before they can be worked up. Nor has it been possible to touch more than the fringe of the subject, even in so far as concerns the work of exploration. An outline of the ecological classification is given so far as present information permits, but as our knowledge increases further subdivision will doubtless be possible.

LITHOPHYTES.

The first plants to invade the bare rock faces are various blue-green algæ. The associations of these cover enormous areas of the cliffs, especially the cave-sandstone cliffs, and are strikingly apparent from a distance as longitudinal black strips. By the invasion of fungi, they are changed into lichen associations, giving a variety of colours to the rock face—black, green, yellow, red, grey, or white—but the lichen associations, though probably much more numerous in point of species, are not of such importance ecologically nor, as far as the writer's observation goes, nearly so extensive as the associations of Cyanophyceæ.

With regard to a portion of the Drakensberg collection made by the writer, Dr. Fritsch writes as follows :

No. 104 (Goodoo Pass, 6000 ft. September 19th, 1915).

This is a composite growth of Cyanophyceæ, consisting in the main of four forms, viz. *Stigonema informe* Kütz., forma; *S. hormoides* Bornet et Flahault, forma; *Schizothrix epiphytica* n. sp.; *Glæocapsa sanguinea* Kütz. These appear to form an inti-

¹ Oettli, M., 'Beiträge z. Ökologie der Felsflora,' Zurich, 1905.

mate association or what I have called a "consortium" (cf. Fritsch in 'New Phytologist,' 1906, p. 158). As far as I can make out the *Glœocapsa sanguinea* has been the first arrival, the two species of *Stigonema* developing upon this early growth. In the present material a good deal of the *Glœocapsa* looks moribund, although a considerable number of fresh and vigorous colonies are to be found among the tangles of *Stigonema*. Of the two species of *Stigonema*, *S. hormoides Bornet et Flahault* forma has the upper hand and is more abundant. *S. informe Kütz.* forma is suffering largely from the growth of *Schizothrix epiphytica n. sp.* This, which would appear to be the most recent arrival, has in many places almost completely enshrouded threads of the *Stigonema* with its red coiling filaments. Between the upright branches of *S. informe* and the *Schizothrix* a struggle for supremacy is going on, analogous to that described by me on p. 540 in my paper in the 'Geographical Journal.'¹

If the sequence of forms just outlined is correct, it ought to be possible to find patches of the rock just colonised by the *Glœocapsa*, perhaps with a thin growth of *Stigonema* commencing on top. Or a small patch of the rock surface might be laid bare and the succession of growth upon it studied on the spot.

No. 105 (Tugela Gorge, 7000 ft.).

A somewhat similar growth to the last, consisting of the same two species of *Stigonema*; *Calothrix parietina* (Naeg.) Thun. var. *africana nov. var.*; *Schizothrix muelleri* Naeg., and *S. epiphytica n. sp.*; *Glœocapsa sanguinea Kütz.*

The last mentioned is again in all probability the first form, being followed by the two species of *Stigonema* and the *Calothrix*, all three being about equally balanced. Both species of *Schizothrix* are uncommon and *S. epiphytica* is not nearly as developed as in No. 104, but it is quite probable that at other points it may attain to the same degree of importance.

No. 133 (Goodoo Pass, 6000 ft.).

This is a practically pure growth of *Calothrix parietina* (Naeg.) Thun. var. *africana nov. var.* It has undoubtedly settled down on a growth of some unicellular member of the *Cyanophyceæ*, the remains of which are still visible, but they are not sufficiently definite to admit of determination.

The samples dealt with by Dr. Fritsch were taken from the

¹ Fritsch, F. E., "The Rôle of Algal Growth in the Colonisation of New Ground and in the Determination of Scenery," 'Geog. Journ.,' November, 1907.

cliffs in the Drakensberg at points many miles apart, so that it will be seen that the succession indicated is a very extensive one, and probably it extends throughout the whole range. During the dry weather the algal covering dries up and peels from the rock in small flakes, but it does not disappear to any great extent or leave the rock again bare.

Different types may be recognised, representing various stages in the succession, as follows:

(1) Cliffs.—Dry, sunny cliffs, or freshly broken rock surfaces, completely devoid of vegetation.

(2) Cliffs which remain almost but not quite dry. Blue-green algæ and lichens form a hard encrustation which can be scraped off with difficulty.

(3) Cliffs which mostly remain dry, but are occasionally completely wet. The Cyanophyceæ, which become slimy when wet, and lichens continue here, also bryophyta, both mosses and hepatics, begin to invade. Sub-types may be distinguished according to whether the cliffs receive much or little light. The following species were collected by the writer in the Mont aux Sources region and identified by Mr. T. R. Sim:

HELIOPHILOUS SPECIES.—*Campylopus chlorotrichus* C. M., *Grimmia apocarpa* Hedw., *Tortella cæspitosa* Scav., *Brachymenium pulchrum*, *Andreaea* sp., *Campylopus* sp. (*sp. nov.*).

OMBROPHILOUS SPECIES.—*Plagiochila corymbulosa* Pears., *P. javanica* N. & M., *Thuidium tamariscinum* Hedw., *Macromitrium lycopodioides* Burch. (also Epiphytic on trees), *Frullania diptera* Nees., *Brachythecium* sp., *Orthotrichum* sp., *Didymodon* sp. *nov.*?, *Hypnum cupressiforme* L., *Bryum stellipilum* C. M., *Rhodobryum syntrichioides* (C. M.) Par.

(4) Rock Flushes.—The substratum is here continually, or almost continually, wet, like it is near minor waterfalls, etc., where the water trickles over the rock face. Blue-green algæ are again found in places where there is continual drip, particularly in sunny situations. Collections of these have

been sent to Dr. Fritsch for identification. There is great variety of Bryophyta, of which the following were collected chiefly in the Tugela Gorge at an altitude of 6000-7000 ft.:

Papillaria floribunda *C. M.*, Papillaria sp., Philo-notis sp., Lejeunea flava *L.*, Weisia viridula *L.*, Rhodobryum syntrichioides *C. M.*, Fissidens taxifolius (*L.*), *Hedw.*, Brachythecium sp., Fimbriaria marginata *Nees.*, Thuidium angustifolium *Jaeg.*, Madot-*theca capensis G.*, Lejeunea (*Ptycholejeunea*) striata *Nees.*, Plagiochila spinulosa (*Dicks.*) *Dum.*, Mnium punctatum *L.*, Bryum umbraculum *Burch.*, *B. bimum Schreb.*, Tortella caespitosa (*Schw.*) *Lempr.*

CHOMOPHYTES.

The general habitat for this class is the rock crevices and rock ledges, and, seeing that the amount of soil, moisture, light, etc., and degree of exposure vary considerably, it is possible to subdivide to as great an extent as one pleases. Probably almost every species differs in its exact requirements. Smith,¹ in dealing with the Arctic-alpine vegetation of Scotland, adopts a provisional grouping of the different habitats, which is used here with slight modifications.

(A) EXPOSED CHOMOPHYTES.

The habitat in this case is a rock ledge which receives full insolation, and where there is no great depth of soil. The plants are fully exposed to the adverse factors of the environment, as given in detail above, and, consequently, show extreme xerophytism.

Very dense woolly coverings are seen in the species of *Helichrysum*, succulence in the *Crassulas*, and reduction of leaf surface in the *Passerinas* and *Ericas*. Root

¹ Smith, W. G., Chap. xiii, 'Types of British Vegetation,' ed. by Tansley (Camb. Univ. Press).

systems are usually fibrous and well developed, and extend into the fissures to obtain the necessary moisture.

The following species are characteristic: *Muraltia saxicola*, *Crassula* several species, *Helichrysum fulgidum*, *H. fulgidum* var. *nanum*, *H. sutherlandi*, *H. chionosphærum*, *H. hypoleucum*, *H. confertum*, *H. setosum*, *Othonna natalensis*, *Felicia* sp., *Erica caffrorum*, *E. cerinthoides*, *E. spp.*, *Passerina filiformis*, *Hypoxis baurii*, *Polystachya othonniana*, *Litanthus pusillus*, *Piperomia reflexa*, *Ficus* sp. (*sp. nov.?*).

The following Pteridophyta: *Asplenium platyneuron*, *A. adiantum-nigrum*, *A. cuneatum*, *Blechnum australe*, *B. inflexum*, *Pellæa hastata*, *Notholæna eckloniana*, *Cheilanthes hirta*, *Mohria caffrorum*, *Polypodium vulgare*, *Selaginella rupes-tris*, and some of the lithophilous mosses and hepatics.

(B) SHELTERED CHOMOPHYTES.

In this type we have much deeper, firmer, and moister soil in the crevices, and the plants are sheltered and consequently grow more luxuriantly. They are more massed together and are of a more mesophytic type. Bulbous forms are characteristic, and often the root system of these consists of long, tough fibres. The species composing this class probably vary considerably in different localities, and further exploration will add to their numbers. Many of the plants included in the list of those belonging to the Fynbosch formation are sheltered chomophytes. The following is a list of species belonging to this class: *Sutherlandia frutescens*, *Helichrysum tenuifolium*, *Aster filifolius*, *Gerbera* sp., *Stœbe cinerea*, *Geum capense*, *Rumex woodii*, *Guthriea capensis*, *Selago flanagani*, *Zaluzianskya goseloides*, *Z. montana*, *Cluytia affinis*, *Scilla natalensis*, *S. kraussii*, *Cyrtanthus* sp., *Hæmanthus hirsutus*, *Tulbaghia leucantha*, *Bar-*

bacenia viscosa, *Ixia* sp., *Gladiolus saundersii*, *Woodsia burgessiana*, *Athyrium scandicinum*, *Mohria caffrorum*, *Polypodium lanceolatum*, *Selaginella depressa*.

(C) SHADE CHOMOPHYTES.

This type differs from the last chiefly in the deficiency of light. Flowering plants are poorly represented, while mosses and ferns are more abundant and characteristic. The greater shelter leads to greater atmospheric humidity, and the plants are therefore of a distinctly mesophilous type. It is not always possible to separate shade chomophytes from the hydrophilous, but the latter are not necessarily shaded.

The following are characteristic species :

Flowering plants.—*Streptocarpus pusilla*, S. spp., *Nemesia foetens* var. *latifolia*, *N. flanagani*, *Plectranthus* sp., *Piperomia reflexa*, *Wahlenbergia montana*, and seedlings of other plants which do not commonly survive.

Pteridophyta.—*Ceterach cordatum*, *Doryopteris concolor*, *Adiantopsis capensis*, *Athyrium scandicinum*, *Selaginella depressa*.

Bryophyta.—*Fissidens taxifolius* (L.) Hedw., *F. bryoides* Hedw., *Calypogeia bidentata* Nees., *Weisia viridula* L., *Weisia* sp. nov. (*W. bewsii* Sim. MSS.), *Weisia* sp. (mixed with last mentioned, but different), *Bryum bimum* Schreb., *Rhodobryum syntrichoides* (C. M.) Par., *Encalypta* sp., *Brachythecium* sp., *Fimbriaria marginata* Nees., *Lejeunea flava* L., *Lepidozia* sp.

(D) HYDROPHILOUS CHOMOPHYTES.

The habitat here is constantly wet. Innumerable streamlets form a network over the faces of the cliffs and the sides of the ravines. The amount of water in them varies greatly.

During the dry season they may dry up altogether, but

after rain-storms they become small torrents. Springs emerge at different altitudes, and in places small alpine bogs are formed. The algæ, mosses, and hepatics already described under the heading of Rock Flushes are characteristic and abundant. Some of the vlei plants of the lower mountain zone occur sporadically at high altitudes and must also be included as hydrophilous chomophytes. The hydrophile type of chomophyte, therefore, forms an interesting transition to the vlei formation of lower altitudes.

The following are representative examples of this type :

Flowering Plants.—*Ranunculus baurii*, *R. cooperi*, *Helichrysum* sp., *Eumorphia sericea*, *Sebæa thomasii*, *Streptocarpus* sp., *Xyris* sp., *Bulbostylis* sp., together with many included in the list of vlei plants.

Pteridophyta.—*Hymenophyllum tunbridgense*, *Cystopteris fragilis*,¹ *Dryopteris bergiana*, *Blechnum attenuata*.

Bryophyta.—*Anomobryum filiforme* *Dicks.*, *Bryum afro-turbinatum* *C. M.*, *Fissidens taxifolius* *Hedw.*, *Riccia fluitans* *L.*, *Fossombronia leucoxantha* *L. & G.*, *Fimbriaria marginata* *Nees.*, *Anthoceros punctatus* *L.*, *A. natalensis* *Sim MSS.*, *Lejeunea flava*, *Encalypta* sp., *Aneura fastigiata* *L.*

10. FYNBOSCH OR MÂQUIS FORMATION.

On part of the main escarpment we get slopes which are too steep for veld, though the cliffs are not quite sheer. A loose soil accumulates with boulders and stones interspersed, and the underlying rock is frequently exposed. Rocks often become loosened and roll down into the nearest ravine. Some of the ravines are small and narrow ; others form great gorges

¹ W. G. Smith includes *Cystopteris fragilis* under shade chomophytes, which is true for Britain with its wetter climate. In Natal it prefers moister localities, and is here included, therefore, under hydrophilous chomophytes.

with steep sides which are covered with this loose débris, while the bottom is filled with enormous boulders, below and over which the mountain stream flows, the water being beautifully clear and very different from the muddy streams of the Midlands. The open talus-slopes receive the greatest amount of insolation, while the smaller ravines vary according to their exposure. There are places which never receive any direct sunlight and are inhabited by shade or hydrophilous chomophytes.

In some of the larger ravines we find trees belonging to the scrub or stream bank types already described, e. g. *Myrsine melanophleas*, *Vangueria lasiantha*, *Cussonia spicata*, *Pterocelastrus* sp., *Excœcaria* sp., and dwarfed yellow-woods. Up to about 7000 ft. *Leucosidea sericea* often dominates.

In the upper ravines, however, and on the loose talus-slopes, we get vegetation consisting of low sclerophyllous shrubs, seldom more than a few feet high, commonly with ericoid and pinoid leaves. Other xerophytic modifications, such as woolly coverings of hairs, are fairly common, especially among the smaller species, and the root systems of all are extensive and fibrous. The mesophytic and hydrophilous chomophytes already described are, however, mixed, and many of the species belonging to this type could be classified among the chomophyte vegetation. This sclerophyllous type is similar to that which is much more extensively developed in the south-western region of Cape Colony, and since it closely resembles the *Mâquis* (*Macchia*) of the Mediterranean region it has been described for Cape Colony under that name by Schimper, Warming, and more recently and in greater detail by Marloth.¹ The Dutch apply the term *Fynbosch* to it in South Africa, and this term is here adopted. The preservation of such local designations serves a very useful purpose in distinguishing the separate developments in different countries of what is essentially the same type, and it is probably better to retain South African names

¹ Marloth, R., 'Das Kapland,' Fischer (Jena, 1908).

for the different formations, e. g. Veld, Vlei, Bush, Fynbosch, etc., rather than to introduce terms from other countries, such as Savannah, Steppe, etc.

Sclerophyllous plant formations like Fynbosch are known as Chaparral in California, Espinal in Chile, and different varieties of the Mediterranean Mâquis are described by Warming.¹ In places in the Drakensberg, Fynbosch appears to be similar to the Mediterranean Garigue. On the exposed slopes, Warming's description of Garigue applies exactly.² "The rocks often lie exposed; but small shrubs ($\frac{1}{2}$ - $1\frac{1}{2}$ metres in height), undershrubs and herbs seize upon the soil and clefts of the rocks, and despite their seeming scantiness, deck these in motley array." Like the Garigue and Mâquis, the Fynbosch is transitional between fellfield and woodland. It has many species in common with the mountain-top vegetation.

The most characteristic species are: *Cliffortia linearifolia*, *C. natalensis*, *C. serrulata*, *C. sp. nov.*, *Myrsine africana*, *Passerina filiformis*, and other species, *Phyllica paniculata*, *Metalasia muricata*, with a great variety of others, of which the *Compositæ* and the *Ericaceæ* are the most prominent. The following list is given partly as the result of the writer's observations and partly taken from other records.

COMPOSITE.—*Helichrysum randii*, *H. trilineatum*, *H. adenocarpum*, *H. fulgidum* var. *monocephalum*, *H. hypoleucum*, *H. retortoides*, *H. appendiculatum*, *H. lanatum*, *H. album*, *H. sutherlandi*, *H. sessile*, *H. infaustum*, *Aster perfoliatus*, *Felicia drakensbergensis*, *F. lævigata*, *F. amelloides*, *Osmites sp.*, *Gymnopentzia pilifera*, *Pentzia cooperi*, *Athanasia montana*, *A. thodei*, *Eumorphia sericea*, *Heteromma simplicifolia*, *Printzia laxa*, *Euryops evansii*, *Athrixia angustissima*, *A. gerrardi*, *A. elata*, *A. piniifolia*, *Cenia hispida*, *Schistostephium cratægifo-*

¹ Warming, E., 'Plant Ecology,' p. 306.

² *Ibid.*, p. 304.

lium, *Senecio tugelensis*, *S. evansii*, *S. macrocephalus* var. *hirsutissimus*, *S. drakensbergensis*, *S. tanacetoides*, *Berkheya grandiflora* var. *alternifolia*, *B. speciosa*, *B. radula*, *B. evansii*, *B. (Stobœa) purpurea*, *Gerbera ambigua*, *G. parva*, *Dicoma anomala* var. *circioides*, *Dimorphotheca nudicaulis* var. *latifolia*.

ERICACEÆ.—*Erica algida*, *E. flanagani*, *E. schlechteri*, *E. oatesii*, *E. caffrorum*, *E. cerinthoides*, *E. woodii*, *E. alopecurus*, *E. frigida*, *E. thodei*.

OTHER ORDERS.—*Muraltia flanagani*, *Polygala hispida*, *Heliophila subulata*, *Silene capensis*, *Dianthus scaber*, *Cerastium dregeanum*, *Psammotropha androsacea*, *Corydalis cracca*, *Geranium incanum*, *G. thodei*, *Pelargonium inquinans*, *P. alchemilloides*, *Sutherlandia frutescens*, *Argyrolobium pilosum*, *Indigofera hedyantha*, *Lotononis wyliei*, *Royena cordata*, *R. hirsuta*, *Valeriana capensis*, *Lobelia preslii*, *Stachys bolusii*, *Salvia stenophylla*, *Schizochilus angustifolius*, *S. gerrardi*, *Brownleea cærulea*, *Asparagus steliatus*, *A. plumosus*, *A. africanus*, *Ixia brevifolia*, *Sandersonia aurantiaca*, *Galtonia candicans*, *Hæmianthus hirsutus*, *Moræa edulis*, *Encephalartos ghellinckii*, and the fern *Cheilanthes multifida*.

The presence of bulbous monocotyledons is a feature worthy of note.

IV. THE SUCCESSION AND INTER-RELATIONSHIPS OF THE PLANT FORMATIONS.

On the cliffs of the Drakensberg the plant succession is as follows: The pioneer vegetation is lithophilous, consisting of various Cyanophyceæ, followed by lichens, mosses and hepatics, and algæ. Different stages can be distinguished, beginning with freshly broken rock surfaces and ending with wet rock flushes. The chomophyte vegetation follows

in the rock crevices and ledges, and four types are distinguished, according to the degree of shelter, shade, and moisture. The hydrophile type of chomophyte connects through alpine bogs with the larger vleis.

On the mountain-top a peculiar type of soil is formed—the mountain-top detritus—which accumulates in the depressions while portions remain bare. The result is that the vegetation is of a somewhat mixed type, having features in common with the cliff vegetation and also with fynbosch, but being on the whole of an intensely xerophytic character, since it is exposed to all the adverse factors of the environment.

The fynbosch, or Mâquis, which occupies the steep and very unstable slopes below the cliffs and also the upper ravines, is an interesting sclerophyllous type transitional to both bush and veld.

Such a type is much more extensively developed in the south-western region of Cape Colony, where the summers are dry, and there it is not confined to high altitudes as in Natal, where the hot season is also the rainy season.

From the fynbosch we get a double succession, one through rocky scrub with *Greyia sutherlandi* dominant, and ordinary scrub with *Leucosidea sericea* dominant, to the mountain type of bush, which contrasts somewhat sharply with Midland bush in its general ecological characters, though not in its floristic composition, and the other through bare rocky fellfield to the mountain or tussock veld.

In the veld itself a careful study of the numerous associated plants throws a considerable amount of light on the succession. A certain class of these are found to be transitional to fynbosch and scrub, and another class (those occupying moist spots in the veld) to vleis. There remains a third class of true associated plants, which grow more closely intermingled with the grasses though usually occupying a different substratum of soil. The double succession referred to should be emphasised, since it illustrates Schimper's basic conception of the distinction between a forest and a grassland climatic

series. In the Drakensberg, as in the rest of Natal, the veld grassland occupies by far the largest area. The bush is strictly confined by the climatic factors and occupies the south-eastern slopes where there is sufficient gradient. It will be seen, therefore, that in this case the climate is determined by the topography.

Bush and veld compete in the occupation of the river-beds, and, if the climatic factors permit, in places we get a distinct type of bush—the Stream Bank type.

The Protea veld is particularly interesting as being a type intermediate between bush and veld.

The accompanying diagram illustrates the inter-relationships of the Drakensberg vegetation, and the writer hopes shortly to extend it to the rest of Natal after certain points regarding the coast-belt have been reinvestigated.

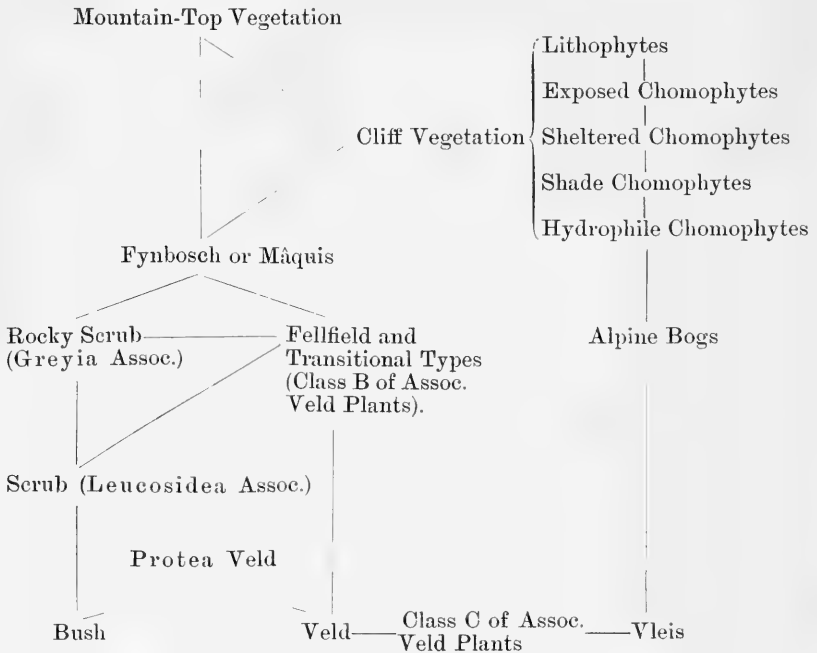


Diagram showing the succession and inter-relationships of the Plant Formations in the Drakensberg.

EXPLANATION OF PLATES XXXVI to XXXIX,

Illustrating Professor J. W. Bews' paper, "The Plant Ecology of the Drakensberg Range."

PLATE XXXVI.

FIG. 1.—Van Reenen's Pass. Tussock Veld with *Protea roupellii* in flower. The Proteaceæ have almost entirely disappeared from the neighbourhood of this pass.

FIG. 2.—Scrub in kloof near Van Reenen. *Leucosidea sericea* dominant with *Buddleia salviæfolia* subdominant. (For description see p. 543.)

PLATE XXXVII.

A general view of the Mont aux Sources from the bed of the Tugela river at an altitude of about 4500 ft. In the river bed *Leucosidea* and Composites such as *Aster filifolius*; on the river bank *Myrsine melanophleas*, Yellow-woods and other species, as named on p. 549. On the valley slopes on both sides, *Protea veld*. Above this the Cave Sandstone Cliffs are conspicuous, the dark stripes and patches being due to *Cyanophyceæ*. Above this, about 4000 ft. of amygdaloidal, basaltic and rhyolitic lavas. See also sections on pp. 516, 517.

PLATE XXXVIII.

Mont aux Sources. Fynbosch or Mâquis formation, as described on p. 560. In the middle of the cliffs the upper Tugela Falls are seen, the height of which has been estimated as 2050 ft.

PLATE XXXIX.

Summit of Mont aux Sources. Cliffs with lithophytes and chomophytes, mostly *Compositæ* (*Helichrysum* spp.)



Boers.

FIG. 1.—*PROTEA ROUPELLII* NEAR VAN REINEN.



Boers.

Allard & Son & West Newman, Ltd.

FIG. 2.—*LEUCOSIDEA* SCRUB AND VELD NEAR VAN REINEN.



Alterton.

MONT AUX SOURCES FROM THE TUGELA RIVER BED.

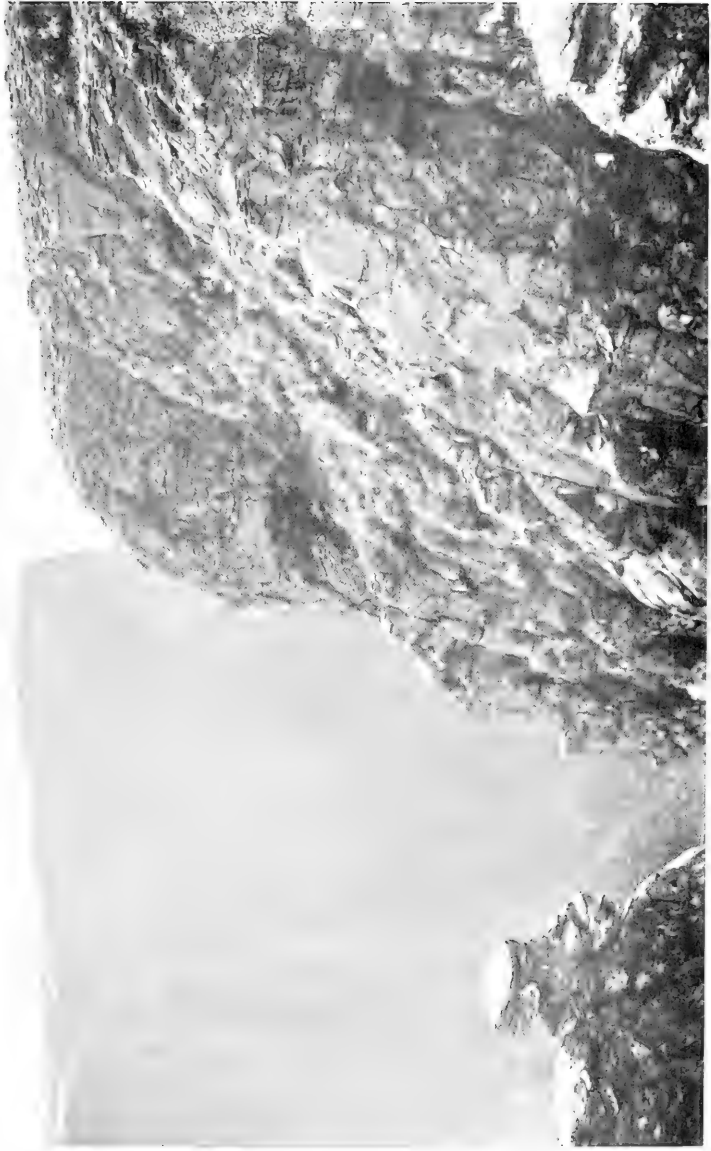
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MONT AUX SOURCES. FENBOSCH OR MIQUIS FORMATION.

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Altenstein.

SUMMIT OF THE MONT AUX SOURCES.

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Contributions to a Knowledge of the Terrestrial Isopoda of Natal.

Part I.

By

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Research Fellow of the University of St. Andrews.

With Plates XL-XLIII.

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INTRODUCTION.

EARLY in 1915 Dr. E. Warren, Director of the Natal Museum, very kindly placed in my hands for identification a small collection of Terrestrial Isopoda from the Museum. Since then Mr. H. C. Burnup has collected further specimens, and Dr. Warren has obtained others from Mr. John Hewitt, Director of the Albany Museum, Grahamstown, Dr. Conrad Akerman, and others.

Unfortunately, many of the species are represented by only single specimens, but as further collecting takes place this will no doubt to a large extent be remedied.

Although there are numerous papers treating of the Terrestrial Isopoda of different regions of the African continent, but few of these relate to South African species, and still fewer to those of Natal.

Up to the present time nearly fifty species have been described from South Africa, but only four or five of these have been recorded from Natal; judging from the collection now in my hands (which includes examples of the genera *Cubaris Brandt*, *Philoscia Latreille*, *Porcellionides Miers*, ? *Niambia Budde-Lund*, and others yet unidentified) there can be little doubt but that a rich and varied fauna awaits discovery.

The eight species here described are referable to the genera *Cubaris Brandt* and *Philoscia Latreille*, and have been chosen simply because there were a number of examples in each case.

The two principal writers on the subject in the past are Dollfus and Budde-Lund. The former in 1895 (14) described seven new species from the Transvaal and Cape Colony, whilst the latter has described a number of species from Cape Colony and Natal (5-12), in some cases from single examples only and in others without any figures, whilst many of his Latin diagnoses are not sufficiently definite to enable identification. It is only fair, however, to state that many of his later species are fully and beautifully figured.

I. DESCRIPTION OF NEW SPECIES.

CUBARIS Brandt.

The hitherto described species of this genus known from South Africa have, with three exceptions, viz., *C. flavescens Brandt*, *C. nigricans Brandt*, and *C. limbatus Brandt*, all been placed in the genus *Armadillo*. As yet the known

forms are fairly widely separated from one another, and few of them have been fully figured or described. The new species here described and figured show little relationship to the above-mentioned species or to species known from elsewhere (2, 3). Budde-Lund (12) has suggested placing all the South African species in the genus *Diploexochus Brandt*, but Brandt's description (4, p. 191) is so very vague that I do not at present feel inclined to follow him.

I. *Cubaris warreni* n. sp. Pl. XL, figs. 1-10.

Body oblong oval, convex, surface with small irregular rugosities in the middle of each mesosomatic segment and raised oval areas laterally; metasome finely granulated. Cephalon (Pl. XL, figs. 1 and 2) small, flanked by the pleural plates of the first mesosomatic segment, anterior margin raised, lateral lobes small; epistome dorsally sloping, raised in the median line and sunken laterally. Eyes large, situated dorso-laterally. Antennulæ short and robust, 3-jointed, with few lateral setæ on the terminal joint. Antennæ (figs. 3 and 4) short and slender, setaceous, 2nd to 5th joints slightly grooved on their outer side; flagellum 2-jointed, the distal joint being two and a half times the length of the proximal one; style elongated with few terminal setæ. First maxillæ (fig. 5), outer lobe terminating in four stout curved spines and six finer inner ones, with long setæ on the outer lateral border; inner lobe rounded distally and with two setose spines. Second maxillæ thin and plate-like. The segments of the mesosome convex, the 1st with expanded pleural plates, anterior and posterior angles acutely pointed, pleural plates of the 2nd-4th segments slightly excavate and their posterior angles produced backwardly, 5th-7th bluntly rounded with the posterior angles produced on the 5th and 6th. Notch and groove on the underside of the inner margin of segments 1 and 2 well developed (fig. 7). Maxillipedes (fig. 6) with outer lobe terminating in a multispinous process and two fine spines, inner lobe with three tooth-like spines. Uropoda (figs. 8 and 9) not extending beyond the

telson, ventrally slightly concave, basal plate thick, strongly raised and convex dorso-laterally, posterior margin pointed, antero-dorsal surface folded, setaceous ventrally, dorsally with triangular-shaped scales; exopodite long, but not extending beyond the posterior margin of the basal plate, setaceous, endopodite rather longer and broader than the exopodite. Telson (fig. 10) longer than the width of the posterior margin and extending a little beyond the uropoda, lateral margins slightly curved, expanded anteriorly and convex, sloping from the median line, with two raised bosses on the anterior margin.

Length 10.5 mm.

Colour (in alcohol) greenish-brown, with lighter-coloured mottling.

Habitat.—Krantzkop, Natal, January 1st, 1915. (E. Warren.)

Type.—In the Natal Museum.

This and the following species belong to a section of the genus characterised by the pointed uropoda and elongated exopodites. The cephalon has the anterior or frontal margin deeply indented, with a sloping epistome dorsally. The antennæ are slender. The oral appendages present no characters of particular importance. The telson is fairly long, exceeding the width of the posterior margin, and is raised in the mid-dorsal portion to form a somewhat triangular eminence with two raised bosses on the anterior margin.

It affords me much pleasure to associate with this interesting species the name of Dr. E. Warren, the Director of the Natal Museum.

2. *Cubaris reticulatus* n. sp. Pl. XL, figs. 11-21.

Body oblong oval, convex, surface finely granulated. Cephalon (Pl. XL, figs. 11 and 12) small, flanked by the pleural plates of the 1st mesosomatic segment, anterior margin raised, with lateral lobes thickened; epistome dorsally sloping, remainder convex. Eyes fairly large, situated dorso-laterally.

Antennulæ short and robust, 3-jointed, with few lateral setæ on terminal joint. Antennæ (figs. 13 and 14) short and slender, setaceous; flagellum 2-jointed, distal joint more than twice the length of the proximal one, style conical with terminal setæ. First maxillæ (fig. 15), outer lobe terminating in four short curved spines and five smaller pointed ones; inner lobe with a single setose spine. Second maxillæ (fig. 16) thin and plate-like, with inner setose lobe. The segments of the mesosome are convex, the 1st with expanded pleural plates, and anterior and posterior angles acutely pointed, remainder almost truncate; notch on the underside of the inner margin of segment 1 very small, margin of the 2nd segment not grooved (fig. 18). Maxillipedes (fig. 17) with outer lobe terminating in a multispinous process and three small spines; the inner lobe has three curved tooth-like spines. Uropoda (figs. 19 and 20) not extending beyond the telson, basal plate thick, strongly raised and convex, posterior margin rounded, antero-dorsal surface expanded and produced laterally as a spine, setaceous; exopodite long, extending almost to the posterior margin of the basal plate, endopodite rather longer and broader, keeled dorsally and ventrally, setaceous. Telson (fig. 21) rather more than twice as long as wide, lateral margins almost parallel, expanded anteriorly, depressed and almost smooth.

Length 7.5 mm.

Colour (in alcohol) yellowish-brown, with two broken darker lines in the mid-dorsal line, and similar lateral ones above the pleural plates, remaining portions with irregular yellowish markings.

Habitat.—Pentrich, near Pietermaritzburg, Natal, September 14th, 1915. (C. Akerman.)

Type.—In the Natal Museum.

This handsome species stands out very conspicuously from any others I know of. The feeble development of the notch and groove on the inner margin of the underside of segments 1 and 2 of the mesosome is interesting; in all other species I

am acquainted with this is a well-marked character (cf. 2, 3). The uropoda and the elongated form of the telson at once serve to distinguish *C. reticulatus* from any other species. Other differences are present in the form of the cephalon, the antennæ, and the 2nd maxillæ.

3. *Cubaris burnupi* *n. sp.* Pl. XLI, figs. 1-10.

Body oblong oval, strongly convex, smooth dorsally. Cephalon (Pl. XLI, figs. 1 and 2) small, flanked by the pleural plates of the first segment of the mesosome, anterior margin well defined, lateral lobes small; epistome dorsally sloping, remainder slightly convex. Eyes of moderate size, situated dorso-laterally. Antennulæ (fig. 3) short and robust, 3-jointed, with few setæ on the distal joint. Antennæ (figs. 4 and 5) short, setaceous, 2nd to 5th joints grooved on their outer side; flagellum 2-jointed, the distal joint being a little over twice as long as the proximal one. First maxillæ (fig. 6) with outer lobe terminating in four stout curved spines and five more slender ones on the inner side. The segments of the mesosome strongly convex, the 1st segment with large expanded pleural plates, anterior and posterior angles pointed; medially the segment is produced forwards (fig. 7), pleural plates of 2nd to 4th segments excavate, remainder truncate or nearly so, posterior angles very slightly produced backwards. Segments 1 and 2 with notch and groove on the underside of the inner margin (fig. 8). Uropoda (fig. 9) not extending beyond the telson, ventrally concave, basal plate thick, strongly raised and convex dorso-laterally, posterior margin truncate, antero-dorsal surface expanded; exopodite small, not extending beyond the inner margin of the basal plate, endopodite slightly more than twice the length of the exopodite, setaceous. Telson (fig. 10), posterior margin wider than the length, almost truncate, lateral margins curved, convex, and smooth.

Length 14.5 × 8 mm.

Colour (in alcohol) greenish-brown, with lighter irregular mottling.

Habitat.—Town Bush, Pietermaritzburg, Natal, April, 1903. (H. C. B. and E. W.)

Type.—In the Natal Museum.

In the form of the antennulæ, cephalon, uropoda, and telson this species differs from any described form. I have much pleasure in associating with it the name of Mr. H. C. Burnup.

4. *Cubaris natalensis* *n. sp.* Pl. XLI, figs. 11–20.

Body oblong oval, convex, smooth. Cephalon (Pl. XLI, figs. 11 and 12) small, flanked by the pleural plates of the 1st segment of the mesosome, anterior margin distinct, lateral lobes small; epistome with sloping dorsal portion, in the middle of which is a diamond-shaped concavity, sunken laterally with median ridge. Eyes of moderate size, situated dorso-laterally. Antennulæ short and robust, 3-jointed. Antennæ (figs. 13 and 14) short, setaceous, 2nd to 5th joints grooved on their outer side; flagellum 2-jointed, the distal joint being twice as long as the proximal one. First maxillæ (fig. 15), outer lobe terminating in four stout curved spines and five smaller inner ones. The segments of the mesosome are convex, almost subequal excepting the first, pleural plates of 2nd to 4th segments slightly excavate, remainder truncate, posterior angles small and very slightly produced backwards. Segments 1 and 2 with well-marked notch and groove on the underside of the inner margin (fig. 17). Maxillipedes (fig. 16) wide and stout, outer lobe terminating in a multi-spinous process and three spines, inner lobe with three tooth-like spines, basal plate setose. Uropoda (figs. 18 and 19) not extending beyond the telson, ventrally concave with thickened rim on the anterior border, basal plate thick, strongly raised and convex dorso-laterally, posterior margin truncate, antero-dorsal surface prominent and widely expanded; exopodite small, extending to the inner margin of the basal plate, endopodite stout and twice the length of exopodite, setaceous. Telson (fig. 20) longer than the width of the posterior margin and extending slightly beyond the uropoda, lateral margins

almost straight, expanded anteriorly, convex and smooth, posterior margin truncate.

