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Some Notes on the Economy of Cockchafer Beetles.

BY

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The Under Secretary,
Department of Agriculture and Stock,
Brisbane.

SIR,—I have the honour to recommend for publication, as Bulletin No. 20 of the Division of Entomology of the Bureau, "Some Notes on the Economy of Cockchafer Beetles."

I have, &c.,

H. T. EASTERBY, Director.

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Some Notes on the Economy of Cockchafer Beetles.

By EDMUND JARVIS, Entomologist.

INTRODUCTION.

THE entomological matter forming the present bulletin has appeared at different times during the past six years in our "Queensland Agricultural Journal," in various articles published under the heading of "Science Notes."

Being of decided economic value, and dealing as it does with questions closely associated with the study and control of some of our primary insect pests of sugar-cane, it has been considered advisable to bring these scattered papers together in a form suitable for reference and additional study in the near future.

Much of the information and many of the suggestions appearing in this bulletin regarding methods of combating cane insects should prove of exceptional interest to young students of economic entomology.

Referring briefly to the question of biological control of scarabæid grubs, it may be of interest to mention that amongst the herbaceous flora of the Cairns district the well-known honey-bearing plants—*Sida acuta, S. retusa,* and *S. cordifolia*—occur here very plentifully, and are much visited by females of our scoliid parasites *Campsomeris tasmaniensis* Sauss. and *C. radula* Fabr.; other common blossoms frequented by the digger-wasps being those of *Urena lobata* Linn. and *Passiflora alba* L. & O.

It should be mentioned for the information of biologists that Meringa Laboratory—which is one of the Experiment Stations attached to the Sugar Bureau—is situated within about 20 deg. of the equator; the mean temperature being about 75 deg. Fah., while the average rainfall is over 90 inches.

The surrounding forest land upon which most of the cane is grown consists of volcanic and rich alluvial soils, some of the latter embracing extensive river flats which at one time supported a scrub vegetation. The trees are mostly small, being representative of such genera as *Eucalyptus, Acacia, Melaleuca, Tristania, Ficus,* &c.

The scrub flora differs entirely from that of the open country. Scattered amongst the taller trees—some of which are food-plants of certain Scarabæidæ attacking sugar-cane—one meets with several varieties of palms; while "Stinging trees" (*Laportea sp.*), bananas, and tree-ferns are noticed in wild profusion rising above an undergrowth consisting of bushes and flowering shrubs, more or less interlaced by vines, bush-ropes, and many other creeping plants.

THE EXOSKELETON IN LEPIDODERMA AS AN INFLUENCING FACTOR IN THE ECONOMY AND CONTROL OF OUR GREYBACK COCKCHAFER.

The following notes, published in 1925, may serve as a fitting preface to subsequent allusions in this bulletin to the external anatomy of our cane beetles.

On a subject so exceedingly complex, which embraces many branches of scientific research, one cannot, in an article of this kind, do much more than touch briefly on a few significant points likely to possess interest for the economic entomologist.

Osteologists tell us they are able to restore the complete skeleton of an animal from examination of such seemingly scanty material as two or three bones, and, in the event of these belonging to some prehistoric monster, to even determine approximately its general appearance and probable habits.

In the case of existing animals, belonging, say, to class Insecta—the entire anatomy of which can be carefully studied in detail—the structure of the exoskeleton is often wonderfully adapted to suit the habits and requirements of each species.

MODIFICATIONS OF THE TROPHI AND COXÆ.

Familiar examples of such adaptations are observable in the mouth parts of mandibulate insects, the maxillæ and mandibles, for instance, being in predaceous coleoptera, such as Cicindelidæ, more or less sickle-shaped, keen, and often furnished with formidable teeth. (See Plate I., p. 39, Figs. 40, 41.)

The structure of these organs, however, in *Lepidoderma albohirtum* (Figs. 2, 3)—a species having no need to catch or retain its hold on struggling insects, &c.—clearly indicates herbivorous habits, these organs being adapted merely for cutting and crushing up leaves of trees.

Take, as another illustration, the formation of the coxæ, which in typical Carabidæ are almost globular, permitting freedom of movement in almost any direction, thus enabling the insect to dart with great rapidity in pursuit of prey; whereas the formation of the coxæ in *albohirtum* (Figs. 27, 27, 27) indicate slow and somewhat cumbrous movement; sufficient, however, to allow the beetle to cling firmly to leaves or crawl leisurely amongst the foliage.

OLFACTORY ORGANS.

It has long been known that the olfactory sense in insects resides mainly in the antennæ (Fig. 4). Chemotropic reaction occurs during periods of mating, oviposition, &c., the sexes in many instances being able to locate each other from long distances by the help of certain subtle odours secreted by special scent-glands; while egg-laden females of insects such as *albohirtum* are similarly guided in the search for food for themselves or for their larvæ.

As previously pointed out by the writer ("Queensland Agricultural Journal," vol. xviii., p. 307, see also page 17 of present bulletin) the olfactory pits or pori found in the antennal lamellæ of *albohirtum* number about 28,000 in the male and 18,000 in the club of a female (Plate I., Figs. 36, 37, 38); the antennal club of the former sex, however, consisting of five plates, while that of the female has only four. Each olfactory pit contains a central peg-shaped body of variable form and length, usually tipped with a short seta, and connected with the olfactory nerve by means of a slender fibre (Fig. 36).

From such facts as insertion of the antennal organs of this species in a groove under the clypeus and labrum in order to protect it from internal injuries, and the club being kept tightly closed when not in use, we may infer that these highly specialised organs are of vital importance to the insect.

CONSISTENCY OF THE CHITINOUS INTEGUMENTS.

If we compare the weight of *albohirtum* with that of other closely related species of Scarabæidæ we shall obtain another hint of economic value. It has been estimated that one pound of greyback beetles represents about 216 specimens; so that in spite of its bulk (see illustration on Plate I., Fig. 39, p. 39) a single individual weighs on an average only 2 scruples—viz., the weight of an ordinary wine cork. *Anoplognathus boisduvali*, an insect scarcely half its size, is, nevertheless, slightly heavier; while *Calloodes grayanus*, although not three-quarters the size of *albohirtum*, turns the scale at about 2½ scruples.

These differences in weight, derived by the author from living specimens, are due to variations in the consistency of the exoskeleton, parts of which in *albohirtum* are so thin as to be almost coriaceous; whereas in *Anoplognathus* and *Calloodes* the chitin is comparatively thick and horny.

SIGNIFICANCE OF THE ORGANS OF FLIGHT.

Studying the structure of the elytra and wings (Figs. 21, 22, 23), we notice that special provision has been made for extended or long-continued flight. The wing-cases (Fig. 21), which are unusually light in proportion to their size, are deeply concave below, and when the beetle is making use of its long, powerful wings—which when fully extended (Fig. 23) possess together a superficial area of 1,672 square millimetres—these elytra project laterally, parachute-like, from each side of the body, thus helping the insect to maintain a steady and straight course through the air.

FORMATION OF THE TIBIÆ AND CLYPEUS.

Again, from the structure of the legs (Figs. 24, 25, 26) we may reasonably assume that *albohirtum* would experience great difficulty when attempting to burrow through hard compact soil; for although its anterior tibiæ (Figs. 24, 30) are undoubtedly formed for digging, they are weakly in proportion to the bulk of this species, while the slender intermediate and posterior tibiæ (Figs. 25, 26, 30) were evidently not made for such strenuous work. Compare these with the tibiæ of a coprid beetle (Figs. 33, 34), which in each pair of legs are strongly toothed, and eminently suited for boring through hard ground. In this connection I may mention that the anterior edge of the clypeus in our greyback (frontal portion of head, Fig. 6), being obtuse, affords little or no help to a beetle endeavouring to force a passage to the surface; whereas in *Bolboceras* both clypeus and mandibles unite to form a sharp-edged spade projecting in front of the head; the mandibles, indeed, which are flattened and concave laterally, being in this genus wonderfully adapted for digging, breaking up, and shovelling particles of soil.

COLOURATION.

The exoskeleton in *albohirtum* is of a uniform dark-reddish brown externally, this colour being more or less hidden under a covering of white scales and hairs. The beetles when feeding usually cling to the under surface of leaves, and, although conspicuous when viewed from the ground, are probably not easily seen from above by birds and other foes on account of portions of the venter (Fig. 20) being without vestiture. Owing to their gregarious habits, however, insectivorous birds chancing to settle in feeding-trees harbouring hundreds of these beetles soon discover them and devour great quantities.

Nature has not accorded this species the marvellous protective colouration so commonly observed in insects of the order Lepidoptera, &c., but has given it—possibly as a compensation—the advantages of (1) overwhelming numbers, (2) a wide range of dietary, and (3) special protection during its egg, larval, and pupal conditions.

A female greyback lays on an average twenty-seven eggs, which, being deposited in a subterranean chamber situated from one to two feet underground, are practically safe from attacks of parasitic and predaceous enemies. Nearly 100 per cent. of these eggs hatch out about a fortnight after deposition; and, despite attacks made by scoliid wasps on the second and third stage grubs, about 90 per cent. of these probably succeed in ultimately pupating.

An infestation of only four larvæ per stool means an emergence the following season from 100 acres of such grub-eaten cane of nearly 49,000,000 cockchafers. Assuming half of these to be females (a low estimate), and deducting an additional 10 per cent. to allow for losses from natural enemies, leaves us 21,000,000 females, which would weigh about 42 tons. However, what I wish to point out is, that the very efficient protection afforded *albohirtum* during its earlier life-cycle stages does not apparently extend to its imago condition, since these beetles when resting in feeding-trees by day are not only fully exposed to attacks from insectivorous birds and tachinid fly parasites, but being at such times in a sleepy or torpid condition are unable to offer effectual resistance. Fortunately this beetle can well afford such thinning of its ranks, which is only one of the many natural controlling agencies designed to prevent excessive and injurious multiplication of a species.

CONTROL MEASURES AS REVEALED THROUGH THE STUDY OF EXTERNAL ANATOMY.

Reverting to those portions of the exoskeleton mentioned above, it is interesting to find that from such structural differences we may derive a few valuable hints with regard to methods of combating this notorious cane pest.

Firstly,—From consideration of its highly specialised antennal organs we have seen that chemotropism doubtless exercises an important influence on the movements of this beetle.

It may be possible, therefore, to attract specimens of either sex from a distance by means of artificial odours resembling those emanating from their favourite food-plants, or other substances, and so lure them into suitably constructed traps.

This fascinating phase of control opens up an exceptionally wide field for investigations of a biochemical nature, and will lead to future discoveries of inestimable value (see page 17 of this bulletin).

Secondly,—By noting the coriaceous texture of the exoskeleton of our greyback, together with its exceptional lightness in weight, we are led to believe that provision has in this way been made for its wide dissemination or migration through agency of the air, by bestowing unusual buoyancy on newly emerged specimens during the period preceding oviposition.

Such assumption is substantiated by examination of the organs of flight, which, as already mentioned, suggest at once the suitability of this species for aerial transportation. Naturally a habit of such vital moment in its economy would materially affect the utility of any artificial control measures brought to bear on the matter, since such factors as (1) the topography of an infested district, (2) its geographical position, (3) the geological nature of the country, and (4) the character, disposition, and relative abundance of timber in the vicinity of grub-affected farms, would each need to be carefully studied in detail before the combined effect of such influences upon the movements of this cane-beetle could be determined.

Thirdly,—With regard to the nature of the dietary of this cockchafer, as betrayed by the structure of its mandibles and maxillæ, I may say that its habit of resting by day amongst leaves of trees in a semi-torpid state has led to adoption by the growers in some districts of the best known remedial method of *collecting* these beetles. The favourite feeding-trees of *albohirtum* are usually visited at daybreak by collectors, and when suddenly shaken or jarred the cockchafers instantly release their hold of the leaves and fall to the ground.