Length 7·5 mm.

Colour (in alcohol) a horny brown with six to seven small whitish markings on each side of the mesosomatic segments.

Habitat.—Krantzkop, Natal, January 1st, 1915. (E. Warren.)

Type.—In the Natal Museum.

This is a very distinct type and easily recognised by the form of the cephalon and the stout uropoda.

5. *Cubaris longicauda* n. sp. Pl. XLI, figs. 21–31.

Body oblong oval, convex, dorsal surface finely granulated. Cephalon (Pl. XLI, figs. 21 and 22) small, flanked by the pleural plates of the first segment of the mesosome, anterior margin distinct, lateral lobes small; epistome almost vertical. Eyes fairly large, situated dorso-laterally. Antennulæ (fig. 23) short, 3-jointed, with few lateral setæ on the distal joint. Antennæ (figs. 24 and 25) rather longer than usual, otherwise typical of the genus. First maxillæ (fig. 26), outer lobe terminating in four stout curved spines and six pointed smaller ones, inner lobe with trilobed head and three setose spines, body indented on the inner side to form a trilaminar border. Second maxillæ (fig. 27) flat with setose inner lobe with two spines at the base, outer lobe terminating somewhat crenate, and with setæ on the inner side. The segments of the mesosome (fig. 29) have the pleural plates well developed with the posterior angles pointed and produced backwards. The notch or tooth on the inner margin of the underside of the 1st segment is very feeble, whilst the groove on the 2nd segment is represented by a slight thickening (fig. 29). Maxillipedes (fig. 28), lobes somewhat stunted and robust. Uropoda (fig. 30) not extending beyond the telson, ventrally slightly concave, basal plate thick, convex, and strongly raised dorso-laterally, posterior margin bluntly rounded, antero-dorsal surface strongly thickened, setaceous ventrally,

dorsally with small triangular-shaped scales; exopodite long, with short terminal style, not extending beyond the posterior margin of the basal plate, endopodite rather longer and broader than the exopodite, setaceous. Telson (fig. 31) nearly twice as long as the width of the posterior margin, not extending beyond the uropoda, lateral margins slightly curved, expanded anteriorly with raised lateral bosses and median keel.

Length 11.5 mm.

Colour (in alcohol) horny-brown, with yellow mottling, pleural plates rather lighter.

Habitat.—Port Alfred, Cape Province, January, 1914. (F. C. Graham.)

Type.—In the Natal Museum.

In the shape of the telson this species bears a slight resemblance to *C. griseo-albus* (*Dollfus*) (14). The rather longer antennæ, the form of the first maxillæ, and the absence of the tooth on the underside of the inner margin of the 1st mesosomatic segment, and the groove on the 2nd segment, are features not hitherto met with in this genus.

6. *Cubaris trilobata* n. sp. Pl. XLII, figs. 1-9.

Body oblong oval, strongly convex, surface smooth. Cephalon (Pl. XLII, figs. 1, 2) small and short, flanked by the pleural plates of the first mesosomatic segment, anterior margin raised, lateral lobes thickened but not pronounced; epistome with diamond-shaped concavity dorsally and a V-shaped ridge ventrally. Eyes fairly large, situated dorso-laterally. Antennulæ (fig. 3) short and robust, with few lateral setæ on terminal joint. Antennæ (fig. 4) slender, sparsely setaceous; flagellum short, distal joint longer than the proximal one. First maxillæ (fig. 5) with outer lobe terminating in four stout curved spines and six smaller pointed ones, inner lobe with trilobed head and three setose spines, body with trilaminar border. The segments of the mesosome are strongly convex, with the pleural plates of

segments 2-4 rounded terminally, those of 5-7 truncate, posterior angles not produced. The notch or tooth on the inner margin of the 1st segment is well developed and there is a definite groove on the 2nd segment (fig. 7). Maxillipedes (fig. 6) with the outer lobe elongated, at the base of the multispinous process are three small spines and a larger one on the outer border, on the inner border is a small pit from whence there arise two spines, a short pointed one and an elongated one with spatulate end. The inner lobe is wide and has three stout tooth-like spines. Uropoda (fig. 8) not extending beyond the telson, ventrally flattened, basal plate thick, convex, and raised dorso-laterally, posterior margin obliquely cut away, antero-dorsal surface thickened; exopodite short, extending to the inner margin of the basal plate, endopodite short and broad, setaceous. Telson (fig. 9) rather longer than the width of the posterior margin, not extending beyond the uropoda, lateral margins strongly curved inwards, expanded anteriorly and slightly raised in the mid-dorsal line, posterior margin almost straight.

Length 11 mm.

Colour (in alcohol) horny brown with irregular dark mottling.

Habitat.—Grahamstown, September, 1915. (J. Hewitt.)

Type.—In the Natal Museum.

In its general shape and colour, and in the trilaminar inner lobe of the 1st maxilla this species shows a distant relationship with *C. longicauda*, but it differs from that species in the form of the cephalon, the presence of the tooth and groove on the underside of the inner margin of the 1st and 2nd mesosomatic segments, the more complicated and elongated lobes of the maxillipedes, and in the form of the uropoda and telson.

PHILOSCIA *Latreille*.

This genus at present includes a somewhat heterogeneous group of species which require separating into definite

genera, founded on sound structural characters. Racovitza (16) has erected the genus *Anaphiloscia*, Stebbing (17) that of *Anchiphiloscia*, and Budde-Lund (10) the genera *Aphiloscia* and *Nahia*. All of these, however, seem to me to differ from *Philoscia* in some quite minor feature, and do not help at all. I shall, therefore, for the present place the South African forms in the genus *Philoscia*; no doubt as more material is examined it will be possible to separate them into two or three distinct genera, each possessing well-marked characters.

Writing of this genus in 1908 Stebbing (17) stated: "At present there are a bewildering number of species in the genus *Philoscia*, many of them very incompletely described, and few, if any of them, completely illustrated. A remedy for this state of affairs will not be easily found. The creatures themselves put difficulties in the way of the student. Their readiness to wander about the world undermines any systematic structure built on geographical distribution. Their variability seems to separate forms which are specifically identical. On the other hand, general resemblance seems to unite forms which, on closer examination, are found to be distinct. Among the appendages the antennæ and uropods afford especially useful characters, and these appendages are particularly liable to be detached or broken. The structure of the pleopods, especially those of the male, is more and more acquiring systematic importance."

An examination of a large quantity of material from different parts of the world has convinced me that the mouth parts, by themselves, are certainly very unsatisfactory for purposes of either generic or specific distinction (1), and this is particularly so in the present genus. Apart from the question of variation, the abdominal appendages (pleopods) are scarcely less so, whilst any classification of the Terrestrial Isopoda founded upon sexual characters always leaves it open for the opposite sex to be described as a distinct species.

fully agree as to the great value of the antennæ and uropoda, and to these I would add the shape of the

cephalon, the mesosomatic and metasomatic segments, and the telson.

7. *Philoscia warreni* n. sp. Pl. XLII, figs. 10-20.

Body oblong oval, smooth, metasome abruptly narrower than the mesosome. Cephalon (Pl. XLII, figs. 10 and 11) small, convex above, no definite frontal margin, rounded, lateral lobes small, epistome flattened with well-marked dorsal ridge. Eyes large, also ocelli, situated dorso-laterally. Antennulæ (fig. 12) short and stout, 3-jointed, terminal joint with few setæ laterally and terminally, proximal end of 3rd joint expanded. Antennæ (figs. 13 and 14) long, 1st joint very short, 2nd and 3rd stout and about equal in length, grooved on their outer side, 4th and 5th joints elongated, the latter the longer; flagellum 3-jointed, the terminal joint has the end thickened and there is a short style. First maxillæ (fig. 15) with the outer lobe terminating in four blunt curved spines, and four shorter ones with bifid terminations; inner lobe produced as a spine on the outer border terminally and with two setose spines on the inner side. Second maxillæ (fig. 16) with setose inner lobe, outer lobe very thin and fragile. The segments of the mesosome somewhat depressed, terminal margin of pleural plates of segments 2-5 rounded, posterior angles inconspicuous, those of the 6th and 7th produced backwards. Maxillipedes (fig. 17) with shortened lobes, outer one terminating in two multispinous processes and one small spine; inner lobe with single spine only. The metasome is abruptly narrower than the mesosome and the pleural plates are not expanded or produced backwards. Uropoda (figs. 18 and 19) extending beyond the telson, basal segment roughly ovoid with raised portions on the inner side and ventro-laterally, with the inner one the endopodite articulates and the exopodite with the ventro-lateral one; exopodite elongated, endopodite half the length of the exopodite, triangular in section, both setaceous. Telson (fig. 20) short and broad, laterally rounded, and produced as a blunt point terminally.

Length 14 mm.

Colour (in alcohol) a silvery-grey with darker irregular markings, variable.

Habitat.—Umbilo Bush, near Durban, Natal, September 16th, 1915. (E. Warren.)

Type.—In the Natal Museum.

This handsome species is easily separated from any known form by the form of the antennæ, in which the first three joints are stoutly built, also by the form of the cephalon, first maxillæ, maxillipedes, uropoda, and telson.

The colour is subject to a considerable amount of variation, approaching sometimes that found in *Philoscia dilectum* *Collge.*; in most cases, however, there is an oval light-coloured marking surrounded by darker pigmentation, just above each pleural plate, and in the mid-dorsal line a somewhat similar light-coloured area on each segment of the mesosome, with a darker one immediately posterior to it.

8. *Philoscia dilectum* *n. sp.* Pl. XLII, figs. 21–31.

Body broadly oval, convex, surface finely granulated, metasome abruptly narrower than the mesosome. Cephalon (Pl. XLII, figs. 21 and 22) small, convex above, frontal margin distinct, lateral lobes absent, epistome concave above dorsal ridge and slightly raised in the median line. Eyes large, also ocelli, situated dorso-laterally. Antennulæ (fig. 23) short, with 1st and 2nd joints stout, 3rd joint with lateral and terminal setæ. Antennæ (figs. 24 and 25) comparatively short, slender, 1st joint larger than usual, 2nd and 3rd almost subequal, 5th the longest, setaceous; flagellum 3-jointed, 1st joint the longest, 2nd and 3rd subequal, with bluntly ending style. First maxillæ (fig. 26) with outer lobe terminating in four stout curved spines, and five shorter ones with bifid terminations; inner lobe truncate terminally with two large setose spines. The segments of the mesosome are convex, terminal margin of the pleural plates truncate, posterior angles on segments 1–3 rounded, on remainder pointed and produced slightly backwards. Maxillipedes

(fig. 27) with short outer lobe, terminating in two multi-spinous processes and a single small spine, inner lobe with three tooth-like spines and one elongated one. The segments of the metasome have the pleural plates produced backwardly as sharp spines (fig. 30). Uropoda extending beyond the telson, basal plate raised on the dorsal surface and expanded on the inner side, ventrally it is produced as a blunt spine on the outer anterior margin, and with a thickened rim on the inner margin; endopodite small and cuneiform, setaceous; exopodite rather short and stout, flattened on the outer side, setaceous. Telson (fig. 31) small, lateral margins rounded, terminally rounded with deep sulcus in the mid-dorsal line.

Length 10·5 mm.

Colour (in alcohol), the pleural plates and the posterior border of the segments are a dark brownish-green, whilst the cephalon and the middle and anterior portion of the segments are marked with irregular oval yellow patches.

Habitat.—Pentrich, near Pietermaritzburg, Natal, September 14th, 1915. (C. Akerman.)

Type.—In the Natal Museum.

This beautifully-marked species is removed from the typical *Philoscia* by a number of important characters, such as the form of the cephalon, the stunted outer lobe of the maxillipedes, the uropoda, telson, and the backwardly produced pleural plates of the metasomatic segments. There are other allied species in the collection, which, when examined, may help in rightly placing them.

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EXPLANATION OF PLATES XL-XLII,

Illustrating Dr. Walter E. Collinge's paper, "Contributions to a Knowledge of the Terrestrial Isopoda of Natal," Part I.

PLATE XL.

1. *Cubaris warreni* n. sp.

FIG. 1.—Dorsal view of the cephalon.

FIG. 2.—Anterior view of the cephalon.

FIG. 3.—Left antenna, dorsal view.

FIG. 4.—Terminal style of antenna.

FIG. 5.—Terminal portion of the inner and outer lobes of the right 1st maxilla, ventral view.

FIG. 6.—Terminal portion of the left maxillipede, ventral view.

FIG. 7.—Underside of the lateral margin of the 1st and 2nd mesosomatic segments.

FIG. 8.—Dorsal view of the right uropod.

FIG. 9.—Ventral view of the right uropod.

FIG. 10.—Dorsal view of the telson, uropoda, and last metasomatic segment.

2. *Cubaris reticulatus* n. sp.

FIG. 11.—Dorsal view of the cephalon.

FIG. 12.—Anterior view of the cephalon.

FIG. 13.—Left antenna, dorsal view.

FIG. 14.—Terminal style of antenna.

FIG. 15.—Terminal portion of the inner and outer lobes of the right 1st maxilla, ventral view.

FIG. 16.—Terminal portion of the right 2nd maxilla, ventral view.

FIG. 17.—Terminal portion of the left maxillipede, ventral view.

FIG. 18.—Underside of the lateral margin of the 1st and 2nd mesosomatic segments.

FIG. 19.—Dorsal view of the right uropod.

FIG. 20.—Ventral view of the right uropod.

FIG. 21.—Dorsal view of the telson, uropoda, and last metasomatic segment.

PLATE XLI.

3. *Cubaris burnupi* n. sp.

FIG. 1.—Dorsal view of the cephalon.

FIG. 2.—Anterior view of the cephalon.

FIG. 3.—Right antennule, ventral view.

FIG. 4.—Left antenna, dorsal view.

FIG. 5.—Terminal style of antenna.

FIG. 6.—Terminal portion of the outer lobe of the right 1st maxilla, ventral view.

FIG. 7.—First mesosomatic segment, dorsal view.

FIG. 8.—Underside of the lateral margin of the 1st and 2nd mesosomatic segments.

FIG. 9.—Dorsal view of the right uropod.

FIG. 10.—Dorsal view of the telson, uropoda, and last metasomatic segment.

4. *Cubaris natalensis* n. sp.

FIG. 11.—Dorsal view of the cephalon.

FIG. 12.—Anterior view of the cephalon.

FIG. 13.—Left antenna, dorsal view.

FIG. 14.—Terminal style of antenna.

FIG. 15.—Terminal portion of the outer lobe of the right 1st maxilla, ventral view.

FIG. 16.—Terminal portion of the left maxillipede, ventral view.

FIG. 17.—Underside of the lateral margin of the 1st and 2nd mesosomatic segments.

FIG. 18.—Dorsal view of the right uropod.

FIG. 19.—Ventral view of the right uropod.

FIG. 20.—Dorsal view of the telson, uropoda, and last metasomatic segment.

5. *Cubaris longicauda* n. sp.

FIG. 21.—Dorsal view of the cephalon.

FIG. 22.—Anterior view of the cephalon.

FIG. 23.—Right antennule, ventral view.

FIG. 24.—Left antenna, dorsal view.

FIG. 25.—Terminal style of antenna.

FIG. 26.—Terminal portions of the inner and outer lobes of the right 1st maxilla, ventral view.

FIG. 27.—Terminal portion of the left 2nd maxilla, ventral view.

FIG. 28.—Terminal portion of the left maxillipede, ventral view.

FIG. 29.—Underside of the lateral margins of the 1st and 2nd mesosomatic segments.

FIG. 30.—Dorsal view of the right uropod.

FIG. 31.—Dorsal view of the telson, uropoda, and last metasomatic segment.

PLATE XLII.

6. *Cubaris trilobata* n. sp.

FIG. 1.—Dorsal view of the cephalon.

FIG. 2.—Anterior view of the cephalon.

FIG. 3.—Left antennule, ventral view.

FIG. 4.—Left antenna, dorsal view.

FIG. 5.—Terminal portion of the inner and outer lobes of the right 1st maxilla, ventral view.

FIG. 6.—Terminal portion of the left maxillipede, ventral view.

FIG. 7.—Underside of the lateral margin of the 1st and 2nd mesosomatic segments.

FIG. 8.—Dorsal view of the right uropod.

FIG. 9.—Dorsal view of the telson, uropoda, and last metasomatic segment.

7. *Philoscia warreni* n. sp.

FIG. 10.—Dorsal view of the cephalon.

FIG. 11.—Anterior view of the cephalon.

FIG. 12.—Left antennule, ventral view.

FIG. 13.—Right antenna, dorsal view.

FIG. 14.—Terminal style of antenna.

FIG. 15.—Terminal portions of the inner and outer lobes of the left 1st maxilla, ventral view.

FIG. 16.—Terminal portion of the left 2nd maxilla, ventral view.

FIG. 17.—Terminal portion of the right maxillipede, ventral view.

FIG. 18.—Dorsal view of the right uropod.

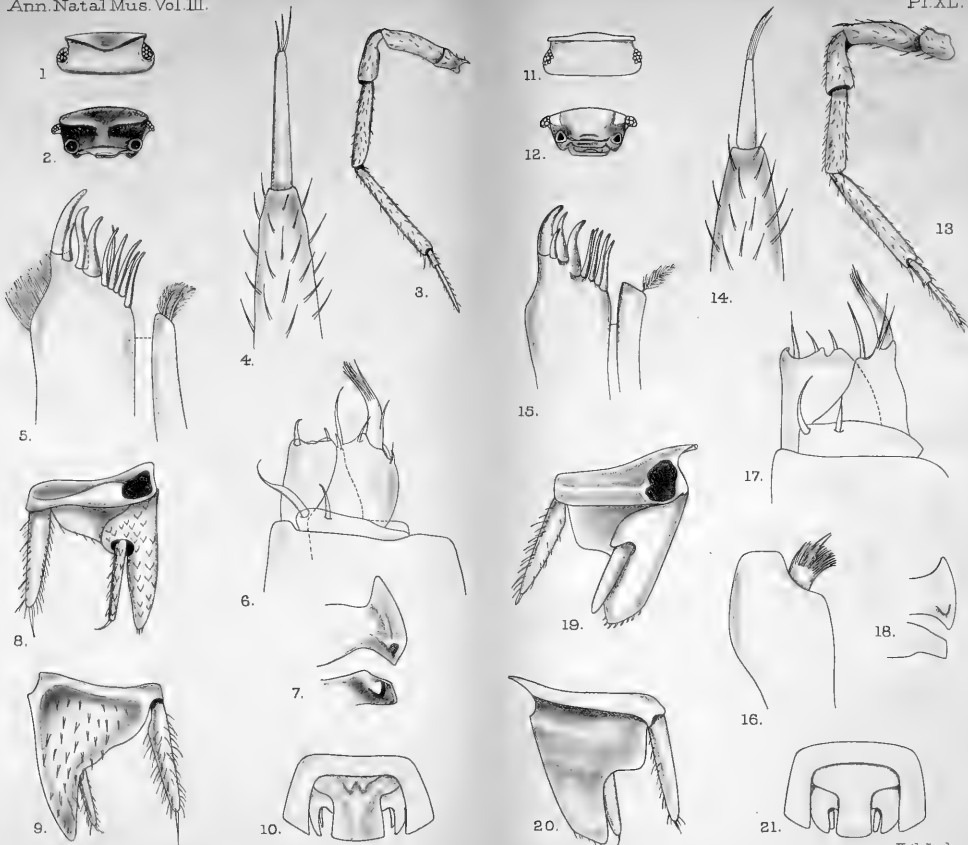
FIG. 19.—Basal portion of the ventral side of the right uropod.

FIG. 20.—Dorsal view of the telson and last metasomatic segment.

8. *Philoscia dilectum* n. sp.

- FIG. 21.—Dorsal view of the cephalon.
FIG. 22.—Anterior view of the cephalon.
FIG. 23.—Left antennule, ventral view.
FIG. 24.—Right antenna, dorsal view.
FIG. 25.—Terminal style of antenna.
FIG. 26.—Terminal portions of the inner and outer lobes of the left 1st maxilla, ventral view.
FIG. 27.—Terminal portion of the left maxillipede, ventral view.
FIG. 28.—Dorsal view of the right uropod.
FIG. 29.—Ventral view of the right uropod.
FIG. 30.—Posterior angle of the pleural plate of the last metasomatic segment.
FIG. 31.—Dorsal view of the telson and last metasomatic segment.
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To the Executive Committee of the Carnegie Trust I desire to express my thanks for a grant to defray the artist's charges for the figures illustrating this paper.

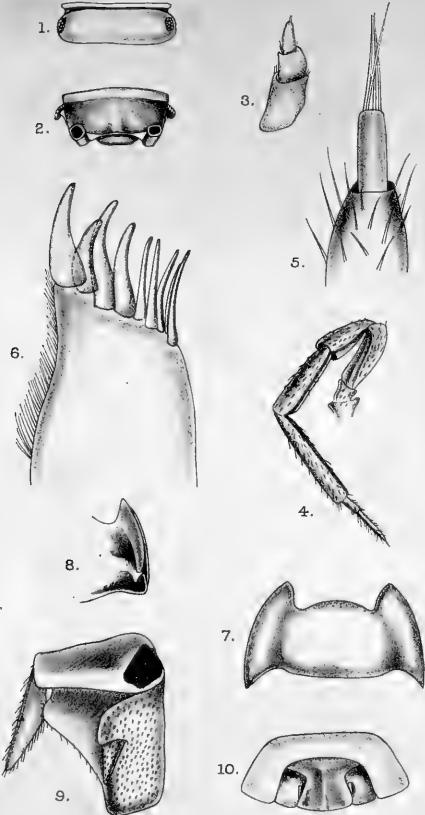


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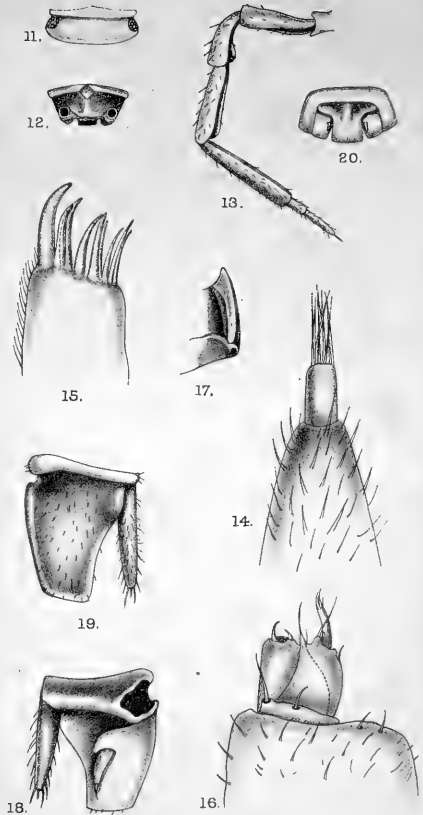
Cubaris warreni sp.n. figs. 1-10.

Cubaris reticulatus sp.n. figs. 11-21.

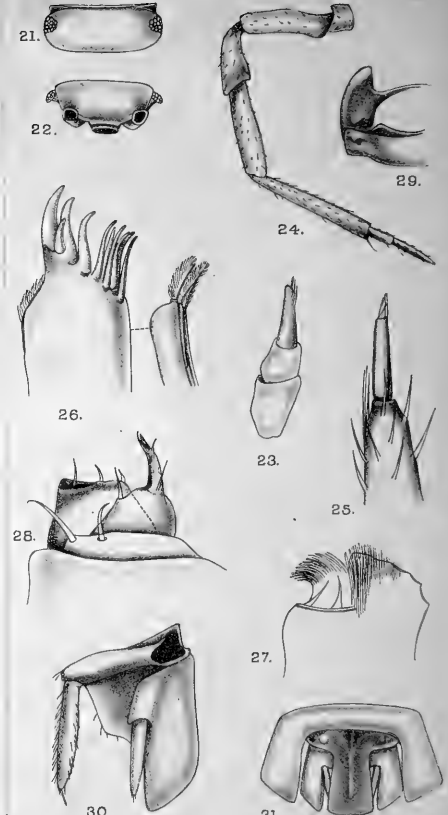


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Cubaris burnupi sp.n. figs. 1-10.

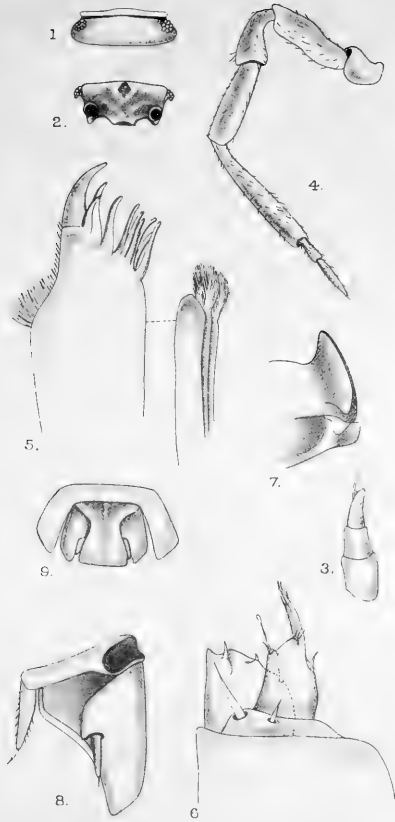


Cubaris natalensis sp.n. figs. 11-20.



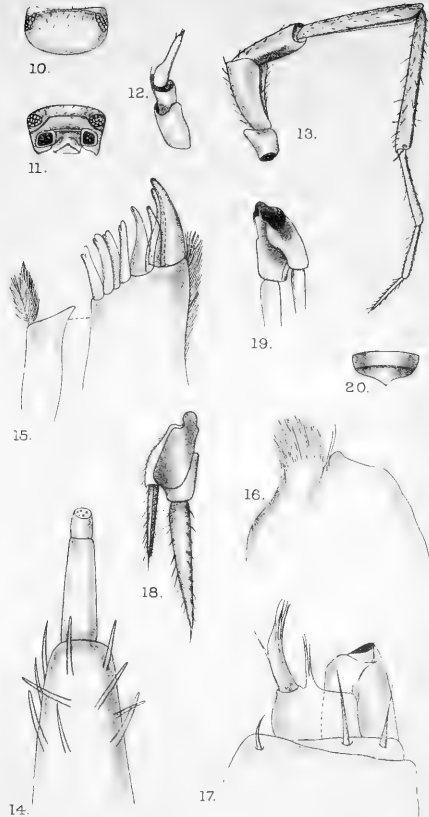
Huth, London.

Cubaris longicauda sp.n. figs. 21-31.

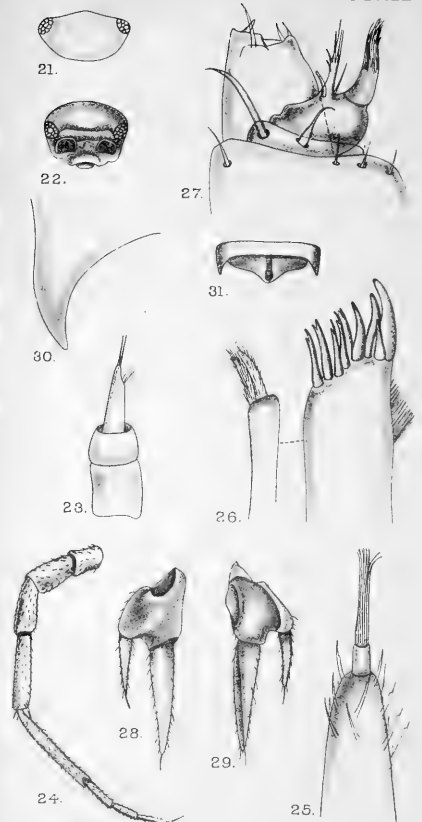


H. G. J. del. ad nat.

Cubaris trilobata sp.n. figs. 1-9.



Philoscia warreni sp.n. figs 10-20.



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Philoscia dilectum sp.n. figs. 21-31.

South African Bagworms.

EDITORIAL NOTE.

THE study of South African bagworms presents many points of great scientific and economic interest; and it is hoped that there may be published in this Journal a series of papers which will treat on the structure, life-histories, and bionomics of the various forms.

It should be remembered that "bagworms" do not constitute a natural group of insects; they belong to several families of moths, and they are here dealt with together on account of the habit which the larvæ have in common of providing for themselves a case or bag in which they live during active life and in which pupation occurs.

Certain marked resemblances in structure and instinct may be observed in the various forms belonging to different families; and investigation is necessary in order to determine whether these are due to phylogenetic relationship, or are examples of convergence arising through like needs imposed by a similar environment.

The rapid change in the habits of certain indigenous insects in attacking the exotic Black Wattle is a menace to the rising wattle industry of Natal, and at the present time bagworms are the most serious of the insect pests which infest the trees. The investigation of these insects has been deputed to Mr. C. B. Hardenberg, Government Entomologist; and his paper

is published in this Journal with the approval of the Chief of the Division of Entomology and the consent of the Secretary of Agriculture for the Union.

The present paper is the first instalment of the series, and it is preceded by systematic descriptions of the imagos by Mr. A. J. T. Janse and Mr. E. Meyrick.

South African Bagworms; Notes on the
Psychidæ and on the genera *Gymnelema* and
Trichocossus, with descriptions of
five new species.

By

A. J. T. Jause, F.E.S.L.

With Plate XLIII.

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ADELIDÆ [ditto].	

PSYCHIDÆ.

The Psychidæ form a group of great phylogenetic and biological interest, as they exhibit many primitive characters which are fairly constant in the whole family, and the larvæ make little dwellings, in which they live from the time they emerge from the egg until they are mature, while the females remain in this bag and may even deposit their eggs therein.

Most lepidopterists place this family in the neighbourhood of the Cossidæ, and the fact that some Cossid-like moths are also case-dwellers, together with the similarity in structure, certainly points to this, although the females of the Cossids are winged, which is never the case in the Psychids.

There must also be a close relationship between the Psychids and certain groups of the Tineidæ; in fact, some genera are placed by one author in the Psychids and by another in the Tineids. The latter view is, I think, correct, as the only similarity is that the females are wingless and that the larvæ are case-dwellers. Considering that wingless females are found in several families not at all related to the Psychidæ, and that we find case-dwellers in the genus *Melasina* for instance (which is certainly a true Tineid), we shall have to rely on structural characters in making a decision.

I therefore remove the genera *Epichnopteryx* and *Fumea* from the Psychidæ. In both genera the hind legs have well-developed middle spurs, and these are, as far as I know, always absent, or at the most very rudimentary, in all of the true Psychids. It is true that the tongue is entirely absent in both genera; but we also find this in several species

of the Tineids; moreover, the development of the tongue is, I think, entirely regulated by the mode of life of the moth.

By removing those species that have spurs we really cut out the whole of Heylaert's subfamilies *Canephorinæ* and *Psychoidinæ* from the *Psychidæ*. The characters of the *Psychidæ*, as I now understand the family, are as follows:

MALE.—Head, thorax, abdomen, femora and tibiæ densely hairy; ocelli large; tongue rudimentary; antennæ strongly pectinated; labial palpi short, covered with hair; maxillary palpi absent; hind tibiæ without any middle spurs, end spurs very short if present; wings covered with hair or hairy scales.¹ Fore wing: *1a* forked with *1b*; *1c* usually becoming coincident with *1b* beyond middle; 5 more or less approximate to 4. Hind wing: *1c* present; vein 8 connected with the cell by a bar or anastomosing with part of upper median or becoming coincident with 7.

FEMALE.—Wingless; without legs or well-developed antennæ. Larvæ and females case-dwellers.

This family is divided by Heylaerts into five subfamilies, of which I retain three, all represented in South Africa.

The following key to the subfamilies is based on that given by Sir G. Hampson in his 'Moths of India,' vol. i, p. 290, who closely followed the classification as originated by Heylaerts.

- | | |
|--|-----------------------|
| 1A. Fore wing with vein <i>1b</i> sending several branches to inner margin | I. <i>ÆCETICINÆ</i> . |
| B. Fore wing with only one branch from <i>1b</i> to inner margin or no branch at all | 2 |
| 2A. Fore wing with one branch from <i>1b</i> to inner margin | II. <i>PSYCHINÆ</i> . |
| B. Fore wing with no branch from <i>1b</i> to inner margin | |
| veins <i>1b</i> and <i>1c</i> anastomosing | III. <i>CHALINÆ</i> . |

I. Subfamily *ÆCETICINÆ* H. S.

Fore wing with vein *1c* anastomosing with *1b*, which emits

¹ The wings are often apparently naked, but in several cases this has been proved to be due to flying. Bred specimens, killed before they could fly, show a certain amount of loose hairy covering.

several branches to the inner margin; veinlet in cell of both wings forked. At present only one genus is known from South Africa.

Genus *CLANIA* *Wlk.*

Clania Wlk., Cat. iv, p. 963, 1855. Type, *lewinii*, from Australia; Hampson, 'Moths of India,' vol. i, p. 291.

Eumeta Wlk., Cat. iv, p. 964, 1855. Type, *cramerii*, from Ceylon.

Cryptothelia Wlk., Cat. iv, p. 970, 1855. Type, *consorta*, from Ceylon and India.

Lansdownia Heyl., Ann. Soc. Ent. Belg. xxv, p. 66, 1881. Type, (?) *macleayi* *L. Guild.*, from Central America.

MALE.—Antennæ bipectinate to tip; fore tibiæ with a long process; wings large and broad; fore wing with vein 4 and 5 stalked; 6 present; 8 and 9 stalked; hind wing with vein 8 sending several branches to the costa.

This genus has a very wide range, having representatives in Central America, Africa, Asia, and Australia.

Clania moddermanni (*Heyl.*). Pl. XLIII, fig. 1.

Eumeta moddermanni Heyl., Ann. Soc. Ent. Belg., xxii, p. lix, 1888; Kirby, Cat. i, p. 503.

MALE.—Head, thorax above and underneath covered with whitish hairs, mixed on the underside with fuscous (XLVI)¹ hairs; antennæ and branches fuscous; legs covered with fuscous hairs mixed with whitish hairs; a fuscous spot at frons; base of antennæ surrounded by pinkish buff (XXIX) hairs; a fuscous line from between the antennæ, becoming forked at base of tegulæ and continued as a single line over the thorax; tegulæ edged by a fuscous line transversely till it reaches an oblique lateral dorsal line of same colour; 1st segments of abdomen with long whitish hairs in middle, and with a tuft of fuscous hairs, the remainder of abdomen on upper side with cinnamon-buff (XXIX) lateral hairs, and those on terminal segment fuscous or fuscous-black; abdomen on underside with two fuscous stripes.

¹ All figures in brackets after the name of the colours refer to Ridgway's 'Color Standards and Nomenclature,' edition 1912.

Fore wing thinly covered with fuscous hairs and scales; costa with a fuscous-black edging; upper and lower median, disco-cellular, vein *1b* and veins 2 to 9 thickly covered with fuscous-black scales; postmedial area between veins 2 to 4 and 7, 8 and terminal area between 4-5 and 6-7 very thinly scaled so as to represent whitish maculæ when the moth is placed above a light underground; inner margin edged with fuscous-black from one-third; cilia very short, fuscous, mixed with fuscous-black.

Hind wing covered evenly with fuscous scales and hairs; all veins, except *1a* and *1c*, sharply defined with fuscous-black; cilia fuscous. Underside of both wings like upper-side, but without the dark scaling on the veins.

With expanded wings 26-30 mm.

HAB.—Ladysmith (September 10th, 1915, bred by C. B. Hardenberg); New Hanover (September 23rd, 1915, bred by C. B. Hardenberg); Pretoria (bred by A. J. T. Janse).

The description given by Heylaerts is very good, and leaves no doubt about the correctness of the identification. In structure this species differs from the Indian species *variegata* in the following details:

Fore wing with the branches from *1b* to inner margin, not from *one* point, but at intervals from one-fourth to two-thirds of the length of this vein, and the branches do not reach the inner margin; stalk of 4 and 5 over one-third, nearly half; 7 remote from stalk of 8, 9; hind wing with *1c* very faint; 4, 5 on a stalk of nearly one-third; 7 not connected by a bar to 8; a very oblique bar from half upper median to 8; sometimes a second short angled erect bar from upper median at three-fourths to the junction of first bar and vein 8; veinlets from 8 to costa very faint; process of fore tibiæ slightly shorter than tibiæ.

SPECIES AUCTORUM:

Eumeta cervina Druce, Proc. Zool. Soc. Lond., p. 684, 1887.

The following description is given by Druce of this species:

“Male like *E. cramerii*, but the primaries redder in colour,

with a marginal row of fine whitish spots, and a dark brown elongated patch at the end of cell. Secondaries smoky brown, with three whitish dots at the apex. Head, thorax and abdomen brown. Antennæ brownish black, tegulæ with white tips; a white spot at the base of the primaries; on the underside the white marginal spots are more distinct than above. Expanse $1\frac{3}{4}$ in. Hab.—West Africa; Gambia; East Africa; Delagoa Bay.

It is impossible to make out from this description if the species is a true *Eumeta* or not, so I leave it provisionally in this genus.

Mr. Junod states in his paper ('Bull. de la Soc. Ent. Belg.,' vol. xxvii, 1899, p. 244) that *Eumeta cervina* is the same as *E. moddermanni*. He seems to make this statement on the authority of Dr. Heylaerts, but after comparing the descriptions carefully, I must come to the conclusion that this is very unlikely. Of course, the description is very short, but even as it is, I do not think it applies in many respects to *E. moddermanni*. The figures Junod gives (pl. iv, fig. 2*a*, *b*) of his specimen and the bag undoubtedly refer to *E. moddermanni*.

SPECIES OMITTED:

Eumeta junodi *Heyl.*, Ann. Soc. Ent. Belg., vol. 34, p. cxxx.

This species has to be placed in the genus *Acanthopsyche*.

Eumeta zelleri *Heyl.*, Ann. Soc. Ent. Belg., vol. 38, p. xcvi; Kirby, Cat. i, p. 503.

I do not think that this species can be maintained, as the description is given of the larva and bag only. The description of the larva is much too general to make the identification certain. The larva and bag do not appear to be sufficiently characteristic. I think that the description of the imago only can be considered as valid and not that of eggs, larvæ, or pupæ, still less of the structure made by the larva to live in.

II. Subfamily PSYCHINÆ.

In this subfamily the veinlets in the cells may be forked or single; the process of the fore tibiæ is absent or present; the fore wing has always one single branch from *1b* to the inner margin.

This subfamily is divided into two genera: (1) *Acanthopsyche* with a long thin process on the fore tibiæ and (2) *Psyche* without such a process. Heylaerts has divided most genera of the *Psychidæ* into a number of subgenera and these have been adopted also by Sir George Hampson in his 'Moths of India.' It is not quite clear to me why some of these groups do not receive a generic position; some of them differ more from each other than some genera do in other families.

Genus ACANTHOPSYCHE *Heyl.*

Acanthopsyche Heyl., Ann. Soc. Ent. Belg., p. 66, 1881. Type, *inquinata Led.*, from Europe; Hmps., 'Moths of India,' vol. i, p. 293.

MALE.—Branches of antennæ getting shorter from middle, but they are still present at the tip; fore tibiæ with a long process.

Subgenus *Dasaratha Moore.*

Dasaratha Moore, P.Z.S.L., p. 396, 1888. Type, *himalayana Moore*, from Punjab; Hmps., 'Moths of India,' vol. i, p. 294.

The following description of this subgenus is given by Hampson:

MALE.—Fore wing with veins *1b* and *1c* anastomosing; vein 6 present; hind wing with vein 6 absent; a bar between veins 7 and 8. The veinlet of the cell of both wings forked.

Acanthopsyche (Dasaratha?) junodi Heyl. (Wattle Bagworm). Pl. XLIII, fig. 2.

Eumeta junodi Heyl., Ann. Soc. Ent. Belg., vol. 34, p. cxxx, 1890.

MALE.—Antennæ and their branches, hairs on legs, head, thorax and abdomen on upper- and underside fuscous. Both

wings glass-like and without any colour; the costæ narrowly edged with fuscous-black; fore wing from base to medial area and along inner margin as far as postmedial area very thinly covered with long fuscous-black hairs; hind wing with still longer hairs of same colour on inner marginal area as far as 1c; cilia of both wings consist of a few ill-developed fuscous scales. Underside as above, but with less hairs.

Exp., 24–26 mm.

HAB.—Probably found all over Natal at altitudes below 5000 ft., and may be expected all over South Africa where wattles are grown. Its original food-plant was doubtless one of the indigenous Acacias.

The subgeneric position of this species is rather uncertain, and it may be necessary to form a new subgenus, as it does not fit well in any known to me. It has to be taken out of the genus *Eumeta* for certain, as vein 1b has only one spur in the fore wing and that spur is very short and faint, never reaching the inner margin in any of the specimens I have seen. The long process of the fore tibiæ is present, though rather hidden in the long hairs. The venation of the fore wing is the same as in *Dasaratha longicauda* Warr except for the spur from 1b which comes in *junodi* from near end of fork of 1a and 1b and in the other species from near end of fork 1b and 1c.

In the hind wing all the veins are free in *junodi*, though 4 and 5 come from a point; 6 is present, the missing vein is distinctly vein 7; 8 is free from base, almost parallel to upper median till half length of cell, then it anastomoses with the upper median and vein 7 for its whole length; 1c is very faint; frenulum very long, nearly half length of costa.

The hair-scales of *junodi* are very loose and come off at once during flight, but even in perfect specimens the hairy covering is very thin.

Subgenus *Ceeticoides* *Hmps.*

Oiketicoides *Heyl.*, Ann. Soc. Ent. Belg., p. 66, 1881. Type *inquinata* *Led.*, from Europe.

Ceeticoides *Hmps.*, 'Moths of India,' vol. i, p. 293.

Hampson gives the following description of this subgenus:

MALE.—Fore wing with vein *1c* anastomosing with *1b*; vein 6 absent in both wings. Hind wing with a bar between vein 7 and 8.

This subgenus is divided into three sections:

I. Veins 4 and 5 of both wings stalked. Fore wing with 7 from cell.

II. Veins 4 and 5 of both wings from cell. Fore wing with 7 stalked with 8, 9.

III. Veins 4 and 5 of fore wing from cell. Fore wing with vein 7 from below angle of cell.

Acanthopsyche (*Eceticoides*) *tristis* *sp. n.* (Thatched Bagworm). Pl. XLIII, fig. 3.

MALE.—Shaft of antennæ and hairs on head, thorax, abdomen and legs cinnamon-buff (XXIX), these hairs are mixed with those of a fuscous colour, especially at the last three segments of the abdomen; branches of antennæ fuscous; wings moderately covered with fuscous hairy scales, leaving the terminal half of fore wing and the terminal third of hind wing slightly more transparent; in fore wing the veins 2–9 are rather darker in this area; costa of fore wing and termen of both wings fuscous-black. Underside like above.

Exp., 20 mm. in 1 male type and 1 male cotype.

HAB.—New Hanover, Natal (bred by C. B. Hardenberg, March 1st, 1915).

This species comes in Section III of the subgenus. The bar of the hind wing is, however, not from vein 7 to 8, but from the upper median at two-thirds to vein 8. It is quite well possible that this bar is actually vein 7, which would then become concurrent with vein 8, and if this is the correct view, vein 6 would be present. The veinlets in both cells are simple; the branch of *1b* in fore wing is distinct, but hardly reaches the inner margin; the stalk of 8, 9 is only one-fourth and 7 is so far away from the stalk that it might as well be vein 6. The fork of *1b* is very long, nearly half the length of vein. Vein *1b* of hind wing is forked and

1c is very faint; 4 and 5 come from a point, and the discocellular is very oblique. Shape of fore wing rather broad and short, costa arched, apex rounded, termen rather erect, nearly straight, tornus somewhat acute. Hind wing rather large, rounded; costa, termen, inner margin, apex and tornus well rounded. The process of fore tibiae thin and slightly longer than the tibia.

Subgenus *Metisa* *Wlk.*

Metisa *Wlk.*, Cat. iv, p. 957, 1855. Type, *plana* *Wlk.*, from India; Hmps., 'Moths of India,' vol. i, p. 296.
Babula *Moore*, I.A.S.B., lix, pt. 2, p. 262, 1890.

The following description of this subgenus is given by Sir G. F. Hampson in his 'Moths of India':

"MALE.—Fore wing with veins 1b and 1c anastomosing; vein 6 present. Hind wing with vein 6 present; 8 coincident with 7¹ to the end of cell."

Acanthopsyche (*Metisa*) *alba* *sp. n.* Pl. XLIII, fig. 4.

MALE.—Antennæ fuscous-black; head and thorax covered with long white hairs; abdomen and legs thinly covered with white and fuscous hairs; wings transparent, without any colour and without any scales or hairs² except along the inner margin of the fore wings, where there are some short whitish hairs, and the same area of the hind wings on which the hairs are longer and white; cilia represented by some short scales only, in both wings fuscous as far as 1b and beyond this vein more whitish; a fuscous edging along the costa in both wings.

Fore wing long and rather narrow; costa nearly straight; apex and tornus rounded; termen oblique, slightly rounded between veins 3-6, and slightly hollowed out at veins 2-3;

¹ According to the figure given, Hampson means here the upper median and not vein 7 itself, which really begins from the upper angle.

² It is quite possible that a specimen just emerging has some loose scales and more hairs on the wings, but the bred specimen I have seen also shows no sign of them.

fork of *1b* fully two-thirds; 4 and 5 stalked for half their length; disco-cellular very oblique; 7 some distance apart from stalk of 8, 9; stalk of 8, 9 nearly half of 9; cell narrow, long, and with two faint veinlets.

Hind wing subtriangular; costa much arched, termen slightly hollowed out at *1c* to 2; inner margin arched; apex and tornus well rounded; *1c* very faint; 4 and 5 on a stalk of half and from lower angle; 8 free from base, then anastomosing with upper median just before half of that vein till near vein 7; cell rather broad and long; a rather well-defined veinlet in middle of cell from near base till below half disco-cellular; a fainter veinlet below it from before half the distance of stalk of 4, 5 and vein 6, where the disco-cellular is angled.

Exp., 29 mm. in type; 25 mm. in Durban specimen.

HAB.—Type, Nkwaleni, Zululand (Janse, caught at light, January 10th, 1916); also another specimen (cotype) from Durban (bred by E. E. Platt, November 4th, 1914).

Mr. Platt sends me the following information about this species: "I found the bags numerous beyond Sydenham in the month of May, and I have noted that it feeds on Wattle or other Acacia. I remember this moth was dead in the breeding-cage when I found it, and concluded it had beaten its scales off. I did not keep the case."

Genus *PSYCHE* *Schrank*.

Psyche Schrank, Fauna Boica, ii. 2 Abth., p. 87, 1802; Hampson. 'Moths of India,' vol. i, p. 297.

The following description is given by Sir G. Hampson:

"MALE.—Antennæ bipectinated to tip, the branches short or long. Fore tibiæ with no spine. Fore wing with 10 to 12 veins; vein *1b* and *1c* anastomosing or separate. Hind wing with 7 to 8 veins."

The specimens which I place in this genus have all lost their fore legs, so that I cannot be certain about the generic

position, but all the other characters taken together leave very little doubt that they must be placed in this genus.

Subgenus *Manatha Moore*.

Manatha Moore, A.M.N.H. (4), xx, p. 346, 1877. Type, *albipes*, from Ceylon; Hampson, 'Moths of India,' vol. i, p. 298.

The following description is given by Hampson:

"MALE.—Fore wing with vein 1*b* and 1*c* anastomosing; 4, 5 and 8, 9 stalked; vein 6 from near upper angle of cell. Hind wing with vein 6 present; a bar between vein 7 and 8."

The three specimens which I take to be *M. æthiops Hampsn.*, bred by Mr. Hardenberg from a long thin thorn-like bag, vary a little in their venation. One specimen (No. *a*) has 4 and 5 of fore wing on a short stalk; another (No. *b*) has these veins springing from one point; the third specimen (No. *c*) has these veins far apart. Specimen *b* has the left hind wing with vein 5 and 6 on a short stalk. In none of the three specimens is vein 8 of hind wing like it is in the typical *Manatha*; there is no bar, but vein 8 is free and more or less parallel to the upper median for half upper median, then it anastomoses with that vein and with vein 7 for about one-fourth of 7, then it goes obliquely to the costa.

Psyche (*Manatha*) *æthiops Hampsn.* Pl. XLIII, fig. 5.

Manatha æthiops Hampsn., A.M.N.H. (8), vol. vi, p. 116, 1910.

I have not been able to compare the three specimens I have with the type specimens (from the Cape Colony), but they correspond sufficiently with the short description to leave little doubt about the correctness of the identification. My specimens, however, show no white scaling on the body; but they are badly rubbed on head, thorax, and abdomen. The wings are thinly covered with buffy-brown (XL) hairs.

HAB.—Three male specimens, bred by C. B. Hardenberg, from bags collected in Westfalia (Zoutpansberg District).

They emerged in Pretoria on April 20th, in 1910. In collection Janse.

Psyche (*Manatha*) *subhyalina* sp. n. Pl. XLIII, fig. 6.

MALE.—Fore wing with branch of *1b* very long and oblique; 4 and 5 on a stalk of one-sixth; 6 from a little below middle of disco-cellular; 7 slightly stalked with stalk of 8, 9, or from a point and from upper angle; 8 and 9 on a stalk of nearly half of 9; 10 and 11 free and parallel to 9; a single veinlet in cell from below 6.

Hind wing with 4 and 5 on a stalk of one-fifth and from lower angle; 6 equally far from 5 and 7; 7 from upper angle; 8 connected with a bar to upper median at four-fifths; disco-cellular very oblique.

Head, thorax, and abdomen above and underneath rather thinly covered with avellaneous (XL) hairs; antennæ and the long branches blackish-brown (XLV); wings subhyaline, thinly covered with avellaneous hairs, mixed with olive-brown (XL) hairs, so as to give a cupreous gloss in certain light. Fore wing with the costa more thickly covered with hairs, so as to become fuscous-black (XLVI); veins fuscous (XLV).

Hind wing like fore wing, but costa not dark and inner-marginal area glossy cinnamon-buff (XXIX). Cilia glossy cinnamon-buff, with a darker sub-basal shade. Under-side as above, but more thinly covered with hair.

Exp., 15–17.5 mm.

HAB.—Type from Nkwaleni, Zululand, January 10th, 1916; three cotypes, one from the same locality, January 11th, 1916; two from Umkomaas, January 18th and 24th, 1914 (Janse, all caught at light).

III. Subfamily CHALIINÆ.

This subfamily is characterised by Hampson ('Moths of India,' vol. i, p. 300) as follows:

Fore wing with vein *1b* and *c* anastomosing, and not sending

any branches to inner margin. Veinlet in cell of both wings: single or forked. Hind tibiæ with no spurs.

The genus *Monda*, which I propose to place temporarily in this subfamily, has some characters which make its position rather uncertain, and may at some future time give rise to the creation of a new subfamily. The running of vein *1c* in the fore wing is quite different from any Psychid known to me. Instead of originating free and then anastomosing with *1b* or remaining free, it is stalked with *1b* for nearly half the length of this vein, which is short, and ends in the inner margin: *1c* then runs parallel to lower median, and ends above the tornus. No spurs or veinlets are given off from these veins.

Genus *MONDA* *Wlk.*

Monda Wlk., Cat. xxxii, p. 406, 1865. Type, *delicatissima Wlk.*, from South Africa.

Proboscis absent; palpi very rudimentary; antennæ short, less than one-third of costa, bipectinate, branches as long as one-third of length of shaft, suddenly becoming shorter at tip, closely ciliated, and each branch ending in one long bristle; fore, mid, and hind legs short, slender, without any processes or spurs, and very sparsely covered with rather long hair. Fore wing triangular; costa slightly hollowed out; apex well rounded; termen erect, somewhat undulating at the veins; tornus well rounded; inner margin nearly straight; cell long, broad at median part of wing; discocellular very oblique. Vein *1b* simple at base, short, ending at inner margin at two-thirds; *1c* stalked with *1b* for nearly half the length of *1b*, then curved upwards and ending above tornus; lower median curved upwards; 2, 3 and 4 far apart and at equal distance; 5 from 4 as far as half distance 3 to 4 and continued in cell as a veinlet; 6 from middle of distance vein 5 to stalk of 8, 9; 7 absent; 8 and 9 on a stalk of three-fourths, originating from upper angle; 10 absent; upper median well curved downwards from base to two-thirds; 11

from upper median at over half of wing length, short and anastomosing with 12 at three-fourths of vein 12.

Hind wing subtriangular, nearly as broad as long; costa slightly arched; apex well rounded; termen rounded and somewhat undulating at the veins; tornus well rounded; inner margin nearly straight; frenulum thin, about one-fourth of costa in length; cell only as long as half the wing and rather narrow. Vein 1*a* rather long and curved; 1*b* long, slightly curved; 1*c* faint, nearly straight and ending in termen near vein 2; 2 from two-thirds upper median; 3 from nearer to lower angle than from vein 2; 4 from lower angle; 5 from near middle of disco-cellular and continued as a veinlet in the cell; 6 absent; 7 from upper angle; upper median connected at half to vein 8 by a short bar, which is oblique and directed basally.

Four South African species, of which I have seen only two, belong to this genus.

Monda delicatissima *Wlk.* Pl. XLIII, fig. 7.

Monda delicatissima *Wlk.*, Cat. xxxii, p. 407, 1865.

MALE.—Antennæ white, ringed with fuscous; branches white with fuscous pecten; head, thorax and abdomen black and sparsely covered with whitish hairs. Wings whitish transparent, sparsely covered with rather short white hairs; apical area rather thickly covered with fuscous hairs, from beyond half along costa, from before disco-cellular and till near vein 3; fuscous scaling between vein 3 and 4 rather thin; two rounded fuscous spots a little distance away from disco-cellular and lower median, one between vein 2 and 3 and one between vein 3 and 4; cilia consisting of rather long white hairs sparingly distributed.

FEMALE.—Wingless.

Exp., 17 mm.

I bred this interesting little moth from small bags supplied to me by Mr. E. E. Platt, Durban. It feeds on *Desmodium incanum* DC.

HAB.—Durban ; Singerton, Barberton District, in June (K. Munro).

Monda rogenhoferi Heyl.

Monda rogenhoferi Heyl., C. R. Soc. Ent. Belg., vol. 34, p. clxxxii, 1891; Kirby, Cat., p. 518; Junod, Bull. de la Soc. Neuch. des Sciences Nat., vol. xxvii, p. 250, pl. iv, fig. 5, 1899.

HAB.—Mozambique, Delagoa Bay ; Durban, Natal.

A specimen bred from a bag collected by the author in the Stella Bush emerged at New Hanover on April 24th, 1916. In collection Janse.

SPECIES AUCTORUM :

Monda major Heyl., C. R. Soc. Ent. Belg., vol. 34, p. clxxxii, 1891; Kirby, Cat., p. 518, Junod, l. c., p. 249, pl. iv, fig. 6a, b.

HAB.—Mozambique, Delagoa Bay.

Monda heylærtsi Junod, Bull. de la Soc. Neuch. des Sciences Nat., vol. xxvii, p. 250, pl. iv, figs. 7a, b, c, 1899.

HAB.—Delagoa Bay.

GENERA AND SPECIES OMITTED :

Fumea trimenii Heyl. (Tineidæ).

Epichnopteryx transvalica Hampson. (Tineidæ).

These species were placed by their respective authors in the Fumeinæ as a subfamily of the Psychidæ, but as they have well-developed middle spurs on the hind tibiæ I exclude them from the true Psychids.

COSSIDÆ.

It is with some hesitation that I keep the genera *Gymnelema* and *Trichocossus* in the family Cossidæ, but at the same time I do not feel at liberty to follow the other alternative, namely, to place them in the Tineidæ, though it is true that the resemblance to the latter family is very great.

Heylaerts placed his genus *Gymnelema* in the Tineidæ between the genera *Melasina Boisd.* and *Diplodoma Zell.* (both true Tineids), in which genera most species, if not all, live in portable cases.

In the *Cossidæ* the larvæ live as a rule in the stems of trees and smaller plants, making galleries in which they also pupate. No true *Cossids* are, as far as I know, free feeders, and to find "bagworm-moths" that have some *Cossid* characters is certainly a point of biological and phylogenetic interest.

The only characters that throw the genera *Gymnelema* and *Trichocossus* out of the *Cossidæ* are the presence of well-developed spurs on the hind tibiæ, and the underdevelopment of vein 1c of the fore wing. The venation of both wings resembles otherwise, perhaps, more the typical *Cossid* wing than the *Melasina* wing.

If we follow Meyrick's classification as given in his 'British Lepidoptera,' we come to the conclusion that the two genera in question have to come in the *Tineina*-group, and not in the *Psychina*-group (in which the *Cossids* come), as the middle spurs of the hind legs are present and well developed. On the other hand, in the *Tineina* vein 5 of fore wing is as a rule less close to 4 than is the case in *Gymnelema* and *Trichocossus*. Also, in these two genera the terminal joint of the palpi is very short, and the whole palpus is covered with long spreading hairs, like a *Psychid*-palpus, while in the *Tineids* the terminal joint is usually rather long and the palpus is covered with dense scales. This is the case even in the allied genus *Melasina*, but in *Diplodoma* the scales are rather loose.

Sir George Hampson, in describing the genus *Trichocossus* (A.M.N.H. ser. 8, vol. vi, p. 134, 1910), states: "This genus may be placed in the *Tineidæ* when the limits of the families are better defined." Of the genus *Gymnelema* (loc. cit.) he writes: "The genus belongs to the undefined borderland between the *Cossidæ* and *Tineidæ*; the distinction will probably be proved to be that the former has vein 1c of the fore wing fully developed and reaching the termen or becoming coincident with 1b; the latter slight and not reaching the termen."

If I knew that placing the genera in question in the

Tineidæ would satisfy Mr. E. Meyrick, I should prefer to do so, as they are more related, I think, to the Tineidæ than to the Cossidæ.

It may be, however, that at a future date a separate family will have to be formed for *Gymnelema*, *Trichocossus* and their allies, as the two genera known to me have certainly several characters peculiar to them as a group.

Pending Mr. Meyrick's view I keep the genera in the family in which they are placed by Sir George Hampson.

The characters of this group (family ?) are as follows :

In male and female, head, thorax, abdomen, femora and tibiæ densely hairy ; antennæ pectinate in male, simple, serrate and ciliate in female ; maxillary palpi and ocelli absent ; labial palpi short, covered with long spreading hairs ; fore tibiæ without a process ; mid tibiæ with two well-developed end spurs ; hind tibiæ with the mid and end spurs well developed ; wings covered with scales.

Fore wing with *1a* forming a long fork with *1b*, which is more or less curved upwards and comes rather close to 2 ; *1c* present for at least half length of wing, then becoming obsolescent ; cell long and rather narrow, with a simple or forked veinlet ; 2 very near to lower angle ; 5 rather close to 4 ; 5 to 12 present.

Hind wing *1c* present ; 2 to 7 free, veins 2 to 8 present ; cell with a forked veinlet ; 8 free, more or less parallel to costa.

The larvæ are case-dwellers.

Genus *GYMNELEMA* *Heyl.* Pl. XLIII, figs. 8, 9, 10.

Gymnelema Heyl., Ann. Soc. Ent. Belg., vol. 35, p. cccclxxv, 1891.

Type, *rougemonti Heyl.* ; *Hmps.*, A.M.N.H., ser. 8, vol. vi, p. 134.

The following description is made from *G. vinctus Wlk.* :

Proboscis absent ; palpi hardly reaching frons, ascending, three-jointed, third joint very short, acute ; antennæ about half length of costa, bipectinate in male ; pecten about three times thickness of shaft, gradually getting shorter to tip and

on one side densely ciliated; antennæ of female shorter than half of costa, serrate and ciliated; fore tibiæ without a process; mid tibiæ with end spurs, inner spur slightly shorter than outer; hind tibiæ with very long mid and moderate hind spurs; tarsæ with long smooth scales.

Fore wing of male about twice as long as broad; costa and inner margin nearly parallel; costa gently arched; apex well rounded; termen oblique, slightly arched; tornus rounded; inner margin first straight, then well curved towards base.

Fore wing in female longer, nearly three times width of wing.

Vein *1a* forms a fork with *1b* of over one-third of *1b*; *1b* much curved towards upper median at two-thirds; *1c* faint and only present for about half, never reaching termen; lower median slightly curved upwards; cell nearly two-thirds of wing; 2 from beyond seven-eighths of lower median; 3 from lower angle; 4 and 2 from nearly the same distance of lower angle; 5 from nearer 4 than 4 from 3 and curved at middle; 6 from two-thirds disco-cellular, which is a little curved between 5 and 6; 7 from near upper angle or from areole; areole formed by 8 or by stalk of 7, 8 and stalk of 9, 10; 9 and 10 from areole, either stalked or free; 11 from near and before middle of upper median; 12 parallel to 11; fork of veinlet in cell very long, from half to one-third (in *G. stygialis* the upper part of the fork is absent).

Hind wing triangular, rather longer in female than in male; costa arched at middle; apex rounded; termen gently hollowed at between 2 to 6; tornus well rounded; inner margin slightly hollowed out; vein *1c* rather faint; cell half of wing; 2 from two-thirds of lower median; 4 from lower angle; 3 from middle of 2 to 4; 5 from one-third, 6 from two-thirds of disco-cellular; 7 from upper angle; upper median curved beyond middle; 8 somewhat parallel to costa.

The type of this genus is unknown to me and comes from Delagoa Bay.

Gymnelema vinctus (Wlk.) (Crossed-stick Bagworm).
Pl. XLIII, fig. 10.

Cossus vinctus Wlk., Cat. xxxii, p. 583, 1865.

Trypanus vinctus (Wlk.), Kirby, Cat. i, p. 863.

Cossus incanescens Butl., A.M.N.H., December, 1875, p. 402.

Gymnelema vinctus (Wlk.), Hmps., A.M.N.H. (8), vol. vi, p. 134.

MALE.—Head and thorax on upper- and underside covered with white and whitish hairs mixed with some fuscous (XLVI) hairs; terminal edge of tegulæ with fuscous hairs forming a transverse line over the thorax, which becomes broader in middle; shaft of antennæ white, with short (3 times shaft) branches of a cream (XVI) colour; legs covered with fuscous hairs mixed with white; abdomen at base whitish mixed with fuscous, terminal two-thirds of abdomen fuscous, hairs on terminal segment whitish, underside with whitish and hair-brown (XLVI) hairs, except last two segments, which have white hairs, lateral hairs on underside fuscous and fuscous-black.

Fore wing white; a broad band of drab (XLVI) scales from below upper median to inner margin between sub-basal and antemedial lines; another oblique band of the same colour, its inner edge from before subterminal at costa to near outer edge of first band at inner margin, its outer edge from subterminal line at costa to postmedial line at inner margin; the two bands become more or less confluent at below lower median, so as to form a semi-circular light patch between that vein and the inner margin; fuscous-black patches on costa at sub-basal, antemedial, and postmedial regions; a number of irregular, broken transverse lines of fuscous and fuscous-black scales, especially in medial and terminal regions; a fuscous terminal line; cilia of fuscous and white scales with a basal line.

Hind wing drab-grey (XLVI); a number of long fuscous hairs on inner marginal area; terminal line and cilia as on upper wing.

Underside: both wings covered with drab (XLVI) scales; terminal line very pronounced; costal and cellular regions of fore wing with fuscous scales.

FEMALE.—Fore wing more elongate; broad fasciæ darker, as they are irrorated with fuscous; costal markings and strigulae less sharply defined and of a fuscous colour; strigulae very diffused at beyond postmedial line; hind wing lighter; underside as in male except that the costal markings of fore wing are more pronounced, especially at apical regions; head, thorax, abdomen and legs covered more uniformly with hair-brown (XLVI) and fuscous hairs.

Exp., male 25 mm., female 34 mm.

HAB.—New Hanover, Natal (bred by C. B. Hardenberg in January and February from the "Crossed-stick" Bagworm).

The specimens of the following localities were all caught at light:

Durban (Green, Cooke); Sarnia in January and February (Williamson, Janse).

Maritzburg in January (Janse); Umkomaas in January (Janse).

The venation 7 to 10 of fore wing varies a little in this species. I have nine males and four females that have 9 and 10 on a stalk from the areole, and three males that have these veins free from the areole. In one male (No. 988) the left wing is normal and 9 and 10 on a stalk from the areole, while the right wing has 7 and 8 on a short stalk from the upper angle, 9 and 10 on a long stalk from the upper median, and no areole is formed at all.

Though I have not been able to get my specimens compared with the type, I have little doubt that my identification is correct, as the description of Walker as well as that of Butler fit my specimens well enough if one allows for more or less pronounced marking.

My specimens agree best with Butler's description, whose species, according to Hampson, is a synonym of Walker's *vinctus*. None of these three writers mention that the larva of this species makes a bag.

Gymnelema stygialis Heyl. Pl. XLIII, fig. 8.

Gymnelema stygialis Heyl., Ann. Soc. Ent. Belg., vol. 35, p. cccclxxv. 1891; Hmps., A.M.N.H. (8), vol. vi, p. 134.

FEMALE.—Head, thorax, abdomen and legs covered with fuscous-black (XLVI) hairs on upper- and underside. Fore wing dusky purplish-black (LIII), regularly irrorated with groups of large white scales, each group consisting of three to six or more scales; the groups are arranged in such a manner as to form transverse interrupted lines which are rather close together; cilia fuscous-black, darker at base and thus forming a well-defined dark line parallel to termen.

Hind wing rather thinly covered with dusky purplish-black scales; cilia as in fore wing.

Underside of both wings fuscous-black; on costa of fore wing about six groups of white scales from one-third of costa to near apex, distance between the spots increased from base towards apex.

Ovipositor long, antimony-yellow (XV), surrounded by long fuscous-black hairs.

Exp., female 27.5 mm.

HAB.—Bred from a bag found by the author at Waterval Onder, Transvaal, emerged on January 9th, 1911.

The following description is given by Sir G. F. Hampson (loc. cit.) of the male, which is unknown to me.

“Wings shorter and comparatively broader; especially the hind wing; fore wing with vein 9, 10 coincident, the white irroration slight, cilia pure white except at tornus; hind wing with some white in cilia towards apex. Exp. 18 mm.

HAB.—White river, Johannesburg and Natal.”

Hampson’s females were up to 30 mm. expansion.

Gymnelema imitata sp. n. Pl. XLIII, fig. 9.

MALE.—Head, thorax, abdomen and tibiae covered with tilleul-buff (XL) and drab (XLVI) very long hairs; fore tarsi white, ringed with fuscous; mid and hind tarsi and

spurs cream-buff (XXX) ringed with fuscous. Fore wing Saccardo's umber (XXIX) irrorated with fuscous; at costa and at base some white scales; a fuscous terminal line; cilia white, drab (XLVI) at base.

Hind wing Saccardo's umber, sprinkled with fuscous scales, darker at inner marginal area, which has also some long tilleul-buff hairs; cilia as in fore wing.

Underside slightly lighter than upperside; some drab-coloured spots on costa of fore wing on second half of wing.

Exp., type 24.5 mm.; cotypes 22.5 mm. and 26 mm.

HAB.—Barberton January 13th, 1911, type and one cotype (caught at light by the author).

Eshowe, Zululand, February 24th, 1916, cotype (bred by C. B. Hardenberg from a bagworm).

The female is unknown to me.

The bag of this moth resembles in many respects that of the Crossed-stick Bagworm, but the moth is decidedly different. I think this species is closely allied to *G. stygialis*.

The venation of this species is not quite constant in the fore wing. The type and one cotype has 7 and 8 stalked and 9 and 10 stalked for about equal length, originating from the areole not far from each other. The cotype from Barberton has only 9 and 10 stalked, 8 from the areole at place of stalk in other specimens, 7 from half way upper angle and 8.

Gymnelema stibarodes (Meyr.).

Melasina stibarodes Meyr., Ann. S.A. Mus., v, p. 378, 1909.

I have lately had the opportunity of examining the cotypes of this species closely, and have come to the conclusion that it is better placed in the genus *Gymnelema*. It is very difficult to define the limits of this genus and those of *Melasina*, but several small differences taken together confirm that there is a difference, and this we notice at once when comparing more typical representatives of both genera with each other in a general way, without entering into details. The general build is much stouter in *Gymnelema*

than in *Melasina*, and the wings are shorter and broader in the former. In the species *stibarodes* the build is very much like *G. imitata* and the bag is almost identical in method of building, and, as Meyrick remarked in his paper on this species, more like one of a Psychid moth than of a Tineid. The palpi of *stibarodes* are covered entirely with hairs which are spreading, like in the typical *Gymnelema*. In *Melasina* all the palpi I have seen are mainly covered with scales which lie close together, though sometimes they have some hairs mixed with the scales, and then also a tendency to spreading and to reduction of length of palpus; never, however, to the extent found in *Gymnelema*. The neuration gives little help, but that 7 and 8 of fore wing are generally stalked, however shortly, points to *Gymnelema* and not to *Melasina*; in the female cotype of *stibarodes* this stalk is as long as we find in *Trichocossus arvensis*. The lack of consistency in the running of these veins in *stibarodes* is also found in *G. imitata*, to which, I think, *stibarodes* is mostly allied.

SPECIES AUCTORUM:

Gymnelema rougemonti *Heyl.*, Ann. Soc. Ent. Belg., vol. 35, p. cclxxv, 1891; *Hmps.* A.M.N.H. (8), vol. vi, p. 134.

HAB.—Delagoa Bay.

Gymnelema leucopasta *Hmps.*, A.M.N.H. (8), vol. vi, p. 135, 1910.

HAB.—Cape Colony.

Gymnelema pulverulenta *Hmps.*, A.M.N.H. (8) vol. vi, p. 135, 1910.

HAB.—White River, Transvaal.

Genus TRICHOCOSSUS *Hmps.*

Trichocossus *Hmps.*, A.M.N.H. (8), vol. vi, p. 133, 1910. Type, *albiguttata* *Hmps.*, from Potchefstroom.

The following description is given by Hampson:

“Proboscis absent; palpi minute, clothed with very long hair; antennæ bipectinate with moderate branches to apex;

head, thorax and abdomen clothed with long hair; the last with the anal tuft long; tibiæ with the spurs long. Fore wing with the costa and inner margin nearly parallel, the apex rounded, the termen evenly curved; veins *1a* and *b* anastomosing and curved upwards beyond middle; *1c* slight; 2 from close to angle of cell; 3 from angle; a forked veinlet in cell: 4, 5, 6 from disco-cellulars at intervals; 7, 8 strongly stalked, from upper angle; 9 from angle; 10, 11 from cell. Hind wing with vein 2 from close to angle of cell; 3 from angle; 4, 5, 6 at intervals from disco-cellulars: 7 from upper angle; a forked veinlet in cell; 8 free."

The species which I place in this genus agrees with the description in nearly every detail. The stalk of 7, 8 is as long as two-thirds of 7 and from upper angle; vein 9 is, however, a little apart from the stalk; the upper part of the forked veinlet in cell is rather faint. In the hind wings the veins 4, 5, 6 are not always at intervals, as my specimen from New Hanover has vein 5 curved at base towards 4 so as to come with that vein from a point.

Trichocossus arvensis *sp. n.* (Meadow Bagworm).

Pl. XLIII, fig. 11.

MALE.—Head, thorax, abdomen, femora and tibiæ covered with white hairs; palpi and hairs under the eyes fuscous (XLVI); shaft of antennæ natal brown (XL), branches fuscous-black four times shaft at middle.

Wings covered with chatura drab (XLVI) scales and with whitish hairs at inner margins; apparently no markings on the two wings either on upper- or on underside; cilia (as far as present, which is only partly on termen, tornus and inner margin of hind wing) white, with fuscous base.

The specimens are in a rather rubbed condition, but the characters are sufficiently distinct to separate them at once from any of the allied species. Moreover, the bag is also very characteristic and has been found in two different localities.

Exp., 19–17.5 mm. (without the cilia, which are absent in the fore wings of both specimens).

FEMALE.—Unknown.

HAB.—Type, from Pretoria, January, 1916. Bred by Mr. K. Munro from a bagworm feeding on *Vernonia krausei*.

The apices of the fore wings of this specimen are somewhat broken and the scales rubbed off the apical part as far as from half of costa to tornus.

Cotype, New Hanover, Natal, January, 1915. Bred by Mr. C. B. Hardenberg. In this specimen the wings are unbroken but more rubbed, and it has also the antennæ missing.

SPECIES AUCTORUM :

Trichocossus albiguttata *Hmps.*, A.M.N.H. (8), vol. vi, p. 134, 1910.

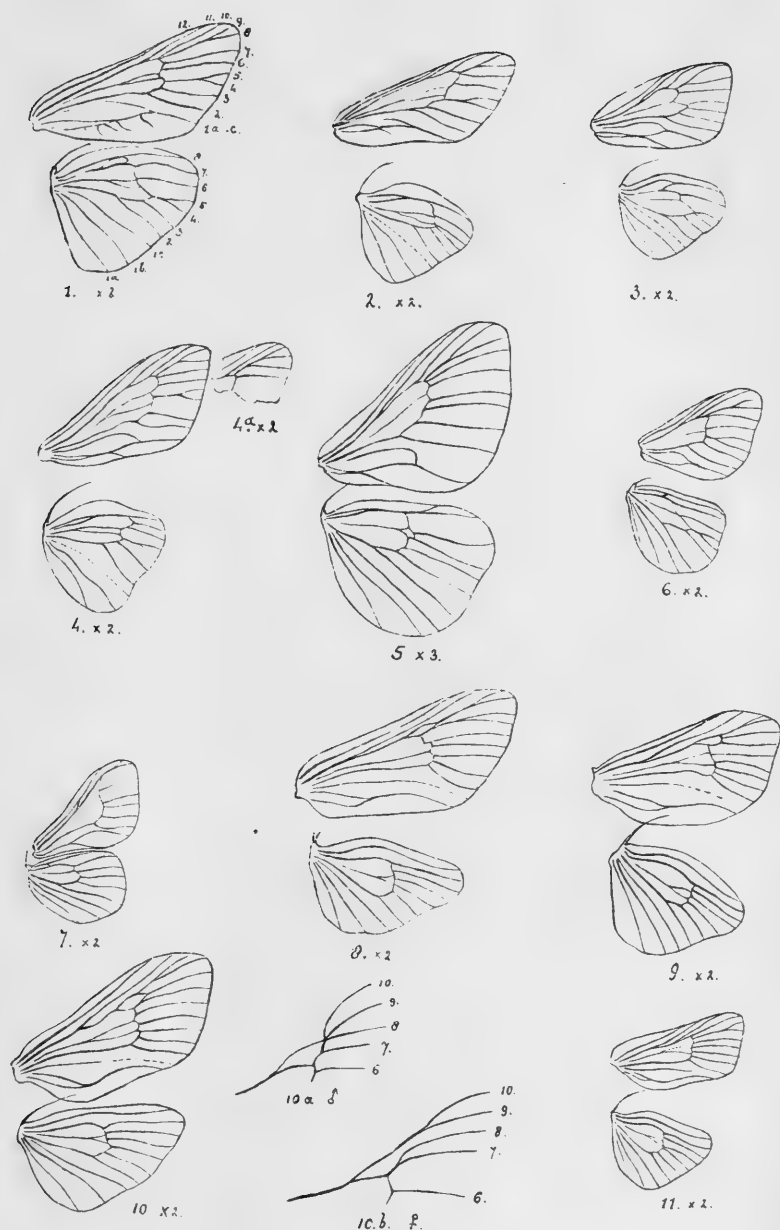
HAB.—Transvaal, Potchefstroom.

EXPLANATION OF PLATE XLIII,

Illustrating Mr. A. J. T. Janse's paper, "South African Bagworms."

Diagrams of fore and hind wings, showing the neuration in the following species of Bagworms.