Fourthly,—We should thank Providence for having denied this dread ravager of our canefields the ability to tunnel through hard soil. The unsuitability of its tibiæ, clypeus, and mandibles for such work, as already alluded to, is seen to be a fact of paramount importance when one realises that merely on account of this weak point certain natural controlling factors are able at times to bring about destruction of these beetles throughout very extensive areas. This happens when a period of drought chances to occur at a time when the beetles, having emerged from the pupæ, are waiting in their underground cells for rain to soften the ground sufficiently to enable them to tunnel to the surface. When forced to wait from eight to ten weeks in pupal chambers, many millions of specimens must inevitably perish; such great natural checks often serving to hold this pest in subjection for two or three years.

Note.—A simple method of mounting the principal sclerites or segments forming the exoskeleton of an insect (devised by the writer in the year 1890) is shown on Plate I., p. 39.

REMARKS ON THE VESTITURE OF CANE BEETLES AND OTHER INSECTS.

The following notes will afford readers a reliable yet very simple means of separating our various root-eating cane beetles by merely comparing specific differences in the relative size, form, and number of the scales scattered over the elytra.

Amongst other specific distinctions characterising certain of our Scarabæidæ attacking sugar-cane, variations in the form and arrangement of the scales on the wing-cases in genera *Lepidoderma* and *Lepidiota* deserve special attention.

This curious vestiture observable in species of class Insecta, and which is believed to be a modified form of the hair, occurs notably in the order Lepidoptera, the mealy, dust-like substance which comes off on one's fingers when handling moths or butterflies being in reality composed of microscopically minute scales of varying form, countless numbers of which cover both the upper and lower surfaces of their membranous wings. In addition to being found throughout this favourite class of insects, many species of Colembola, Thysanura, Trichoptera, &c., are amply provided with scales.

Before considering the colour and structure of such vestiture, however, it will be of interest to glance for a moment at the origin, development, and uses of scales.

Their growth from certain large cells situated just below the epidermis appears to have been first observed nearly forty years ago, and more recently (1896) Mayer noticed that about three weeks before a butterfly emerges from its pupa these hypodermal cells may be seen protruding slightly above the level of the epidermis (Plate II., Fig. 1, p. 41). At a later stage they become larger and project from the tops of a series of ridges thrown up at regular intervals across the wing, which ultimately develop in the imago condition into parallel rows of scales overlapping each other and covering the membrane lying between them.

According to Kellogg their primary use is to protect the body; while other scientists think that these scales serve to stiffen the wings or to prevent a too speedy evaporation of moisture from the body. The support advanced in favour of the latter view is, that among Colembola, &c., they are found only on those species inhabiting comparatively dry situations, and that scaleless forms if exposed to similar conditions of temperature will soon die. Such inference should, I think, be received with caution, since the scaleless Colembola in question—in addition to furnishing an illustration that scaly covering can be done without by such insects—could hardly be expected, when transferred from a congenial environment established during the course of centuries, to endure a changed condition of life.

The possession of scales doubtless benefits insects in other ways than that of perhaps checking a too speedy evaporation of moisture from the body. Numerous species of Curculionidæ (Weevils), for example, occurring in the Cairns district of North Queensland, although little in evidence during the day, and usually flying at night-time (*Leptops*, *Orthorrhinus*, &c.), are freely covered with scales; whilst others of very similar habits and structure, and living in the same locality, have no vestiture whatever. Again, many weevils resting on leaves most of the day in hot sunshine are found to be either densely clothed with scales (*Stenocorynus*), provided with them sparingly or in patches (*Belus*), or entirely without scales (*Ectocemus*); (see Plate II., p. 41).

Amongst sun-loving beetles belonging to the Buprestidæ, practically all of our species are destitute of scales, which when present are usually placed in isolated tufts or bands (*Cisseis*, *Protætia*). The occurrence of scales on certain flower-frequenting coleoptera which have the elytra about uniform in thickness or consistency, appears, therefore, to afford strong evidence of such vestiture being intended to serve some purpose other than that of checking evaporation of moisture from the body.

Although perhaps helping to protect the comparatively soft integuments of various micro-lepidoptera from mechanical injuries, or to stiffen their delicate wings, I am inclined to believe that, in this and some other orders of class Insecta, scales are intended primarily to preserve such species from danger by bestowing upon them colours as will best match or harmonise with those of the flowers, leaves, bark, &c., on which they usually rest when in repose. Amongst Lepidoptera, such so-called protective colouration is certainly displayed in a marvellous manner; having attained, perhaps, its highest expression in the well-known Indian leaf butterfly (*Kallima inachis*), the under surface of whose wings exhibit an exact representation of a brown decaying leaf, showing the midrib, branching veins, and in some specimens blotches in imitation of stains caused by fungi or wet on the surface of rotting leaves.

When scales occur in tufts or patches on the elytra of beetles—as already noticed in the case of Buprestidæ—these variously coloured scales often tend to disguise the presence of the insect by camouflaging its general appearance, size, and body surface, this mode of protection being often seen in species of Cerambycidæ belonging to such genera as *Rhytiphora, Clytra, Glenes, Batocera,* &c. Similarly, scales when present in Curculionidæ sometimes afford protective colouration, evidences of which are not wanting in the genera *Cryptorhynchus, Euteles,* &c. Lastly, it should be mentioned that the presence of scales on lepidopterous insects makes possible that riotous feast of colour which to many of us recalls pleasant memories of childhood's eager chase after some bright-winged butterfly in days when the glamour of early youth cast a golden glow over such simple joys of life.

> A radiance divine is pencilled there,
> On wings ablaze with countless jewels bright.

Although often unconscious of the spiritual significance of colour as displayed in the insect and floral worlds, its all-pervading influence is, nevertheless, constantly seeking in a thousand ways to reveal to us the beauty of truth.

STRUCTURE OF THE SCALES IN CANE INSECTS.

We will now consider very briefly the structure of the various scales found on our cane beetles, comparing their form with that of those occurring on certain primitive species of class Insecta. Scales, as already mentioned, are said to be merely modified hairs, and if we examine the wings of mecopterous and trichopterous insects, the latter of which family are said to be closely allied to lepidopterous species, we shall find numerous examples of remarkable hair-like scales. An interesting variation in the form of these occurs in one of our common Queensland Caddis flies, in which they pass from a decided linear to a broader shape (Fig. 2).

The gradual transition from such more or less primitive vestiture to that displayed by butterflies and other lepidopterous insects is effected insensibly by a beautiful diversification in the size, shape, and structure of scales, which vary, for instance, from those with from two to four acutely lanceolate projections (*Acræa*, Fig. 3), leaf-shaped (Psychidæ, Fig. 4), to elongate to broadly oblong (*Morpho* and *Papilio*, Figs. 5 and 6, on Plate II., p. 41).

Again, in moths belonging to the family Glyphipterygidæ, wonderful scales often occur on the patagia, some of these (Fig. 7) being more or less hair-like, spatulate, or clavate, measuring as much as 0·38 mm. by 0·03 mm. In the group Coleoptera one meets with scales of strange formation in species of *Batocera, Leptops, Cryptorhynchus, Mimadoretus,* &c. (Figs. 8, 9, 10, 19, Plate II., p. 41).

With regard to Scarabæidæ, commencing with our common greyback cockchafer, *Lepidoderma albohirtum* Waterh., we find the wing-cases of this insect to be uniformly clothed with rather large boat-shaped scales (Fig. 11), measuring 0·20 by 0·06 mm. These project from the surface of the elytra at an angle of about 20 deg., appearing at such times (viewed with a pocket lens) of elongate pear-shaped form; the obtuse basal portion of each scale touching or overlapping others slightly, while the free projecting ends taper gradually to a point. Being very convex above they are concave beneath, the lower ends being attached to the chitin by a short stalk-like root.

As a result of microscopical examination, I am disposed to believe that in *albohirtum* they serve to aid the beetle during its escape from the ground. In addition to the free ends of these scales being directed backwards, the edges of each (especially where close to the point) are fringed with exceedingly minute spines which also face towards the anal segment (Plate II., Fig. 11).

In all probability, therefore, such vestiture helps this cane beetle to retain its grip on the ground whilst tunnelling to the surface; the position of these scales serving to prevent unintentional retrogressive movement during its upward journey through compact soil. In illustration of this the reader should hold a greyback cockchafer firmly, and pass a finger lightly over the surface of its elytra. During the passage from head to tail one feels only a silky smoothness, but in the opposite direction a decided roughness and resistance to the touch.

Our species of *Lepidiota* are characterised mainly by the possession of flattened scales of almost circular outline, which do not, like those of *Lepidoderma,* project from the surface, but rest in shallow concavities in the elytra.

In *Lepidiota frenchi* Blackb. and *L. consobrina* Gir. they are rounded, slightly convex above, and finely granulate (Figs. 12, 13); those on the elytra of the latter species being 0·13 mm. in diameter, while on *frenchi* they measure 0·10 mm. These scales, which are scattered thinly over the wing-cases of both the above species, are barely visible to the naked eye as minute white specks, and viewed collectively produce the effect of a pale whitish bloom overspreading the reddish-brown ground colour of the wing-covers.

In *Lepidiota caudata* Blackb. the scales are very much smaller, 0·06 mm., and also more sparingly distributed, imparting to freshly emerged specimens a faint opalescent sheen (Fig. 14).

The scales of *Lepidiota rothei* Blackb. (Fig. 15) differ from those of the preceding species in being egg-shaped instead of circular, 0·08 by 0·05 mm. In *Lepidiota grata* Blackb., a beetle closely related to *rothei*, they are elongate-oval, 0·08 by 0·03 mm. (Fig. 16).

In this connection it is interesting to note that in the allied genus *Rhopœa* some of the species possess long linear scales which taper from the swollen basal portion to a point, and are very quill-like in appearance; while in *Lachnosterna*, again, they are longer and practically resemble hairs (Figs. 17, 18).

So closely does the imago of *frenchi* compare with that of *Lepidiota consobrina* Gir. in general structure, that for many years systematists failed to recognise them as being specifically distinct (see Bulletin No. 3 of this office, 1917).

Similarly, *L. rothei* and *L. grata* (known then as *Lepidiota No. 215*) were classed by some entomologists as being one and the same species until attention was drawn by the present writer to marked dissimilarity between the scales of these two cane-beetles (Bulletin No. 3, p. 39, 1917 edition).

As a matter of convenience, during identification I have considered the vestiture of the elytra only; but it should be mentioned here that scales on the ventral surface, sides, legs, &c., on a few of our Scarabæidæ affecting cane often differ slightly in form and arrangement from those on the elytra in individual specimens, thereby affording additional specific distinctions.

All scales figured on Plate II. are of the same magnification, in order that relative differences in size may be appreciated at a glance. Although so diminutive, each scale is composed of two separate layers or lamellæ, parallel to one another, and kept apart by chitinous filaments, the intervening space being at first filled with protoplasm which is afterwards withdrawn. In Lepidoptera the surface of the upper plate or lamella is usually thrown into a series of parallel ridges or carinations, which are often connected transversely by numerous striæ (Fig. 4).

On the wings of species adorned with metallic colours, such striations generally exceed 1,000 to the millimetre (1,300 in *Morpho*) (Fig. 5), but in other lepidopterous insects may be about 100 to the millimetre or even less. In certain blue metallic scales occurring on the wings of *Papilio ulysses* the concavities between the striations are closely packed transversely with innumerable minute irregular carinations (Fig. 6).

In those of our cane-beetles, however, which vary in colour from whitish to very pale yellow, the surface instead of being striated in this manner is minutely granulate, although in many other coleopterous insects the occurrence of more or less parallel rows of striæ is not uncommon (Figs. 9, 19).

THE INFLUENCE OF CHEMOTROPISM ON LEPIDODERMA ALBOHIRTUM WATERH.