- Fig. 1.—× 2. *Clania modernannia* (*Heyl.*).
 Fig. 2.—× 2. *Acanthopsyche junodi* (*Heyl.*).
 Fig. 3.—× 2. *Acanthopsyche tristis* *sp. n.*
 Fig. 4.—× 2. *Acanthopsyche alba* *sp. n.* Fig. 4a. Variation.
 Fig. 5.—× 3. *Psyche* (*Manatha*) *æthiops* (*Hypson.*).
 Fig. 6.—× 2. *Psyche* (*Manatha*) *subhyalina* *sp. n.*
 Fig. 7.—× 2. *Monda delicatissima* *Wlk.*
 Fig. 8.—× 2. *Gymnelema stygialis* *Heyl.*
 Fig. 9.—× 2. *Gymnelema imitata* *sp. n.*
 Fig. 10.—× 2. *Gymnelema vinctus* (*Wlk.*). Figs. 10a ♂ and 10b ♀. Variations.
 Fig. 11.—× 2. *Trichocossus arvensis* *sp. n.*



Janse del. et lith.

1. *Clania moddermanni* (Heyl). 2. *Acanthopsyche junodi* (Heyl). 3. *A. tristis* sp. n.
 4. *A. alba* sp. n. 5. *Psyche* (Manatha) *aethiops* (Hmps.). 6. *Psyche* (Manatha) *subhyalina* sp. n.
 7. *Monda delicatissima* Wik. 8. *Gymnelema stygialis* Heyl. 9. *G. imitata* sp. n.
 10. *G. vinctus* (Wik). 11. *Trichocossus arvensis* sp. n.



Descriptions of Some New South African Microlepidopterous Bagworms.

By

E. Meyrick, B.A., F.R.S.

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TINEIDÆ.

Fumea obscurata sp. n.

MALE.—11 mm. Head, palpi, thorax and abdomen dark fuscous, palpi short, loosely haired. Antennal pectinations five. Fore wings elongate, posteriorly slightly dilated, costa moderately arched, apex obtuse, termen slightly rounded, oblique: dark fuscous-grey: cilia concolorous. Hind wings dark fuscous; cilia grey, becoming dark fuscous towards base.

HAB.—New Hanover, in December (Hardenberg), one specimen.

Type in collection Janse.

Melasina cnaphalodes sp. n.

MALE.—18 mm. Head, palpi and thorax brownish, palpi short, slender, thorax with moderate crest. Antennal pectina-

tions four. Abdomen fuscous. Fore wings elongate, moderate, rather dilated posteriorly, costa gently arched, apex rounded, termen rounded, rather oblique; 7 and 8 long stalked; brownish suffusedly clouded with fuscous and transversely strigulated or reticulated with dark fuscous, forming two or three small spots beneath costa posteriorly: cilia brownish, basal third rather dark fuscous. Hind wings dark fuscous; cilia fuscous, basal third darker.

HAB.—Clan Syndicate, in December (Hardenberg), one specimen. Also a female attributed to the same species, but with wings unexpanded and rubbed.

Type in collection Janse.

Melasina picea sp. n.

MALE AND FEMALE.—Male 19 mm. Female 22 mm. Head, palpi, thorax and abdomen fuscous, palpi short, slender. Antennal pectinations of male five. Fore wings elongate, moderate, rather dilated posteriorly, costa gently arched, apex rounded, termen rather obliquely rounded; all veins separate; fuscous, suffusedly strigulated with dark fuscous, forming three or four small spots on costa posteriorly: cilia fuscous. Hind wing dark fuscous; cilia fuscous, with darker basal line.

HAB.—Clan Syndicate, in January (Hardenberg), three specimens. Closely allied to *cnaphalodes* but truly distinct; the different neuration, more obscure colouring, and costal (not subcostal) posterior spots are discriminating characters.

Melasina tyrophanes sp. n.

MALE.—16–18 mm. Head pale yellowish. Palpi whitish, with dark fuscous hair-scales. Antennal pectinations slender, five. Thorax and abdomen rather dark fuscous. Fore wings elongate, posteriorly somewhat dilated, costa gently arched, apex obtuse, termen obliquely rounded; rather dark fuscous, faintly purplish-tinged: cilia fuscous. Hind wings pale yellowish, base and apex narrowly infuscated, or whole wing

thickly strewn with dark fuscous scales; cilia pale yellowish, sometimes greyish-tinged, round apex and upper part of termen suffused with fuscous. Under-surface of hind wings pale yellowish, sometimes infuscated.

HAB.—New Hanover, in August and October (Hardenberg), three specimens.

Melasina craterodes *sp. n.*

FEMALE.—18 mm. Head, palpi, antennæ, thorax and abdomen dark fuscous; palpi short, slender; antennæ shortly pectinated, clothed with dense rough scales above except towards apex, apical portion whitish-grey. Fore wings elongate, posteriorly dilated, costa gently arched, apex obtuse, termen obliquely rounded; dark grey, with some black transverse interrupted striæ and strigulæ, costal edge whitish-grey between these; a straight somewhat oblique blackish fascia before middle; a second beyond middle, becoming much broader on costal half, and enclosing a grey-whitish dot on costa; a blackish subterminal streak, parallel to termen on upper two-thirds: cilia pale brassy-ochreous, mixed with grey, towards tips whitish. Hind wings dark fuscous; cilia brassy-fuscous.

HAB.—New Hanover, in February (Hardenberg), one specimen.

Allied to *primella*, but with very different palpi. Larval case 8 mm. long, subcylindrical, narrowed at extremities, composed of silk covered with refuse, strengthened with a series of twigs attached rather spirally round median area.

ADELIDÆ.

Ceromitia xanthocoma *sp. n.*

FEMALE.—15 mm. Head densely haired on crown, wholly ochreous-orange. Labial and maxillary palpi short, whitish. Antennæ white, towards base grey. Thorax rather dark purplish-grey. Abdomen dark grey. Fore wings elongate,

rather narrow, posteriorly somewhat dilated, costa gently arched, apex obtuse, termen very obliquely rounded; veins 2-10 unusually approximated, 11 widely remote; rather dark purple-grey: cilia grey. Hind wings and cilia rather dark grey.

HAB.—New Hanover (Hardenberg), one specimen.

Nearest *iolitha*, from which it is distinguished by the wholly orange head and unusually approximated veins.

South African Bagworms: their Transformations, Life-history, and Economic Importance.

PART I.

By

C. B. Hardenberg, M.A.,

Government Entomologist in Charge of Wattle Insect Investigations.

With Plates XLIV-XLVI and 6 Text-figures.

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INTRODUCTION.

DURING the past two years the writer has been engaged in a study of the Wattle Bagworm, *Acanthopsyche junodi* (*Heylaerts*), fam. Psychidæ, and other insects injurious to the Black Wattle, *Acacia mollissima* *Wild.*, for the purpose of finding means for their control and thus minimising their injury to the wattle plantations. It was soon found that, apart from the ordinary Wattle Bagworm, there were several other species, not as common, to be sure, but deserving more than passing notice as being potential wattle pests. A number of these have already firmly established themselves on the wattle as their principal, if not exclusive, food-plant, others are just beginning to take to it, while still another group of bagworms, although not counting the wattle amongst their usual food-plants, will readily eat it when it is offered to them and will pass through their usual transformations on this diet. When we consider that the Wattle Bagworm, above mentioned, some ten or fifteen years ago was in this same stage of transition from its native host-plants, the Thorn bushes, consisting of various species of *Acacia*, to the cultivated Black Wattle, and that it is at present considered by the wattle growers as their worst pest, we have reason to fear that within the near future these other bagworms will also begin to frequent the Black Wattle to a greater extent than now, and that this tree, from an occasional food-plant, may become a preferred one.

It is natural, therefore, that we should have taken a great interest in all such species of bagworms which are to be found either on the wattles themselves or on the other vegetation in and around the wattle plantations. Some two dozen various kinds of bagworms have been found thus far. Of these, six have been noticed to subsist almost exclusively on the Black Wattle, five others frequent the wattle occasionally, although this is not their usual food-plant, while the others have thus far not been taken on the wattle itself, and as yet confine their depredations to the other vegetation in and around

the plantations. But even the majority of these will feed on wattle leaves when they are offered to them.

The knowledge at present available about South African bagworms appears to be very scanty indeed. While the cases of some half-dozen species have been figured and roughly described, their larvæ and adults are for the greater part unknown, and are not yet represented in the collections of our museums and of private collectors of Lepidoptera. The study of the life-histories and transformations of these bagworms furnishes an as yet practically unexplored and very interesting field of investigation, and, while admitting that our knowledge on these points is still very fragmentary, the information gained thus far is here published for the purpose of stimulating interest in these curious insects, which appear to have been much neglected in the past.

Bagworms in other countries.—In other parts of the Old World the bagworms are well represented, and have received considerable attention. From Australia, Froggatt mentions thirteen species, mostly of the larger and more curious kinds, as having been described up till 1907. From India some fifty species are known, as mentioned in Maxwell-Lefroy's 'Indian Insect Life,' while Central Europe also shows the considerable number of thirty-five species. We may thus safely assume that the twenty-four different kinds which up till now have come to our notice represent only a fraction of the total number to be found. Those about to be discussed here are nearly all such as have been taken in Umvoti County, Natal, in connection with the Wattle Insect Investigation, and the search of other localities will doubtless bring many more species to light.

I. GENERAL SHORT OUTLINE OF THE LIFE HISTORY OF BAGWORMS.

(1) THE BAGS.

The popular name "bagworms" has been given to these creatures on account of their peculiar larval habits. The

caterpillar does not live exposed, but is concealed in a bag of its own manufacture, which it carries about with it. The popular names in other countries, "Basket worms" of the Americans, "Bicho de Cesto" of the Spanish, "Sackträger" of the Germans, all have reference to this same curious habit; the last-mentioned name being more nearly correct as it actually indicates that the bag is being carried about. But the name which most accurately expresses the condition is that given to these insects by the Zulus, "u-Mahambanendhlwana," meaning a creature which carries its house with it.

When the larva hatches from the egg, its first care, before starting to feed, is to construct its little house. This is done by gnawing small pieces of leaf or other substance on which it happens to be, and weaving these together with silk spun from its mouth into a collar which is fastened around the neck. To this successive rings are added until the creature is entirely encased in a conical bag, narrowest at its posterior end, and into which it can entirely withdraw when danger threatens. This silken casing is added to as the larva grows; and, as feeding progresses, little bits of the food-plant are attached to the casing. This is done in various ways, characteristic for each species.

The formation of the first bag may take place before the distribution of the larvæ occurs or afterwards, but in any case before the larva starts feeding.

The adornment of the tube as a rule proceeds gradually as the caterpillar feeds and grows, but we have reason to think that in some species, such as *Fumea obscurata* *Meyr.* and *Melasina picea* *Meyr.*, for instance, this does not happen until the larva has become fully grown and makes ready for pupation.

As these various adornments are in nearly all cases parts of the food-plant, it follows that the same species of bagworm may bear different aspects according to the plant on which the caterpillar has been feeding. But the method of the attachment is always the same for a given species, no matter

what the food-plant, and it is this, and the shape of its silken casing, which gives to each species of bagworm its characteristic appearance.

In external aspect there is a great variety: some species are much more careful architects than others. The Wattle Bagworm, *Acanthopsyche junodi* (*Heylaerts*) (Pl. XLIV, fig. 1), takes off irregular pieces of whatever part of the food-plant is within its reach and anything which may be attached to it, and fastens it at one end only to the bag, so that the result is a bag of irregular surface, adorned with leaves, sticks, seed-pods, or even other bags which happened to be hanging on to the leaf on which it was feeding.

Another such careless builder is what we have called the "Thatched Bagworm," *Acanthopsyche tristis* *Janse*, but here only the blades of grass are used, and as the silken tube in the case of this species is more cylindrical, the entire bag has a longer and narrower appearance (fig. 2).

The "Gum Bagworm," *Melasina stelitis* *Meyrick* (fig. 3), uses pieces of the broad-leaved foliage on which it feeds, cuts it into more or less square pieces, about a quarter of an inch each way, which it fastens with one side on to its bag. These are rather closely applied to the surface of the bag, those of the one layer slightly overlapping those of the preceding one, and as a result we have a bag which, although made of the same material and in a similar manner to that of the Wattle Bagworm, has an entirely different aspect. The distinction between the two can be more readily seen than described.

The most careless builder of all is *Melasina picea* *Meyr.* (fig. 4), a species which, for want of a better name, we have called the "Rubbish Bagworm" from the construction of its bag. It accepts anything which it finds on the ground: remains of beetles, flat egg-cases of spiders, chips of bark, sticks, dried leaves, etc., everything is made use of. These objects are attached to the case in a very irregular fashion, lengthwise, crosswise, or at any angle, so that when the creature is resting on the ground it can hardly be

distinguished from the miscellaneous débris with which the ground is covered.

The "Lictor Bagworm," *Clania moddermanni Heylaerts* (fig. 5), uses small sticks which are rounded off at both ends and are attached lengthwise to the bag and fastened along their entire length. These sticks are as long as or longer than the inner casing, and, being put parallel and close together, give the bag a solid, cylindrical appearance. The sticks are not all of equal length and generally there are one or two extending beyond the bag for a considerable distance.

The "Grass Bagworm" (fig. 6) (species as yet undetermined) takes thin, hollow grass-culms, cut off to approximately equal sizes, and attaches them lengthwise to its bag, giving the appearance of a neat, cylindrical little bundle. These hollow straws are fastened to the silken case, if not for their entire length, then at least for a considerable distance.

Another group of bagworms are in the habit of attaching the various adornments crosswise to their bags. The "Meadow Bagworm," *Trichocossus arvensis Janse*, whose bag is shown in fig. 7, takes for this purpose small pieces of the blades of grass, which are smoothly applied to the casing over their entire length, thus following its curvature. The result is a smooth, more or less cylindrical bag, lined transversely.

The "Crossed-stick Bagworm," *Gymnelema vinetus* (*Wlk.*), of the Cossidæ, takes small pieces of grass culms, or little twigs, or the midribs of leaves, which are attached to the casings tangentially at about their middle, the free ends projecting (fig. 8). Each following stick has its end crossed over that of the preceding one, and the outline of the bag, around the projecting ends of the component sticks, becomes roughly pentagonal, the diameter of the bag, and thus the length of the sides, increasing toward the upper end, the mouth or neck, of the bag.

A similar, but less regular, arrangement of the sticks is a

feature of the bag of *Gymnelema stygialis* *Hampson* (fig. 9), another Cossid bagworm; while a third species, *Acanthopsyche alba* *Janse*, carefully spins a silken webbing over the outside of its bag, thus making it appear as if it were an old discarded bag covered with a spider's web (fig. 10).

Still another group of bagworms, also using small sticks, arrange the material neither lengthwise nor crosswise but at a slight angle, and as these sticks are of increasing lengths towards the upper end of the bag, this covering assumes a spiral aspect. Three species of these "Spiral Bagworms," all species of *Melasina*, fam. *Tineidæ*, have come to our notice, evincing various degrees of neatness in the arrangement of the material. We have distinguished them as the "Clear Spiral," (*Melasina tyrophanes* *Meyr.* fig. 11), the "Webbed Spiral" (*Melasina enaphalodes* *Meyr.* fig. 12), and the "Rough Spiral Bagworm" (*Melasina craterodes* *Meyr.* fig. 13).

Then there is another species, the "Thorn Bagworm" (*Melasina halientis* *Meyr.* fig. 14), which uses nothing but the fine particles of the leaf or bark on which it feeds. These are arranged into smooth narrow collars, and the bag is made up of a series of these which are accurately joined together, and, increasing in diameter towards the mouth end, form a bag, shaped like a smooth greyish-brown thorn. Still another, the "Sand Bagworm" (*Fumea obscurata* *Meyr.* fig. 15), which lives at the roots of grasses, uses almost nothing but sand-grains in the construction of its bag, and resembles a true caddice-worm in this respect.

Lastly, we may mention a group of bagworms which are distinguished from all the previous ones in that they make no silken tube to which to attach various extraneous materials. The caterpillars merely construct a dwelling by glueing pieces of leaf together, leaving a variously shaped cavity in which the larva lives. The "Flat Bagworm" (*Ceromitia xanthocoma* *Meyr.* fig. 16) makes its case from pieces of the blades of grass, which are arranged transversely and are

smoothly and accurately joined together at their sides. There is one layer of these on the dorsal side and one on the ventral side of the creature. These layers are only very slightly convex and leave but a narrow slit-like cavity between them. In this space, which is very wide but very low, the little worm lies concealed. As an additional protection the dorsal covering is carried a little farther forward than the ventral, so that, when feeding, the larva does not need to expose itself at all. A very similar arrangement we find in the case of the "Flat Leaf Bagworm" (fig. 17). Here the case is made of pieces of leaf, rounded off at one end and slightly concave at the other, the anterior end. Two or three such pieces form each side of the bag which is found attached to the tree trunks. A third species of this group, the "Seed Bagworm" (Pl. XLV, fig. 1), uses three narrow, pointed pieces of leaf or grass which are joined side to side so as to leave a narrow cavity, shaped like a three-sided pyramid. The entire structure resembles in size, shape and colour a part of a grass-flower which has been blown against the branch or trunk, and is very difficult to detect.

All these structures are undoubtedly protective, and made with the object of imitating the surroundings under which the species originally lived. They serve primarily as a protection during the resting stage or pupation period; for most, if not all, pass the winter in this condition. During the summer the protection offered is, in the case of most of these bagworms, not so great; but this need not be, for at that time insect life is plentiful, and as the bagworm withdraws into its bag at the slightest disturbance, it is doubtful whether an insectivorous bird would take much trouble to secure it while other food is plentiful and near at hand. In the winter the conditions are different, and a greater amount of protection is afforded by the bag of withered leaves or dried sticks which blend with the general colour scheme of the vegetation at that time. In order to judge in how far the protection aimed at is being secured we must look for these various bagworms in the winter, and amongst their natural surroundings

on their original food-plants; and our experience has been that such as are conspicuous enough during the summer are difficult to locate amongst the dry vegetation in the winter.

(2) THE LARVÆ.

The bagworm caterpillars are as a rule of a characteristic appearance, being dull grey to dark brown in colour, smooth, soft-bodied, and having the three thoracic segments provided with dorsal chitinised plates; these segments being the only parts of the body which are normally exposed when feeding or crawling. In a few cases the first abdominal segment may also have a dorsal chitinised thickening, but usually the abdomen is soft and membranous.

In all cases where we have had occasion to observe the newly hatched larvæ we found them bearing a remarkable aspect and assuming a characteristic attitude. The thorax is very large and massive, while the abdomen is slender and conical, and is carried elevated at almost right angles to the thorax. This pronounced dorso-flexion, so very abnormal in insect larvæ, is probably a character arising from the habitual position of the body during the feeding period of the caterpillar; for normally, when crawling or feeding, the bagworm is attached to the underside of the leaf or stalk with the bag hanging downward, and the body is thus continually curved dorsad at the juncture of thorax and abdomen.

The continuous carrying of the heavy bag would be expected to give rise to a modification in the structure of the body of the caterpillar. We find that the thoracic legs which have to bear the weight have become very well developed; the coxæ are massive, meeting in the median line, the legs are stout and the claws are strong, so as to enable the insect to retain its hold. And as the bag, which is usually fairly large and roomy, might slip off while hanging down, if the caterpillar had not been especially adapted to cope with this emergency, we find that the abdominal and anal prolegs, although not being used for locomotion, as in the case of the

exposed feeders, are not rudimentary, as might be supposed, but are well developed and provided with hooks which are strongly curved and sharply pointed so as to hook into the silken lining of the bag. Nevertheless, the legs have become so short as to be entirely useless for locomotion when the creature is removed from its bag.

The bagworm caterpillars are very tidy in their habits. When we open one of the bags we find the inside always dry and scrupulously clean. Ejecta and cast skins are removed at once, as the presence of excrement and larval skins would favour the development of fungi and decay with the slight degree of moisture always present in the bag, due to the emanations of the living occupant.

Excessive moisture is their greatest enemy and quickly proves fatal to them. We thus find that the bagworms (at least such as we have had occasion to observe more closely) do not feed during a rain or mist, but they will postpone their meal until the foliage has dried. If the weather conditions are such that they are forced to feed during the rainy weather—and the young larvæ especially cannot stand a fast of long duration—we find that a disease of a bacterial nature quickly appears amongst them with disastrous results. This may be due to two causes: (*a*) the wet food may not agree with them and cause digestive disorders, as a result of which the evacuations become fluid and the inside of the bag becomes soiled, since they cannot be quickly and completely removed like the solid normal pellets. Under such atmospheric conditions we find as a rule a great number of soiled bags which either are empty, having been abandoned by their inhabitant, or contain a flaccid, diseased larva; or (*b*) the drops of water carried in by the larva when retreating into its bag after feeding may increase the degree of moisture inside the bag to an extent which affects the larva unfavourably.

Whatever the primary cause, we find that under these conditions the caterpillars behave abnormally. They turn around in their bag, and such as are able to leave it through the opening at the lower end start making a new bag. While engaged in

this the caterpillar is exposed to its various enemies and the unfavourable conditions of the atmosphere, and thus it makes haste to construct its new dwelling. It is therefore not very fastidious and takes old abandoned bags which it finds on the leaves to supply part of the new covering. The result is a compound bag, made up of from two to five others, of which we find only one inhabited.

(3) THE PUPÆ.

When the time for pupation approaches, the larva makes preparations to still further secure its retreat and to establish for itself a safe place in which to pass the all-important period of pupation. Generally the creature moves with its bag to a less conspicuous place, or one where its bag blends more perfectly with its surroundings, so as to enjoy additional protection. The clustering of the "Wattle Bagworm" on the stem and in the forks of the branches, where it is more obscured by the surrounding foliage; the retreat of the "Meadow Bagworm" and the "Crossed-stick Bagworm" amongst the exposed roots of the grasses and low plants on the surface of the ground, where it can hardly be distinguished from the normal litter covering these places; the attachment of the "Thatched Bagworm" to the underside of stone ledges or in corners where waste material is allowed to accumulate; the adornment, in the case of the "Rubbish Bagworm" with all kinds of débris found on the ground—all these may be classed under such precautionary measures.

Secondly the case is made more secure against possible intruders or accidents. The upper end or neck is closed tightly, while usually the lower part of the bag is filled up with a loose irregular webbing of silk which would entangle any of the smaller parasites, spiders or ants which might probe the opening. The lower aperture must be left open so as to allow the moth to escape, or the abdomen of the male to enter for copulation, as the case may be. The bags are more firmly attached, in some cases by a strand of silk spun around the

twig, or the neck of the bag is closely applied to the bark of the tree and firmly fastened all around. In other cases the bag is provided with a fairly long strand of silk so that the bag will swing and offer no resistance when hit by any object. Thus a bird pecking at it would be unable to pierce the covering, the bag retreating before every blow aimed at it.

Having thus secured for itself the maximum amount of safety against external enemies, the caterpillar now makes ready for its transformation. In some cases a true cocoon is made inside the bag in the shape of an inner bag of finely woven, very tough, white silk, which is attached at both upper and lower ends to the outer bag, but free in the middle. In other cases no such elaborate preparations are made, but the larva probably contents itself with an additional layer of silk to the inside of the bag.

Thus far, the caterpillar has remained in its normal attitude, that is with its head toward the mouth or upper end of the bag. It now turns round so that it faces the lower end (through which the moth emerges) and pupates. The last moult cannot be removed from the bag as it is now closed, also the pupa would be unable to make the necessary movements for the expulsion of the exuviae, so that we find the dried skin of the last moult in the bag near its upper end.

The length of the pupa stage has in the majority of the bagworm species not been ascertained, but from such as we have had the opportunity to make observations on it appears that the actual pupal period is very short as compared with the length of the resting stage of the caterpillar.

(4) THE IMAGOS.

There is a great diversity amongst the moths of the various bagworms, not only in the type and general habits of the males, but especially in the different degree of degeneration of the females. With regard to this we can roughly divide such bagworms as are here under discussion into four groups. In the first group, comprising the Wattle Bagworm,

the Lictor Bagworm, the Thatched Bagworm, and in fact all the bagworms of the true Psychid type, only the males are winged, while the females are vermiform, wingless creatures which never leave their bag during their short period of reproductive activity. In the Wattle Bagworm all vestiges of legs have disappeared in the female, while in the females of the others, the Lictor and the Thatched Bagworms, these legs are rudimentary and are represented by forked membranous appendages of the thorax.

In the second group, to which belongs the Sand Bagworm, the females are destitute of wings, but have functional legs. The female leaves the bag, but remains attached to it on the outside near the lower end, and deposits her eggs in that position.

In the third group, the Webbed Spiral Bagworm and other species of *Melasina*, we find the females with rudimentary wings and functional legs. These females are capable of restricted locomotion only, and remain attached to their bags.

In the fourth group, including the Crossed-stick Bagworms and other Cossids and also some species of *Melasina*, the females are fully developed moths, and fly actively like the males.

We find also a great diversity in the habits of flight in connection with the reproductive functions. In those groups where the females are incapable of locomotion the males are very active creatures. The massive thorax, the pointed fore wings with the small hind wings and the short pointed abdomen, indicate that they are strong, rapid flyers. They fly during the daytime, the Wattle Bagworm in the sunshine only during the brightest part of the day, and the Thatched Bagworm and the Lictor Bagworm in the late afternoon.

Thus far we have had no opportunity to observe, under natural field conditions, the males of the second and third group, but in the laboratory they became active in the evening and they are probably crepuscular in their habits.

Of the Crossed-stick Bagworm, as a representative of the fourth group, we know that both sexes fly at night, and are then attracted by the light. Specimens of both sexes have been captured as late as 11 p.m. on the window in front of a lamp.

In all the groups the length of life of the male is very short, a few days at the most. The females enjoy a longer period, and may live for several weeks.

(5) REPRODUCTION.

From our present experiences we are inclined to believe that parthenogenesis does not occur in any of the species of bagworms which we have observed. In all these the males appear to be as plentiful as the females, or are even in the majority, and we have failed in all our experiments to hatch young from eggs laid by females to which males had had no access. In the case of some European species of bagworms a number of parthenogenetic generations are followed by the emergence of individuals of both sexes and mating takes place. We have bred only a few generations of certain bagworms, but all have proved to be of both sexes, and we are probably safe in deciding that these species of bagworms only reproduce in the normal, sexual manner.

Egg-laying.—The females of the first group deposit their eggs in the empty pupa-case. The female is merely an animated mass of eggs, lying with its head downward, facing the lower opening of the bag, the eggs are pushed out and gradually fill the upper cavity of the pupa-case until the female is spent. The body of the female shrivels and retreats until at last it drops out of the bag to the ground and dies. The eggs are closely packed together and are mixed with a quantity of hairs from the abdomen of the female. To these hairs are added very fine strands of silk, the origin of which has not yet been ascertained.

The fecundity of the females is amazing; in the Wattle Bagworm we have counted a maximum of over 3000 eggs, the

average being about 2300. This enormous amount of eggs is apparently necessary to counteract the great mortality amongst the young at the time of their distribution.

In those groups where the females leave their bags, but remain attached to it, the eggs have been observed to be laid on the outside of the bag. It has been claimed for a certain species of bagworm with similar habits that the eggs were deposited inside the bag by the female thrusting her ovipositor through the neck of the bag, but we have thus far not been able to observe any such procedure on the part of these bagworms; the eggs were always laid on the outside of the bag or on the bottom of the breeding cage.

In the case of the females of the fourth group, which have well-developed wings, it appears that the eggs may be deposited anywhere, as we have found them usually on the bottom of the breeding cage in which the moths were confined. The fecundity of these actively flying females is much less than that of those moths which remain in or on their bags. In the former case such an enormous reproduction is not required, as the female can do her share in the distribution, and the eggs are deposited in places where they are concealed and on or near the food-plant of the young caterpillar. In the case of the confined females the young play an entirely passive rôle in their distribution (the wind being the principal agent), and are thus subject to numerous vicissitudes with a more or less remote chance of their being transported to a suitable food-plant, while with the species in which the females are active this distribution has already taken place before the young have hatched, and they at once find their food ready for them. The mortality amongst these is thus apt to be very much less than in the former case, and a great productivity on the part of the female is not therefore so essential. In fact, it would probably be unfavourable, as the heavy mass of eggs might impair the flight of the parent, and thus restrict the area of distribution.

(6) SEASONAL HISTORY.

In this respect the various species of bagworm also behave very differently. Of those we have bred thus far, the Wattle Bagworm is the only species in which the adults emerge in mid-winter. Fertilisation takes place at that time, but the incubation for the eggs is long—two months—while the growth of the young is comparatively slow, and so there is only one generation a year. In the case of the Rubbish Bagworm the conditions are reversed, the moths appearing in mid-summer—January—and here we also have reason to believe that there is only one generation a year. Of the other species the moths are found to emerge at various parts of the season (mostly in mid-summer), and their life-histories have not yet been followed closely during the entire year, so that we do not know their life-cycle accurately. As to the Crossed-stick Bagworm, we have reason to believe that there are two generations in a year, since moths have been found swarming during the early spring and again in February.

II. SYSTEMATIC POSITION OF BAGWORMS.

The determination of the moths reared from these various bagworms shows that the species all belong to one of the three families: Psychidæ (the Wattle Bagworm, *Acanthopsyche junodi* (Heyl.), the Lictor Bagworm, *Clania moddermanni* Heyl., the Thatched Bagworm, *Acanthopsyche tristis* Janse, and the Meadow Bagworm, *Trichocossus arvensis* Janse); Cossidæ (the Crossed-stick Bagworm, and the Webbed-crossed-stick); and Tineidæ (various species of *Melasina* and *Ceromitia*). It is interesting to note that the families mentioned are all of the lower and less specialised ones, being placed in the phylogenetic scheme near the Trichoptera, from which, according to some authors, the Lepidoptera have developed. The larvæ of the other members of these families, so far as known, are all concealed feeders, either living in the wood, like the Cossidæ, or mining in the

leaves or feeding between leaves which have been drawn together, as in many Tineidæ. This is an indication that the concealed feeding habit is the more primitive one, and the life-histories of the larvæ of these bagworms thus confirm the low position of the families to which the bagworms had been assigned on the strength of the structural characters of the adults.

The habit of building larval cases which are carried about by their inhabitants has been reported from the following families :

(1) Perophoridæ (Lacosomidæ).—Example: *Perophora sanguinolenta*, the "Hammock Moth" of South-America.

(2) Pyralidæ.—Example: *Cænodomus hockingii* *Walsingham* and species of the genus *Nymphula*.

(3) Psychidæ.—The larvæ are case-bearers without exception. Kirby in his Catalogue in 1892 mentions 206 species of true Psychids, and undoubtedly there are many more.

(4) Talæporidæ.—The larvæ of these are also without exception bagworms.

(5) Coleophoridæ.—Example: *Amphisbatis incongruella* *Stt.* Many species in this family are leaf-miners in their early stages, making a bag in the later instars of their larval life.

(6) Gelechiidæ, subfamily *Œcophorinæ*.—Example: *Fumea limulus* and *Borkhausenia flavifrontella* *Hb.*

(7) Tineidæ, subfamilies *Teichobiinæ* and *Adelinæ*.—The members of these two subfamilies are without exception case-bearers.

(8) Tortricidæ.—The case-bearing habit is known only in one species of the family, *Exartema latifasciana* *Hw.* which lives on moss in a bag made of the same material.

(9) Cossidæ.—Members of the genera *Gymnelema* and *Trichocossus*.

In the species to be discussed we have paid much attention to the larval and pupal stages. Descriptions of caterpillars

of South African Heterocera are very few, and such as exist are usually based on the last instar and are confined to general statements as to size and colour-pattern. No detailed, careful descriptions are available. This is greatly to be regretted, both from an economic and a scientific point of view.

Let us consider the question first from the economic side. It is almost without exception the caterpillar, not the adult insect, which causes the damage, and it is this stage of the insect's life which is sent to the entomologist together with the complaint about its depredations. In the absence of reliable descriptions (and, owing to the scarcity of preserved larval skins, careful comparison with known specimens of which the adults have been bred is usually impossible), it is necessary to breed the insect to its adult stage before its identity can be ascertained without a doubt. Anyone who has tried to rear such larvæ, sent in from a distance, sometimes without the food-plant and in a closed box, realises the comparatively small chance of success. What with the parasites from which such specimens often suffer, the weakly and often diseased condition of the larvæ, the paucity of material and the artificial conditions under which it has to be reared, not to mention an often compulsory change of food-plant, the specimens either die before pupation, or, if a pupa is formed it is often so lacking in vitality that the moth does not emerge. Determination of the species in question then depends entirely on the examination of the pre-adult stages.

With the state of our present knowledge (or rather lack of it) of South African caterpillars, there are thus many chances of wrong determination, even in cases of some of the most common and widely-known pests. As an instance I may mention that a larva, found hibernating under the bark of a pear-tree, was at once declared by one of our most experienced entomologists to be that of the Codlin Moth, while subsequent rearing of the specimens by the writer proved it to be an entirely different species. Also, the moths of two different species may look extremely alike, except to the Micro-Lepi-

doptera expert, while a careful examination of the larvæ and pupæ shows the differences at once.

For these reasons alone the careful study and description of the larvæ and pupæ are essential in the discussion of a species; but there is still another very important reason. When we desire to determine the benefit derived from the presence of certain insectivorous birds or other animals which make, at certain times at least, insects a part of their diet, it becomes necessary to examine the stomachs or ejecta of such birds or quadrupeds, and to scrutinise the chitinous remains of any insect which may be found therein. It is evident that only the more strongly chitinised parts will escape the digestive and crushing action of stomach or gizzard, and we find in general only head-cases, mouth-parts, or feet, to guide us in our determination. Unless these parts have been carefully figured and described we are at a loss to say with certainty whether a certain injurious species is being preyed upon by the alleged predaceous enemy.

From a purely scientific standpoint the study of the immature stages is equally important, as they will show characters which may assist in clearing up doubtful points in the relationships of certain groups, relations which have been based almost exclusively on the characters (wing venation) of the adults. The study of the position of the setæ on the caterpillars has come much to the fore in this connection in recent years, and has proved to be of great importance in establishing such relationships. And here the study of the first instar of the larva is of the greatest importance. The first instar of the caterpillar is the most primitive condition, and at this stage it is more apt to show its phylogenetic relationships than in the succeeding instars. With the successive moults numerous changes occur which are due to adaptation to the environment, either to afford concealment, or to guard against the attacks of parasites or predaceous enemies. No cases are known to the writer where larvæ in the first instar have been parasitised, while the smaller size of the newly-hatched larvæ, and the usually more or less concealed position of the eggs

deposited by the parent moth, make them probably less easily detected. In addition to this, the young larvæ, being small, find their food close at hand, and there is no necessity for travelling in search of food. Since it is the movement of an object which attracts attention, this certain amount of immobility on the part of the first instar larva doubtless aids in its protection. With succeeding moults the necessity for protection, especially in the case of exposed feeders, becomes greater, and therefore most remarkable changes in colour-pattern and armament make their appearance. In the case of the Bombycine, Lymantrid, and Lasiocampid moths, there is an enormous development of secondary hair which obscures the position of the primary setæ. In many of these we have found that this secondary hair is either absent in the first instar or so feebly developed as to allow the primary setæ to be recognised with certainty. In other cases, as in the Saturniidæ, where the colour-pattern shows a great diversity in the various species, the first instars (when no colour-pattern has yet been developed) of the larvæ of the different species look remarkably alike.

We have thus endeavoured, wherever possible, to obtain the first instars of the caterpillars, and have described them in detail. In a good many cases, however, this has not been possible, since the bagworms as a rule do not mate readily in captivity. This article is based on the results of a couple of seasons' breeding only, and there will be necessarily many gaps which remain to be filled in by subsequent investigation.

III. DETAILED ACCOUNT OF SPECIES.

1. *Acanthopsyche junodi* (*Heylaerts*).

The Wattle Bagworm—Fam. Psychidæ.

This species is by far the most common bagworm in Natal, and is probably one of the most widely distributed through South Africa. It has been found from near Port Elizabeth (Cape Colony) to the Groot Spelonken in the Zoutpansberg

District of the Northern Transvaal, and its occurrence in South Africa is probably co-extensive with that of its original food-plants, the native thorn-bushes, consisting of various species of *Acacia* and *Mimosa*. In Natal it is the Bagworm par excellence, and it has become notorious during the last decade as one of the worst pests of the Black Wattle plantations. What was merely an "entomological curiosity" some fifteen years ago has evolved into a pest of prime economic importance within the last few years, seriously threatening the Black Wattle industry in Natal. So extensive became its spread, and so serious its injury to the wattles, that it was realised necessary to make this insect (with other wattle pests) the subject of a special investigation by the Department of Agriculture. Our work on this and the numerous other species of insects injurious to the Black Wattle (*Acacia mollissima Wild.*) has now been in progress for about three years, and, while studying the Wattle Bagworm primarily from an economic standpoint, many other matters of interest concerning the biology of the species have been observed, which appear not to have been recorded before.

(1) LITERATURE.

The insect has been known in the wattle plantations for a great many years, and as early as 1889 it was noticed by the then Natal Entomologist, Claude Fuller; but, though widespread, it did not appear to cause any appreciable injury and was not considered of economic importance.

In 1899 Claude Fuller published the first more or less detailed account of the life-history of this insect in his Annual Report for that year, where we find three pages devoted to it. In 1909 the same author published an account of this bagworm and some half-dozen others as Bulletin No. XVI of the Natal Department of Agriculture, in which he devoted some seven pages to the life-history of the Wattle Bagworm. Owing to the outbreak of 1911-12 in the New Hanover area, another, more detailed investigation of the Wattle Bagworm

problem was undertaken by him, the results of which he embodied in an article of some fifty pages, which appeared in the 'Agricultural Journal of the Union of South Africa' for June, July, and August, 1913. In this article over forty pages were taken up with general discussion and the economic aspect of the bagworm, while about nine pages were devoted to the life-history of the insect in question.

These published accounts of the bagworm, based as they necessarily were on more or less chance and discontinuous observations, do not entirely agree with each other, nor are they fully in accord with our observations during the past seasons. They unavoidably treat the insect almost exclusively from the economic point of view, while the scientific aspect has not received the consideration which it so richly deserves.

(2) SYSTEMATIC POSITION.

The species belongs to the family of Psychidæ, sub-family Psychinæ, and was described by Heylaerts in the 'Ann. Soc. Entomol. Belg.,' vol. xxxiv, p. cxxx (1890) as *Eumeta junodi*. Janse in his 'Notes on the South African Psychidæ' places it in the genus *Acanthopsyche*, while in Fuller's articles, mentioned above, it is always referred to as *Chalioides junodi*, but I do not know on which authority. The species has been described from male specimens only; the female has not been described.