Most scientists are aware of the fact that insects as a rule react positively, or, in other words, are attracted towards their food or that of their offspring by the presence of certain odours emanating from it; which, although of a nature far too subtle for us to perceive, are nevertheless appreciable to creatures endowed with highly specialised olfactory organs.

Chemotropic reaction occurs also during the periods of mating and oviposition, the sexes in many instances being able to approach and find each other, although separated by long distances, by the aid of certain odours secreted by special scent-glands; while egg-laden female insects are similarly guided while searching for suitable food for their future larvæ.

Entomologists have not been slow to realise the economic significance of this method of combating insect pests, much attention having been given of late years to the construction of various bait-traps for attracting fruit-flies, vine-moths, &c.

With regard to the question of controlling our greyback cane beetle by the use of aromas, we have good reasons for assuming that the movements of this insect are very sensibly affected by forces of a chemotropic nature, which probably exercise important influences on the flight of the females during the period of ten to fourteen days preceding the commencement of egg-laying.

Initial experimentation with aromas was carried out by the present writer in December 1915, when it was discovered that greyback cockchafers reacted negatively towards such odours as cajeput oil, acetic and carbolic acids, nitrobenzine, oil of almonds, &c., but were not in the least influenced by odours arising from oil of cloves, fish oils, or even fumes of 40 per cent. formalin.

The olfactory sensibilities of this species, however, were amply demonstrated, and I felt justified in believing that reaction of a positive nature under field conditions should be attainable. With view to securing additional data these experiments were continued during December 1921, the odours used being placed in small tins 4 in.

deep by 3½ in. diameter, and resembling those emitted from the stem and foliage of chief food-plants of this beetle, and from decaying vegetation, soils, roots, &c.

Some of these bait-traps were exposed in canefields, being simply let into the ground between cane-rows, with upper edge level with the surface, while others were hung amongst the branches of a large native fig (*Ficus pilosa*), a favourite feeding-tree of *L. albohirtum* (see "Queensland Agricultural Journal," vol. xvii., p. 38).

With reference to the anatomy of the antennal organs in genus *Lepidoderma*, it will be noticed by referring to Plate III., p. 43, that the four plates composing the club are closely covered with exceedingly minute olfactory pits or pori (Fig. 1), each containing a central peg-shaped body of variable form and length, tipped with a short seta or bristle (Figs. 5, 5, 5, 5). An outline of a vertical section of four of these marvellous pits is shown greatly magnified at Fig. 2, and a plan of two of them at Fig. 3. Each peg is connected with the olfactory nerve by means of a delicate fibre, indicated diagrammatically in the section at Figs. 4, 4, 4, 4.

These pits, which occur in the chitinous portion of both sides of the two inner lamellæ of the female, and on the inner surfaces of the outer plates, number about 18,500, and in male specimens 24,500. In the latter sex, however, the club consists of five plates, the fifth being usually smaller than the others.

While feeding or resting on the trees in a torpid condition the antennal lamellæ are held close together in the form of a solid-looking club, but when flying or under the influence of excitement the insect opens them out fan-wise, in order to expose to the air the greatest number of olfactory nerve fibres (Fig. 6).

There can be no doubt that the highly sensitive antennæ of this beetle help it to locate the position of favourite feeding-trees, since isolated specimens of such figs as *Ficus pilosa*, *F. Cunninghamii*, &c., are generally loaded with beetles each season, although often growing alongside or close to food-plants that happen to be less palatable. We experimented later on (1923-4) with a large variety of aromas, comprising various essential oils and aromatic essences, &c., distilled, or extracted by the process of enfleurage, from favourite food-plants of our greyback cane-beetle. I have already pointed out the importance of this ideal control method (Reports, September 1914 and November 1921, Bulletin No. 17, p. 68), which may enable us to capture the female bettles before they have had time to deposit eggs.

In the event of success in this connection being obtained, it would then be a comparatively simple matter to design suitable traps, that when baited with the attractive aroma could be so arranged in canefields as to lure to destruction most of the invading beetles.

The following Science Notes, which were contributed by the writer at a meeting of the Pan-Pacific Congress held in Sydney during August last, proved of great interest to economic entomologists.

This matter was included under the general subject-heading of "Commercial Value of Useful Carnivorous Parasites," and, seeing that it deals exclusively with little known useful insects associated in Queensland with sugar-cane, should, I think, be brought under the notice of our growers.

THE ECONOMIC VALUE OF CERTAIN QUEENSLAND PARASITIC INSECTS.

1. *APANTELES NONAGRIÆ* OLIFF.

During the course of breeding experiments conducted by the writer at Meringa Laboratory 1921 to 1922, it was found that the period occupied by this species from the date of oviposition to subsequent emergence of the imagines varied from two to three weeks under an average shade temperature of about 82 deg. Fahr.

Parasites derived from cocoons collected from bored sticks in canefields at Pyramid near Gordonvale were placed during 4th to 6th December in a cage containing a single caterpillar of *Phragmatiphila truncata* Walk., which had been allowed to crawl behind a leaf-sheath of a healthy ratoon shoot previously planted in the cage.

From a single female specimen introduced into this cage with five males, no less than ninety-three of these braconid parasites were obtained from this one caterpillar on 27th December (twenty-one days later). On 28th December some of these wasps were put into another cage containing a larva of *truncata,* and only nine days later cocoons of *nonagriæ* were discovered in this breeding-cage, from which parasites finally emerged on 12th January, giving just a fortnight for the complete life-cycle period.

Apanteles nonagriæ probably attacks more than one species of noctuid, as it very likely continues to produce successive broods during summer months, although its usual host *truncata* is rarely noticed in canefields here after December.

Mounted specimens of this tiny parasite were exhibited to entomologists attending the Sydney meeting of the Congress.

2. *LABIA SP.* (EARWIG).

This predaceous insect is exceedingly common in the Cairns district, where it occurs plentifully in canefields, hiding behind leaf-sheaths of standing cane or among the unfolding heart-leaves.

The following data regarding its habits, obtained by the writer in 1918, will be found of economic interest:—

When confined separately in large glass tubes containing a portion of cane-leaf infested with plant lice (*Aphis sacchari* Zehnt.), four of these earwigs consumed between them 120 aphides in seven hours. Upon being introduced into the tubes they pounced without loss of time on their defenceless prey, seizing an aphis with their sharp mandibles and holding the succulent morsel aloft while engaged in eating it. Each capture was generally followed by a quick backward movement of a few paces, the earwig then standing motionless until ready for another mouthful. It was amusing to observe, with the aid of a powerful reading glass, how little colonies of aphides scattered in consternation as the enemy walked coolly into their midst and started snapping them up one after another with relentless indifference. The first victims were often viviparous females, but larvæ, nymphs, and winged imagines were also devoured with equal relish.

One of these earwigs was next allowed to run up the leaf of a large growing cane-plant on which colonies of *Aphis sacchari* had been established and were breeding. About a minute after its release, having travelled 10 or 12 in., it encountered an assemblage of plant lice, and at once started to clear them off, eating a dozen or more with scarcely a pause, in a manner that left no room for doubt regarding the nature of one of its favourite foods under natural conditions. When examined four days later the foliage of this plant was perfectly clean and not an aphis could be found upon it.

This earwig is positively phototropic in a very marked degree towards artificial light, such illuminants as acetylene or benzine proving specially attractive. The imago form varies in length from 13 to 16 mm., and is of a general dark reddish-brown colour, with thorax, tegmina, and legs light yellow, and a conspicuous brown stripe down the centre of wing-covers. The anal cerci of the male are longer and more slender than those of the opposite sex, and much widened at the base laterally in the form of an obtuse triangle.

Living specimens which had been captured at Meringa during July were exhibited in Sydney at the Pan-Pacific Conference. About fifty of these earwigs were transported safely in a couple of glass test-tubes measuring 7 by 1½ in.; the mouth being plugged with cotton-wool, while provision was made also for indulgence of the thigmotropic habits common to Forficulidæ. These specimens continued alive and healthy in the tubes for two months or longer, requiring little or no attention during this period; so that introduction of this useful predator into other countries to combat injurious species of Aphidiidæ could be very easily effected.

A point worth mentioning in this connection is that during a sojourn of thirteen years in North Queensland I have never found this earwig amongst or in the immediate vicinity of household foods, although on certain evenings thousands will enter a house, attracted by lamp-light, &c. Being arboreal in habits, this species evidently leaves any dwellings to which it may have been attracted by artificial lights, as soon as daylight appears.

3. *CHALÆNIUS AUSTRALIS* DEJ.

Larvæ of this eminently predaceous beetle were observed by the writer during February 1920 destroying caterpillars of *Laphygma exempta* Walk., which were devouring leaves of maize and sugar-cane on a plantation at Meringa near Cairns. They occurred rather commonly in the affected area, attacking chiefly any caterpillars traversing the ground between cane-stools, but also exploring the foliage in search of larvæ. Directly one of these predators encountered a caterpillar it instantly buried its keen mandibles deeply in the body near the head, and then simply hung on, while the unfortunate victim, vainly endeavouring to shake off its foe, twisted and rapidly rolled over and over convulsively. Such struggles seldom lasted more than a minute, at the end of which time even large caterpillars became too weakened to offer further resistance, and suffered the enemy to greedily imbibe their life-juices until its swollen body could hold no more. This larva, which runs with agility, is exceedingly active and pugnacious, residing mostly underground in small holes, sun-cracks, or other suitable cover.

While in confinement they were fed on noctuid larvæ and pupæ, and soon pupated at the bottom of breeding-cages filled with damp soil. Their pupal condition during March (one of our hottest months) lasted only seven days, the mean temperature at the time being about 87 deg. Fahr. The larva of this carabid beetle is black, of typical campodeoid form, and slightly exceeds 13 mm. in length. The beetle is 16 mm. long with pronotum and head shining green above and deeply punctulate; elytra dull purplish brown edged with green, and often suffused with iridescent pink, each elytron with eight parallel rows of punctures. Ventral surface of body and legs shining black; palpi and basal joints of antennæ reddish brown.

4. *CAMPSOMERIS TASMANIENSIS* SAUSS. and *C. RADULA* FABR.

(Figs. 1, 2, 2a-2c, Plates IV., V.)

Notes on the life-cycle and habits of these scoliid wasps, including descriptions of the various host-grubs attacked by them, will be found on pages 24-29 of the present bulletin.

The following data, however, accumulated by the writer during 1917 to 1919, regarding the number of eggs obtained from individual wasps, will doubtless be of interest to parasitologists:—

C. tasmaniensis (female caught in canefield): Laid 65 eggs, produced 26 wasps—13 male, 13 female.

C. radula (female captured in canefield): Laid 25 eggs; produced 18 wasps—8 male, 10 female.

C. radula (3 females caught in canefield): No. 1 laid 23 eggs; produced 17 wasps—8 male, 9 female. No. 2 laid 34 eggs; produced 5 wasps—2 male, 3 female. No. 3 laid 49 eggs; produced 11 wasps—2 male, 9 female.

C. tasmaniensis (females bred in office; presumably unfertilised, although male was confined in the same cage with them): No. 1 laid 95 eggs; produced 42 wasps from 88 cocoons; all male. No. 2 laid 62 eggs; produced 34 wasps, 45 cocoons; all male.

C. radula (female bred in office, presumably not fertile, although a male was confined in same cage): Laid 69 eggs; 51 cocoons, 32 wasps; all male.

C. radula (females bred from eggs laid in office; no male put in cage with them): No. 1 laid 19 eggs; produced 6 wasps—5 male, 1 female. No. 2 laid 19 eggs; produced 4 wasps; all male.

C. tasmaniensis (females of second generation, bred in office and purposely kept from male wasps): No. 1 laid 84 eggs; 45 cocoons, 38 wasps—37 male, 1 female. No. 2 laid 43 eggs; produced 24 wasps; all male.