(3) THE EGG.

DESCRIPTION.—Egg 0.88 by 0.75 mm., ellipsoidal in shape. Colour a creamy white, darkening with age, becoming grey to dark grey when hatching approaches. Egg-membrane soft, colourless, smooth, apparently without sculpture. A micropyle could not be distinguished.

DEPOSITION.—The eggs of a female are not deposited separately, but all in one mass, mixed with hairs from the abdomen. They are contained inside the pupa-case of the

female at the posterior end, filling this part of the case up to the third or even second abdominal segment. The chrysalis containing the egg-mass is encased in a bag of strong white silk (the cocoon or inner bag) which is stretched as a central tube in the bagworm-case, attached to both the anterior and posterior ends.

DEVELOPMENT.—External changes: As the egg becomes older it changes from the fresh cream colour to a dirty yellowish white, and later to greyish white, ultimately to dark grey with a black spot indicating the head and thorax of the developing larva. The incubation period is from sixty to sixty-five days.

(4) THE LARVA.

FIRST INSTAR.

Length upon emergence 1·9 mm.; ground colour cartridge-buff¹ (XXX); head jet black; dorsal thoracic shields, plate on eighth abdominal segment and anal plate Van Dyke brown (XXVIII); the third thoracic shield divided by a median stripe of the ground colour. Prespiracular plates of second and third thoracic segments concolorous with dorsal shields, other setiferous plates drab (XLVI). Thoracic legs snuff-brown (XXIX); leg-plates of abdominal and anal prolegs buffy brown (XL); claws of prolegs bistre (XXIX).

The larva (text-fig. 1, A) is more or less cylindrical, very slightly flattened dorso-ventrally. While in most caterpillars the head is very large upon hatching and the body tapers from the neck caudad, we find here that the width of the head is surpassed by that of the thorax, which is massive, especially the third thoracic segment, and from the posterior edge of it the abdomen tapers gradually down to the tail, like a cone. The great strength of the third thoracic segment is probably necessitated by the

¹ The colours mentioned are those of Ridgway's 'Colour Standards and Nomenclature,' edition 1912; the numbers refer to the plates in this publication.

habit of the young larva of carrying its abdomen elevated at nearly right angles, the point of flexion being at the juncture of the third thoracic and first abdominal segments. Owing to the light ground colour of the body, the chitinised setiferous plates on the abdominal segments stand out clearly and sharply defined.

During the first instar the head and thorax are of a uniform colour without the distinctive pattern which is acquired in the third and fourth instars.

HEAD.—Width of headcase 0.45 mm. Adfrontals not separated from parietals (text-fig. 1, B), front reaching to two-thirds the distance to the vertex. Frontal punctures high up, close together. Frontal setæ placed above the punctures, far apart and half-way up the front. Lower adfrontal setæ opposite frontal setæ, upper adfrontals near apex of front, adfrontal puncture near lower setæ. Setæ 1 and 3 of parietals rudimentary or absent, 2 below and laterad of upper adfrontals.

Antennæ.—Second joint short, only slightly longer than the third and fourth combined (text-fig. 1, c).

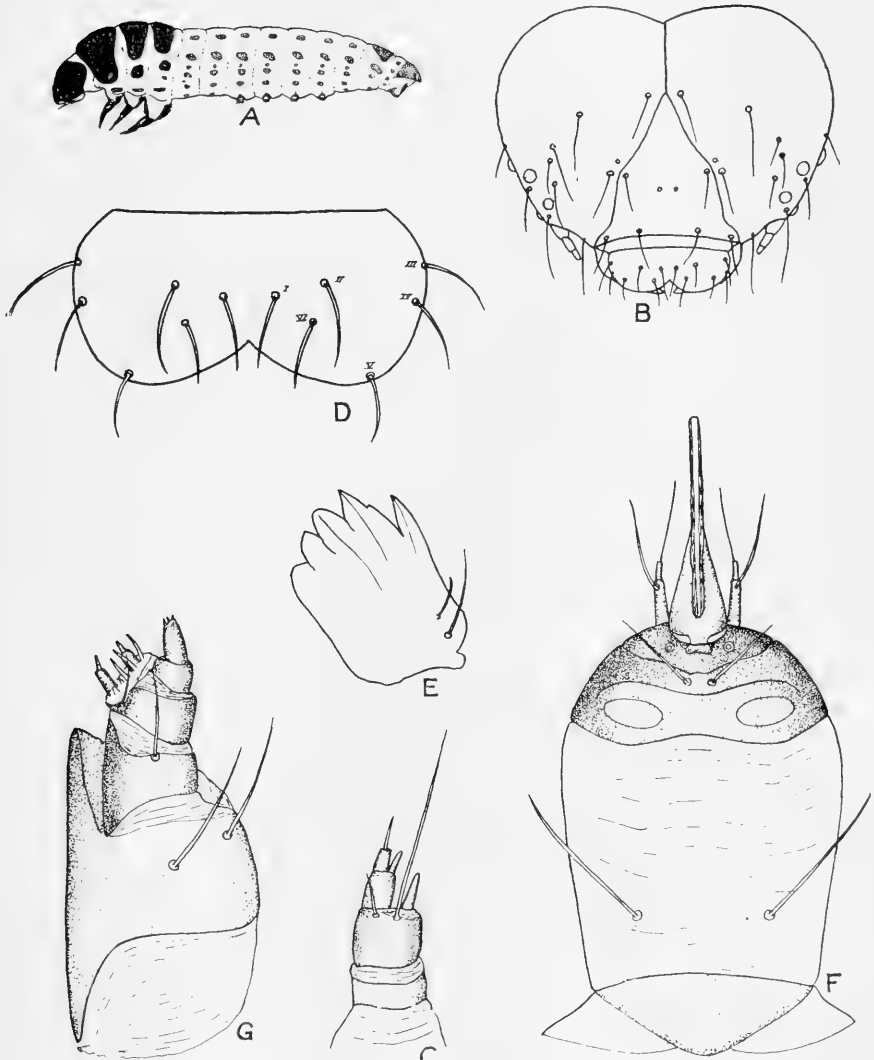
Clypeus.—Not differentiated from the front (B), the setæ 1 and 2 as usual near the distal edge, distance between them about half of that between 1 of right and left side.

Mandibles.—Short, sub-quadrate, with broad base, the outer edge slightly concave and sub-parallel to the median edge (E). Cutting edge armed with five teeth, the inner three blunt, the others acute, the second tooth (from the outside) the largest and with a step on its outer surface. Mandibular setæ 1 and 2 close together and situated on basal fourth of the mandible.

Labrum.—Outer angles broadly rounded, median notch about one-third of the total height, tip of indentation acute (D). Setæ 1, 2 and 3 in a line directed latero-cephalad, 4 and 5 sub-marginal, 6 not marginal but has moved up towards 1 and is situated about in line with 1 and 5.

Maxillæ.—Cardo very small, triangular; stipes broad, massive, the inner edge where it joins the mentum elongated

TEXT-FIG. 1.



Acanthopsyche junodi (Heylaerts). Larva, first instar.

- A. Side view. $\times 25$. B. Front view of head, showing position of setae. $\times 100$. C. Antenna. $\times 200$. D. Labrum. $\times 360$. E. Mandible, showing step on second tooth. $\times 200$. F. Labium. $\times 200$. G. Maxilla. $\times 200$.

and strongly chitinised; of the exposed, lateral aspect only the middle part chitinised, the basal and apical parts membranous (G). The middle part bears two setæ. Palpifer broad and short, bearing one seta at its distal edge. Palpus three-jointed, the two basal joints annular, the last in the shape of a cone bearing several small sense papillæ at the tip. The basal joint has one seta placed more mediad than that on the palpifer. Attached to the median aspect of the first and second palpal joint we find the remains of the maxillary lobes, consisting of two cylindrical processes, each with a sense-cone at its tip and three dagger-shaped sense-hairs. Three minute sense-cones are situated in front of the maxillary lobes.

Labium.—Characterised by a very strong development of the chitinous sclerites of the mentum (F). Mentum with two short setæ near the median line. Labial palpi two-jointed, slender, terminal joint about half as long as basal joint. Submentum for the greater part membranous and bearing two long setæ near its posterior third.

THORAX.—The thoracic segments, as mentioned, are very massive, and each is provided with a broad dorsal chitinous shield (Pl. XLVI, fig. 3). On the prothorax this shield is fused with the prespiracular plate and is pierced by the prothoracic spiracle; on the meso- and metathorax the prespiracular wart is separate from the dorsal shield. This prespiracular wart bears two setæ. The subventral wart or plate is also armed with two setæ. The legs are strong, the claws pointed and slightly curved mediad at the tip, with a median lobe at the base. Coxæ large, the chitinous coxal plates meeting in the median line. Thoracic plates unicolourous, no pattern as yet apparent. On the third thoracic segment the dorsal shield on each side does not reach the median line.

ABDOMEN.—The abdominal segments are narrow, except the eighth, with several chitinised setiferous plates (Pl. XLVI, figs. 1, 2). On segments 3 to 6 these plates are seven on each side: the dorsal with one seta (1), the subdorsal with one

seta (2), the lateral or supra-spiracular with one seta (3) and exceptionally with a minute one (3*a*), in front of this, the sublateral or subspiracular with two setæ (4 and 5), the subventral without any setæ, the outer leg-plate with a group of two setæ (7), and the ventral with one seta (8). The first abdominal bears in addition to the plates mentioned a mid-dorsal plate, which is unarmed.

The prolegs on segments 3 to 6 bear nine to eleven (exceptionally twelve) hooklets (fig. 4), the numbers on several specimens examined being as follows :

Segment.	1		2		3		4	
	Right.	Left.	Right.	Left.	Right.	Left.	Right.	Left.
Abd. 3 .	10	9	10	10	11	10	10	10
Abd. 4 .	9	9	9	11	12	10	11	9
Abd. 5 .	10	9	11	9	11	9	10	10
Abd. 6 .	10	11	11	10	12	10	10	9
Anal .	8	8	8	9	9	9	8	8

The spiracles are situated just below the supra-spiracular plate and are small. On abd. 7 the plate corresponding to the outer leg-plate bears only one seta. On abd. 8 the dorsal and subdorsal plates are fused into one which extends to the medial line and there meets the one from the other side. The supra-spiracular and part of the subspiracular (with one of its two setæ) are also fused into one and this is pierced by the spiracle, which is larger than those on the other abdominal segments. The position and number of the setæ are the same as on the other segments, but here (and also on abd. 9), group 7 consists of one seta only. On abd. 9 the dorsal plate has extended mediad till it meets the one from the other side, while apparently the subdorsal and supra-spiracular plates have fused into one (thus bearing two

setæ), while the subventral plate is wanting. The anal plate on abd. 10 contains four setæ on each side, three of which are marginal. The anal legs are almost entirely surrounded by a chitinous ring bearing three setæ on its lateral aspect, one on the median, and four setæ on its caudal aspect. The hooklets on the anal legs are longer and more robust than those on the abdominal legs and are eight to nine in number. The skin behind and between the anal legs is furnished with numerous small sharp-pointed papillae.

SECOND INSTAR.

Length of larva 6 mm. Ground-colour of caterpillar flesh-colour (XIV). Head, thoracic shields and plates, coxæ, thoracic legs and anal plate and leg-plates of anal prolegs light seal brown (XXXIV), setiferous plates on 8th and 9th abd. segments chestnut brown (XIV), those on the other segments russet (XV).

The thorax has no longer the preponderance in size which was so conspicuous in the first instar; the widest part of the larva is now at the second abdominal segment, from which it tapers gradually, both cephalad and caudad.

HEAD.—Width of head-case 0.83 mm. Head resembles that of the first instar larva, but the suture between frons and clypeus is now indicated. Adfrontals still fused with parietals. Head uniformly coloured; no pattern is yet apparent.

THORAX.—On that part of the prothoracic shields corresponding to the prespiracular wart two more setæ have appeared, one dorso-caudad, one dorso-cephalad of the original (Pl. XLVI, fig. 7). The subventral plate has also gained one seta and now bears three. On meso- and metathorax additional setæ have appeared on the prespiracular (subspiracular) plate, and a minute one just in front of this, while the setæ on the subventral plate have increased to three.

ABDOMEN.—On the abdominal segments the subventral plate

now bears one seta (6) while group 7 has increased to its normal number of three setæ, instead of two as in the previous instar (fig. 6). On abd. segments 1 and 2 these are divided, so that one of them is implanted on the enlarged mid-ventral plate and the other two on the small wart corresponding with the leg-plate in the proleg bearing segments. The hooks on the abdominal prolegs have doubled and range now from 18 to 20 in number (fig. 6). These are placed in a single loop, not entirely closed, the opening facing medio-caudad. Abd. 7 resembles that of the first instar, except for the appearance of setæ 6 (fig. 5). Abd. 8 shows the dorsal plate now divided in two halves, widely separated in the median line, and the development of the seta 6 as on the preceding segments. On abd. 9 the dorsal plates are also widely separated in the median line, the subspiracular plate is split in two, each bearing one seta, while in addition there has appeared on the subventral plate a seta 6. On abd. 10 the arrangement of the setæ on the anal plate has remained the same, the anal legs have acquired a posterior leg-plate with four strong setæ and on the lateral leg-plate group 7 now consists of three setæ as on the other abd. segments. Hooks of anal prolegs doubled, and these are now 16 to 18 in number.

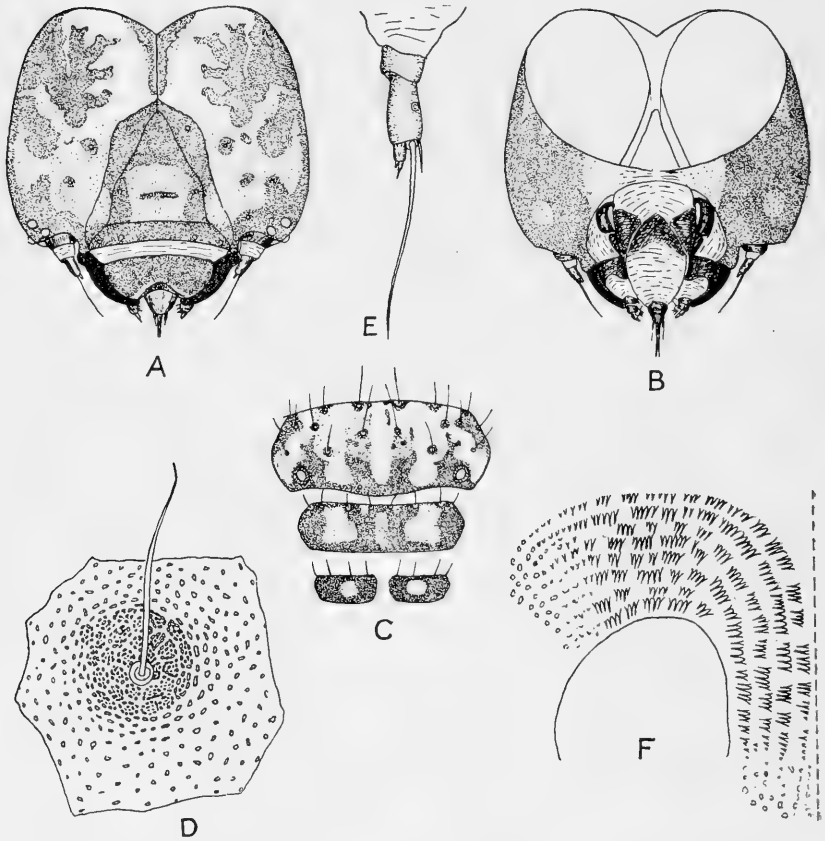
THIRD INSTAR.

Length of larva 9 mm. Ground colour of caterpillar purplish vinaceous (XXXIX). Head, pattern on prothoracic shield, thoracic shields, thoracic plates, legs, anal plate and leg-plates on anal prolegs, hooks and abdominal prolegs chestnut brown (XIV), setiferous plates on abdominal segments cinnamon brown (XV), ground colour of thoracic shields salmon buff (XIV), body more flattened dorso-ventrally, with the greatest width at the caudal edge of the second abdominal segment.

HEAD.—Width of head-case 1.7 mm. Suture between parietals and adfrontals now indicated, especially on the

upper part of the latter. Relative position of setæ the same

TEXT-FIG. 2.



Acanthopsyche junodi (Heylaerts). Larva.

- A. Front view of head of larva in third instar, showing pattern; setæ omitted. $\times 25$. B. Ventral aspect of head of larva in third instar showing pattern; setæ omitted. $\times 25$. C. Dorsal thoracic shields of larva in third instar, showing pattern. $\times 24$. D. Portion of skin around seta 8 on fourth abdominal segment of larva in fourth instar. $\times 200$. E. Antenna of larva in third instar. $\times 200$. F. Armament of skin between and behind anal legs in nearly full-grown larva. $\times 200$.

as in previous instars. There is a faint indication of a darker pattern on the head, which, however, appears only on magni-

fication, and is as yet not visible to the naked eye (text-fig. 2, A, B). The structure of the head-capsule now shows up as consisting of irregular plaques, giving the appearance of alligator skin. These plaques are especially apparent on the parietals, and are larger and more darkly pigmented on the areas which make up the pattern. On the front they are not distinct, the surface here appears finely pitted.

Antennæ.—Second joint now considerably enlarged, four times as long as the third and fourth joints combined (text-fig. 2, E).

THORAX.—The prothoracic shield is no longer uniformly coloured, but the dark area is now interrupted by several lighter spots, as shown in text-fig. 2, c. There is one mid-dorsal oval spot in the median line, and a broader subdorsal, just above the spiracle, broadening out cephalad to the front edge of the shield. A similar subspiracular light spot starts below the spiracle and extends dorso-cephalad until it meets the subdorsal. On the front half of the neck-shield these three light areas meet, and this entire part is thus light-coloured, except for small dark patches around the bases of the setæ. The position of the setæ corresponds to that during the previous instar. On the mesothoracic shield also we find the first indications of a developing pattern in the shape of a diffused narrow mid-dorsal and a broader sub-dorsal area of lighter colour. The metathoracic shield shows a mere indication of a suffused light-coloured sub-dorsal patch. On the intersegmental membrane between the second and third thoracic segments there has appeared a rudimentary spiracle. A pair of ventral plates, fused in the middle line and bearing two setæ, have appeared behind the coxæ of the third thoracic legs.

ABDOMEN.—On the first and second abdominal segments a rudimentary seta is found in front of the spiracle. Otherwise they agree in the arrangement of plates and setæ with the conditions found in the second instar. Abd. 3 to 6 show no differences from the second instar. Prolegs bear on the average twenty hooklets. On Abd. 7 there is no change,

except that group 7 now consists of two setæ. Abd. 8 is as in second instar. Abd. 9 also as in second instar, with the addition of a rudimentary seta in front of the single one representing group 7. Abd. 10 no change except a heavier chitinisation. Anal legs with 16 to 17 hooklets.

Over the entire body of the larva a great change has occurred in the composition of the skin. While during the first two instars the skin appeared as a structureless membrane, we find this now strengthened and toughened by numerous minute granular plates (text-fig. 2, D). These are somewhat more prominent on the cephalic edges of the segments, and become especially developed at the front edge of the anal segment, where they form a strong band across the dorsal and ventral aspect. Between and posterior to the anal legs the skin is armed with numerous finely pointed teeth directed towards the base of the leg. They are arranged roughly in parallel bands surrounding the medial and caudal part of the leg-plate, and gradually become smaller, and merge into the chitinous tuberosities of the surrounding skin.

This structure of the skin becomes more and more pronounced with succeeding instars, and reaches its greatest development in the ante-penultimate instar (text-fig. 2, F). In the last stage the amount of chitinisation of the skin is considerably reduced.

FOURTH INSTAR.

Length of larva 21 mm. at end of instar, width 6 mm., the place of greatest width at middle of third abdominal segment. General colour of body sorghum brown (XXXIX); on first two abdominal segments Hay's brown (XXIX). Ground colour of thoracic shield maize yellow (IV), ground colour of head auburn (II), markings on head, thorax, thoracic plates and legs, plates on first abdominal segment, anal plates and legs, seal brown (XXIX), plates on other segments and abdominal legs Hay's brown (XXIX).

HEAD.—Width of head-case 3 mm. Adfrontals now distinctly separated from parietals, broad, reaching to two-thirds

the distance between base of clypeus and notch of vertex. Parietals with distinct pattern as shown in text-fig. 2, A. Mandibles with five teeth which are now blunt, the outer two the larger. Labrum strongly chitinised, median notch rounded. Otherwise no change from the conditions in the previous instar.

THORAX.—There is no change from the conditions in the third instar except a stronger pigmentation and a more pronounced pattern on the thoracic shields.

ABDOMEN.—No differences in the arrangement of plates and setæ as compared with the previous instar. The small rudimentary seta in front of the spiracle (3a?) present on all abdominal segments. Number of hooklets on abdominal prolegs irregular, varying between 18 and 22, on anal legs from 16 to 18.

FIFTH INSTAR.

The larva reaches a length of 34 mm. Ground colour of body on sides and ventral aspect of abd. 3-6 cinnamon drab (XLVI), on back and ventral aspect of other abdominal segments fuscous black. Setiferous plates on abdominal segments, hooks of prolegs and anal leg, fuscous black (XLVI), anal plate, anal leg-plates, markings on thorax and on head black. Ground colour of head and anterior edges of thoracic shields argus brown (III), ground colour of thoracic shields maize yellow (IV). Spiracles xanthine orange (III). Thoracic legs fuscous black (XLVI) with spots of maize yellow (III) on the coxæ and one subventral on the post coxal plates of the third thoracic segment.

HEAD.—Width of head-case 4 mm. The pattern on the head has undergone no radical change.

THORAX.—On the thoracic segments the pattern has become more broken up, the light ground colour more pronounced, especially on the second and third thoracic segments. On the coxal plates the light spot has also appeared. The structure, position of setæ, etc., otherwise agree with those in the fourth instar.

The number of hooklets of the prolegs varies. The arrangement on three examples, selected at random, was as follows:

Segment.	1		2		3	
	Right.	Left.	Right.	Left.	Right.	Left.
Abd. 3 . . .	18	18	22	20	16	15
Abd. 4 . . .	20	21	24	20	20	16
Abd. 5 . . .	20	20	24	18	18	16
Abd. 6 . . .	20	22	20	20	16	20
Anal	15	17	17	18	16	19

It appears that the males do not pass through the instar corresponding to this fifth instar of the female. Measurements taken of male caterpillars (which remain much smaller than the female) gave a width of the head-case of 3 mm. only, corresponding to that of the fourth instar of the female, and during this fourth instar all caterpillars collected are about of equal size. After the females have moulted they continue growing and feeding, and during this time we find the caterpillars approximately in two sizes, those that will develop into females being the larger.

The omission of this instar on the part of the males becomes still more probable in view of the fact that the males pupate fully a month before the females.

SIXTH INSTAR (ULTIMATE OR PREPUPAL INSTAR).

Length of female from 24 to 34 mm., average 28 mm., that of the males 22 mm. Ground colour of body on ventral aspect light ochraceous salmon (XV), dorsal aspect orange cinnamon (XXIX). Thoracic and abdominal legs, setiferous plates, ground colour of head and thoracic shields light buff (XV),

anal plate, anal legplates, dorsal setiferous plates on abd. 8 and 9, as also the pattern on thoracic shields, Verona brown (XXIX), pattern on head cinnamon (XXIX). The structure and arrangement of setæ and hooks on prolegs have not changed. The thoracic legs have become comparatively shorter. The entire larva now appears as if re-modelled without growth within the old skin. Width of head-case of female 3.65 mm., that of male 3 mm.

Here we find the remarkable occurrence that after moulting the larva is actually smaller than in the preceding instar and during this instar no food is taken, no growth takes place, and there appears to be an actual shrinkage. As the larva does not expose itself to the outside air and light, it does not acquire its full coloration as in the previous instars, but remains in the pale state characteristic of a newly moulted larva. The actual length of this stage has not been ascertained, for if the larva be disturbed and the bag opened for examination, it immediately proceeds to repair the damage. As the tax on the spinning glands is already fairly heavy, having to spin the cocoon, the extra effort of repairing the bag from day to day (and frequent examination would be necessary) would so weaken the larva that it would probably succumb before pupating, especially when we consider that no food is taken to replace the wasted energy.

(5) HABITS OF THE LARVA.

The habits of the larva of *Acanthopsyche junodi* (in common with many other *Psychidæ*) are abnormal in many ways, and different from those of the great majority of caterpillars. These peculiarities in behaviour are the result mainly of two factors. The first of these, and the principal one, acting during the earlier part of the life of the insect, is that the distribution of the species is not allotted to the parent moth, but that this responsibility has fallen on the young caterpillar. The second factor is the necessity on the part of the defenceless larva for concealment and protection against predaceous and parasitic enemies.

A. Instincts developed in connection with the distribution of the species.—Apart from the ordinary considerations which render a distribution of the individuals advantageous to the maintenance of the species, a dispersal is doubly necessary in the case of the Psychidæ on account of the enormous productivity of the female (see later). In order to facilitate this distribution over a wide area, there have been developed on the part of the larva, during its first instar, three special instincts, in contrast with most caterpillars, namely :

- (a) A decided positive phototropism.
- (b) An extensive use of the spinning glands.
- (c) A meandering instinct.

(a) Phototropism.—When the young caterpillars emerge from the eggs they find themselves confined in the empty chrysalis-case of the female which after depositing the eggs has dropped to the ground. They crawl out of the pupa-case through the lower opening of the bag and move toward the place of the greatest light. When bred in a room, they gathered on that side of the breeding cage which faced the window; and when brought to the table for removal to breeding-cages they all crawled towards the window, which was soon covered with an immense number of young bagworms that had escaped through the small apertures in the gauze with which the cages were covered. On hatching under normal conditions in the plantations, this instinct prompts them to go to the outside edge of the block or to the tops of the trees. Where the trees have been cut down during the winter for barking, and the branches, with the bags attached to them, are left lying on the ground, preparatory to the subsequent burning when the weather becomes favourable, we see the upper layers of this brushwood and the standing stumps covered with bagworms, all as a result of this phototropic instinct.

This instinct remains, though not in so pronounced a manner, throughout the feeding period of the caterpillar. As a result of this we see that the tips of the trees are first defoliated

and also the outer branches of such trees as form the outside edge of a block. It also causes the larva to feed on the young tips of the foliage, as long as any leaves are being produced. Toward the end of the feeding period we find a reversal of this instinct; the larva now prefers a more concealed spot in which to pass its pupal stage.

(b) The extensive use of the spinning glands.—While in the majority of caterpillars the spinning glands are not brought into full use until the time for pupation approaches, when the manufacture of a cocoon becomes necessary, we find here that one of the first acts of the young larva is the spinning of a long silken thread. By means of this it descends from the parent bag, and, attaching the thread to a twig or branch, a sheet of webbing is made on which the larva travels up and down. This webbing is extremely light and is disturbed by the slightest air-current. This same webbing is produced when the larva has reached the exposed parts of the trees or brushwood, and the area where the larvæ have been hatching by the thousands looks as if covered with a layer of spider-web. In later instars the spinning glands are almost exclusively used in the construction of the bag, and only when the food-supply runs short does the caterpillar again construct long threads of silk by means of which it descends, and either reaches the ground and crawls to another tree, or is swayed by the wind to the branch of a neighbouring tree to which it then attaches itself.

(c) The meandering instinct.—As a third additional provision to safeguard the distribution of the species we have on the part of the young larva the peculiar instinct that it will not feed during the first few days of its existence. It appears that its desire for a certain amount of travelling has to be satisfied before it will settle down to feed and construct its dwelling. This increases the difficulty of rearing the specimens in captivity from the egg, as the majority of the minute caterpillars leave the fresh young wattle twigs supplied to them and start travelling about. As will be shown later, the conditions in a plantation after a heavy

infestation are unfavourable to a continued existence of the species therein, and this travelling instinct to a certain extent prevents the larvæ from settling in the same spot where their pregenitors have been bred.

B. Agents in the distribution.—As the distribution of the species is not effected by the flight of the adult, like in the majority of *Lepidoptera*, the period in the life of the insect when this all-important process takes place has been transferred from the adult stage to the first instar of the larval life. In this, except for offering opportunities to facilitate this distribution, the larva plays an entirely passive rôle, and is dependent on external agencies. These agents fall under three heads, each responsible for a distinctive type of infestation of a new area.

(a) Wind.—By far the principal agent, favouring distribution over wide areas, is the wind. Due to their exposed position on the edges of plantations or on the tips of the trees, brushwood, stumps, etc., the larvæ are easily accessible to any air currents, while their lightness, caused by the long silken thread, allows of their being readily picked up and carried for considerable distances. An analogy of this procedure is found in the well-known example of the so-called "Balloon Spiders." During the hatching period of the egg (the later part of August and until the beginning of October) the climatic conditions in this country are such that heavy wind-storms are an almost daily occurrence. The wind rises about nine o'clock in the morning and, usually, dies down towards evening. These wind-storms are often characterised by the presence of eddies, and the young bagworms are either driven before the wind or carried up in the vortex to higher strata. In this way they may be carried for miles, and when the wind dies down and the air becomes calm the bagworms slowly descend and fall literally out of the sky on trees, grass, and other objects indiscriminately. Countless numbers perish by landing in places unsuitable for their existence, but such as happen to alight on one of their many food-plants have a chance to attach themselves and start feeding. The writer

has several times, while walking in the evening, found a number of bagworms attached to his clothing, which could only have settled in this manner. On another occasion it was found that some four dozen young wattle trees, grown in tins on the laboratory grounds for experimental purposes, had become thoroughly infested overnight with young bagworms; the nearest plantation, or food-plants, on which these could have hatched being a couple of miles away. In this way we must account for a sudden general or gross infestation of a new plantation or block which had previously shown no signs of bagworm injury.

It sometimes happens, but such cases are rare, that the young bagworms are forcibly driven before the wind into another plantation near by. When this happens we find that the first few lines of trees have become grossly infested, the infestation becoming thinner and thinner as we penetrate deeper into the block. Only one such lateral or side infestation has come to the writer's notice, the manner of infestation being such as to leave no room for any other explanation. Evidences of this will be, of course, more conclusive when the wind has struck the block athwart the rows of trees; if the wind passes through the plantation in the direction of the rows the bagworms may be carried inward for a considerable distance, or even the entire length of the rows, and the distinctive type of such an infestation will be lost.

The heavy wind-storms, which are so prevalent during the late winter and early spring, may even carry the young bagworms after they have made their bag. During the first few days after the bag is made the young bagworm feeds on the upper surface of the leaf and is rather loosely attached. The writer has seen such small bags dropping out of the sky in the same manner as the naked caterpillars.

(b) Birds.—It is evident that on account of the exposed position of the young bagworms there are many opportunities for them to attach themselves to the feet and plumage of a bird resting temporarily in the trees of an infested plantation.

These birds flying away will carry the young bagworms with them, and when the bird comes to rest on another tree they can crawl off and establish themselves there. In a block which has already been loaded with bagworms as a result of wind infestation, the arrival of these few extra individuals will not make any difference, but where this has occurred in a plantation or block free from bagworms the results are rather striking, in that we find in the entire block only a tree or two infested at the tip. This may be distinguished as a true bird infestation, cases of which are by no means rare and account for the presence of bagworms in small numbers in plantations which, through an exceptionally favourable position, escape the gross infestation by wind or air currents. Inappreciable at first, such occurrences may give rise to an accumulative infestation in succeeding years (see later).

Another agent which could cause a similar type of infestation might be furnished by insects flying through the webbing made by the young bagworms, and carrying some larvæ along with them. Fuller suggests cockchafer beetles as the most likely to be the carriers in this case. Of course, it would have to be a fairly robust type of flying insect, as the smaller ones would become hopelessly entangled in the mass of webbing. But, unfortunately for the hypothesis, the cockchafer beetles have not yet made their appearance during the hatching period of the bagworms, their time of emergence being about a month to six weeks after the hatching of bagworms and their distribution is passed. As a matter of fact, the writer has examined several flying insects for the presence of young bagworms attached to them, but has not been able to find any evidence to support this theory. While not precluding the possibility of such an occurrence, the probabilities are so slight as to make this possible factor negligible.

(c) Mammals.—We meet sometimes with another type of infestation, which excludes the possibility of its having been caused by the wind or by a bird, and which only can have been caused by some other individual carrier. This is the type which I have called a sporadic infestation, where

we find in a young plantation that a single tree or group of trees has become thoroughly infested, the remainder of the plantation or block being free from bagworms. The most plausible explanation therefore is that a hare or buck, passing through the web-covered brushwood, has carried a considerable number of bagworms with it, and entering the plantation of young trees near by has rested in the grass at the base of one of the trees, and the bagworms have crawled off the carrier and ascended the tree or trees in its immediate vicinity. Such cases we find in blocks of young trees where the canopy is not yet formed and there is a great deal of grass growing, which would afford shelter and a hiding place during the day to such an animal. As the trees are accessible to light all around, the bagworms do not in response to their phototropic instinct ascend the tree to the top, but feed on the ends of the branches, and we find the tree infested with bagworms from top to bottom. Several such centres may be found in one block, showing the spots where the carrying animal had sought a temporary halting or resting place.

Both these local bird and sporadic infestations may act as centres for the spread of the insect in a new locality, and in the course of a few years may increase to a more general infestation of the entire block. This is what we have termed an accumulative infestation, as distinguished from the general or gross infestation, caused by wind as the carrying agent. By the wattle growers the two are often confused, because the beginnings of an accumulative infestation are not noticed, and it is only when the block becomes thoroughly infested that attention is drawn to it, and this is then described as a sudden appearance of the bagworms in enormous numbers. We are generally able, however, to prove the accumulative nature of the infestation by the presence of old bags scattered over a few centres in the plantation.

C. Instincts developed in connection with the protection of the larva.—These find their expression in the formation of a bag as a protective covering during the feeding period of the larval life, and the gregarious habit

which develops when the larva has stopped feeding and is ready to enter the pre-pupal and pupal stages.

The first act of the young bagworm, after its dispersal has been accomplished and its meandering instinct has been satisfied, is to construct a bag for concealment. This bag is at first conical, widest at the head end of the larva, and during the first days of the first instar it is carried upwards, while the caterpillar feeds on the upper surface of the leaf. Within a few days it starts feeding on the underside, and the bag hangs downwards; the larva, when moving, crawling along the under surface of the twig or branch. In both these positions the abdomen is deflected dorsad at its juncture with the thorax, the entire weight being carried by the thoracic legs alone. The abdominal and anal prolegs are not used in locomotion, and are probably only brought into play in so far as they hook into the silk lining of the bag and prevent this from slipping off, or the larva from being dislodged by a sudden jerk. When a full-grown larva is removed from its bag and put back on the tree it then also only uses its thoracic legs in locomotion, and moves with a pronounced dorso-flexion of the abdomen, and along the underside of the branches. Even when placed on a flat surface it does not crawl in a straight line, using both thoracic and abdominal prolegs, but moves on its thoracic legs only, the abdomen being held bent upwards and its caudal part curved ventrad. While it would not be possible for the abdominal prolegs to grasp a small twig between them, as they are very short and rather widely separated so that their hook-bearing surfaces could not be sufficiently approximated, it is clear, from its method of locomotion on a horizontal surface, that the larva has lost through disuse the power of co-ordination in respect to these organs. The points of the hooks are directed outwards, so that, when the planta is pushed out, these hooks are spread and hook into the silk of the surface against which the sole is pressed. The points of these hooks are extremely long and sharp.

The bag, as stated, is at first conical and just roomy enough

to enclose the larva. With subsequent growth the bag is enlarged and from conical becomes oval, that is, wide in the centre and narrow at each end. The space inside is now larger than the volume of the larva requires. The manner in which the change in the form of the bag is brought about we have not been able to observe. As the larva feeds, particles of the leaves and twigs are being thrown back and attached to the neck of the bag for a short distance. No regularity is observed except in so far that all these particles are attached lengthwise, and, as they are fastened for a short distance only, they project tangentially in the direction of the long axis of the bag. During the feeding they are loosely attached. The firmer attachment is probably accomplished during the night, as in order to do this the larva will have to expose itself for a considerable distance, and it may in some cases even be necessary for it to leave the shelter of its bag. Everything which may be attached to the branch or leaf, such as seed-pods, parts of twigs, even other pieces of insect architecture are indiscriminately made use of, and the result is at times a very curious mixture of ingredients.

According to the plant on which the bagworm is feeding, the composition of the bag-covering, and thus its aspect, varies considerably, but the oval shape and the partial longitudinal attachment of the component particles are constant characters.

Toward the later instars the differences between the male and the female bags become apparent; the bag of the female is large and plump, while that of the male is shorter and has a longer point, but it is not relatively narrower. These differences are not absolute, since according to variations in food-supply we may find small females and large males, and it is therefore not always possible to judge with certainty from the appearance of the bag the sex of its occupant. Measurements of several hundreds of bags, containing mature larvæ, gave the following results:

Male bags: Average length 46·95 mm., width 17·32 mm.
Maximum length 56 mm., width 21 mm.
Minimum length 39 mm., width 15 mm.

Female bags: Average length 53.59 mm., width 18.25 mm.

Maximum length 63 mm., width 22 mm.

Minimum length 46 mm., width 15 mm.

the differences in length being thus more pronounced than those in the width of the bag.

D. Feeding habits.—While feeding may take place at any time during the day, it is mostly done during the early part of the morning, as soon as the dew has evaporated off the leaves. Usually no feeding takes place during the hottest part of the day, nor during a rain or mist, when the foliage is wet. No feeding has been observed during the night, but it is possible that the larva shows some activity during that period in making enlargements to its bag.

The inside of the bag is scrupulously clean, ejecta and cast skins being carefully removed, as the presence of these might influence the health of the caterpillar.

Food-plants.—The original food of *Acanthopsyche junodi* was doubtless furnished by the leaves of *Acacia horrida*, *A. caffra*, and other species of *Acacia* which form a great part of the native thorn bush flora. Alice Pegler, in an article in 'Grocott's Penny Mail,' Grahamstown, December 1st, 1909 (reprinted in 'Agricultural Journal of the Union of South Africa,' vol. vi, p. 215, 1909), writes that *A. melanoxyton* is occasionally attacked, and mentions as another native food-plant *Loranthus dregei*. We have found it also on *Combretum glomeruliflorum*, and undoubtedly continued observations will reveal a great many more native plants which will furnish a means of subsistence for the larva of this species.