C. radula (females of second generation bred in office and kept from males): No. 1 laid 47 eggs; 38 cocoons; 32 wasps; all male. No. 2 laid 31 eggs; produced 20 wasps; all male.

C. radula (female wasp of third generation bred in office and kept from contact with males): Laid 17 eggs; 4 cocoons; 2 wasps; both male.

EARLY STAGES OF MACROSIAGON (EMENADIA) CUCULLATA MACL.

The eggs of this rhipiphorid beetle, which are exceedingly minute (barely visible with the naked eye), white, and of elliptical form, measure about 0·156 by 0·45 mm.

They are placed close together, to the number of 100 or more, but without definite arrangement, amongst the hairs of a leaf, being distributed at random over an area of about 1 to 2 sq. in. of the lower surface.

These eggs, although kept under quite dry conditions in glass tubes, commenced to darken a fortnight later, becoming black and finally hatching after seventeen and a-half days.

The tiny, active triungulin (representing the first larval instar) resembles in general appearance that of a closely related European species named *Rhipiphora paradoxus*, and, like that insect, probably makes its way at first into flowers usually visited by hymenoptera, hoping to attach itself to some scoliid wasp and be carried underground; which would afford the triungulin a chance to enter the larva when hatched from the egg deposited by the wasp on its paralysed host-grub.

A female specimen of *Campsomeris tasmaniensis* was placed by us for a few seconds in a large test-tube containing about 25 triungulins of *cucullata*, and then immediately put under chloroform.

Examination revealed numbers of these curious larvæ tightly embracing various hairs on the tarsi, clypeus, neck, pronotum, &c., of the digger-wasp. Even in so brief a space of time, and while this wasp was in active motion, they had contrived to jump upon or lay hold of it and securely attach themselves. Upon the latter reviving and becoming aware of the presence of these minute enemies, it endeavoured to brush them off, but only succeeded in killing one and removing two others.

Subsequently these triungulins were carried underground by their host, and after oviposition had taken place one of them remained on an egg attached to the paralysed grub for three days, making no attempt apparently to pierce the chorion, but seeming to await hatching of the egg. Unfortunately, the latter, being injured by an acarus, did not hatch, so we were not able to observe the behaviour of this hyper-parasite towards the tiny scoliid maggot. Its first larval instar is probably passed, like that of *Rhipiphorus*, inside the young maggot of the digger-wasp.

This triungulin is a black and almost microscopic insect, barely visible to the naked eye, measuring 0·53 by 0·213 mm. greatest body length and width, and 0·695 mm. from front of head to end of anal bristles. By aid of a sucker situated ventrally on the anal segment it is able when necessary to stand on its tail, thus leaving all legs free when about to lay hold of insects to be used as carriers. It appears likely that almost any nectar-loving species of hymenoptera or diptera, irrespective of size or economy, might be made use of by this triungulin, and serve to transport it from flower to flower until its carrier chanced to alight on blossoms habitually visited by scoliid or other burrowing wasps, some of which might prove suitable hosts.

I may mention that some of the leaves on which these eggs were found proved to be glandiferous, two or three cup-like honey-bearing glands being situated on the edge of the leaf, close to the petiole. Perhaps this beetle purposely selects such leaves in order that her offspring may find nourishment prior to commencement of their travels, and at the same time be afforded a better chance of meeting with insect carriers in the shape of small flies, &c., which might be attracted to sweet secretions.

FACTORS FAVOURABLE TO THE INCREASE OF DIGGER-WASP PARASITES.

The following notes should be of interest to entomologists engaged in the study of biological control of insect-pests.

1. AN ABUNDANT FOOD SUPPLY FOR THE LARVA.

Owing to some of our root-eating Scarabæidæ having a two-year life-cycle, cane grubs may be found commonly at all times, although occurring in greatest profusion in the Cairns district from March to August. One species of *Lepidoderma*, three of *Lepidiota*, and one of *Anoplognathus* are freely parasitised by *Campsomeris tasmaniensis* Sauss. and *C. radula* Fabr. (Plates IV. and V., pp. 45, 47). The two favourite hosts, however, are *Lepidoderma albohirtum* Waterh. and *Lepidiota frenchi* Blackb.

Although previously reported (Bull. No. 7, Div. Entom., p. 15, 1918) that *radula* would not oviposit on grubs of *Dasygnathus australis-dejeani* Macl., subsequent experiments by the writer with the autumn brood of this wasp, during May of the following year, demonstrated that specimens of *radula* bred in our laboratory would very often victimise larvæ of this dynastid beetle. The negative results of former experiments in this connection may have been due to the fact that the wasps used in the first instance had been ovipositing regularly for some days prior to capture, on grubs of *frenchi*, and so had become accustomed to the fighting tactics of that species. In the absence of other hosts, females of *radula* when just fertilised if meeting with *australis-dejeani* in cane-fields might possibly parasitise them as a matter of course.

I am inclined to believe that, under natural conditions, both *radula* and *tasmaniensis*, throughout their aerial existence, usually oviposit for the most part on grubs of the first suitable host encountered by them. We may reasonably assume that a wasp, after such initiatory contact, would profit by its experience, and be able thenceforward, even before entering the ground, to detect the presence of grubs similar to those first met with on a plantation, and possibly distinguish them at once from those of related hosts chancing to occur on the same area.

At Gordonvale the Scarabæidæ attacked represent not only different genera but three distinct sub-families, the larvæ of which, varying as they must necessarily do in habits and to some extent in structure, would probably adopt slightly different fighting methods when defending themselves from digger-wasps. As an illustration of this (one of several cases) I may mention that a *bred* specimen of *tasmaniensis* that had from the first been regularly supplied with third-stage grubs of *L. albohirtum*—and during a period of 21 days had paralysed and oviposited upon no less than 48 specimens of this host—upon being suddenly caged with a third-stage grub of *Anoplognathus boisduvali*, gave battle as usual, but was overpowered and cut in pieces by this new host; having, presumably, failed to immediately vary what had become its habitual method of attack in order to meet a changed and unfamiliar mode of defence.

Strangely enough, the victorious grub in this instance was that of the smaller and less aggressive of the two hosts concerned.

As mentioned by the writer (Bull. No. 7, Div. Entom., p. 21, 1918), the laying of each wasp egg is preceded by a duel in which the parasite, although generally the winner, does not always escape unharmed. The seriousness of these subterranean combats is evidenced by the nature of the wounds received. For example, a specimen of *tasmaniensis* that had lived 50 days in confinement, and eventually succumbed to such injuries after laying 65 eggs, was found to have lost ten joints of one antenna, four intermediate tarsal joints, and the same number from its hind feet; while a bred specimen of *radula* died from the effects of a gaping abdominal wound, after depositing 43 eggs.

The continuous supply of food furnished by grubs of these various root-eating Scarabæidæ, coupled with the fact of our average temperature during autumn and winter being about 73 deg. Fahr., enables species of *Campsomeris* to breed unceasingly, and produce successive generations about every three months.

The lowest temperature recorded by the writer at Meringa during 1919 was 40 deg. Fahr. at 6.30 a.m.; yet, a few hours later at 11 a.m., the morning being sunny, plenty of female digger-wasps were seen flying to blossoms of *Sida acuta* and *retusa*.

Grubs nearing the end of the second instar appear to be readily victimised by these scoliids. We have many records, for instance, of wasps of average size ovipositing on small second-stage *Lepidiota frenchi*, and conversely of female wasps of abnormally small size, parasitising big third-stage grubs of *L. albohirtum*.

Such readiness to oviposit on any host-grub chancing to be available, whether large or small, while naturally enhancing the economic value of these scoliid parasites in Queensland, would add greatly to their usefulness in other countries into which they might later on be introduced as possible controlling agents against root-eating scarabæid grubs.

The larval stage of the six hosts enumerated above occurs in the Cairns district during the following periods:—*L. albohirtum*, plentifully, from February to July; *D. australis-dejeani*, commonly, from January to May; *L. rothei*, locally plentiful from March to August; *L. frenchi* and *caudata*, and *A. boisduvali*, commonly at all times.

The table given below, which should be of interest to parasitologists, indicates the extreme measurements met with in adult females of both species of *Campsomeris* (see Plates IV. and V., on pages 45 and 47), together with the average length and width of second and third stage grubs of each of the six hosts concerned:—

Maximum and Minimum Length and Width of Scoliid Wasps.

—	Minimum.	Maximum.
Campsomeris tasmaniensis Sauss.	22 x 5·50 mm.	30 x 7 mm.
Campsomeris radula Fabr.	16 x 6·50 mm.	27 x 6 mm.

Average Size of Hosts (curved form).

	2nd instar.	3rd instar.
Lepidoderma albohirtum Waterh.	22 x 7·50 mm.	30 x 12 mm.
Lepidiota frenchi Blackb.	16 x 6·50 mm.	25 x 10 mm.
Lepidiota rothei Blackb.	9 x 4 mm.	14 x 6·75 mm.
Lepidiota caudata Blackb.	21 x 7 mm.	29 x 11 mm.
Anoplognathus boisduvali Boisd.	16 x 5 mm.	24 x 9 mm.
Dasygnathus australis-dejeani Macl.	12 x 6 mm.	18 x 10 mm.

2. AN ANNUAL PRODUCTION OF ABOUT FOUR BROODS.

In all probability the economic value of *Campsomeris tasmaniensis* and *C. radula* in Queensland is largely due to such factors as the abundant food supply above mentioned coupled with a favourable average annual temperature, which together make possible the occurrence each year of at least four generations of wasps.

Spring Brood.

The first or spring brood is apparently derived from females which have started to lay towards the end of September, the earliest eggs from *radula* having been obtained on the 22nd and 27th of this month, on hosts *Lepidiota frenchi* and *Anoplognathus boisduvali;* and from *tasmaniensis* on the 27th and 28th, deposited on the latter host. Egg-laying, however, becomes general towards the end of October, and continues into November. Emergence of imagines from this brood takes place

about the middle of December, extending into January. Thus, a specimen of *radula* captured 26th September, upon being supplied a month later with third-stage *frenchi* grubs, laid 23 eggs between the dates 27th October and 25th November.

A few of these were destroyed by acari, while from the remainder eight male and nine female wasps were procured, between 16th December and 7th January. The life-cycle of wasps of this brood is about 47 days; the duration of the egg, larval, and intra-cocoon stages being 3, 8, and 36 days, respectively; while the average shade temperature during the period of this metamorphosis in 1917 was about 77 deg. Fahr.

Summer Brood.

No definite time can be assigned for the commencement of the second generation, as the preceding one merges insensibly into it.

Approximately, the period occupied by this brood dates from middle of December to middle of February. Female wasps of the first brood are able to oviposit within twenty-four hours after leaving the cocoons, and being parthenogenetic need not delay egg-laying until after mating. Under natural conditions copulation probably takes place almost at once, as the males, that appear a few days before the females, usually remain near the spot from which they have emerged, flying restlessly to and fro over the surface of the ground, evidently anticipating appearance of the latter sex.

Such behaviour may be a response on the part of this insect to chemotropic influences induced by occurrence in the soil of cocoons containing female wasps, and furnishes a very striking example of tropic reaction. In the present instance this curious chemotropic force actually compelled numerous specimens of male digger-wasps, bred by the writer at Meringa in 1918, to haunt our laboratory verandas for several days after liberation, instead of accepting their freedom and flying off to the fields in search of food or suitable partners. During this period of expectancy they frequently entered and flew about the building, and when the doors were closed they could often be seen knocking themselves against the glass outside the laboratory windows, endeavouring to get back into the room in which were the breeding-trays containing female cocoons.