With the clearing of the thorn bush and the planting of the congeneric *A. mollissima* the bagworm has adapted itself very readily to this tree, and, the food-supply being now practically unlimited, has thrived exceedingly.

Besides these, the bagworm has lately become troublesome as a pest to various ornamental trees and fruit trees. Amongst the former we have found it on oak, roses, poplar, Pride of India, *Pinus insignis* and some of the less oleaceous

Eucalypti, while the privet is occasionally attacked. Amongst the fruit trees may be mentioned: apple, plum, cherry, apricot and guava. Peach, pear, and quince do not seem to be favoured, neither the citrus trees nor vines. We have seen quarter-grown bags on citrus trees in a heavily infested neighbourhood, but they did not reach maturity; while on peach, under similar circumstances, we have found the young bagworms eating the rind of the young fruit.

Character and degree of injury.—While the young bagworms to a certain extent destroy the blossoms of the wattle, the main injury is the destruction of the foliage. Not only are the young leaves eaten off as fast as they appear, and the entire tree defoliated, but even the bark of the young shoots is chewed off when the food becomes scarce.

Besides this injury to the tree due to the removal of the foliage, the bagworm often causes another kind of damage during its resting period. When it attaches its bag, preparatory for pupation, it fastens it securely to a twig by means of a strong silken strand stretched tightly around it. This strand acts as a ligature, the flow of the sap downward is interfered with and a swelling occurs just above the strand. Ultimately the strand cuts in deeper and deeper, and with a sudden gust of wind the distal part breaks off. The writer has seen the tops of several young trees destroyed in this manner.

Where the bagworms gather in clumps on the stem of the tree, generally near a fork, for pupation, they attach themselves by gnawing off a considerable portion of the bark, the particles of which are interwoven with the silk by which they are attached. The injury caused by the two last procedures may be considerable.

Progress of infestation.—At first the caterpillars gather on the tops of the trees, which are defoliated in the early part of the season (November). After this the larvæ slowly travel downwards, consuming more and more of the foliage, so that by the end of December the majority of the trees have become bare, and new growth is kept down as

it appears. The infested plantations can be recognised at a distance by the reddish-brown colour. This condition remains until the end of the feeding period (end of February and first half of March), after which the tree has a chance to grow again, provided the conditions as to rainfall are favourable. Generally, however, the rains practically cease by the beginning of March and the trees remain bare until the following spring. This means, apart from other considerations, the loss of a full season's growth; and where thousands of acres are affected, the commercial loss is very considerable.

E. Parasites and enemies.—Four species of Hymenopterous parasites have been bred from the caterpillar of *A. junodi*, and the same number of Tachinidæ. None of these have as yet been determined. The total number of bagworms killed by these various parasities amounts to only about 24 per cent. under the most favourable conditions; so that, from an economic point of view, they are not of great importance.

Predaceous enemies.—Amongst these, insectivorous birds take first place. The Yellow Weaver Bird has been observed to be an industrious destroyer of bagworms in the fall, watching for the caterpillar to expose itself when feeding or crawling, when with a quick jerk the insect is pulled out of its bag. Fuller mentions the Little Silver-eyed Bird of the thorns as "carefully examining the lower entrance of the bag to capture, perchance, an emerging male or waiting female, or even the young caterpillars." Alice Pegler in 'Grocott's Penny Mail,' mentioned above, states that Sprews are the chief robbers in the Cape Province, while Mr. T. M. Mackenzie has reported to me that a small green parrot occurring in the plantations will break off a twig to which the bagworms are attached, tear open the bag with its strong beak and eat its contents; but I have not been able to observe this myself.

During the resting stage in the winter-time many of the bagworms are devoured by rats. This is especially the case in young and grassy plantations. The bag is gnawed open,

usually from the top, and the pupa extracted. Sometimes the bags are thus attacked *in situ*, sometimes they are torn off the branches and collected at the base of the tree, there to be consumed at leisure. The rodents responsible for this destruction belong to two species, *Mus concha* and *Mus zuluensis*.

F. Diseases of the Wattle Bagworm.—The Wattle Bagworm is subject to various diseases, all of which attack it in the caterpillar stage. The most important of these is:

The Bagworm Fungus—*Isaria psychidæ* *Pole Evans*.—This was first found by T. M. Mackenzie in his plantation at Cramond, Natal, and has since been distributed through many wattle plantations in Umvoti County and elsewhere. The spores of this fungus, when they are attached to the leaves, are eaten by the bagworm. Arriving in the stomach of the insect, the spores germinate and grow, the fungus threads ramifying through the body of the caterpillar until it becomes a solid mass of hyphæ. The caterpillar dies in about five days after infection, and the body becomes mummified. The fungus continues to increase until it grows through the bag and appears on the outside, where spores are formed as conspicuous white pustules. These spores are distributed by the wind and dropping on the leaves are in turn eaten by other bagworms, which thus become infected.

Those bagworms which are attacked early in the season, when they are still very young, die and drop to the ground, and, being still very small, are easily overlooked. The older caterpillars which are infected later in the season may reach the stage when they stop feeding and attach themselves. It is from such specimens that we usually see the fungus grow out of the bags in the fall. Even of these later infected bagworms a great number drop to the ground, and we have noticed in some plantations the ground covered with such fungus-killed bagworms.

Notwithstanding the deadly nature of the fungus and the progressive infection which takes place during the season, the disease is not sufficient to check the pest to any appreciable

extent, as in every plantation known to me, where the fungus is well established, heavy losses due to bagworm injury still occur. This appears to be mainly due to the circumstance that when the bagworms begin to attach themselves they do so as a rule fairly low down on the trees. When the spores are being produced from the infected bags they, in order to be effective, must reach the young bagworms on the tops of the trees, where they are feeding at that time. The spores must therefore be carried up, and this probably occurs only under exceptional circumstances. This is presumably the reason why the majority of the bagworms become infected only at a later stage in their larval life when they are feeding on the lower branches of the trees. For these reasons the fungus is not as effective as otherwise it might be.

Actual counts of some twenty thousand bagworms, gathered in an infected plantation, showed that of the bagworms which reach the resting stage the maximum of fungus-infested individuals was only 22·5 per cent. of the total number. This was in a plantation where the fungus had been well established, and which was suffering from a gross infestation of bagworms for the third consecutive season, conditions which would seem to be very favourable to promote the maximum efficiency of the fungus. This percentage is, of course, not high enough for the effective control of the bagworm by this means alone.

Other diseases.—Besides the fungus there are many other diseases to which the bagworm is subject. Most of these are as yet of an unknown character, but are probably of an intestinal nature. One of these, which we have repeatedly noticed in the laboratory, causes constipation of the larva with an untimely death as the ultimate result. The caterpillar generally succumbs at a very early age.

Another disease is more of the nature of dysentery, and appears to be induced by the consumption of wet food. It is especially prevalent amongst the young bagworms, and is probably the cause of the death of so many after a prolonged wet spell. We have noticed that the bagworm stops feeding

during a rain or mist, and only starts again after the foliage has dried. The older bagworms can withstand starvation for a considerable time, and can thus safely pass through a rain or mist of several days' duration, but the young cannot starve as long. If there be a prolonged period of continuous rain or mist, so that the foliage has no chance to dry, the young larvæ are by hunger compelled to eat wet food. This apparently causes a disease (dysentery) by which they are killed. Or it may be that this wet diet causes more fluid evacuations, as a result of which the bag becomes soiled inside. The larva then leaves its bag and tries to construct a new dwelling. During this time, when the larvæ are unprotected against the inclemency of the weather and against enemies, probably a great many of them perish. Such as survive, in their haste to make a new bag, take any material which comes handy, and old bags, deserted by their inhabitants, are often made use of. In this case we find a great percentage of so-called compound bags, made up of several, sometimes as many as four or five, of which only one is occupied. An abundance of such bags in a plantation is a sure sign that the conditions have been at some time unfavourable to the bagworms.

In addition to the diseases here enumerated, there are still others of an unknown nature, which attack the older bagworms. The effect is a blackening and ultimate mummification of the larvæ, and many of the older bags which were opened showed evidence of this form of disease. In fact, these diseases may destroy more bagworms than the fungus. We have found amongst several thousands of bags, collected in the resting stage, that 30 per cent. of the larvæ had been killed off by these diseases.

As far as we know, none of these diseases are contagious; we have found an abundance of perfectly healthy larvæ amongst the diseased caterpillars.

An undoubtedly contagious disease has been noted during the season of 1913-14. Our attention was first called to it by Mr. H. Holley of Wartburg, who noticed a great number of dead bagworms in a corner of a plot about forty

acres in extent. When the writer visited this plantation a few days after being notified, the disease had spread over about one-tenth of the block, starting from the corner where first noticed; and in that affected area I found 95 per cent. of the bagworms dead. A month later this plantation was again visited, this time in company with the Government Plant Pathologist, and we found then the entire block infected, so much so that after a couple of hours' search over the entire forty acres we could find only two live bagworms.

Later on, the same, or a very similar, disease was found in the plantation of Mr. E. T. Hill of Seven Oaks, and evidences of its presence have since been found at several other plantations.

The efforts to isolate and artificially propagate this disease have thus far not been successful.

All these diseases undoubtedly depend for their virulence to a great extent on climatic conditions, and their efficiency as a natural check to the bagworm therefore varies from year to year. They constitute a factor which is as yet beyond human control and thus must remain unsatisfactory. We can artificially promote the spread of some of these diseases, but cannot control their action.

(6) THE COCOON.

Toward the end of the feeding period, just before the larva undergoes its last moult, it prepares for the pupation by putting an extra inner lining to the bag. This inner lining is very thin and closely applied to the original silken covering. It serves to cover the irregularities of the inner surface; and the inside of the bag, which with increasing age has become somewhat discoloured, is now clean, white, smooth, and somewhat shiny. This inner lining made, the larva moults into the last instar. After this no more food is taken, and the caterpillar remains light in colour. Soon after its moult it begins to spin its cocoon. This consists of a

cylinder of tough white silk, attached to the upper and the lower neck of the bag and free in the centre, extending as a hollow column through the centre of the cavity of the bag, and just wide enough to accommodate the pupa to be formed. The caterpillar then turns round and lies with its head facing the lower opening. The change into the chrysalis now takes place, and the last larval skin, much broken and compressed, is pushed to the very top of the cocoon. The males pupate about a month earlier than the females.

(7) THE PUPA.

Male Pupa.—Length of pupa 12 mm., width 4.25 mm., with the place of greatest width across the humeri or place of insertion of the front wings, depth 4.75 mm. near the caudal edge of the mesothorax.

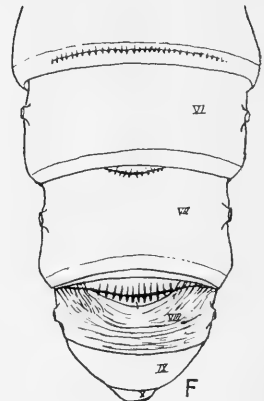
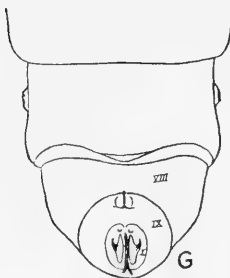
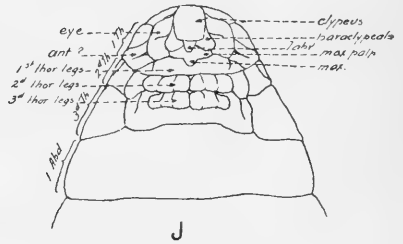
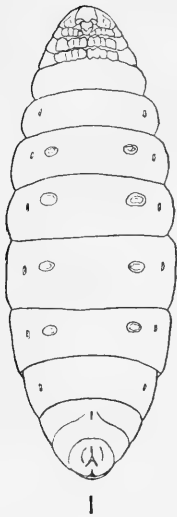
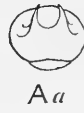
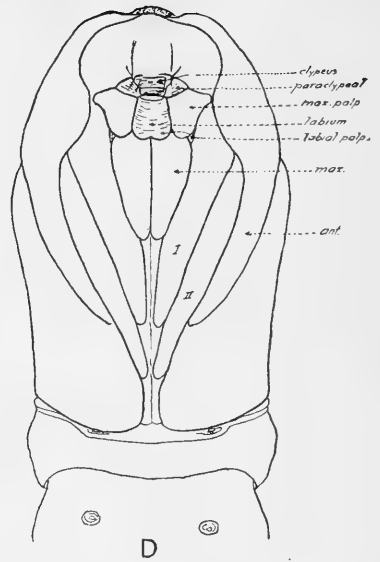
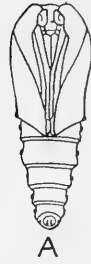
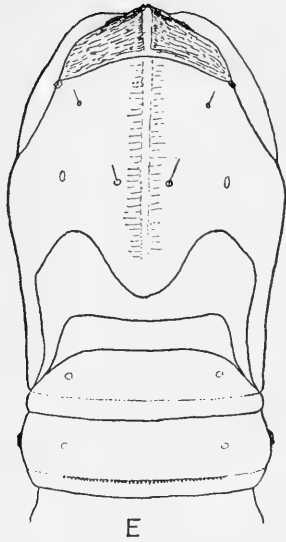
General form slender, with humped back due to the prominence of the mesothorax, and with the last three segments of the abdomen curved ventrad. The entire pupa has a somewhat shrunken appearance, not plump and rounded like most other pupæ. Posterior edges of the abdominal segments very prominent, giving the abdomen a telescoped appearance (text-fig. 3, A, B, C).

General impression of sculpture: smooth, subshiny.

Colour dark reddish brown, nearly black when mature, ventral aspect of wing-cases and the last two abdominal segments lighter in colour. There is no bloom on the pupa.

Head medium-sized, slightly protruding ventrad, shiny, very finely punctulate (text-fig. 3, D). Clypeus short, transversely striate, directed dorso-caudad, thus causing a transverse depression in the pupa at the end of the labrum. Paraclypeal pieces distinct, roughly triangular in outline, flat and transversely striated, not convex and rugose as in many Psychidæ. Labium long with the labial palpi minute, showing as small rounded lobes at its distal end. Maxillary palpi large, distinct, extending caudad as far as the tip of the labial palpi.

TEXT-FIG. 3.



No glazed eye visible, this being apparently covered by the broadened basal part of the antenna-cases which extend caudad nearly as far as those of the first legs.

On top of the head is a slight median swelling, somewhat rugose, continued in a blunt, low, median ridge on the prothorax, the cocoon breaker. The entire dorsal aspect of the prothorax is deeply striated transversely. Near the anterior edge it bears a small setiferous puncture on each side of the median line.

Mesothorax massive, slightly striated transversely, median line very slightly raised (text-fig. 3, E). On its dorsal aspect it bears a prominent tubercle on each side of the median line, bearing a short seta. Laterad and latero-cephalad of these there are two other similar but smaller punctures.

Anterior wing-cases reaching caudad only as far as the end of the third abdominal segment. Posterior lateral angles of wing-cases rounded, the two ventral angles slightly divergent. Metathorax very narrow on the median line. Anterior angle of insertion of hind wing-cases broadly rounded, obtuse. Posterior wing-cases extending in some pupæ beyond the posterior lateral angle of the front wing-cases and half-way along their ventral edge. Posterior lateral corner of these hind wing-cases rounded and situated at the middle of the second abdominal segment. Near anterior edge of metanotum there is a setiferous tubercle on each side of the median line.

All the abdominal segments bear setæ corresponding in position to the large primary setæ of the caterpillar, and a dark oval non-setiferous spot just mediad of the spiracle. Abdominal segments 3 to 5 have a row of small teeth on the middle of the posterior declivity of the segment, which

TEXT-FIG. 3.—*Acanthopsyche junodi* (Heylaerts). Pupa.

A. A, a. Male pupa, ventral view. $\times 2.5$. B. B, b. Male pupa, side view. $\times 2.5$ C. Male pupa, dorsal aspect. $\times 2.5$. D. Male pupa, anterior portion, ventral aspect. $\times 15$. E. Male pupa, anterior portion, dorsal view. $\times 15$. F. Male pupa, caudal end, dorsal view. $\times 15$. G. Male pupa, caudal end, ventral aspect. $\times 15$. H. Female pupa, dorsal aspect. $\times 4$. I. Female pupa, ventral view. $\times 4$. J. Female pupa, anterior portion, ventral aspect. $\times 8$.



teeth reach their greatest development on abd. 5 (c, r). They are composed of a narrow base, flattened laterally, the tip of the teeth recurved cephalad and ending in a short seta. On abd. segment 6 these teeth are wanting, and the segment is unarmed. On abd. 7 we find at the cephalic margin a small crescent-shaped plate, which bears on its caudal edge a number (8 to 14) of sharp-pointed teeth, flattened dorso-ventrally and directed caudad (r). Abd. 8, which with the following segments is deflexed ventrad, also bears a toothed plate like abd. 7, but stronger, and with more (12 to 14) teeth directed caudad. The setæ are longer than those on the preceding segments. Abd. 9 appears to be unarmed, and bears on its ventral aspect the genital scar (g). Abd. 10 is still more deflected ventrad. Cremaster absent, but instead of this there are two sharp hooks derived from the anal prolegs, flattened laterally, slightly divergent, with broad base, and with strong, sharply pointed hook directed cephalad.

Female Pupa.—Length 15 to 20 mm., vermiform, cylindrical with tapering ends. Abdominal segments 2 to 6 well-marked, strongly segmented, large; thoracic segments and first abdominal segment narrow, contracted, and less distinctly separated. Abdominal segments 7 to 10 smooth, appearing nearly confluent (text-fig. 3, H).

General colour reddish brown, the posterior third of the segments with an olivaceous tint. Head, thoracic segments, and dorsal aspect of abdominal segments 1 to 7, darker pigmented.

Head small, deflected ventrad, mouth-parts distinctly visible, clypeus small, triangular: paraclypeals prominent (J). Maxillæ small, with large maxillary palpi. Leg-cases small, transverse, semi-detached in young pupæ, becoming more obtect as pupa matures. Thoracic segments with median dorsal ridge (cocoon breaker?), meso- and metathoracic segments have in addition a slight transverse ridge which bears four setiferous tubercles (H). Abdominal segments 2 to 5 bear on their dorsal aspect a row of small spines, directed cephalad and arising from the middle of the posterior declivity of each

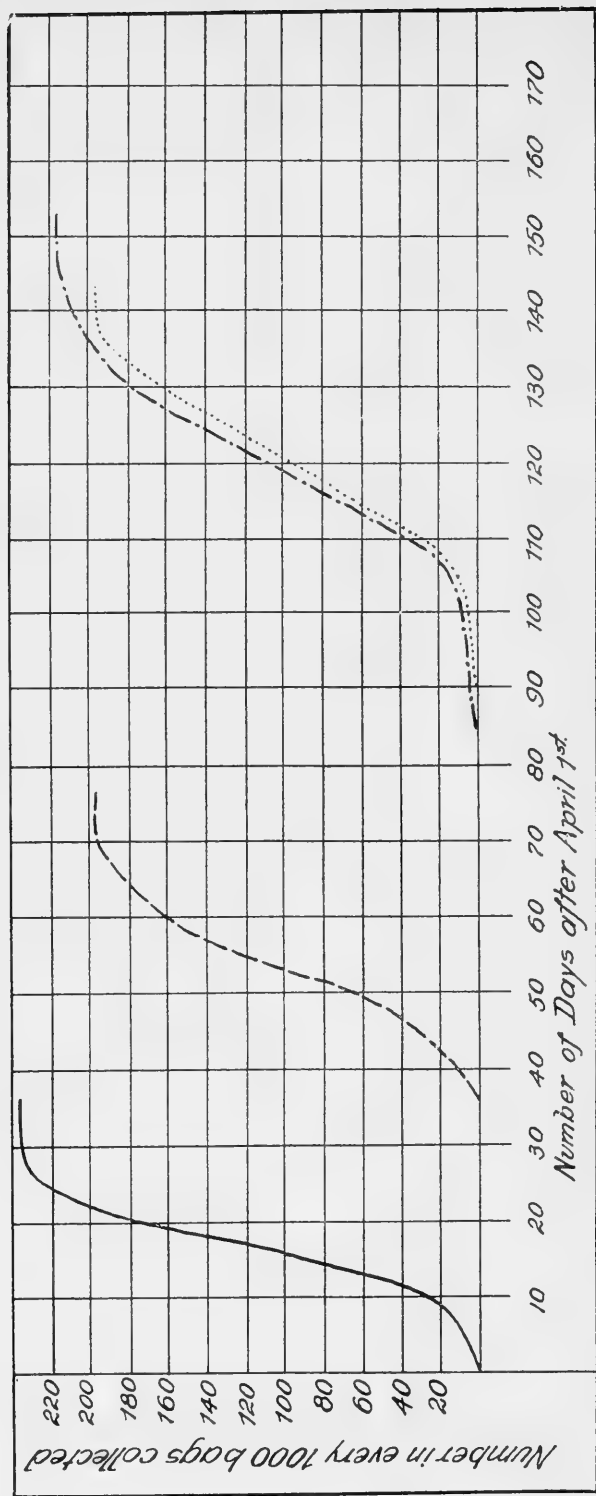
segment; segments 6 to 8 unarmed. All of the segments 2-7 each show a dark puncture dorsad of the spiracle.

Abdominal segments 1 to 6 strongly striated transversely on their dorsal aspect; ventral aspect, as also the whole of segment 8, practically smooth. Last segment with a minute hook ventrally situated and directed cephalo-ventrad (1).

Duration of the pupa-stage.—Individual records of the length of the pupa stage are not available, owing to the practical difficulty in rearing the adult after repeated disturbance of the larva in the prepupal stage or the pupa itself; but from a comparison between the pupation curve and emergence curve in text-fig. 4 we can readily deduce the average duration of the pupal period. These curves are based upon the examination of one thousand bags collected in a certain block every week, weather permitting, from April 9th until September 10th, some twenty thousand bags in all. From these curves we see that the males began to pupate during the first week in April, the number of male pupæ per thousand bags rapidly increasing, until at the end of the month a maximum was reached, showing that the male larvæ had completed their pupation. This percentage remained practically stationary, allowing for slight variations in the various lots, until the middle of June, after which some isolated males began to appear. The maximum emergence of males, shown by the empty pupa-cases, was reached on August 16th, the main emergence starting about the middle of June. Therefore, taking as an average the period from the middle of the pupation curve, April 17th, to the middle of the emergence curve, July 31st, we find for the duration of the pupa stage the average of three months and thirteen days.

The females did not start to pupate until about a month after the males, the first female pupæ having been observed on May 10th; the maximum, showing that practically all had pupated, occurred about the middle of June. Shortly afterwards the first female adults were found. The general emergence, if it may be so called, started about the middle of

TEXT-FIG. 4.



— Pupation, males

- - - Pupation, females

- · - · - Emergence, males

····· Emergence, females

Acanthopsyche junodi (Heislants). Pupation and emergence curves of males and females.

July, and reached a maximum during the second week in August, the average duration of the pupa stage of the female being two months and seven days.

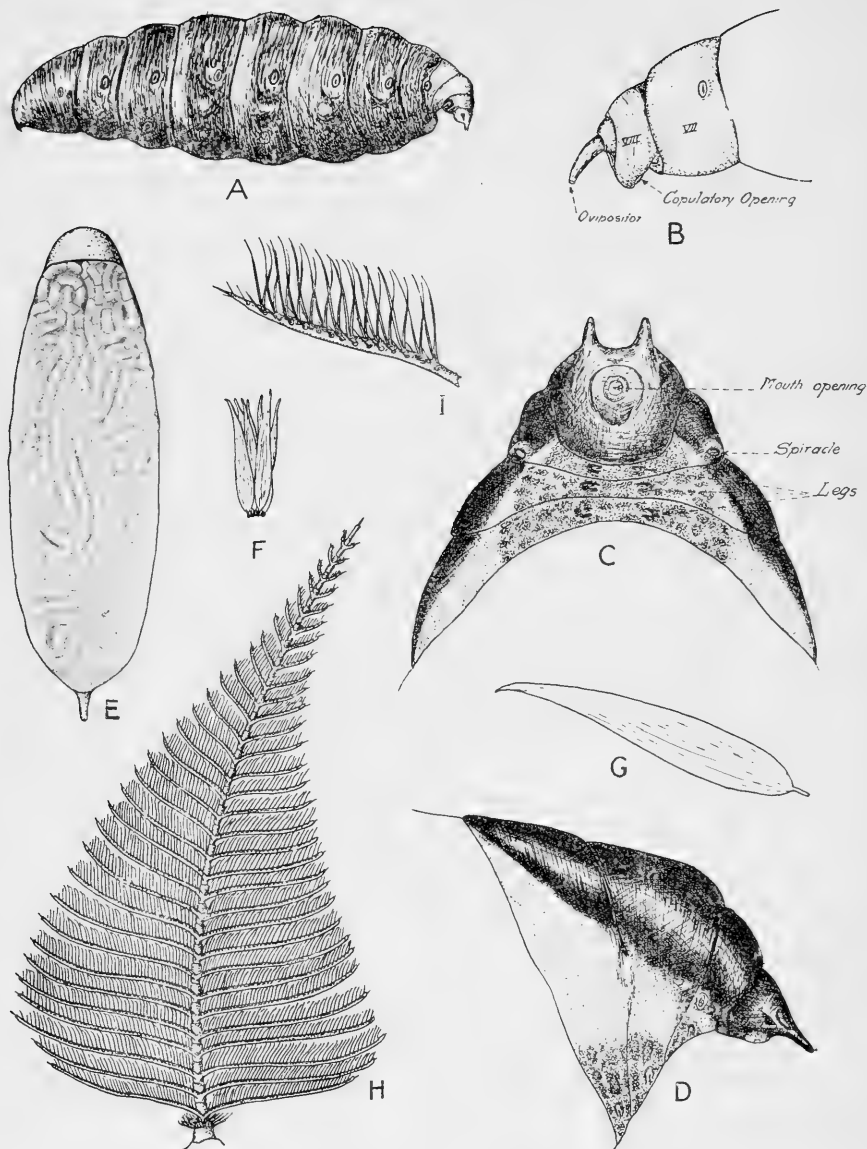
We thus see that, although the females keep on feeding for a month longer than the males, yet their pupation period is roughly a month shorter, so that adult males and females appear almost simultaneously.

(8) THE IMAGO.

Emergence of Males.—When the time of emergence approaches, the pupa works its way partly out of the lower end of the bag, until it protrudes far enough to free the wing-cases and the legs. The pupa then splits in the usual manner, and the moth after emergence crawls on to the side of the bag, where it remains motionless to allow the wings to dry and harden. The time from the first extrusion of the pupa until the moth is ready to fly is very short, the entire process being accomplished in about ten minutes. Emergence takes place in the middle of the day, generally between the hours of 11 a.m. and 3 p.m. The moths are active and on the wing during the hours of the brightest sunshine. Sunshine is a very important agent in promoting emergence, and in young plantations, or on the edges of the blocks, where the sun has more easy access to the bags, the moths appear earlier than in the centre of old shady plantations.

Emergence of Females.—The female does not leave the chrysalis case. When mature, the anterior part of the pupa is pushed off like a cap, exposing the head and the first two thoracic segments of the female moth. The seam along which this cap is severed is on the ventral side fairly regular; it follows one of the intersegmental incisions, and is here probably made by a restricted turning motion of the head of the insect, which is armed with two pointed prongs on its ventral aspect (text-fig. 5, c). The ventral slit thus made, a pushing forward of the enclosed moth removes the anterior part of the pupa case, which thus breaks along the edge of one of the

TEXT-FIG. 5.



Acanthopsyche junodi (Heylaerts). Imago.
 A. Female in chrysalis-case, side view. $\times 4$. B. Posterior segments of the abdomen of female, side view. $\times 8$. C. Female, head and thorax, ventral aspect. $\times 16$. D. Female, head and thorax, side view. $\times 16$. E. Female, opened dorsally, showing the mass of eggs. $\times 4$. F. Tuft of scales of body-segments of female $\times 12$. G. Single scale from tuft; note curved point, constricted base, and striation of surface. $\times 36$. H. Antenna of male, showing pectinations. $\times 20$. I. A single ramus of antenna. $\times 250$.

thoracic segments on the ventral side and tears off irregularly on the dorsal side. Normally this anterior part of the female, including the head and the first two, or all, thoracic segments, is the only portion of the moth which is exposed during the reproductive period (text-fig. 5, A).

Percentage of individuals reaching maturity.—The mortality amongst the young after hatching and during the earlier larval instars is beyond computation. Owing to the distribution by external agencies, their finding a suitable food-plant is a matter of chance, and such as find favourable surroundings suffer from many vicissitudes during their first larval instars, amongst which unfavourable weather conditions play a most important rôle, by favouring the development of diseases of various kinds. Of those which pass this infantile stage and become healthy, feeding bagworms, we have found that toward the end of the feeding period only about one-quarter reach the pupa stage. Our examination of some twenty thousand bags, gathered from week to week in lots of a thousand each, showed that the average number of males which pupated was 230 per thousand, of the females, which have a longer feeding period, 190 per thousand, the deaths being principally caused by parasitism. Of this average of 230 male pupæ, only 210 male moths emerged, due to the fact that some twenty of these larvæ, though parasitised, had been strong enough to pupate, the parasite emerging from the pupa later. Of the females there was practically no difference between the number of pupæ formed and the number of moths emerging.

The adults.—The male moth was described originally by Heylaerts in the 'Ann. Soc. Ent. Belg.,' vol. xxiv, p. cxxx (1890) under the name *Eumeta junodi*, but the species is now placed by Janse in the genus *Acanthopsyche*, and the latter author gives a re-description of the male of this species. The female has, so far as known, not been described, and a description therefore follows:

Acanthopsyche junodi (Heylaerts)—Female.—Wingless. Length 18 to 22 mm., vermiform, body-wall soft and

transparent. Head and part of thoracic segments chitinised, the extent of this chitinous area increasing caudad. Colour of body cartridge buff (XXX), diffused with pale pinkish buff (XXIX), sternum of three thoracic segments dull blue-violet (XXXVI). Head deflected ventrad, conical, bearing two slender, pointed, slightly diverging prongs, arising from the vertex. Ventral aspect of head very convex. Antennae and trophi absent. A pigmented black spot on each side near the base of the prongs.

Thorax small, partly chitinised, sterna of first and second, sternum and pleuræ of third segment membranous (text-fig. 5, c). Thoracic legs rudimentary, represented by a minute papilla, surrounded by a chitinous ring, with larval arrangement of setæ. Chitinised parts of thorax smooth, shiny.

Abdominal segments large, membranous, surrounded by a ring of downy hairs, mixed with scales (text-fig. 5, f, g). These rings are incomplete on the first few abdominal segments, being represented on abd. 1 and 2 by a paired ventral and prespiracular tuft, on segments 3, 4 and 5 by a paired ventral, a prespiracular and paired sub-dorsal tufts, and become practically complete on segments 6 and 7. On abd. 8 only the subdorsal tufts remain, while abd. 9 and 10 are devoid of these hairs. Colour of hairs light buff (XV), of scales yellow ochre (XV), the latter predominating on the sixth and seventh abdominal segments.

New Hanover, Natal, July 1915, bred by C. B. Hardenberg. Type (alcoholic specimen) in collection Hardenberg.

(9) HABITS OF THE IMAGOS.

The males are very active, quick and strong flyers, as is indicated by the broad, massive thorax and slender, pointed abdomen. At the moment the wings are sufficiently expanded and hardened, the moth takes flight in search of the female.

While normally under ordinary plantation conditions the flight need be but short, as the females are near, the males

are well capable of long-sustained flights. Several cases have come under our observation where females have been visited by males which could only have come from a couple of miles distant. Flying only takes place in the bright sunlight and during the hottest part of the day, roughly between 10 a.m. and 3 p.m., while if the sun be temporarily obscured by a cloud, no males are to be seen.

Fuller, in his various discussions on the bagworm, mentioned previously, maintains that the males are very weak flyers and can only fly for a short distance. His observations were based on moths bred in the laboratory, and under those conditions, in the absence of sun and free air, the moths make no attempt to fly and visit the females, even when the latter are confined in the same breeding cage.

This strong power of flight, although no longer necessary under the plantation conditions, may well have been advantageous, or even essential, under the original environment, namely in the scattered thorn bush, where the species used to breed. Here long distances might have to be covered across the veld before a receptive female was found, and in the absence of warning coloration or any other means of defence, its only safety from birds would lie in a quick flight. The transparency of its wings (the few hairy scales with which the wings are covered on emergence are shaken off with the first vibrations) also assists in making the moth very inconspicuous in its flight across the open spaces.

Copulation.—The male, upon finding a female bag, alights at the lower end, and with its wings and antennæ (text-fig. 5, H, I) vibrating continuously it endeavours to introduce its abdomen through the neck of the bag. This is usually accomplished in a few minutes, the neck of the bag being partly invaginated in the process. Now with a series of efforts the abdomen is fully stretched so as to reach the female. The normal length of the abdomen of the male is about 5 mm., but after full extension it reaches a total length of 20 mm., at which point the intersegmental membranes are stretched to their fullest extent and apparently the limit is reached. But even this

would not be sufficient to reach the end of the abdomen of the female (which lies head downward) so as to effect copulation in the usual manner, and, as a matter of fact, this does not take place. We have opened the bags at various periods, from five to twenty minutes after the male had alighted, and in no case have we seen the abdomen of the male extending further than just inside the anterior edge of the chrysalis case of the female. We are therefore inclined to believe that copulation takes place in the following manner. The male pushes up its abdomen through the neck of the bag until it reaches the edge of the chrysalis-case of the female. Here the abdomen is inserted for a short distance between the body of the female and the pupa-case, the two prongs on the head of the female probably acting as a guide, and the semen is injected into the cavity of the chrysalis. The spermatozoa travel upwards, assisted probably by movements of the female's abdomen, until they reach the eggs which are being deposited in the upper end of the chrysalis case, where they permeate the mass and fertilise them.

Apart from the apparent physical impossibility of the normal method of copulation, we have the following evidence which tends to support this view of the way in which fertilisation is accomplished :

(a) Often some of the eggs have already been laid before copulation takes place.

(b) The freshly laid eggs are soft, and frequently polyhedral through mutual pressure ; later, presumably after fertilisation they become rounded and firmer.

(c) The eggs are, as a rule, not all fertile ; between the developing eggs there are found a number of such as have remained soft and have shrivelled, showing that the spermatozoa of the male did not permeate the entire mass.

After the "copulation" is completed, the male withdraws from the bag and flies away. Whether it is able to fertilise another female we have not been able to ascertain. Although conceivably this may happen under natural conditions, we have never observed plural copulation on the part of the

male taking place in captivity, nor have we found any case where the female bag was visited successively by more than one male. Nevertheless we have not unfrequently seen two males on a female bag simultaneously, each one penetrating the neck of the bag, apparently oblivious of the presence of the other.

It frequently happens that the male is not able to extricate itself, and it then dies attached to the bag. In this case the neck of the bag remains obstructed, and the young hatching from the eggs cannot escape, and they perish in the bag.

The life of the adult male, from data obtained in captivity, is short, about three to four days.

While the male during the short period of its life is extremely active, the female during its adult stage remains in its chrysalis-case almost motionless. At most, if the male be tardy in arriving, it will crawl down and expose its head through the neck of the bag, retreating again upon the arrival of the male. Should, however, no male make its appearance, the female will expose itself further and further, until it drops out of the bag and dies. Such females as have dropped out of their bags are not attractive to the males, and invariably die without having been fertilised. The female moth lives for about a month.

Parthenogenesis.—While it is claimed that in some species of the *Psychidæ* parthenogenetic reproduction may take place for several generations in succession, we have no evidence which would make us inclined to believe that this occurs in the case of *A. junodi*. The great number of males would make parthenogenesis unnecessary and in fact unlikely, and in our experiments we have never found fertile eggs in cages from which males had been excluded.

Egg-laying.—Immediately after copulation, and sometimes even before, egg-laying begins. The eggs are deposited in the upper part of the chrysalis-case, where they are tightly packed and mixed with the hairs and scales from the abdomen of the female. As the chrysalis becomes filled the body of the female shrinks (Pl. XLV, fig. 13) and retreats until, when

all the eggs are laid, the empty female drops out of the bag and dies.

Fertility.—The fecundity of the female bagworm is remarkable. Fuller, in his first account of the Wattle Bagworm in 1899, gave the number of eggs for one female as 1600, while in his later account, in August, 1913, he said: "Some six hundred eggs are laid; the number may be more or less in accord with the size of the female. Actual counts of eggs in 1911 and 1912 ranged from five hundred to seven hundred and fifty per female."

Our counts of several egg-masses during 1913 and 1914 gave the following results:

Locality.	Year.	Number of eggs in bag.							
New Hanover	1913	1977	—	—	—	—	—	—	—
Wartburg	1913	1544	1888	2604	2678	3098	—	—	—
Greytown	1913	1177	1670	2197	—	—	—	—	—
Clan Syndi- cate	1914	438	678	910	984	997	1023	1082	
		1090	1101	1101	1206	1211	1349	1410	
		1416	1433	1517	1564	1584	1599	1605	

From this table it is evident that the fertility of the female varies considerably, ranging from a minimum of 438 in a specimen from the Clan Syndicate plantation to a maximum of 3098 obtained from a female in the Wartburg plantations.

The Wartburg specimens were collected in a plantation where the infestation was slight, and the bagworms were thus allowed to develop to their full extent. We see that the range here is from 1544 to 3098, with an average of 2380 per female. This is a high average and will only be reached under the most favourable conditions.

The Greytown specimens were obtained from a block where a sudden heavy infestation had occurred, resulting in complete defoliation of the trees before the bagworms had become full-grown. As a result a certain amount of starvation had taken place, which, while not being sufficiently severe to

cause the death of the bagworms, checked their development and produced mature insects which were below the average in size. Here the maximum was 2197 and the minimum 1177, with an average of 1661. This agrees closely with Fuller's first figure (1600) given in 1899, his specimens probably having been obtained from a locality or a tree where just such conditions prevailed.