With reference to the duration of this second brood, the following statement, derived from comprehensive data secured by the writer during 1917-18, may be taken as fairly conclusive:—

The average length of egg and larval stages of *tasmaniensis* equal $3\frac{1}{2}$ and $7\frac{1}{2}$ days respectively; while the intra-cocoon condition (from 7th October to 11th February, at a mean shade temperature of 87 deg. Fahr.) occupies a period of 36 days for male and $38\frac{1}{2}$ days for female wasps; the minimum and maximum numbers for the male being 31 and 40, and for the opposite sex 32 and 43 days.

The number of eggs obtained from a couple of caught specimens of this species, which were deposited in cages on grubs of *Lepidiota frenchi*, was 65, from which were bred 15 males and 16 females. Quite likely, however, additional eggs may have been laid by these two wasps prior to capture.

Another wasp, which was caught 19th December, and lived 48 days in confinement, deposited no less than 65 eggs, from which resulted 13 males and the same number of females.

AUTUMN BROOD.

The specimens of *C. tasmaniensis* bred at our laboratory on 11th and 14th March deposited collectively 157 eggs upon grubs of *L. albohirtum*, these resulting in 113 cocoons, from which were obtained, between 11th May and 16th August, a total of 76 wasps, all being of the male sex. Bred males had been confined with these two females for some days in a breeding-cage directly after emergence of the latter, but, presumably, conditions conducive to mating had not been established. Perhaps the cage used was too small (12 by 15 in.), or did not get sufficient sunlight.

Possibly newly bred males do not copulate until after having flown for a few days in the open. It should be mentioned, however, that a wasp bred here on 5th January, and confined for a time with a male in a small glass jar only 6 in. high containing damp soil, apparently succeeded in copulating under such seemingly unfavourable conditions, since it deposited 49 eggs, from which were derived 3 males and 11 females. We may assume from the foregoing results that temperature and humidity probably play an important part in this connection. Absence of female wasps in the above-mentioned autumn broods was certainly not due to seasonal influences, for a check experiment conducted by the writer the following year (May 1919) with female wasps captured in the field, and therefore probably fertilised, proved this autumn brood to consist, like the earlier ones, of wasps of both sexes in about equal proportions.

WINTER BROOD.

Eggs producing this brood are laid in June or July. The cooler weather, as one might expect, retards development of the life-cycle stages, and eggs which during summer weather hatch about the third day after deposition require from 7 to 10 days or even longer during winter months, while the period occupied by the combined egg and larval stages varies from 18 to 24 days, under an average shade temperature of about 68 deg. Fahr. These combined stages, however, throughout January (summer brood) occupy a period of only 12 days, the temperature at that time being about 82 deg. Fahr.

Nine specimens of *tasmaniensis*, captured between the 8th and 10th July, laid collectively 92 eggs on third-stage grubs of *albohirtum*, which ultimately yielded 20 male and 8 female wasps, emerging between the 8th and 26th October.

It will be seen from the above that these four broods, if taken together, represent a period of about 270 days. This, if extended over twelve months, would permit of an interval of about thirty days between each brood, thus allowing a wide margin for various natural breaks affecting breeding activities of the wasps, such as drought conditions, wet weather, cloudy days, &c.

SOME MELOLONTHID BEETLES ATTACKING SUGAR-CANE.

The insects described below, although in some cases of little economic importance, include at least two, possibly three, very destructive species, viz., *Lepidiota frenchi* Blackb., *B. caudata* Blackb., and *L. trichosterna* Lea. Fortunately the grubs of *frenchi*, which are almost as large as those of *albohirtum* (greyback cockchafer), do not damage cane-roots each season. Although about half its life-cycle is occupied by the first and second larval instars, the grubs of the former insect do not during this extended period effect noticeable injury to cane. Both *Lepidiota frenchi* and *caudata* are very destructive to roots of various grasses, appearing in some respects to take the place in North Queensland of some of the larger species of *Haplonycha*, two of which, viz. *H. obesa* and *nigrescens*, are said by C. French, F.L.S., to be decidedly harmful to pasture land in Victoria. The grubs of *Lepidiota frenchi* occur freely throughout forest land in the Cairns district, subsisting largely on roots of the common blady grass (*Imperata arundinacea*), while those of *caudata*, which usually inhabit scrub lands, appear to be very partial to roots of *Paspalum platycaule*. Out of 43 grubs of the latter species collected at random from amongst roots of this grass at Deeral in 1916, no less than 88 per cent. were found to be those of *caudata*.

LEPIDIOTA FRENCHI BLACKB.

This cockchafer may be seen on the wing during November or December, generally being in evidence about a week later than the "greyback."

Emergence takes place at twilight (about 6.45 p.m.), when, suddenly and without warning of any kind, myriads of these beetles arise simultaneously from every quarter, and commence wildly dashing to and fro, thousands being in view at the same time, which in their erratic flight constantly knock against the cane-leaves, each sudden impact being plainly audible at a distance of several yards. In addition to this oft-repeated sound, the air—so still a few minutes before—vibrates with a continuous humming note, due to the accumulated buzzing of countless numbers of these beetles.

It may be of passing interest to mention that the writer upon testing this note with a tuning fork found it to be B natural—eight tones below the middle C of a piano at concert pitch—and very different from the deep tremulous drone that characterises the flight of our greyback cane-beetles.

Upon catching a specimen of *frenchi* one notices a faint whitish bloom overspreading the general body colour of reddish brown, which looked at with a pocket lens is at once seen to be due to the presence of numberless tiny, white, circular scales, each resting in a minute puncture (see Plate II., Fig. 12, p. 41). The outer edges of the prothorax of this insect are dark red, turned up slightly and symmetrically scalloped, the hind margin of same being densely bordered with these curious scales. The ventral surface of body, including the legs, is thickly clothed with white scales, which on the thoracic plates vary from circular to pear-shaped, and near the coxæ are replaced by long silvery hairs.

The four life-cycle stages have been fully described by the present writer in Bull. No. 5, Div. Entom., of our Sugar Bureau, so need not be given here.

Although in evidence each season, *frenchi*, as already stated, is only excessively abundant every second year.

The attitude assumed while mating is rather curious, the female alone clinging to the leaf-blade or other support (not the male, as inadvertently stated in Bulletin No. 5 of this office), the male hanging motionless head downwards in mid-air supported only by the genital organs, and having the venter of body exposed to view.

LEPIDIOTA CONSOBRINA GIR.

This species closely resembles the preceding in general appearance and colouration. It emerges from the ground, however, about three weeks earlier than *L. frenchi*, is of local occurrence, and much rarer on forest country. If closely examined it will be found to possess the following specific differences:—

The Larva.—Setæ on venter of anal segment of both species are arranged in the form of a pear-shaped figure, which in *consobrina* is elongated, having two parallel rows of short bristles (see illustration on page 47 of Bull. No. 18). Width of head, 7·20 mm. (in *frenchi* 5 mm.).

The Beetle.—Average length $1\frac{1}{8}$ in. (*frenchi* 1 in.). Antennal joints Nos. 6 and 7 in male, stouter than in female. Teeth on outer edge of front tibiæ having the points more obtuse than in *frenchi*, and not equidistant. Front tibial spur stouter and blunter than that of *frenchi*. The ventral transverse bands of scales on abdominal segments 1 to 4 narrower centrally and on sub-ventral area than in *frenchi* (see Bull. No. 5, pp. 5, 13). In addition to the above differences the circular scales on the elytra of this species are noticeably larger than those of *frenchi* (see Plate II., Fig. 13, p. 41). Grubs of this beetle are frequently found under cane-stools and in localities near scrub land, where this species occurs abundantly, probably causing more or less serious injury to the roots.

LEPIDIOTA TRICHOSTERNA LEA.

This beetle is of a uniform light yellowish-brown colour. The antennal club in both sexes is short and 3-lamellate, that of the male being the longer and of darker shade of brown. The elytra in both sexes are sprinkled with numerous minute pale-yellow scales of lineal form, tapering to a point at each end.

The grubs of this cockchafer resemble those of related species of *Lepidiota*, from which they differ in having the vestiture on venter of anal segment arranged in the form of a central path (shorter than in *Lepidoderma albohirtum*) consisting of two parallel rows of dark-brown bristles, ten on each side. This beetle is common in portions of Southern Queensland, where it has been recorded as being destructive to roots of sugar-cane.

LEPIDIOTA ROTHEI BLACKB.

This dark, shining, reddish-brown beetle emerges from forest land about the same time as *frenchi*, from which it differs in being much smaller (17·50 mm.), and in having the white scales on its elytra pear-shaped instead of circular (see Plate II., Fig. 15, p. 41). Although grubs of *rothei* are often found under cane, their presence is probably due in many cases to these beetles having been attracted to such spots by a thick growth of weeds between the rows. In habits and mode of occurrence this species closely resembles *frenchi*, from which, however, it differs in having a life-cycle of only one year, and in being a cane-beetle of minor economic importance.

LEPIDIOTA GRATA BLACKB.

This insect bears a close resemblance to *L. rothei* Blackb., from which it differs, however, in possessing smaller scales on the elytra, in being slightly larger, the centre of the clypeus more deeply notched, the centro-ventral area of the abdomen less densely scaled, and in having darker legs. In addition to the foregoing distinctions, this species has a two-year life-cycle.

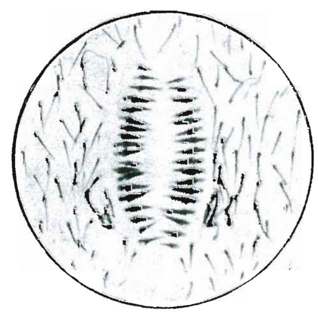


FIG. 1.

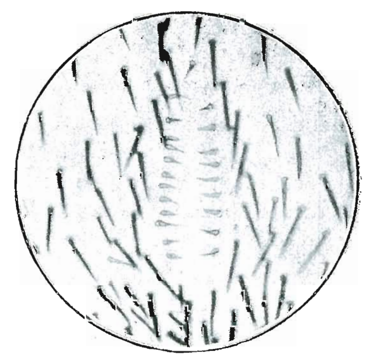


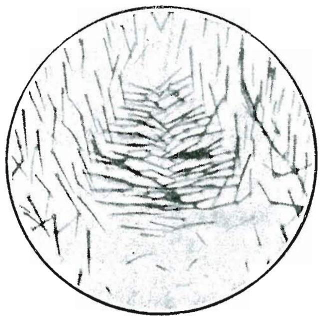
FIG. 2

Arrangement of the ventral bristles on anal segments of grubs of *Lepidiota grata* Blkb. (Fig. 1), and *L. rothei* Blkb. (Fig. 2).

Its larva can be easily distinguished from that of *rothei* by the different arrangement of the bristles on the ventral surface of the anal segments, as shown by the accompanying micro-photographs on page 31. The beetles emerge at a different time from those of *Lepidiota rothei*, and fly very freely to acetylene lights.

LEPIDIOTA CAUDATA BLACKB.

This is a very interesting cane-beetle, which in the vicinity of scrub land at Babinda and elsewhere appears on the wing during September, and in some localities is believed to be a pest of premier importance. Its grubs are about as large as those of our greyback cockchafer, and able to inflict serious injury to cane-roots. They can readily be separated from those of both *albohirtum* and *frenchi*, with which they are often confused, by the arrangement of the anal bristles, as shown by the



Arrangement of ventral bristles on grubs of *Lepidiota caudata* Blkb.

above micro-photograph. Freshly emerged beetles are dark purplish brown, with a glossy opalescent sheen. The dorsal surface is sparingly and minutely punctulate, the scales, although of circular form, being much smaller than those of *frenchi* (Plate II., Fig. 14, p. 41).

L. caudata has a two-year life-cycle, and does not occur on open forest country.

ON THE HABITS AND COLOURATION OF SOME QUEENSLAND RUTELLINÆ.

The beetles figured on Plate VI., p. 49, include two or three of our most beautiful species of coleoptera.

Possibly the so-called "Gold Beetle" (Fig. 3) may have resembled that mystical species immortalised by Edgar Allan Poe in his weird tale entitled "The Gold Bug." In the Cairns district, where this species is not uncommon locally, it is said to feed on the foliage of a wild *Hibiscus* having large yellow flowers, which usually flourishes in swampy situations.

A closely related but slightly larger cockchafer, *Anoplognathus mastersi* McLeay, which is of a lovely metallic greenish-gold colour, is considered by some of the growers at Ingham and Macknade to be destructive to sugar-cane.

It may interest readers to know that the bright colours of Rutellinæ, and of many other coleopterous insects possessing brilliant shades of blue, green, violet, &c., are due in part to the surface of the elytra or wing-cases being formed of innumerable microscopical concavities or wrinkles. In *A. punctulatus* and *smaragdinus* (Figs. 4 and 6, p. 49), each of these countless puncturations is surrounded by striæ, and forms the centre of a four to six sided figure. In the case of *frenchi* the colour appears to be of a chemico-physical nature, being due to diffraction of the rays of light falling on such surface irregularities, combined with an underlying reflecting pigment: thus, if a specimen be left for a month or two in alcohol or formalin this pigment is destroyed, the beetle then becoming of a uniform light-brown colour; whereas, if killed and dried without delay, the golden splendour of the insect is permanently retained, owing to this underlying pigment—which is secreted by the hypodermal cells—being enclosed in airtight sacs.

ANOMALA AUSTRALASIÆ BLACKB.

(Plate VI., Fig. 1, p. 49.)

The egg and early larval instars of this species—not hitherto published in our bulletins—were worked out by the writer during 1918-19, and are of interest from a scientific standpoint.

A female beetle captured on the 28th November, and confined at once in a breeding-cage, was found when examined nine days later to have laid 18 eggs. These varied in size, so were probably deposited on different days. They hatched on 17th December (nineteen days after capture of the beetle); and a couple of months later (17th February) several third-stage larvæ were found. Other beetles, caged on 5th December, produced eggs six days later, which hatched on 20th December (fifteen days after capture of the beetles). By about the middle of April nearly all the grubs bred during the course of these investigations had moulted into stage 3, and early in May were commencing to pupate.

Description of Egg.

Nearly spherical, smooth, milky white, and measuring 2·25 mm. longest axis; ten eggs in a straight line, touching end to end, equalling 22·50 mm. These eggs are laid separately in the soil, no chamber or enlargement being provided to allow for swelling of the embryo.

Description of Newly Hatched Larva Before Feeding.

Dirty white, yellowish brown towards and on anal segment. Head, legs, and antennæ light yellow, trophi reddish brown. Body sprinkled with golden hairs. When inactive this grub assumes a doubled-up posture, ball-like in form, but is able to stretch to its fullest length, and crawl quickly on its ventral or stomach surface. A day or two after hatching the body darkens to bluish brown.

Description of First Larval Instar.

General colour bluish grey; head pale fulvous, width of same 2·70 mm. Length, doubled-up position, 9 mm.; length fully extended 16 mm. Legs whitish yellow. Disposition of body hairs, very similar to that of stages 2 and 3. Anal path on posterior ventral surface distinct and defined by short setæ.

Description of Second Larval Instar.

General colouration pale bluish yellow, somewhat shining. Head, legs, and spiracles fulvous; mandibles and labrum castaneous, the former darker towards the tips; peritremes very open, and with exception of first thoracic equi-sized. Body clothed with reddish-brown hairs, rather long and sparingly distributed on thoracic and first abdominal segments. Posterior area of venter of anal segment with numerous short recurved scattered hairs, and exceptionally with no indication of an anal path.

The colour of this beetle is dark bronze-green, more or less clouded in certain lights with lustrous shades of pink.

Although the grubs of this species occur commonly at times in canefields, they do not effect serious damage to the roots of cane plants, appearing to subsist mainly upon decaying humus found under trash, or formed by the rotting rind, &c., of old sets.

REPSIMUS ÆNEUS FABR.

(Plate VI., Fig. 2, p. 49.)

The general ground colour of this beautiful beetle is chrome-green; most specimens, however, being flushed with coppery or steely-blue tints, while the reflected high lights flash with lovely pale golden-green. It can be identified easily by the structure of the hind legs, which are longer and much thicker than the others.

The writer observed several of these insects during January 1915, flying around a stunted eucalypt on the sides of Mount Pyramid. One of them had been attacked and killed by a pentatomid bug (*Amyotea hamata* Walk.) which was observed to be resting on a gum-leaf, supporting the weight of the beetle in mid-air at the end of its proboscis, whilst engaged in sucking the juices of the victim. According to W. W. Froggatt, these rutellids are common around Sydney, where they are found clinging to low bushes.

ANOPLOGNATHUS PUNCTULATUS OLIFF. AND *A. SMARAGDINUS* OHAUS.

(Plate VI., Figs. 4 and 6, p. 49.)

These two insects, as will be seen by the plate, differ noticeably in form, and although both are of a rich uniform green—an almost pure oxide of chromium—the shade of colour in *smaragdinus* is lightened with more yellow, producing a lustrous effect not present in *punctulatus*. The pygidium and under surface of the latter insect, including the legs, is dark coppery-brown with light greenish-gold reflections; while *smaragdinus* is green below, with lighter golden-brown legs, and pygidium the same colour as its elytra.

Neither of these beetles is known to be of economic importance, or have, up to the present, been recorded from canefields.

ANOPLOSTETHUS LÆTUS R. AND J.

(Plate VI., Figs. 7, 8, 9, p. 49.)

This species is perhaps one of our most lovely scarabæid beetles, and is remarkable for possessing four distinct varieties.

The green specimens are reported to be about four times as plentiful as the other varieties, two of which (Nos. 8 and 9 on Plate VI., p. 49) generally occur in about equal proportions.

Change of colour in perfectly developed insects is believed by Krukenberg to result from change of food, and can be explained by alteration of the underlying pigment through heat and light. Such alteration, however, is generally effected gradually, so would scarcely apply in the present instance, unless on the supposition that an interval of a week or more may elapse between the appearance of early specimens and those constituting a larger and later emergence of these beetles.

Unfortunately, the colour in this species is of a less enduring quality than those characterising the beetles alluded to above. The beautiful glossy alizarin green variety does not fade appreciably in dried specimens, whereas the red form shown at Fig. 8 changes to brown madder; and the pinkish opalescent violet variety darkens to a warm monochrome after death. In the fourth and very much rarer orange-chrome variety of this beetle the colour is of a still more fugitive nature.

A second species of the genus *Anoplostethus*, viz., *A. opalinus*, is recorded by Froggatt as being of a beautiful pale opaline green colour, and peculiar to Western Australia.

ANOPLOGNATHUS BOISDUVALI BOISD. "CHRISTMAS BEETLE."

(Plate VI., Fig. 5, p. 49.)

The larvæ of this insect were mentioned by the present writer in 1915 as occurring plentifully at times among cane-roots in both light and heavy classes of soil, but showing preference for sandy loams.

The favourite food-plant of the beetle is *Eucalyptus platyphylla*, a tree having white smooth bark, and, as denoted by its specific title, very broad leaves. It is not uncommon to find suckers springing from green stumps of this gum-tree with leaves 8 to 10 in. in length and 6 to 8 in width.

The general colour of this beetle when alive is pale creamy grey, with a distinct silvery lustre and faint green and pink iridescence. The silvery sheen, however, fades after death, being replaced by pink-ochraceous. Each elytron has about ten rows of coarse punctures, half of which are straight, and clouded in places with smoky brown, all ten rows enclosing numerous smaller brown punctures.

The suture between the wing-cases is green, while the outer edges of the elytra are bordered with golden brown. Head, pronotum, and scutellum metallic greenish gold, finely punctulate. Pygidium bright green edged with blue. Ventral area iridescent coppery green; thorax, legs, and anterior margins of abdominal segments more or less clothed with short white hairs. Tibiæ and tarsi purple. This species ranks about third in economic importance amongst our root-eating Scarabæidæ attacking sugar-cane in Northern Queensland.

Plates I. to VI

Plate I.

External Anatomy of Greyback Cane-beetle.

EXPLANATION OF PLATE I.

(Figures 1 to 32 are of natural size.)

Fig. 1—Labrum (upper lip).
Fig. 2—Maxilla. A, cardo; B, palpus (3-jointed); H, stipe.
Fig. 3—Mandibles (jaws).
Fig. 4—Antenna. C, scape; D, pedicellus; E, club.
Fig. 5—Labium (lower lip). F, palpus (2-jointed).
Fig. 6—Head.
Fig. 7—Pronotum.
Fig. 8—Prosternum.
Fig. 9—Mesonotum and scutellum.
Fig. 10—Mesosternum. G, episternum.
Fig. 11—Metanotum.
Fig. 12—Metasternum.
Fig. 13—Episternum and epimerum.
Fig. 14—Prothorax.
Fig. 15—Mesothorax.
Fig. 16—Metathorax.
Fig. 17—Abdomen.
Fig. 18—Dorsal abdominal surface.
Fig. 19—Pygidium.
Fig. 20—Ventral abdominal surface.
Fig. 21—Elytra.
Fig. 22—Wing, as folded under elytron.
Fig. 23—Wing extended for flight.
Fig. 24—Anterior leg.
Fig. 25—Intermediate leg.
Fig. 26—Posterior leg.
Fig. 27—Coxæ.
Fig. 28—Trochanter.
Fig. 29—Femora (thighs).
Fig. 30—Tibiæ (shanks of legs).
Fig. 31—Tarsi (feet).
Fig. 32—Claws of tarsi.
Fig. 33—Posterior tibia of *Bolboceros*.
Fig. 34—Anterior tibia of *Bolboceros*.
Fig. 35—Labium of *albohirtum* (magnified). (Original.)
Fig. 36—Diagrammatic Vertical section through plate of antennal club of *albohirtum*, showing olfactory pits.
Fig. 37—Plan of an olfactory pit.
Fig. 38—Photograph of portion of surface of an antennal plate, showing arrangement of olfactory pits.
Fig. 39—Female of *Lepidoderma albohirtum* (natural size).
Fig. 40—Maxilla of *Harpus calignosus* (after Folsom).
Fig. 41—Mandible of *Cicindela* (magnified, after Hagen).
Fig. 42—Mandible of *L. albohirtum* (magnified). (Original.)