The females of the Clan Syndicate plantations were gathered from a block which had suffered severely from bagworm attack for two or three successive seasons, each time resulting in a complete defoliation, and where the conditions otherwise were very unfavourable for the normal development of the bagworm. Here we see that with an average of 1209 the number of eggs drops as low as 438, the maximum being 1605. The maximum does not even reach the average of the Wartburg lot. The Clan Syndicate bags can thus no longer be considered as representing the normal reproductive power of the bagworm, but are interesting as showing how this function depends to a great extent on the size and vigour of the female, determined by the conditions prevailing during the feeding period of the larva. Apparently the bags on the contents of which Fuller based his later conclusions in 1913 were obtained from such an unfavourable area, for the years 1911 and 1912 were successive seasons of unprecedented infestation.

Taking into consideration the most favourable, the normal and the most unfavourable localities, we come to a mean average of 1756 eggs per female, which we may consider a fair indication of the multiplication of the bagworm over the entire area of its distribution. The actual number of eggs deposited by any one female may greatly excel or fall far below this average, depending on local conditions.

(10) LIFE-CYCLE.

The incubation period of the eggs, judging from the time of copulation to the hatching of the eggs, is about two months, the average being sixty-two days.

As the males are emerging during a period of about six weeks, it follows that the hatching of the young caterpillars also stretches over a similar period, namely from the middle of August until the beginning of October.

The life-cycle of the species may be briefly represented by the accompanying diagram (text-fig. 6).

The Wattle Bagworm has been discussed at some length, because it is by far the most important from an economic

TEXT-FIG. 6.

	Jan	Feb.	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec.
1914									♀+	•		
1915	—	—	—	—	♂♂	♂♂	♂♂	♂♂	♂+	♂+	♂+	—
					♀♂	♀♂	♀♂	♀♂	♀+	♀+	♀+	—
						•	•	•	•	•	•	—

— *Larvae* ○ *Pupae* + *Imagines* • *Eggs*

Acanthopsyche junodi (Heylaerts).

NOTE.—The above diagram shows the development of the entire generation, not of one particular brood.

point of view, and as such has been studied in greater detail than the other Psychidæ, and also because its life-history is typical of the family. Of the remaining members of the family, as also of the bagworms of the other families, our data are as yet more incomplete, and therefore these species must be treated more briefly.

EXPLANATION OF PLATES XLIV-XLVI,

Illustrating Mr. C. B. Hardenberg's paper, "South African Bagworms," Part I.

PLATE XLIV.

FIG. 1.—Nat. size. Wattle Bagworm, *Acanthopsyche junodi* (Heylaerts).

FIG. 2.—Nat. size. Thatched Bagworm, *Acanthopsyche tristis* Jansé.

FIG. 3.—Nat. size. Gum Bagworm, *Melasina stelitidis* Meyr.

FIG. 4.—Nat. size. Rubbish Bagworm, *Melasina picea* Meyr.

FIG. 5.—Nat. size. Lictor Bagworm, *Clania moddermanni* (Heyl.).

FIG. 6.—× 3. Grass Bagworm (species undetermined).

FIG. 7.—Nat. size. Meadow Bagworm, *Trichocossus arvensis* Jansé.

FIG. 8.—Nat. size. Crossed-stick Bagworm, *Gymnelema vinctus* (Wlk.).

FIG. 9.—Nat. size. *Gymnelema stygialis* Hmps.

FIG. 10.—Nat. size. Webbed-crossed-stick Bagworm, *Acanthopsyche alba* Jansé.

FIG. 11.—× 3. Clear Spiral Bagworm, *Melasina tyrophanes* Meyr.

FIG. 12.—× 3. Webbed Spiral Bagworm, *Melasina enaphalodes* Meyr.

FIG. 13.—× 3. Rough Spiral Bagworm, *Melasina craterodes* Meyr.

FIG. 14.—Nat. size. Thorn Bagworm, *Melasina halieutis* Meyr.

FIG. 15.—× 3. Sand Bagworm, *Fumea obscurata* Meyr.

FIG. 16.—× 3. Flat Bagworm, *Ceromitia xanthocoma* Meyr.

FIG. 17.—× 3. Flat Leaf Bagworm (undetermined Tineid).

PLATE XLV.

FIG. 1.—× 3. Seed Bagworm (undetermined species).

FIG. 2.—× 3. Gibson's Bagworm, *Manatha æthiops* Hmps.

FIG. 3.—Nat. size. Lichen Bagworm (undetermined).

FIG. 4.—Nat. size. Gravel Bagworm (undetermined).

FIG. 5.—Nat. size. Sectional Bagworm, *Melasina circophora* Meyr.

FIG. 6.—Nat. size. Trunk Bagworm (undetermined).

FIG. 7.—× 3. Lesser Lictor Bagworm (undetermined).

FIG. 8.—× 3. Delicate Bagworm, *Monda delicatissima* *Wlk.*

FIG. 9.—× 3. Turret Bagworm, *Monda rogenhoferi* *Heyl.*

FIG. 10.—× 3. Single-stick Bagworm. A small hollow twig is adapted as a dwelling and carried about by the larva. In the figure on the right the stick is opened, showing the pupa contained therein.

FIG. 11.—× 3. Single-straw Bagworm. A hollow straw is adapted as a dwelling. In the figure on the right the straw is opened, showing the empty pupa-case.

Acanthopsyche junodi (*Heylaerts*).

FIG. 12.—Nat. size. Male bag on the right; female bag on the left, showing inner bag and female imago in chrysalis case.

FIG. 13.—Nat. size. Lower figure, female moth nearly spent; upper figure, chrysalis case filled with eggs; a single egg is shown in centre.

FIG. 14.—Nat. size. Male moth with the body of normal length.

FIG. 15.—Nat. size. Male moth with the body extended for copulation.

FIG. 16.—Nat. size. Female bag with two male moths both trying to copulate.

FIG. 17.—Nat. size. Same bag as fig. 16, opened to show the female inside, and the abdomens of the two males entering the neck of the bag.

PLATE XLVI.

Acanthopsyche junodi (*Heylaerts*).

FIG. 1.—Larva, first instar; plan of abdominal segments 10-7, showing the arrangement of the setiferous plates and the setæ. The hooks on anal proleg have been drawn relatively too large.

FIG. 2.—Larva, first instar; plan of abdominal segments 6-3, showing distinguishing names of the plates.

FIG. 3.—Larva, first instar; plan of abdominal segments 2-1 and thoracic segments 3-1.

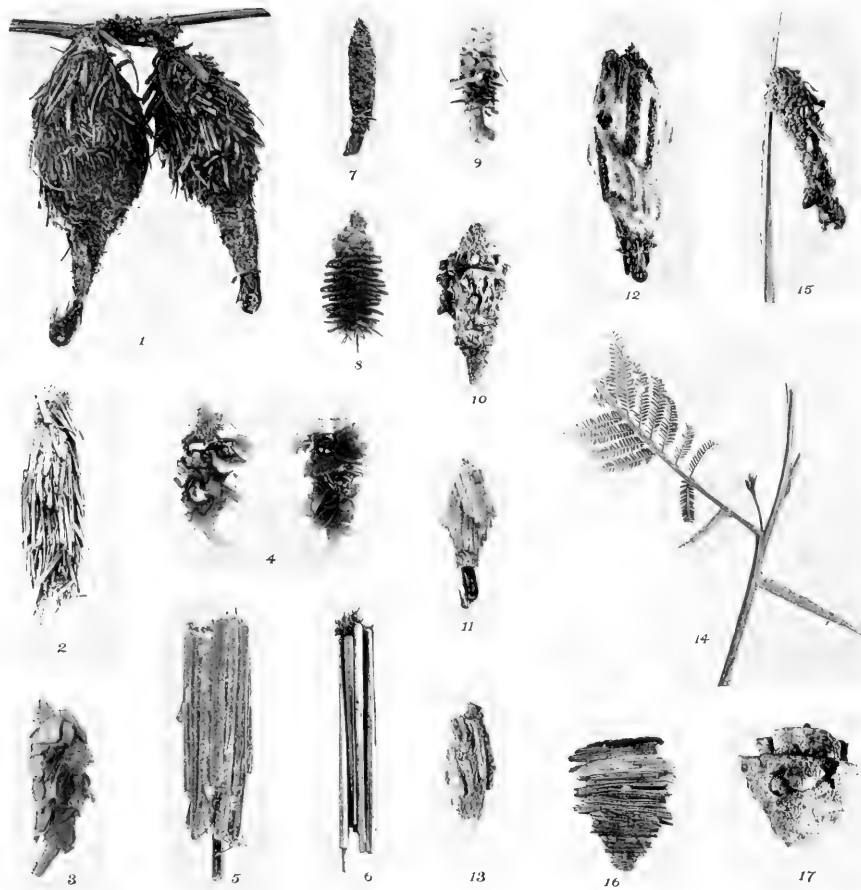
FIG. 4.—Larva, first instar; plate of abdominal proleg of larva, showing the small number of hooks and only two setæ (group "7").

FIG. 5.—Larva, second instar; plan of abdominal segments 10-7, showing the setiferous plates and the setæ.

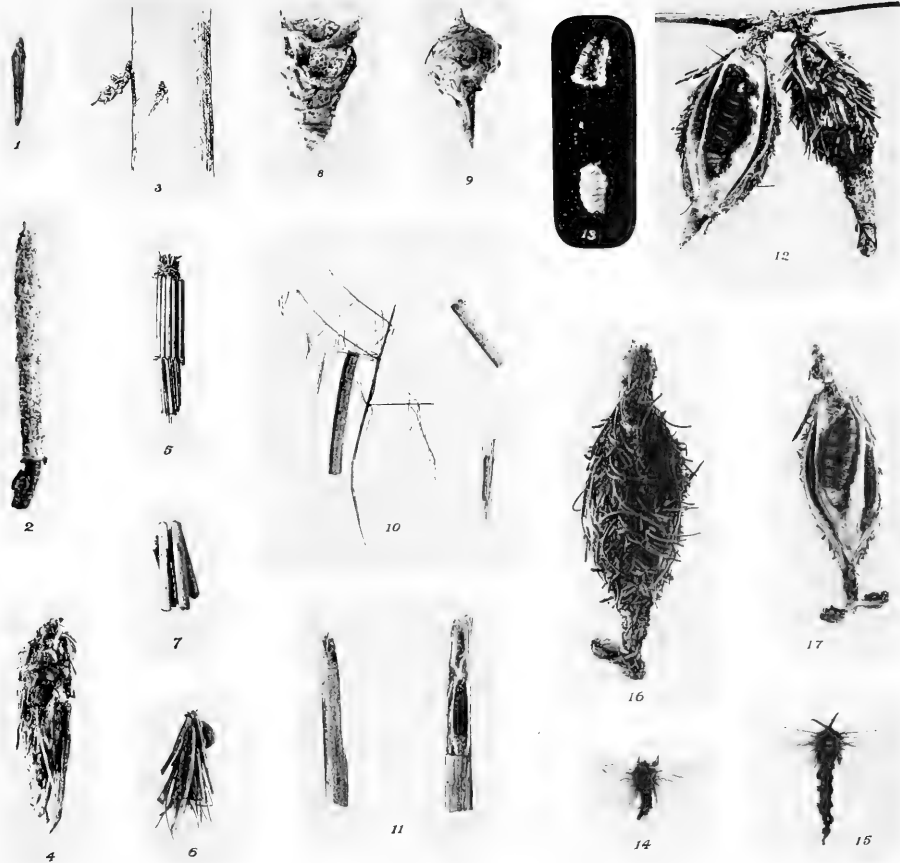
FIG. 6.—Larva, second instar; plan of abdominal segments 6-3.

FIG. 7.—Larva, second instar; plan of abdominal segments 2-1, and thoracic segments 3-1.

FIG. 8.—Larva, fourth instar; plate of abdominal proleg of larva, showing fully developed number of hooks and the full number of three setæ (group "7").

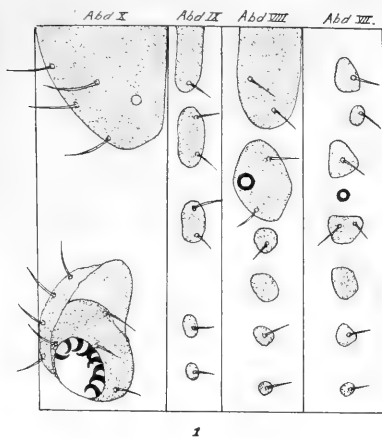


BAGS OF VARIOUS BAGWORMS.

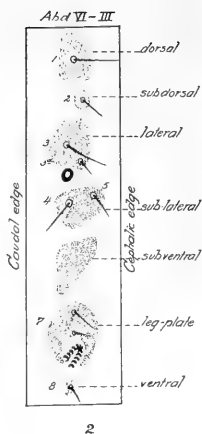


BAGS OF VARIOUS BAGWORMS

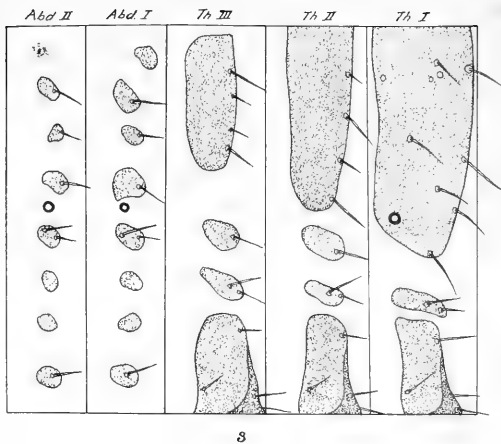
ACANTHOPSYCHE JUNODI (HEVLAEPTIS)



1



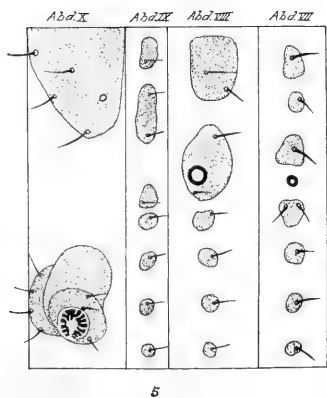
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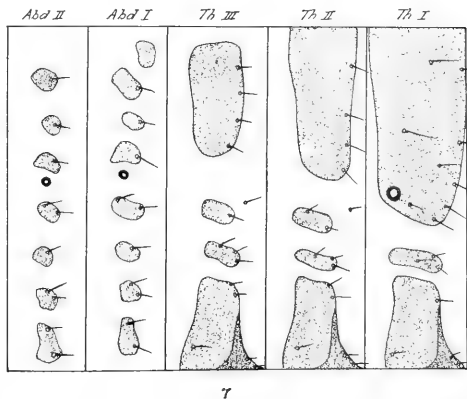
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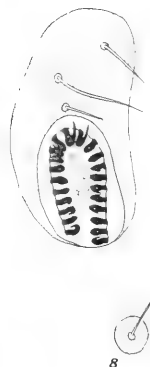
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7



8

Descriptions of New South African Arachnida.

By

John Hewitt,

Director, Albany Museum, Grahamstown.

With Plate XLVII and 4 Text-figures.

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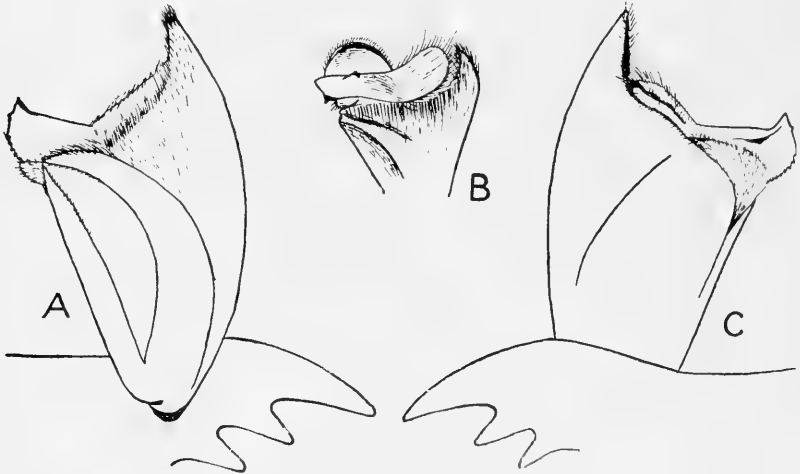
ORDER SOLIFUGÆ.

Hemiblossia idioceras sp. nov. Text-fig. 1, A-C.

THE type of this species is a single adult male example from Kimberley collected by Bro. J. H. Power (November, 1915). The species closely resembles *H. o'neili Purcell* in coloration, but has a more complicated flagellum. The fourth tarsus is unsegmented, and carries on each side six

spines, whereas, according to Dr. Purcell's figure (Ann. S. Af. Mus. ii, p. 218), there are only five spines in *o'neili*. I may remark, however, that the spine-armature in specimens from Alicedale which appear to be referable to *o'neili* does not agree with the above-mentioned figure, but resembles that of *idioceras*, which has three spines, instead of two, on the distal portion of the tarsus.

TEXT-FIG. 1.



Hemiblossia idioceras, sp. n.

- A. Flagellum of adult male seen from mesial side. $\times 44$. B. Distal end of flagellum in face view, also portion of mesial surface. $\times 32$. C. Flagellum from outer side. $\times 44$.

The description of *o'neili* contains no allusion to the presence of some characteristic thickened bristles on the sternites, a secondary sexual character of adult males; such bristles certainly occur in our Alicedale specimens, and are present in the form now described.

Flagellum.—The main portion of the flagellum is a thin flat lamina rotatable at the base; on its mesial side, upper and lower out-growths of the lamina approximate to form an elongated flattish pouch which occupies almost the whole length of the flagellum, and has a long and fairly wide slit-

like opening along the middle, the edges of which remain separate distally but fuse proximally (text-fig. 1). The distal margin of the lamina is flattened out, and presents a foliaceous concave extension on its outer side inferiorly—the side adjacent to the chelicera—the sides of this extension gradually converging proximally into a slight keel which runs for a short distance along the outer surface of the lamina ventrally. The dorsal margin of the flagellum is slightly curved, and has an acutely pointed termination: the ventral margin is almost straight. The distal margins are for the most part fringed with hairs. The stridulatory area of the chelicera presents seven longitudinal ridges.

Sternites.—Modified hairs are present on the third post-genital sternite as numerous long stout rods, finely pointed at the apex; there are roughly about twenty on each side, arranged irregularly and rather sparsely. In the neighbourhood of these hairs is a bright yellow exudate. Numerous hairs of this kind, but more slender, are also found on the first post-genital sternite.

Measurements.—Total length 9 mm., length of flagellum about 1·2 mm.

ORDER ARANEÆ.

Fam. CTENIZIDÆ.

Stasimopus longipalpis *sp. nov.* Pl. XLVII, fig. 5.

This species is founded on three adult male examples from Kimberley, collected by Bro. J. H. Power.

Colour.—Carapace dark brown or pale brown; legs also brown, the two anterior pairs and the palp being somewhat darker than the hinder two pairs, except on the distal portions of those appendages, which are pale.

Carapace.—As long as the tibia of the palp, longer than tibia I. The three keels do not reach back so far as the fovea. The surface more or less lightly sculptured or roughened throughout, being nowhere quite smooth. Anterior

margin of anterior row of eyes in a straight line; anterior medians slightly nearer to the laterals than to each other.

Pedipalps.—Pressed forwards, the tip reaches a point about one-quarter to one-third of the distance along the tarsus of the first leg, or only to the end of metatarsus I; patella considerably longer than that of the first leg and a little longer than tibia I.

Legs.—All the tarsi scopulate below, but no trace of a scopula on the metatarsi. Tarsus I without spines or with only a single one on the posterior side, or with one on the posterior side and two on the anterior side; II without spines or with a single one on the anterior side or on both sides; III with 0–1 spine anteriorly and 0–2 posteriorly; IV with 5–11 spines anteriorly but 0 posteriorly. Metatarsus I without strong spines along the mesial area inferiorly or with only 1. Tibia I very slightly shorter than metatarsus I, with about 5–10 spines on the lower surfaces besides those at the apex inferiorly; tibia III with 1, 2 or 3 spines near the distal edge superiorly on the anterior side, and 3 or 4 on the posterior side superiorly. Patella I without spines below, III with a discontinuous strip of about 5 or 6 short, weak spines on the anterior side, but no distal patch of spinules above; IV with an anterior patch of spinules extending about three-fifths of the length of the anterior side. Paired tarsal claws of fourth leg with a basal comb of 2 or 3 teeth, or even only 1 may be well developed.

Measurements.—Largest specimen: total length 11·0 mm., length of carapace 5·65 mm., breadth of same 4·9 mm., length of tibia of palp 5·8 mm., of patella of palp 5·4 mm., of metatarsus I 5·1 mm., of tibia I 4·8 mm.; of patella I 3 mm.; of metatarsus IV 5·4 mm.

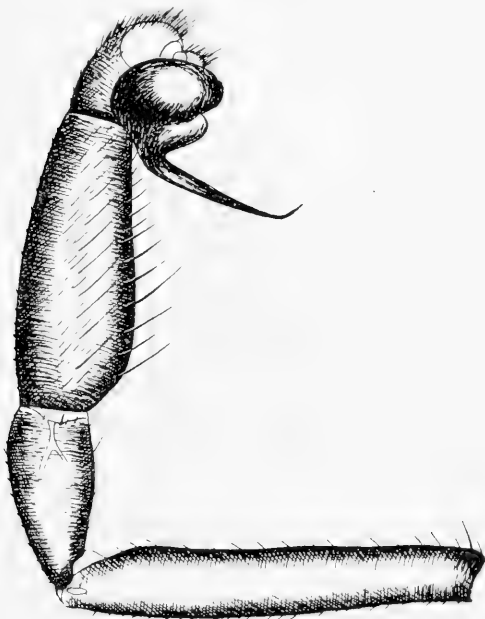
Stasimopus insculptus Poc. var. *peddiensis* var. n.

Pl. XLVII, figs. 6 and 7, and text-fig. 2.

The types of this form are four adult male examples collected at Peddie by Mr. B. Marais during March, 1916.

They are approximately equal in size, and share the same coloration, being entirely black above except the metatarsi and tarsi of the legs, which are reddish. They are slightly smaller than the type of *insculptus*, the carapace of which is 4.5 mm. long (not 6 mm. as stated by Pocock¹ in the original

TEXT-FIG. 2.



Stasimopus insculptus var. *peddiensis* var. *nov.*

Palp of adult male. × 16.

description); in the Peddie specimens the carapace is about 4 mm. long. They differ from *insculptus* as follows:

Metatarsus I without spines below or at the sides, apart from those at the apex, or only a single spinule on each side in the distal half, or even three spinules on the posterior side; tibia I without spines inferiorly (*insculptus* has several strong spines inferiorly); tarsus I with 0-3 spines on the anterior side, and 0-4 on the posterior side.

¹ *Ann. Mag. Nat. Hist.*, 7, vii, p. 285.

The tibia of the palp seems short and comparatively stout, being swollen towards the base, and not quite twice as long as the patella. The spine of the palpal organ is elongated, so much so that if it were straightened out in a line with the axis of the bulb the whole organ would be quite as long as the tibia of the palp.

Total length 10 mm., length of tibia of palp 2·35 mm., of first leg 15·3 mm., of fourth leg 16·8 mm.

The female of this form closely resembles that of *S. insculptus* Poc., and was referred to in my key ('Albany Museum Records,' iii, p. 84) as connecting together *artifex* and *insculptus*. It has neither spines nor spiniform setae at the apex of metatarsus III inferiorly, though stiffish setae may be present.

Stasimopus spinipes sp. nov. Pl. XLVII, figs 3 and 4.

The types of this species are two adult males collected at East London during the earlier part of June, 1916, by Dr. Geo. Rattray, who presented them along with numerous female examples to the Albany Museum.

Colour.—Black throughout, except the two distal segments of each leg which are red, the tibia, tarsus, and bulb of the palp which are brown, the sternum and ventral surfaces of coxæ III and IV which are castaneous, the lung-opercula and genital sternite which are yellow, and the spinners which are pale.

Carapace.—Without hairs on the head region, except several in front of the antero-median eyes. The usual three keels are present, the mesial one being continued backwards to the fovea. The surface is roughened throughout, except in the head-groove laterally and between the three keels dorsally. The eyes of the anterior row are comparatively large and close together, much more so than in *schönlandi*: the distance between an antero-lateral and antero-median is considerably less than the long diameter of the former, and distinctly less than the diameter of the latter. The carapace

is a little longer than metatarsus IV or than the tibia and tarsus of the palp.

Pedipalp.—Pressed forwards the palp extends as far as the proximal fourth of metatarsus I. The patella is a trifle shorter than patella I.

Legs.—All the tarsi are scopulate below, but no trace of a scopula on the metatarsi. Tarsus I with short strong spines on each side, 7–16 anteriorly and 8–21 posteriorly; II also with rather numerous spines on each side; IV with about 10–15 rather weak spines posteriorly but more numerous and stronger ones anteriorly. Metatarsus I with numerous strong spines in several rows on each side, and one or two may, or may not, occur along the mesial surface inferiorly, the mesial area on the whole being devoid of spines. Tibia I distinctly shorter than metatarsus I, thickly spined below; tibia III without a group of spinules at the apex dorsally, or such spinules when present are small and weak. The patch of minute spines on the anterior surface of patella IV extends about two-thirds of the length of the segment.

Measurements.—Total length 21·0 mm., length of carapace 7·5 mm., of patella I 3·5 mm., of tibia I 4·7 mm., of patella of palp 3·0 mm.

The palpal measurements of these specimens may point to a relationship with the Grahamstown species *S. schönlandi* Poc., the ocular characters of which are, however, pronouncedly different from those of *spinipes*, whilst apparently the spinulation of the lower surface of metatarsus I will distinguish the two forms. Probably the species is closely related to *S. insculptus* Poc. and to *S. qumbu mihi*, though the palps of the latter species are relatively shorter than in East London specimens.

The characters of the female are sharply separated from those of *schönlandi*, and agree very closely with those of the section including *insculptus* Poc., *kolbei* Purc., *ken-tanicus* Purc., *umtaticus* Purc. and *qumbu mihi* (see :Records Albany Mus., iii, p. 84). There is no trace of

spines or spiniform setae at the apex of metatarsus III inferiorly. At the apex of the tibia of the palp superiorly is a group of spinules. In the larger specimen and several others, patella III has a number of short stout red spinules at the apex superiorly, similar to those on the tibia, but in somewhat smaller examples, though apparently adult, such spinules are quite absent or weak.

The antero-lateral eyes are very large, their long diameter being considerably greater than the distance between antero-median and antero-lateral; the posterior lateral eyes are much smaller than the anterior laterals. The patch of spinules at the apex of tibia I dorsally is rather longer than that at the base of the metatarsus. The carapace and appendages are usually dark castaneous, and the abdomen infuscated above; sometimes the two distal segments of each leg are paler than the more proximal segments, and more or less tinged with red. Length of carapace 11.0 mm., breadth of carapace 9.3 mm., breadth of ocular area 3.0 mm.

The large series of female specimens collected by Dr. Rattray at East London seems to be referable to a single species. They are considerably smaller than specimens from Debe Nek, and from the neighbourhood of King Williamstown, which presumably belong to *insculptus* Poc. Perhaps they are co-specific with one or both of the two forms described by Dr. Purcell from the Kentani district, viz. *S. kolbei* and *S. kentanicus*. The question cannot be finally solved until adult males of these species are available.

The adult females from East London are smaller than those found at Peddie, but very similar in structural characters; examples of approximately equal size can be distinguished by the characters of the posterior row of eyes, which are all larger in *peddiensis* than in *spinipes*, the disparity in size between the anterior and posterior laterals being greater in *spinipes*.

In distinguishing the species of *Stasimopus* on the characters of adult males the most convenient character is

that based on the varying length of the palp and of its segments. It should be noted, however, that large and small males of the same species present some appreciable difference in this respect; in small males the palpal segments tend to become rather more elongated than in large ones of the same species. I give tentatively the following key:

PRELIMINARY KEY TO THE SPECIES OF THE GENUS
STASIMOPUS,

BASED ON STRUCTURAL CHARACTERS OF THE ADULT MALES.

- I. 1. Pressed forwards the palp reaches a point about $\frac{1}{3}$ or $\frac{1}{5}$ of the distance along tibia I, the patella distinctly shorter than patella I: metatarsus I not scopulate, with strong spines on either side but not along the median area inferiorly: tarsus I with 2 or 3 spines on the anterior side and 7-8 on the posterior side, IV with a strip of spines along the anterior side except in the basal $\frac{1}{3}$ or $\frac{2}{5}$: tibia III with a few spinules at the apex above: the three keels of the carapace are depressed, the lateral ones flattened out and transversely ridged, the ridges becoming lost in the reticulation of the sides of the cephalic area. (King Williamstown.) *S. insculptus* Poc.
- a. Similar to the typical *insculptus* but differing as follows: Metatarsus I without spines or spinules below or at the sides, or only with one or several spinules at the sides. (Peddie.)
S. insculptus var. *peddiensis* var. nov.
- b. Similar to *insculptus* but differing as follows: Metatarsus I with strong spines below both over the median area and at the sides and bearing a few scopular hairs near the apex: tibia III with a dense patch of short spinules at the apex above: tarsus I with 10-12 spines on both anterior and posterior sides, IV with many spines on the anterior side and about 13 on the posterior side. (Qumbu.)
S. qumbu Hwitt.
2. Pressed forwards the palp not quite reaching the apex of tibia I, the patella short, half as long as tibia I:

metatarsus I scopulate below in the distal fifth or sixth, the under side thickly spined on each side, and also with 1-3 spines along the median line: tarsus I with 1-2 spines on the posterior side but none on the anterior side, III with 4-6 anterior and 7-9 posterior spines, IV with 2-3 on the posterior side and 14-15 on the anterior side: carapace with 3 low keels, the lateral ones abbreviated behind, the median one continued to the fovea. (Bushman's Drift, near Ashton.)

S. brevivalpis Purcell.

3. Pressed forwards the palp reaches a point about $\frac{3}{4}$ of the distance along tibia I, the patella subequal to patella I in length: metatarsi I and II scopulate at the apex below, I without strong spines along the midline inferiorly: tarsus I without spines anteriorly but with 1 posteriorly, IV with 10 spines anteriorly and 2 posteriorly, III with only 1 spine on each side: carapace with the 3 keels obsolete, only the median one being distinguishable posteriorly. (Worcester.)

S. erythrognathus Purcell.

- II. 1. Pressed forwards the palp reaches a point about $\frac{1}{2}$ of the distance along metatarsus I, the patella very slightly shorter than patella I: metatarsus I not scopulate inferiorly, with strong spines below both over the median area and at the sides: tarsus I with 3-7 spines anteriorly but 7-8 posteriorly, IV with many spines anteriorly and 8-12 posteriorly: the 3 keels of the carapace are flattened, especially the median one. (Grahamstown.)

S. schönlandi Poc.

- a. Similar to *schönlandi* but differing as follows:

Metatarsus I without strong spines on the median area inferiorly, or only 1 or 2: distance between anterolateral and anteromedian eyes less than the diameter of the latter (much greater in *schönlandi*): median keel of carapace distinct from the ocular area to the fovea: distal segments of palp brown (red in *schönlandi*.) (East London.)

S. spinipes sp. nov.

- b. Similar to *schönlandi* but differing thus: A weak but distinct scopula at apex of metatarsi I and II and no spines along the median area of this segment: tarsus I with 1 spine anteriorly and 2 posteriorly: the

3 carapace keels fairly sharp and carrying long hairs which also occur on the ocular area. (Bedford; the type females however came from Pearston and Jansenville.)

S. astutus Poc.

a. Similar to *astutus* but differing thus:

Palp when stretched forwards barely reaching or only slightly surpassing the apex of tibia I: metatarsi I and II with only a few scopular hairs apically below: anterior row of eyes rather more distinctly procurved than in *astutus*. (Alicedale; the type female from Perseverance, near Port Elizabeth; the same species was found by me (23/6/1916) at Grahamstown on the drive above the Grey reservoir.)

S. patersonæ Hwtt.

III. 1. Pressed forwards the palp reaches a point about $\frac{1}{3}$ of the distance along metatarsus I or a trifle further, the patella very slightly longer than patella I: metatarsus I with a few scopular hairs at the apex inferiorly and without spines along the median area inferiorly: patella III with a single spine anteriorly in the middle and in addition with some weak, short, subspiniiform setæ, also with several spines on the distal edge, but dorsally there is no distal patch of spinules: tarsus III with 6 or 7 spines on its anterior side situated in the distal half, I with 1-2 anteriorly and 2-3 posteriorly: claws of tarsus IV with a basal comb of about 7 teeth, the more distal ones being short but not sharply separated from the rest of the series: lateral keels of carapace depressed, only distinct along their inner edges and obsolete in the hinder half: anterior margin of anterior row of eyes in a straight line. (Vredefort Rd.)

S. nigellus Poc.

2. Pressed forwards the palp reaches a point $\frac{2}{3}$ of the distance along metatarsus I: the patella considerably longer than patella I but a little shorter than tibia I: metatarsus I not scopulate and without strong spines on the mesial area below: patella III with a strip of 6-9 weak spines anteriorly: tarsus III with 1 anterior spine and 1-3 posterior spines, IV with 7 anterior and 1 posterior spines. (Bloemfontein.)

S. minor Hwtt.

- IV. 1. Patella of palp slightly longer than patella I, appreciably shorter than tibia I, the tibia and tarsus together considerably shorter than the carapace: tarsus IV with numerous spines on both sides and III also with numerous spines in a continuous band on both sides: metatarsus I not scopulate, inferiorly with strong spines both over the median area and at the sides: the 3 keels of the carapace prominent throughout and reaching back almost as far as the fovea. (Vredefort Rd.?) *S. gigas* Hewitt
2. Pressed forwards the palp reaches a point $\frac{3}{5}$ of the distance along metatarsus I, patella longer than patella I but much shorter than tibia I, the tibia and tarsus together slightly shorter than the carapace: metatarsus I not scopulate, inferiorly without spines along the median area: tarsus III with about 14 spines on each side, IV numerous spined on both sides: the 3 keels of the carapace well developed anteriorly but absent posteriorly, none of them approaching the fovea. (Steynsburg.)
S. steynsburgensis Hewitt
- V. 1. Pressed forwards the palp reaches almost to the tip of the first leg, the patella being about $1\frac{1}{2}$ times as long as patella I and only very slightly shorter than tibia I: tarsus I with 4-5 spines anteriorly and 6-7 posteriorly: metatarsus I not scopulate and without spines along the median line inferiorly or only an odd one proximally. (Pretoria.)
S. robertsi Hewitt.
2. Pressed forwards the palp reaches to the end of metatarsus I or slightly beyond, the patella being a little longer than tibia I and $1\frac{1}{5}$ times as long as patella I: tarsus I with 0-2 spines anteriorly and 0-1 spine posteriorly: metatarsus I not scopulate and without spines along the median area inferiorly or with only one. (Kimberley.) *S. longipalpis* Hewitt.
- VI. 1. Differing from all the above-mentioned species in that tarsus IV is not scopulate: pressed forwards the palp reaches to the tip of the first leg, the patella being distinctly longer than tibia I, the tibia being longer than metatarsus IV, which again is subequal to the carapace in length. (Graaff Reinet.)
S. palpiger Poc.

- a. Very near to palpiger but apparently differing as follows: Pressed forwards the palp extends beyond the apex of metatarsus I, the patella at least equal to tibia I in length, the tibia as long as metatarsus IV and very distinctly longer than the carapace.
(Hanover.) *S. schreineri* Purcell.

Fam. DIPLURIDÆ.

Lepthercus rattrayi *sp. nov.* Pl. XLVII, figs. 1 and 2, and text-fig. 3, A-E.

The type of this species is an adult male example collected at East London by Dr. Geo. Rattray and Master G. Rattray during May, 1916. The females present no conspicuous structural characters which would serve to separate them generically from *Hermacha Sim.*, except perhaps in the weaker scopulæ of the tarsi, but the adult male differs considerably from that of any known species of *Hermacha* in the modification of the first leg. The male agrees more closely with that of *L. dregei* Purcell (Trans. S. Af. Phil. Soc., xi, p. 379, 1902) from the Zuurberg, but differs therefrom in the armature of the maxillæ, in the dentition of the chelicerae, and in the modification of the first metatarsus; the female of *dregei* is unknown.

Colour.—The general colour is dull brown, the surfaces of the carapace, abdomen, and appendages being thickly covered with long silky appressed pale brown hairs; on the abdomen and appendages these are accompanied by stiffer black hairs more sparsely disposed. The silky hairs on the carapace, chelicerae, and coxæ of the legs and palps are paler than those on the femora of the legs, which are almost olivaceous, but the silky hairs of the patellæ and more distal segments of the legs are almost as pale as those on the carapace. The posterior spinners are conspicuously banded, the tips of the terminal segments, and the articular membranes between the various segments, being almost white.

Carapace.—The lateral margins converge in front so that the anterior margin is narrow. The radial depressions are obscured by the clothing of hair. The fovea is transverse. Stiffish black hairs fringe the margins in the posterior half, a few occur just in front of the ocular area, and several weaker ones near the fovea. The carapace is as long as the metatarsus and half the tarsus of the fourth leg.

Ocular area.—Anterior row of eyes decidedly procurved when seen from above, the antero-laterals being one-half longer than the medians and distant from the anterior margin of the carapace about the length of a median. Posterior row of eyes slightly recurved, the laterals being distinctly smaller and shorter than the anterior laterals, whilst the medians, which are oval, are a trifle longer than the anterior medians.

Labium.—Mucous, but maxillæ armed with numerous (about fifty) minute cusps at the base in a small patch.

Cheliceræ.—With nine teeth in the inner row; the outer row is obsolete.