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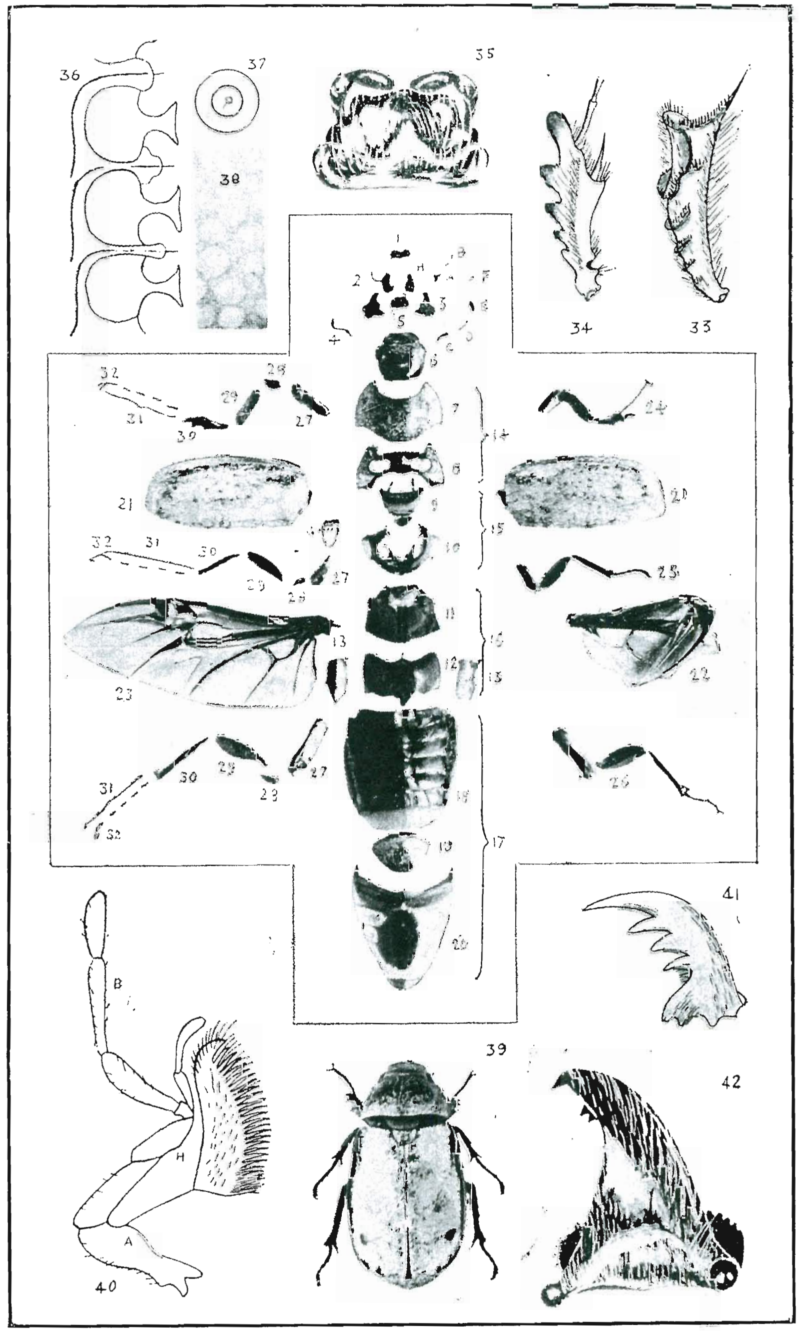
Plate I.



EXTERNAL ANATOMY OF GREYBACK CANE BEETLE
(*Lepidoderma albohirtum* Waterh.).

Plate II.

On the Vestiture of Cane-beetles and Other Insects.

EXPLANATION OF PLATE II.

Fig. 1—Longitudinal section through one wall only of the upper wing of a butterfly; showing development of three of the scales, from hypodermal cells.

Fig. 2—Hair-like scales, from forewing of Mecopterous insect.

Fig. 3—Scales from the wing of *Acræa andromacha.*

Fig. 4—Scale from wing of a species of Psychidæ (Bag Moth).

Fig. 5—Scales from the forewing of *Morpho ega.*

Fig. 6—Scales from the wing of *Papilio ulysses.*

Fig. 7—Scales from wing of a species of Glyphipterygidæ.

Fig. 8—Linear-shaped scales from the elytron of *Batocera.*

Fig. 9—Convex scales from the elytra of *Cryptorhynchus.*

Fig. 10—Moniliform scales from elytra of *Mimadoretus* sp.

Fig. 11—Scale from a wing-case of *Lepidoderma albohirtum.*

Fig. 12—Scale from an elytron of *Lepidiota frenchi.*

Fig. 13—Scale from an elytron of *Lepidiota consobrina.*

Fig. 14—Scale from an elytron of *Lepidiota caudata.*

Fig. 15—Scale from an elytron of *Lepidiota rothei.*

Fig. 16—Scale from an elytron of *Lepidiota grata.*

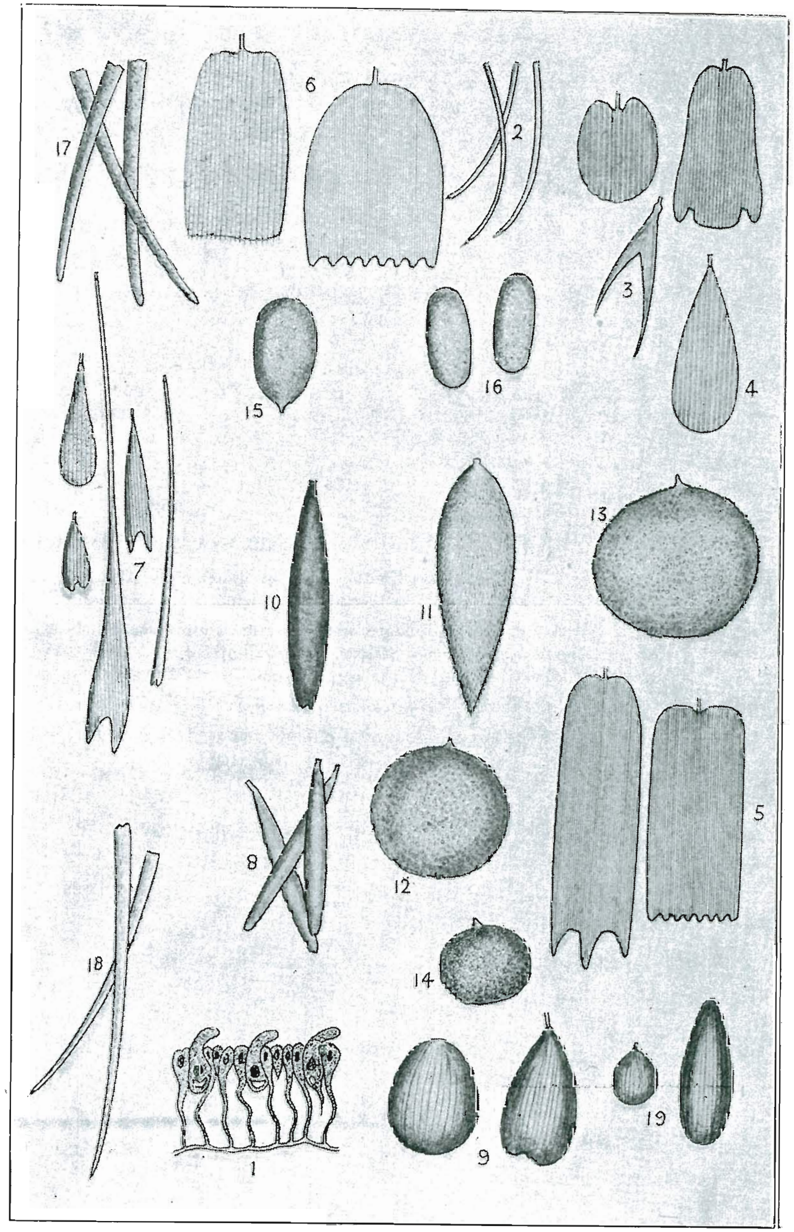
Fig. 17—Hair-like scales from the elytra of *Rhopæa* sp.

Fig. 18—Long hair-like scales from elytra of *Lachnosterna.*

Fig. 19—Convex shell-like scales from the elytra of Leptops.

Note.—Fig. 1 after Mayer; Figs. 2 to 19 original. All scales magnified 200 diameters.

Plate II.



On the Vestiture of Cane-beetles and Other Insects

Plate III.

EXPLANATION OF PLATE III.

Fig. 1—Olfactory pits in lamella of antennal club of *Lepidoderma albohirtum* Waterh.; × 620.

Fig. 2—Diagrammatic section through same, showing four pits or pori containing central pegs with apical setæ (5, 5); connected with olfactory nerves (4, 4); × about 9,000.

Fig. 3—Plan of two olfactory pits, showing sensitive pegs.

Fig. 6—Antennal club of female with lamellæ opened out; × 28.

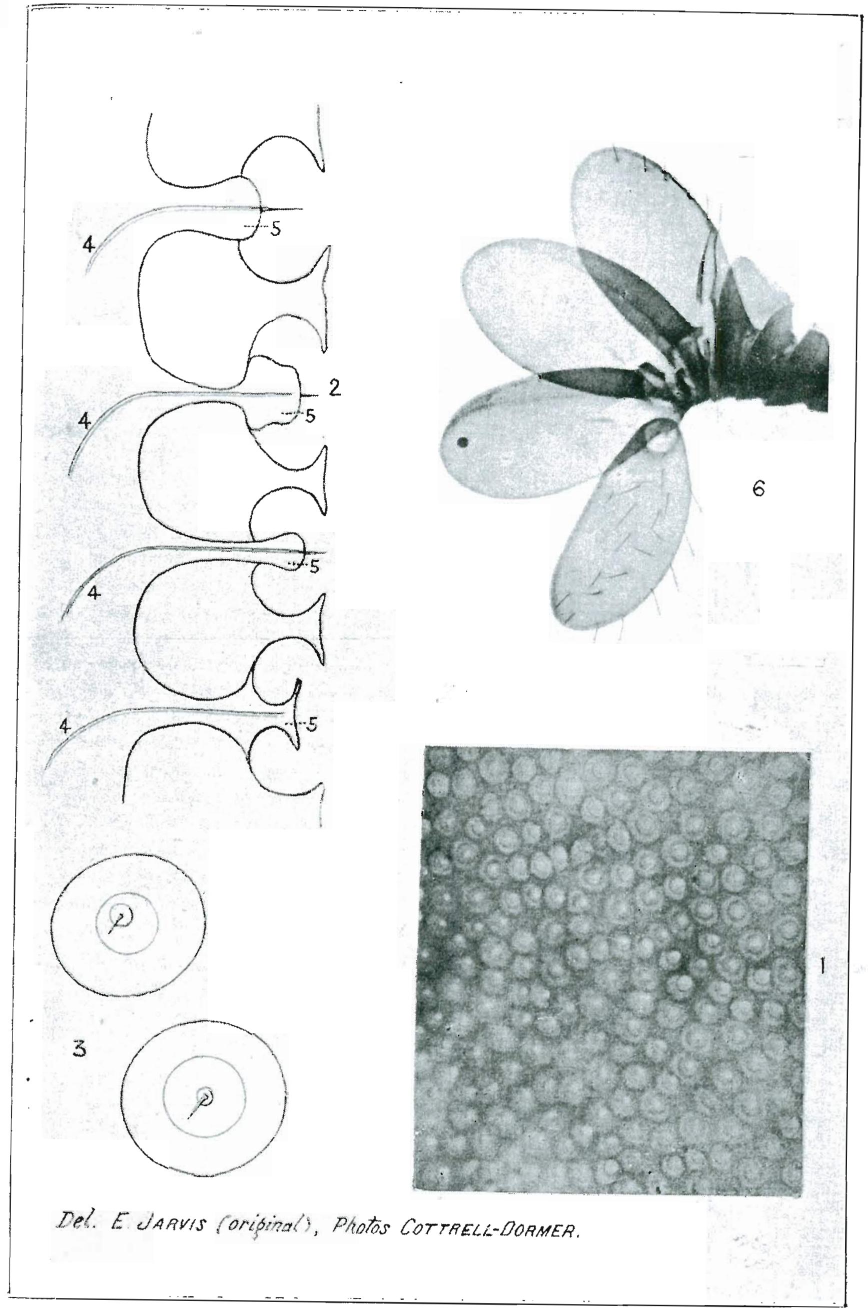


Plate IV.

Common Scoliid Wasps of North Queensland.

EXPLANATION OF PLATE IV.

Fig. 1—*Campsomeris tasmaniensis* Sauss., female, the usual colouration (natural size.)

Fig. 2—Male wasp of same (natural size).

2*a*—Showing the two characteristic yellow spots (magnified 5 times).

2*b*—Pygidium with no yellow, which is characteristic of this species (magnified 9 times).

2*c*—Labrum, showing characteristic dark central spot.

Fig. 3—*C. tasmaniensis,* a variety of the female (natural size).

Fig. 4—*C. carinifrons* Turner, female (natural size).

Fig. 5—*Scolia formosa*, female (natural size).