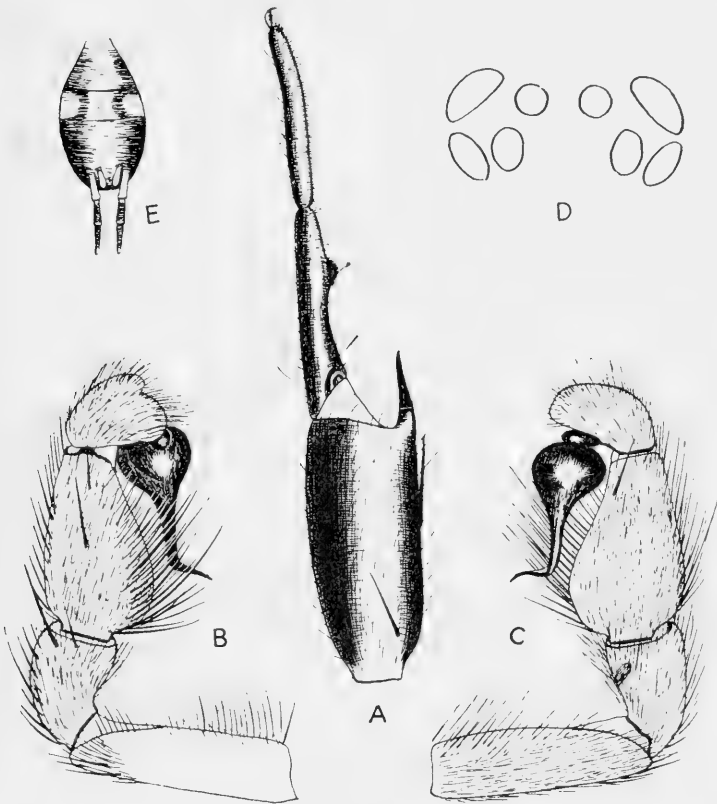
Pedipalps.—Superiorly the femur carries a number of curved bristles but no distinct spines; there is a weak spine at the apex of the patella superiorly on the inner side; there is a setiform spine on the inner surface of the tibia, and a number of long stout setæ superiorly and inferiorly. The tarsus is without spines or bristles. The spine of the bulbal organ is fairly long and stout, being longer than the bulb; it is strongly twisted.

Posterior spinners.—Long and slender, decidedly longer than the sternum and labium together, being approximately two-thirds as long as the abdomen. In side view the three segments are about equal in length, the slender apical segment being only a little longer than the penultimate segment.

Legs.—Tarsus I is long and slender, longer than II. All the tarsi are scopulate, the scopula of IV, and to a less extent of III, being divided by a mesial strip of setæ; in III the setæ and scopular hairs are not so easily distinguished, the setæ being finer than in IV. The scopular hairs at the

distal end of each tarsus are elongated into a terminal tuft; a small median tarsal claw is present, this being fairly conspicuous on tarsus IV. Metatarsus I is slightly bowed,

TEXT-FIG. 3.



Lepthercus rattrayi, sp. n.

- A. Distal segments of the right leg of the first pair, seen from the outer side: adult male. $\times 13$. B. Palp of adult male viewed from the inner side. $\times 19$. C. Palp of adult male viewed from the outer side. $\times 19$. D. Eyes of adult female in dorsal view. $\times 37$. E. Lower surface of abdomen of adult female. $\times 2\frac{3}{4}$.

and on its ventral surface presents a conspicuous rounded protuberance at a point nearly two-thirds of the length of the

segment from its base; this is covered with numerous black spinules. There is a pair of spines at the apex inferiorly, one on the inner surface about halfway along the segment, and one on the lower surface externally just proximal to the protuberance. A distinct scopula is only present in the distal half of the segment, though scattered scopular hairs occur in the basal half also. Tibia I stouter than the patella, and very much stouter than the metatarsus; at the apex inferiorly is a strong projecting spur, bearing a slightly curved stout spine at its end; on the lower and lateral surfaces there are also about 6 long but rather weak spines. In the pale articular membrane between the tibia and metatarsus inferiorly there is a well-defined indurated brown area at the base of the latter; this also occurs as an isolated element on the second leg, and is more or less distinctly represented on III and IV. Patella I with a weak spine near the apex on the inner side. Metatarsus II with 2 spines at the apex inferiorly, also 5 on the lower surface and 2 or 3 on the inner surface; the scopula is fairly well developed in the distal half of the segment. Tibia II has 3 spines at the apex inferiorly and 3 on the lower surface, also 2 on the inner surface. The tibiæ and metatarsi of III and IV bear long, strong spines, the metatarsi being devoid of scopular hairs. The femora superiorly bear long spiniform bristles.

Sternum.—The margins are fringed with bristles; the general surface carries brown silky hairs and black stiff hairs.

Abdomen.—On the dorsal surface anteriorly there are some long curved bristles.

Measurements.—Total length (including spinners and chelicerae) 14.5 mm., length of carapace 4.75 mm., breadth of carapace 3.5 mm., length of metatarsus of fourth leg 3.65 mm., length of posterior spinners 3.65 mm.

The female greatly resembles the male in general characters. The chelicerae have 10 teeth in the inner row, and the outer row is represented by a series of minute denticles, the end of the outer series being opposite to the eighth tooth

from the distal end of the main row. All the tarsi are scopulate, the scopula of II being divided by a thin median strip of setæ, and III and IV by a broader strip. Metatarsus I with 2 spines at the apex inferiorly, and 3 on the lower surface, II with 2 at the apex and 4 on the lower surface. The anterior spinners are a trifle more than two diameters apart. The terminal segment of the superior spinners is subequal to the basal segment and barely one and a quarter times the length of the middle segment. Labium without apical teeth. Surfaces of body and appendages clothed with pale brown hairs, the abdomen showing no pattern or markings superiorly.

The carapace is broader anteriorly than in the male.

Measurements.—Total length 17·75 mm., length of carapace 5·4 mm., breadth of carapace 3·8 mm., length of posterior spinners 4 mm., length of tibia of first leg 2·5 mm.

This genus probably approaches *Brachythele Auss.* and *Hapalothele Lenz.* It does not seem to agree with any of the Diplurine genera recorded from Australia by H. R. Hogg or by W. J. Rainbow, nor with the South American genera dealt with by the late F. O. Pickard-Cambridge. Most of the genera belonging to this section, the *Brachytheleæ* of Mr. H. R. Hogg, are very imperfectly known, and no author has had sufficient material at his disposal for correlating the genera of different zoological regions.

The genus *Hermacha* is also represented at East London. The females are larger than those of the species above described. Young specimens of *Hermacha* can be distinguished from females of *L. rattrayi* by the presence of one or two cusps on the labium, the weaker spinulation of the first and second metatarsi, and the greater elongation of the terminal segment of the posterior spinners relative to the middle segment. Another related species, *Hermachola grahami mihi*, which occurs at Grahamstown, has the terminal segment of the posterior spinners considerably

longer than the middle segment, and is at once distinguished from *L. rattrayi* by the relative paucity of fine hairs on its surfaces, the dark dorsal pattern of the abdomen being conspicuously displayed through the weak covering of hair; the characters of the adult male are very different in the two species.

Fam. CLUBIONIDÆ.

Amaurobioides africanus *sp. nov.* Pl. XLVII, fig. 8,
and text-fig. 4, A-D.

The species described under this name is based on a series of adult male and female specimens collected recently at East London by Dr. Geo. Rattray and his son, Master G. Rattray. Specimens were first discovered on the seaward face of the rocks near Bats Cave; their retreats, made of tough silk, lodged in the pits and crevices of the rock surface, were situated near to or just below the average high-water mark, where they were liable to complete submergence at spring tides. Other examples were found on rocks between tide marks along the banks of the Buffalo River, and a few at Cove Rock. After visiting their habitats on various occasions, Dr. Rattray is satisfied that many of these retreats are not necessarily submerged at each invasion of the tide, but are often merely drenched by the spray of the waves. On the other hand, he found numerous small retreats occupied by immature specimens amongst the wet seaweed exposed at low water, and these retreats must certainly be submerged every high tide.

The species closely resembles the other two recorded members of the genus, viz. *A. maritima* *O. P. Cambr.* (Proc. Zool. Soc., 1883, p. 356, pl. xxxvi, fig. 3), the types of which were sent to Mr. Pickard-Cambridge labelled "marine spiders," having been found on rocks in the sea at Allday Bay, Otago, N.Z., and *A. piscator* *Hogg* ('Sub-antarctic Islands of New Zealand,' Wellington, 1909, article

ix, p. 162, pl. vii, fig. 4) from the Campbell Islands, where this species also was found on rocks.

Some months ago I submitted immature examples from East London to Mr. H. R. Hogg, who very kindly compared them with the types of *piscator*, afterwards reporting that he was unable to find any essential difference in structure between the South African and New Zealand specimens. Apparently, therefore, the only satisfactory basis of distinction between *africanus* and *piscator* is that which may possibly be offered by the external sexual characters. The males of the New Zealand species have not been described in either case, and the epigynal character of the adult female of *A. piscator*, as figured by Mr. Hogg, appears to be quite distinct from that of *africanus*, the characters of which are constant in the series of six or seven adult specimens now at my disposal.

Colour.—Carapace brown, becoming black-brown on the ocular area. Chelicerae black-brown throughout, except in the terminal half of the fang, which is reddish. Lip and maxillae reddish-brown. Legs and sternum pale brown. Upper surface of abdomen yellow, with a median dark tree pattern constituted by a series of six dark transverse chevrons, the three anterior ones being connected together by a median stripe which extends considerably in advance of the most anterior chevron. The anterior chevron is much broader than any of the succeeding ones, and the second is broader than the third, though not quite so long. Towards the posterior end of the abdomen, the colour is dark throughout except for faint indications of yellow stripes. The lateral surfaces of the abdomen are dark with three yellow, backwardly directed, oblique stripes. These stripes superiorly pass into the yellow of the dorsal surface, but inferiorly the two posterior ones taper finely and end blindly near the posterior end of the abdomen, whilst the anterior one is quite short and broad, not extending far towards the ventral surface. The ventral surface of the abdomen is pale, the dark coloration of the sides gradually merging therewith.

This pattern on the dorsal and lateral surfaces of the

abdomen is very similar to, but not quite identical with, that of the New Zealand species. In those species, according to Mr. Hogg's recent notes on *piscator* and judging from the original figure of *A. maritima*, the dorsal surface presents a yellow pattern on a dark background rather than dark on yellow as in *africanus*.

Carapace.—The ocular characters are not quite as described in *piscator*. In the hind row, the distance between each pair is distinctly greater than the diameter of the posterior lateral. The area of the anterior laterals is quite twice as great as that of the posterior medians, and is a little larger than that of the posterior laterals. The distance between anterior and posterior laterals is about two-thirds the diameter of the latter. (In both the New Zealand species the lateral eyes seem to be rather more widely separated from each other.) At the sides and in front, the ocular area projects above the general surface of the carapace; posteriorly, however, along its whole width, the ocular area passes quite insensibly into the general surface of the carapace. Apart from the general clothing of short grey hairs, there are a few scattered long black hairs on the carapace; these latter are most numerous in the ocular region. Viewed under a high power of the microscope, the grey hairs are seen to be finely ciliate. A long stiff hair projects upwards from between the antero-median eyes.

Labium.—This is not nearly so much constricted at the base as represented in the figure of *piscator*. (Mr. Hogg informs me that the constriction indicated in the figure of that species is only a surface depression.)

Sternum.—The anterior margin is narrow and slightly curved. It is broadest opposite to the coxæ of the second pair of legs.

Chelicerae.—The lateral and upper surfaces of the basal joint are rather coarsely sculptured, except towards the apex, where they are smooth; there is a very prominent basal spot with smooth surface. The fang is stout and not very long; there is on the outer side a slight transverse constriction

situated about one-third of the length of the fang from its base; there are two cutting edges, both very finely serrated, and separated from each other by a groove; they take origin at points in a line with the constriction of the outer surface. In the more ventral dental series the largest tooth is that at the base, the other two being also fairly large; the dorsal dental series has quite a small basal tooth, the middle tooth being a trifle larger than that at the apex.

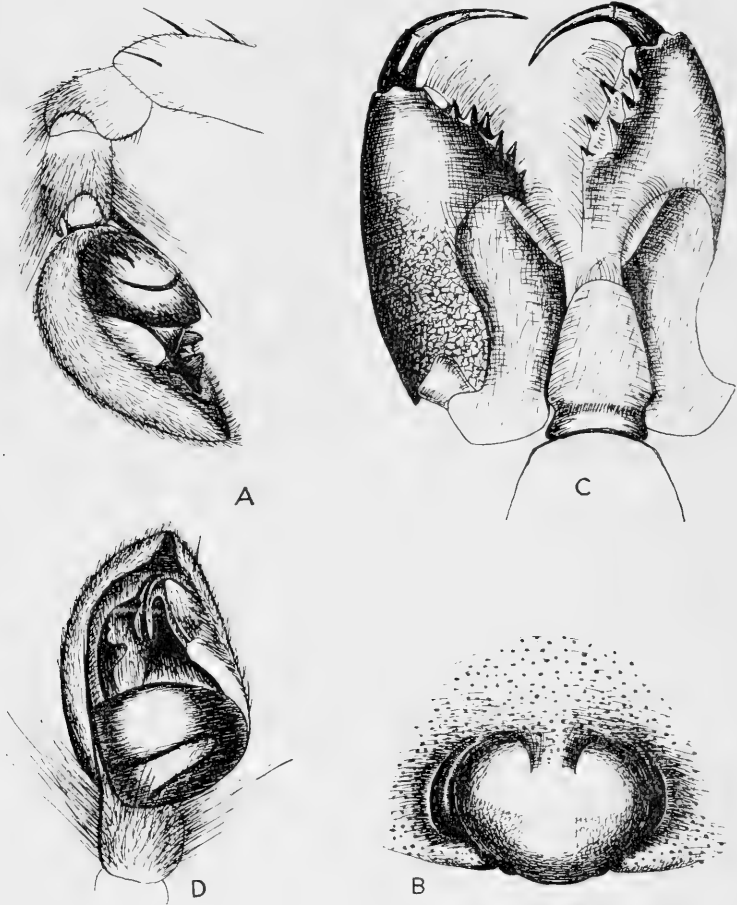
Legs.—The proportions of the legs are precisely the same as in *piscator*, according to Mr. Hogg. Metatarsus I with a pair of spines inferiorly near the base; II likewise, and in addition with 1 on the anterior surface; III with a pair near the base inferiorly, about 5 near the apex, also 1 on the anterior surface and 1 on the posterior surface; IV with 3 or 4 near the apex, 1 on the posterior surface and 1 on the ventral surface near the base on its anterior side. Tibia I with 3 pairs of spines inferiorly; II with 2 spines at the apex inferiorly and 2 along the lower surface on the posterior side; III with 2 spines at the apex inferiorly, 1 on the lower surface and 1 on each side; IV with 2 at the apex inferiorly, 2 on the lower surface, and 1 on the posterior side. On each femur there are 4 or 3 setiform spines superiorly; the lower surfaces of the femora are devoid of spines. The first, second, and fourth legs are subequal, the first being a mere trifle longer than the second, which again only very slightly exceeds the fourth; the third leg is shortest. The tarsal claws of the fourth leg carry eight teeth.

Spinnerets.—The inferior pair are decidedly the stoutest, and the superior pair most slender. The middle pair are just a little shorter than the other pairs. The apical joint is quite small in both inferior and superior spinners, especially in the latter. The position of the colulus is marked by a tuft of hairs, but there is no distinct prominence.

Epigyne.—The genital plate is fairly large and conspicuous. There is a median rounded area, the surface of which is strongly convex: this is bounded on either side by a deep furrow which opens freely anteriorly, but ends blindly

posteriorly before reaching the genital fold, although a superficial groove extends backwards therefrom to the neighbour-

TEXT-FIG. 4.



Amaurobioides africanus sp. n.

- A. Palp of adult male, with tarsus in side view. $\times 22$. B. Epigyne of adult female (the hairs of the surrounding surfaces are not indicated). $\times 45$. C. Mouth-parts of adult female. $\times 19$. D. Tibia and tarsus of palp of adult male, the tarsus being viewed from below. $\times 22$.

hood of the genital pore. The median rounded area is smooth

and glabrous, but the surrounding surfaces are roughened and strongly hairy.

The adult male closely resembles the female but is a little smaller. The carapace is also slightly different in shape, being more decidedly narrowed anteriorly; the anterior width is considerably less than the greatest width of the carapace. The leg proportions are as follows: First leg a trifle longer than the second, which is very distinctly longer than the fourth, but this again is only slightly longer than the third. The fangs are weaker than those of the female, and the surface constriction on the outer side is obsolete. The palp is short, extending only a trifle beyond the apex of the femur of the first leg. Its segments, as far as the tarsus, are approximately of equal thickness. The femur has three or four spines superiorly. There are two or three long stiff bristles and numerous long hairs near the apex of the tibia; one or two somewhat weaker bristles also occur at the apex of the patella. Projecting from the apex of the tibia, in a line with the axis of the segment, there is a very long, straight, stiff process gradually tapering to a fine point, and in a similar situation on the opposite side of the segment is a short finger-like process rounded at the tip. The patella is without apical processes. The tarsus is a little longer than the patella and tibia together.

Measurements.—Total length, female 13 mm., male 9·8 mm.; anterior breadth of carapace, female 2·75 mm., male 2·0 mm.; greatest breadth of carapace, female 3·5 mm., male 2·9 mm.; length of carapace, female 4·5 mm., male 3·75 mm.; length of first leg, female 13·75 mm., male 13·3 mm.; length of third leg, female 11·5 mm., male 10·8 mm.; length of fourth leg, female 13·2 mm., male 11·8 mm.

The discovery of this species on our shores opens up an interesting problem, to which, however, no final solution can be offered at present. It may eventually be found that the genus is widely distributed in the southern hemisphere, when

the distribution may perhaps be adequately explained through the agency of winds, especially if the species inhabiting remote and isolated areas prove to be absolutely identical. Yet, one is tempted to correlate the positive facts now known with those presented by such groups as the Migine spiders, which have been recorded from the following regions: Southern Africa, Madagascar, New Zealand, Australia, Tasmania, and Chili; in the Migidæ, at any rate, it is very improbable that winds are of any importance as factors in the dispersal of species.

ADDENDUM, *December, 1916.*—Since the above account was written, I have received a further note from Mr. Hogg relating to the characters of the adult female. He considers that the features of the epigyne will distinguish *africanus* from *piscator*, but adds that the smallness of the difference is certainly remarkable.

With regard to the mode of distribution of these creatures, their occurrence amongst entangled seaweeds at low water seems to point to the possibility of passive dispersal on floating seaweeds. I am indebted to Mr. W. Tyson, the authority on South African seaweeds, for some important information bearing on this question. Briefly stated, the main facts are as follows: In the south of the Indian Ocean is a strong western equatorial current which meets the east coasts of Madagascar and of the mainland, and is deflected southwards, gradually diminishing in intensity as it approaches Cape Agulhas. There is also a fairly constant antarctic current passing in a south-easterly direction from the Cape to Australia; this divides into two portions, one running along the south coast of Australia, the other turning northwards into the equatorial region and eventually entering the western equatorial current. Certain facts of distribution of seaweeds are most readily explained on the assumption of dispersal through oceanic current agency. Many species at the Cape are recorded only from there and from Australia. And again, many tropical and subtropical marine algæ are

brought to Natal and even to Cape Agulhas by the warm currents which flow southwards from the Indian Ocean.

EXPLANATION OF PLATE XLVII,

Illustrating Mr. John Hewitt's paper, "Descriptions of New South African Arachnida."

FIGS. 1 and 2.—Adult female and male of *Lepthercus rattrayi* *sp. nov.*, both slightly enlarged. (The abdomen of the male shows faint transverse stripes posteriorly, the surface having been denuded of hairs.)

FIGS. 3 and 4.—Adult female and male of *Stasimopus spinipes* *sp. nov.*, natural size.

FIG. 5.—Adult male of *Stasimopus longipalpis* *sp. nov.*, natural size.

FIGS. 6 and 7.—Adult female and male of *Stasimopus insculptus* *var. peddiensis* *var. nov.*, natural size.

FIG. 8.—Adult female of *Amaurobioides africanus* *sp. nov.*, enlarged slightly.





1



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8

SOUTH AFRICAN SPIDERS.

FIGS. 1 (♀), 2 (♂).—*Lepthercus rattrayi* sp. n. FIGS. 3 (♀), 4 (♂).—*Stasi-
mopus spinipes* sp. n. FIG. 5 (♂).—*S. longipalpis* sp. n. FIGS. 6 (♀),
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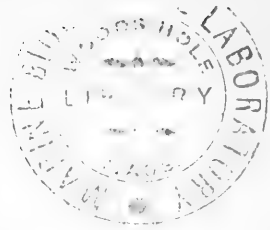
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(EXCLUDING MOLLUSCA).

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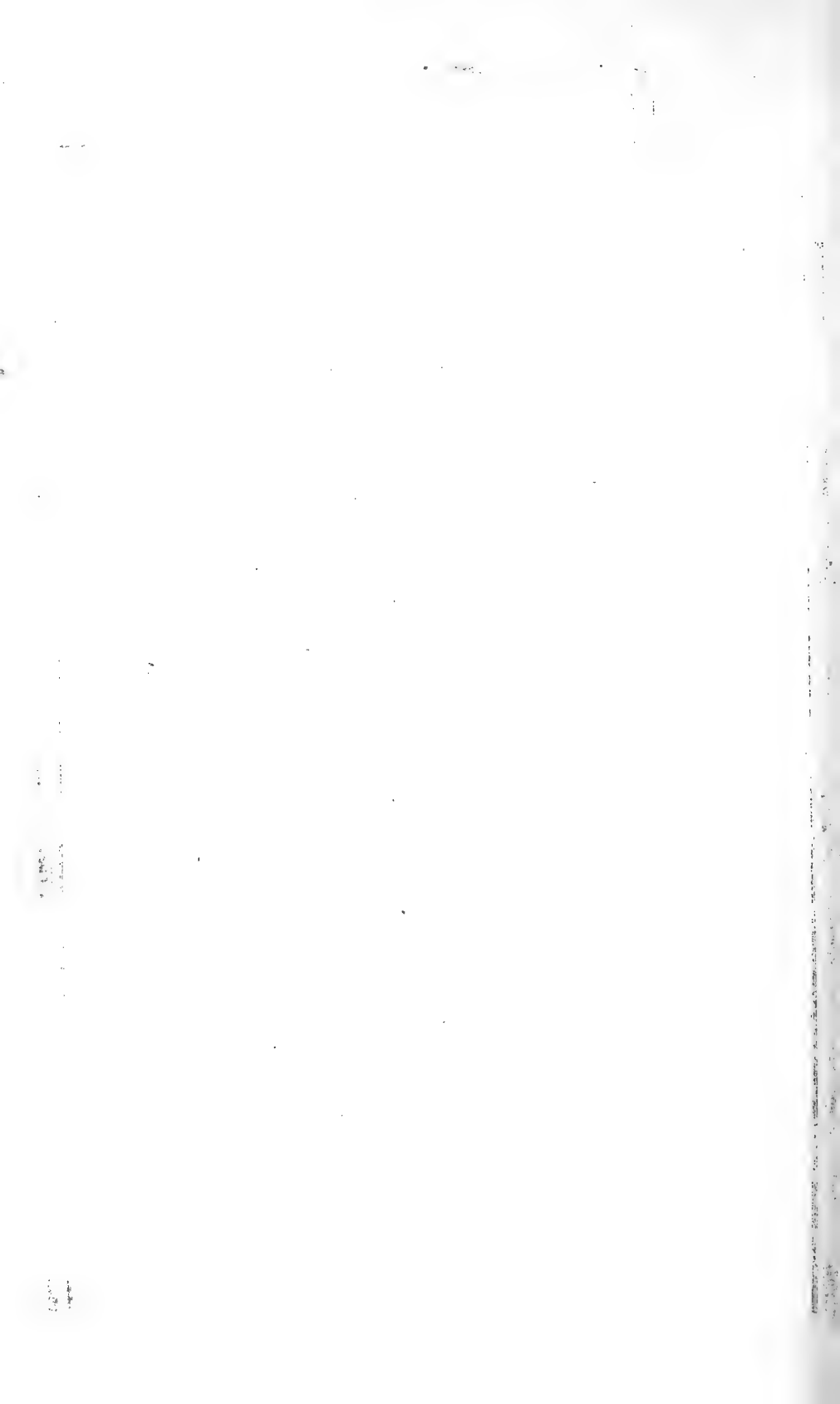
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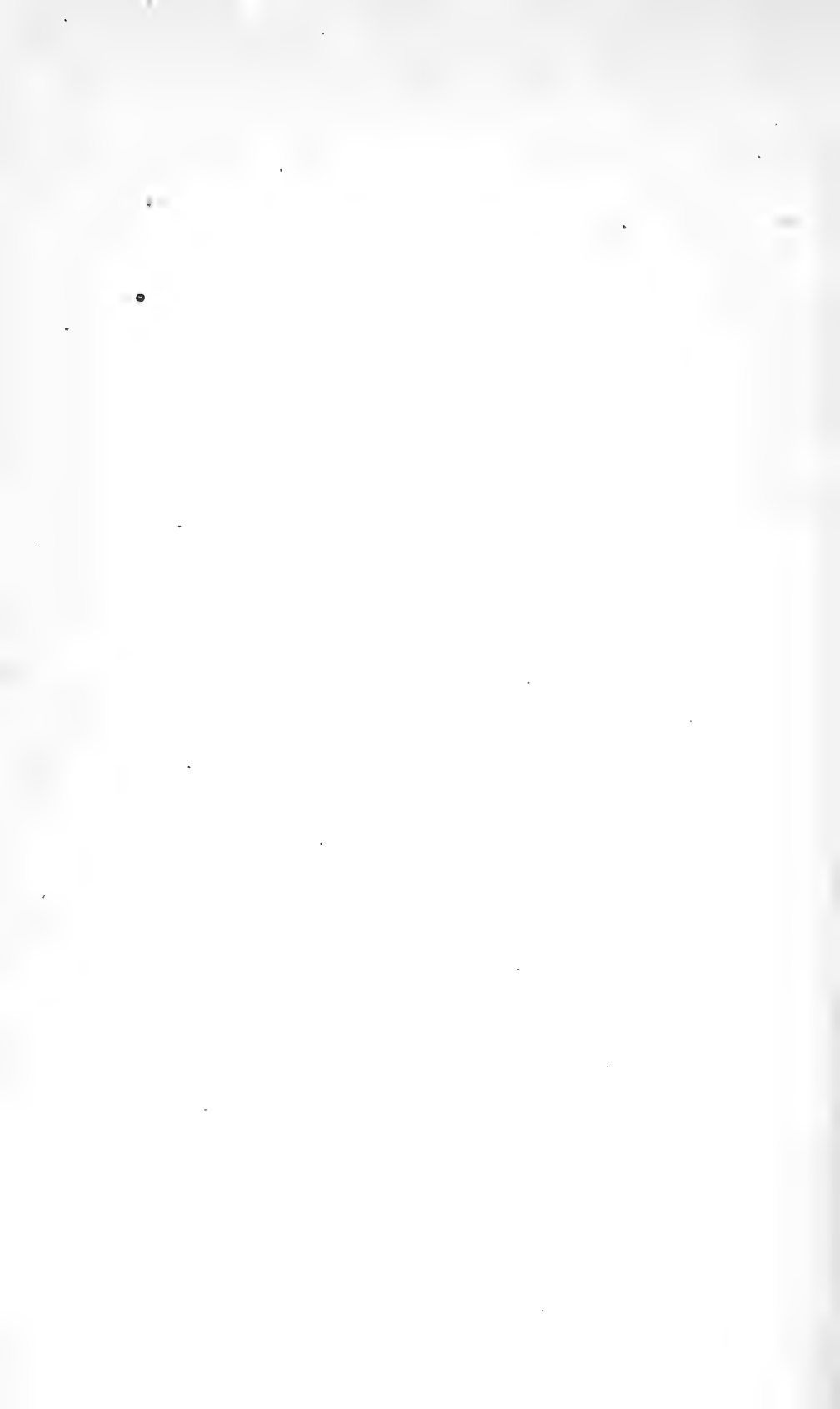
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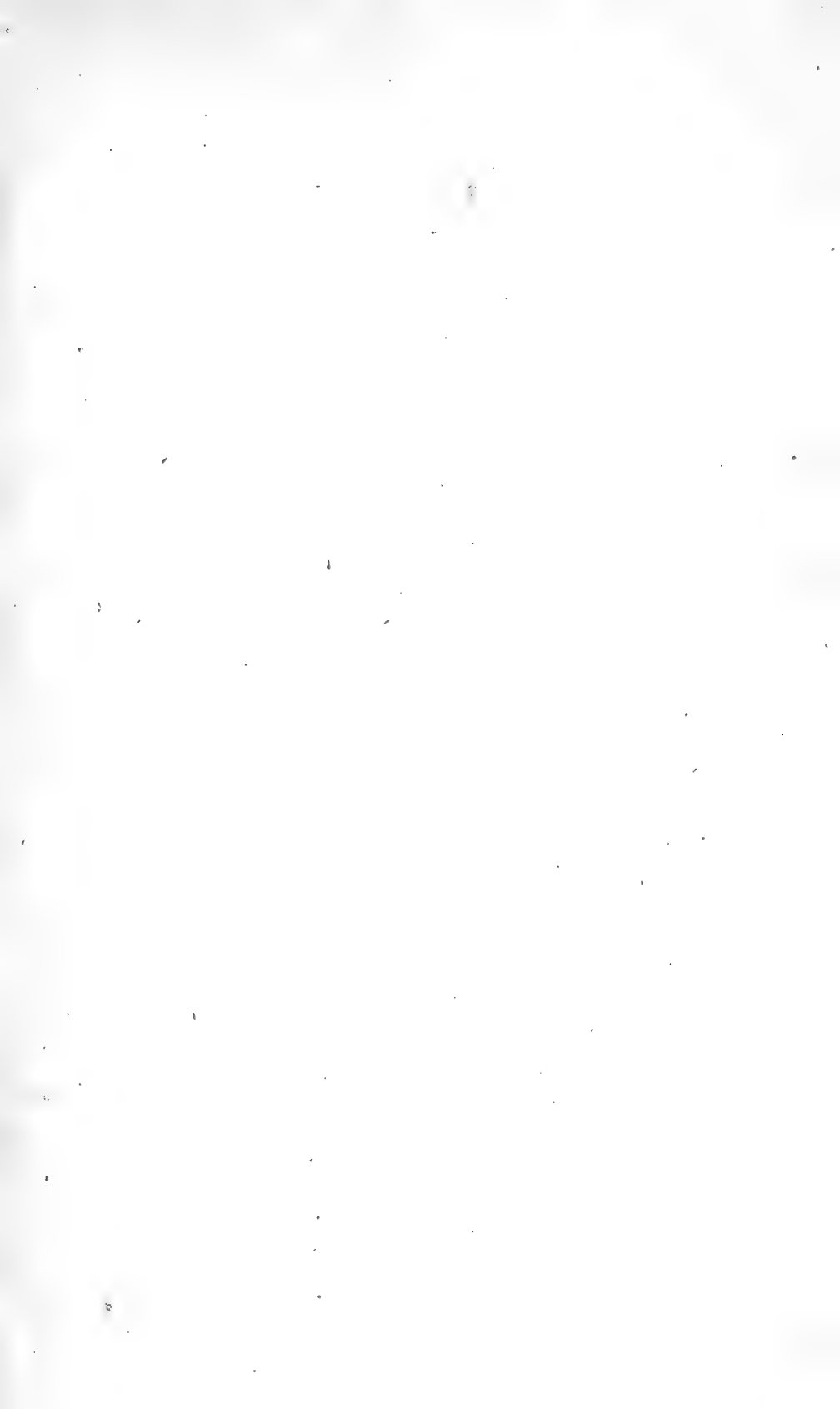
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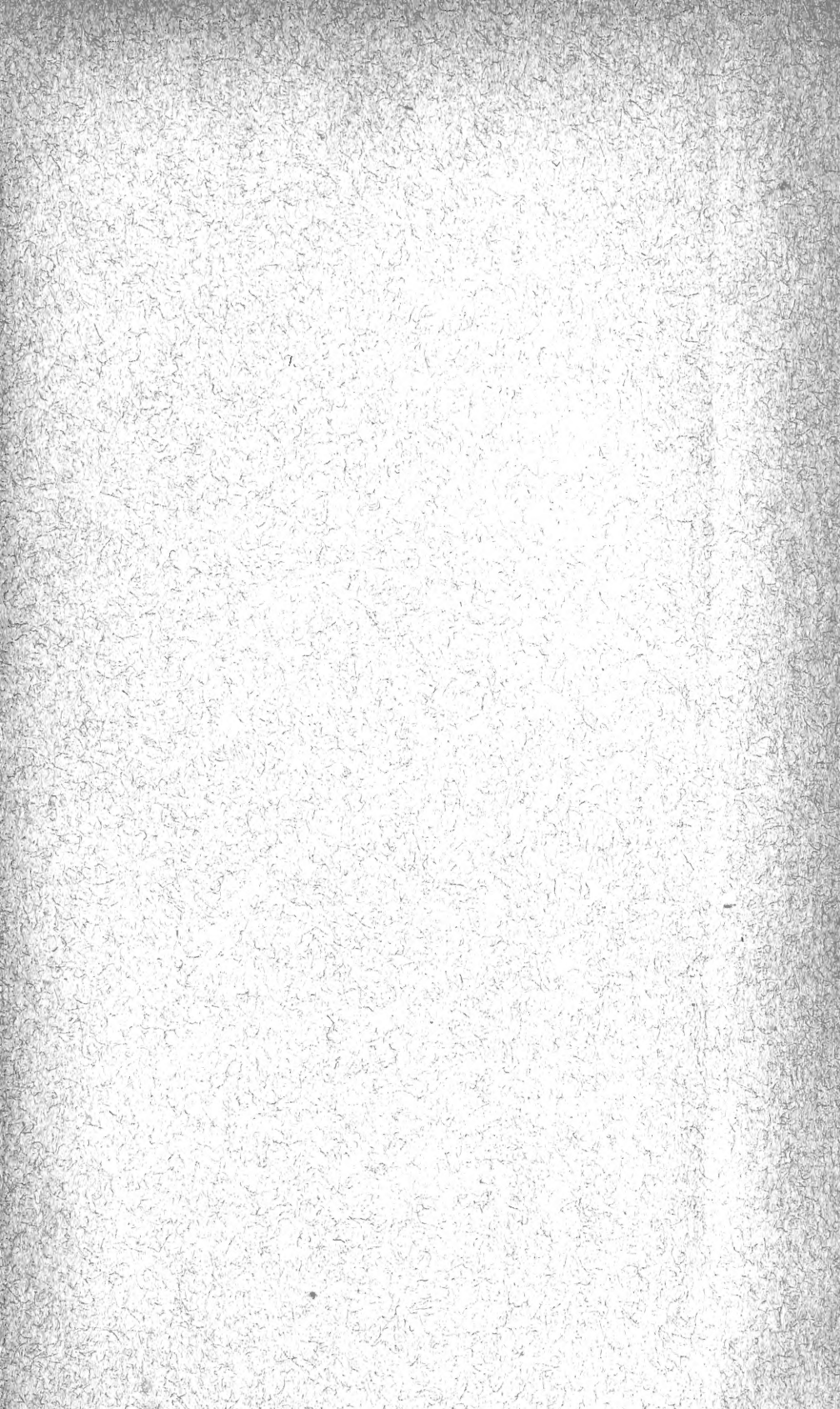
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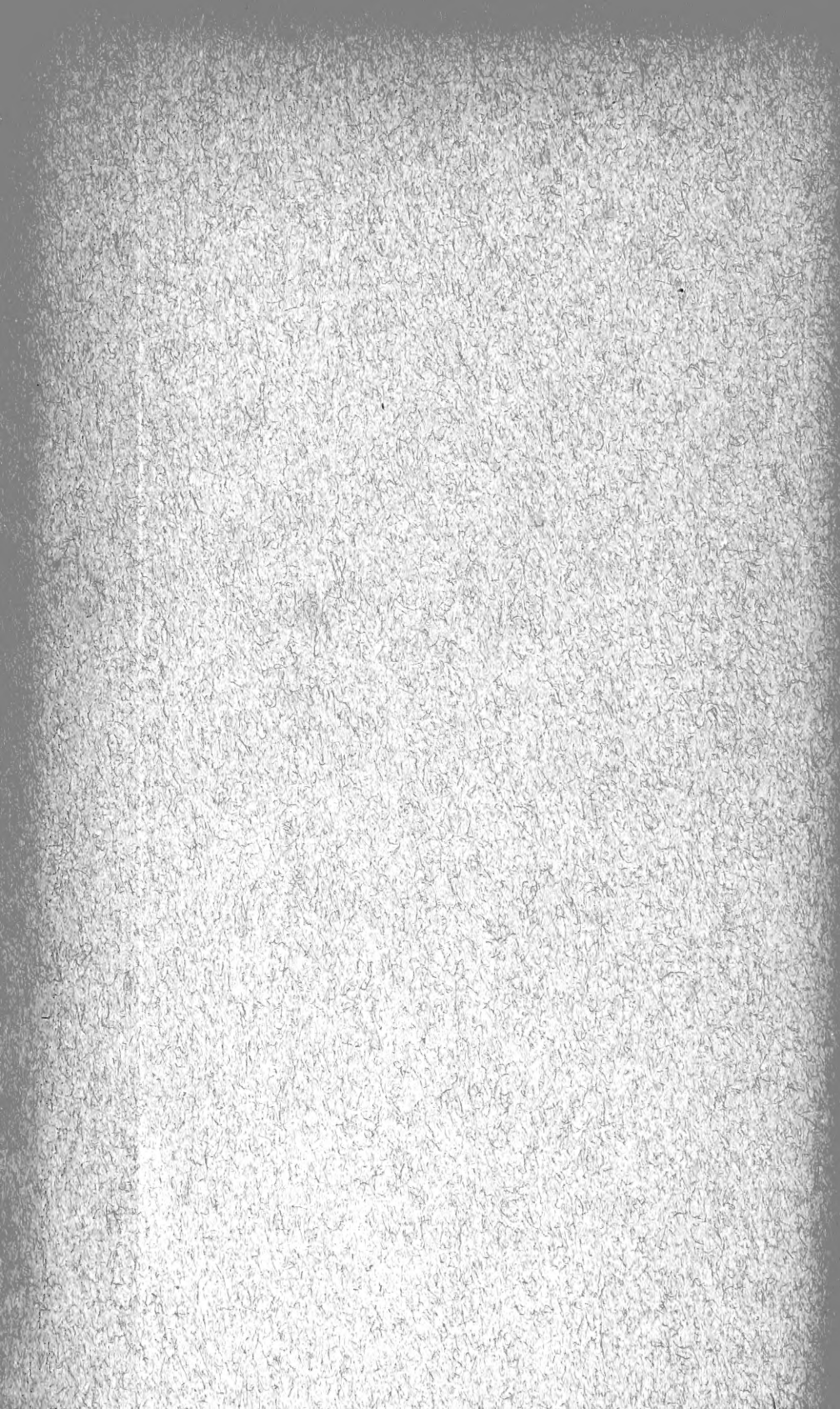




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