Fig. 6—*Campsomeris ferruginea* Fabr., female (natural size).

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Plate IV.

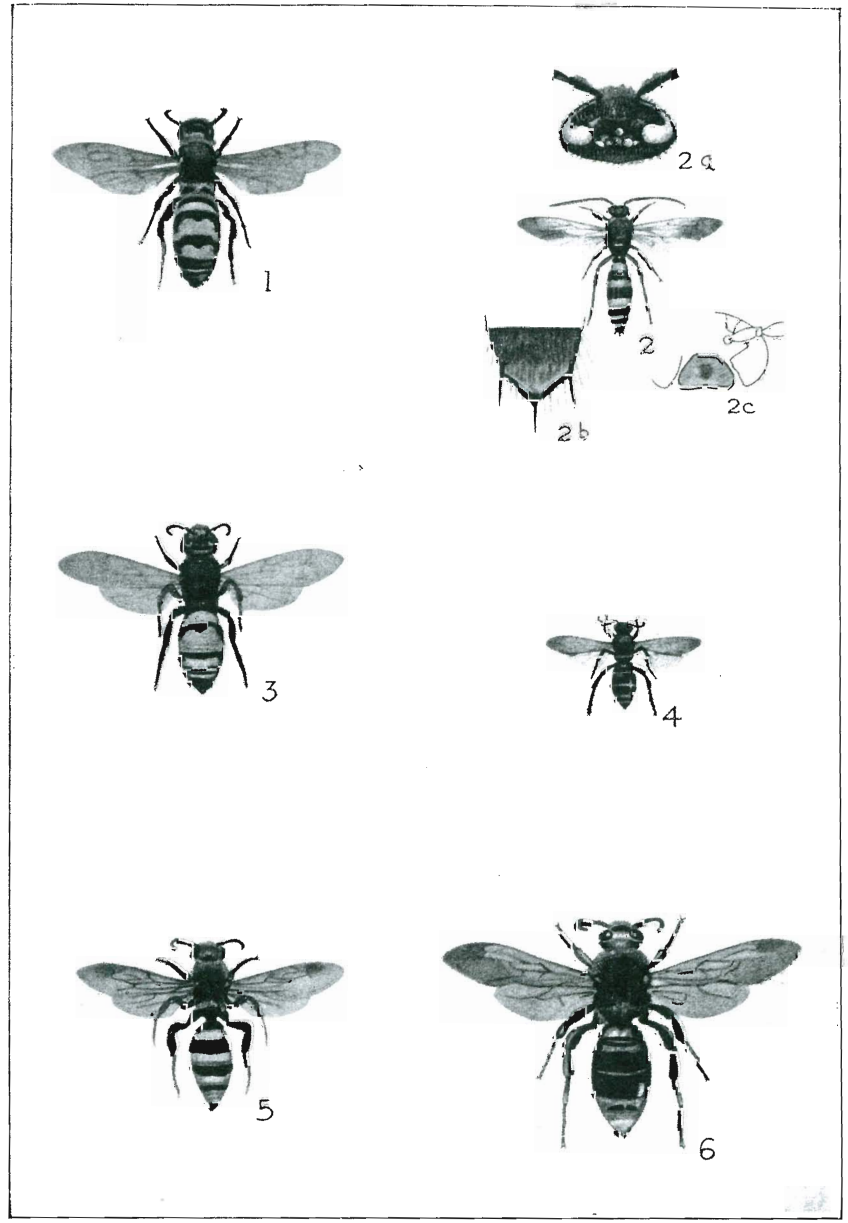

Plate V.

EXPLANATION OF PLATE V.

Fig. 1—Adult female (natural size).

Fig. 2—Adult male (natural size)

2*a*—Vertex of head, showing the three characteristic yellow spots (magnified 5 times).

2*b*—Labrum, plain, which is characteristic of this species (magnified 5 times).

2*c*—Pygidium, with characteristic yellow on proximal portion (magnified 7 times).

Fig. 3—Paralysed grub, showing usual position of the wasp egg (natural size).

Fig. 4—The egg (two views highly magnified).

Fig. 5—A male wasp larva feeding, age seven days (natural size).

Fig. 6—A female larva, ten days old, still feeding.

Fig. 7—Cocoon of the digger-wasp, in cell (natural size).

Fig. 8—Pupa of same, in cocoon (magnified twice).

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Plate V.

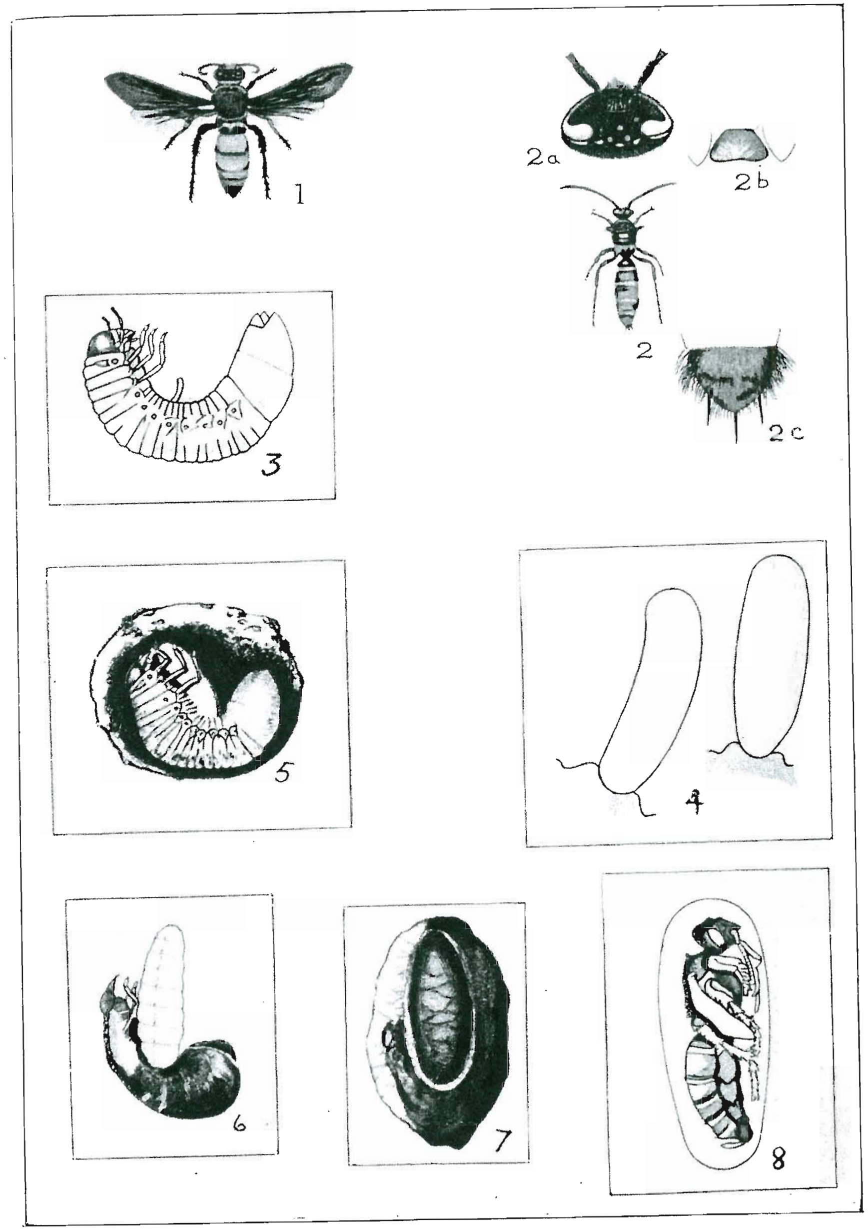


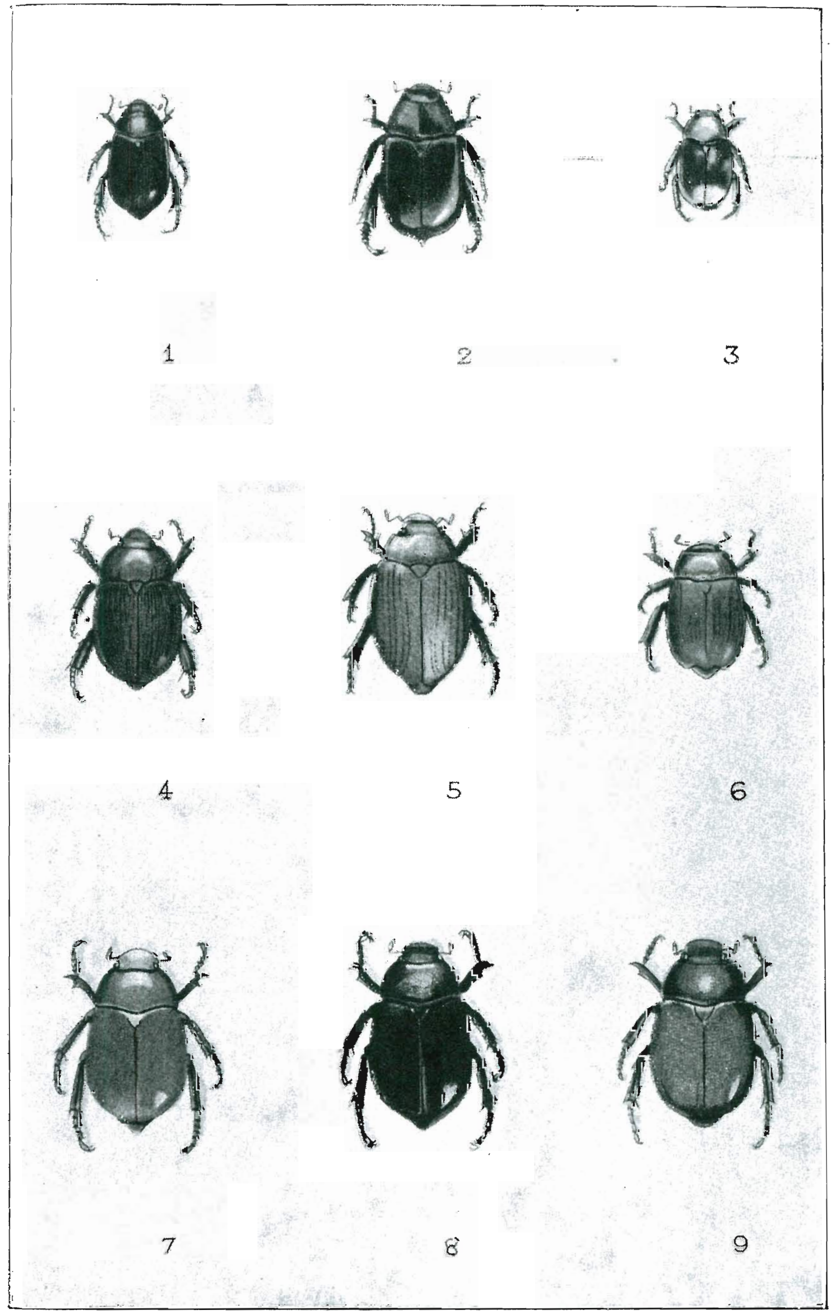
Plate VI.

EXPLANATION OF PLATE VI.

Fig. 1—*Anomala australasiæ* Blkb.
Fig. 2—*Repsimus æneus* Fabr.
Fig. 3—*Anoplognathus frenchi* Macl.
Fig. 4—*Anoplognathus punctulatus* Oll.
Fig. 5—*Anoplognathus boisduvali* Boisd.
Fig. 6—*Anoplognathus smaragdinus* Ohaus.
Fig. 7—*Anoplostethus lætus* R. & J. (green variety)
Fig. 8—*Anoplostethus lætus* R. & J. (red variety).
Fig. 9—*Anoplostethus lætus* R. & J. (violet variety).

(All figures natural size.

Del., E. Jarvis.]



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