Dimorphism and Parthenogenesis in Halictine Bees

By TARLTON RAYMENT, F.R.Z.S.

(Plates xx-xxii, figs. 1-6.)

The phenomenon of virgin birth, parthenogenesis, has always held a peculiar attraction, not only for the biologist, but even more so for the layman, but owing to the difficulties surrounding the study, the latter seldom has an opportunity to observe it in living material. He is, therefore, compelled to accept, though it must be admitted not without certain mental reservations, the carefully acquired evidence presented by the zoologists.

Perhaps in no other natural group can the investigator find more intresting material for study than the fossorial gregarious bees in the genus *Halictus*. But again the technical difficulties are so formidable that the research is confined to a few workers with a highly specialised knowledge of the HYMENOPTERA. The late Professor W. M. Wheeler (1933) regarded halictine bees as an extremely difficult Family to investigate.

The author has had several hundreds of halictine colonies under observation during many years of research, and the "nests" of one species, *Halictus dimorphus* Raym., was under daily observation for two years by one of his assistants, Lynette Young; a sustained watch that must surely constitute a record in the literature of the apoidea.

Since much of the evidence accumulated during that long period is often in direct conflict with the findings published by European Hymenopterists—there have been no other investigators in Australia—the author deems it advisable to present the established facts for the consideration of zoologists throughout the world.

It was the practice of the early systematists to divide the APOIDEA into two great classes, OBTUSILINGUES, with a short wide glossa, and ACUTILINGUES with a longer pointed glossa. That classification had, however, to be abandoned when it was demonstrated that the two forms of glossa co-exist in the Australian genus *Meroglossa*, the female organ being obtuse, that of the male acute.

It would have given a clearer picture of the phylogeny by dividing the Families according to the period required for larval development; those which take a year, such as *Paracolletes*, *Hylaeus* and *Megachile*, and those whose larvae develop in three or four months, i.e. *Halictus*, *Exoneura*, *Trigona*.

It is a strange law of the APOIDEA that the higher the evolutionary status, the shorter the larval period. For example, the highest group of all, the hive-bee *Apis*, requires only three weeks, while the sole perfect female, the "queen," matures in about sixteen days.

All halictine bees have an acute glossa; in some it is long; in others short, but a constant generic character is seen in the caudal rima or furrow, a groove on the apical segment of the female abdomen. The dorsum of the metanotum or metathorax, is invariably sculptured with rugae, more or less resembling ranges of microscopic mountains, and the structure of this part is a stable specific character. The hind calcar of the female, with few exceptions, bears a number of coarse teeth, and these, too, provide a specific character. The wings are hyaline, richly iridescent, with three cubital cells, which may be identified from the drawings. The nervures are somewhat subject to mutation.

All bees have at least some forked hairs, but *Halictus* is not specially endowed, and most of the hairs are present on the posterior legs. In the group of metallic-coloured *Halicti*, in the subgenus *Chloralictus*, the gaster often bears a light scopa of curled hairs, but the bulk of the pollen is carried on the femora and tibiae.

Chloralictine bees are smaller, 7 mm. or so, but *Halictus*, sensu stricto, are generally larger, up to 14 mm., black, and not at all metallic, with much more white or golden hair, often in bands across the abdomen. There are in both groups surprising departures from the 3-brood sequence.

Halictus leucorhinus Ckll., the largest of the Australian species, has only one generation for the season; a bisexual one, emerging in midsummer. The bees are a-wing for a mere month, and then disappear. *H. goraeensis* Raym., another large species, has three discrete broods, yet *H. lanarius* Sm., although closely related in structure, has a very different sequence; females and males hibernating over the winter in their natal cells.

The nesting site may be in volcanic loam, but clay, and even pure sand, are favoured by others, and the bees experience no difficulty in excavating in any type of soil. The chief digging implements are primarily the dentate hind calcar, or digging-spur, and secondarily the bidentate mandibulae. The teeth of the calcar are thrust downwards, paring off the soil. Small pebbles are often wedged between the teeth, and rarely one is broken off.

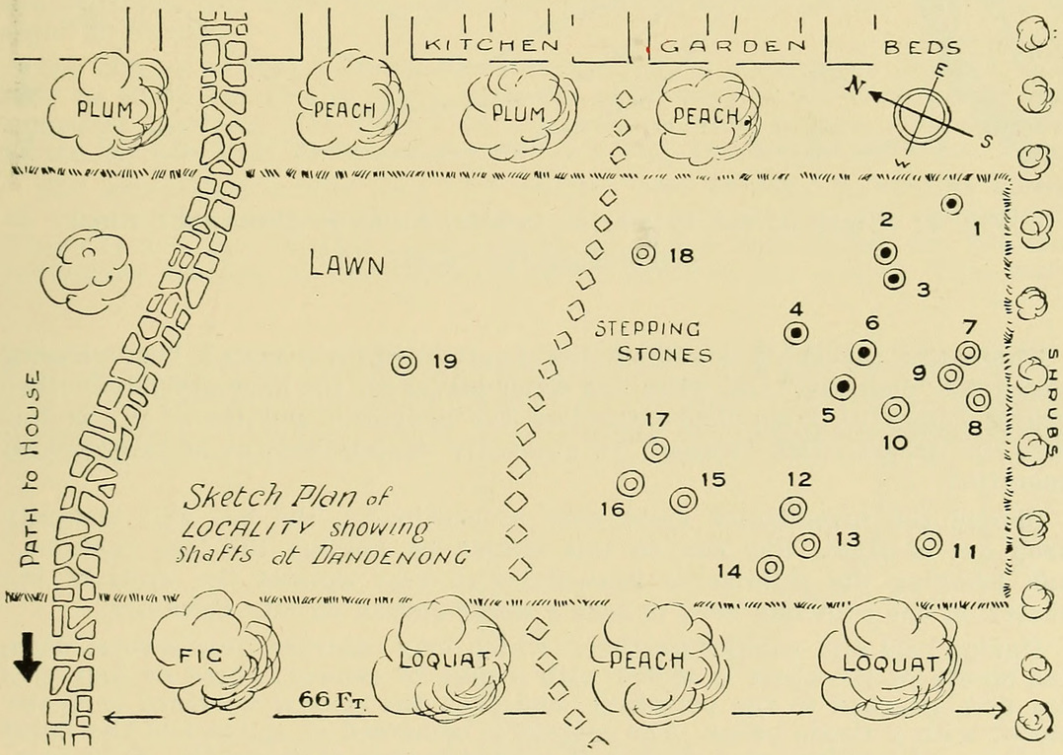

Fig. 1: Plan of site at Dandenong, Victoria, occupied by *Halictus dimorphus* Raym. The six "nests" of the season 1948 are indicated by black centres; those of 1949 white, and represent the increase of 13 colonies.

The loose periphery of the "pit-mouth" would soon collapse under the busy traffic if it were not reinforced with a rim of cement. This material is plastered down quite smooth with the caudal plate of the abdomen, and dries extremely hard.

The biology of *Halictus* (*Chloralictus*) *dimorphus* Raym., will be described in detail, and the habits of several other Australian species will be compared with it. If the season be followed, rather than the calendar, then the cycle begins at the end of August, early spring, when the first signs of halictine life will be a blackish-green head suddenly popping out of the earthen debris blocking the mouth of the shaft.

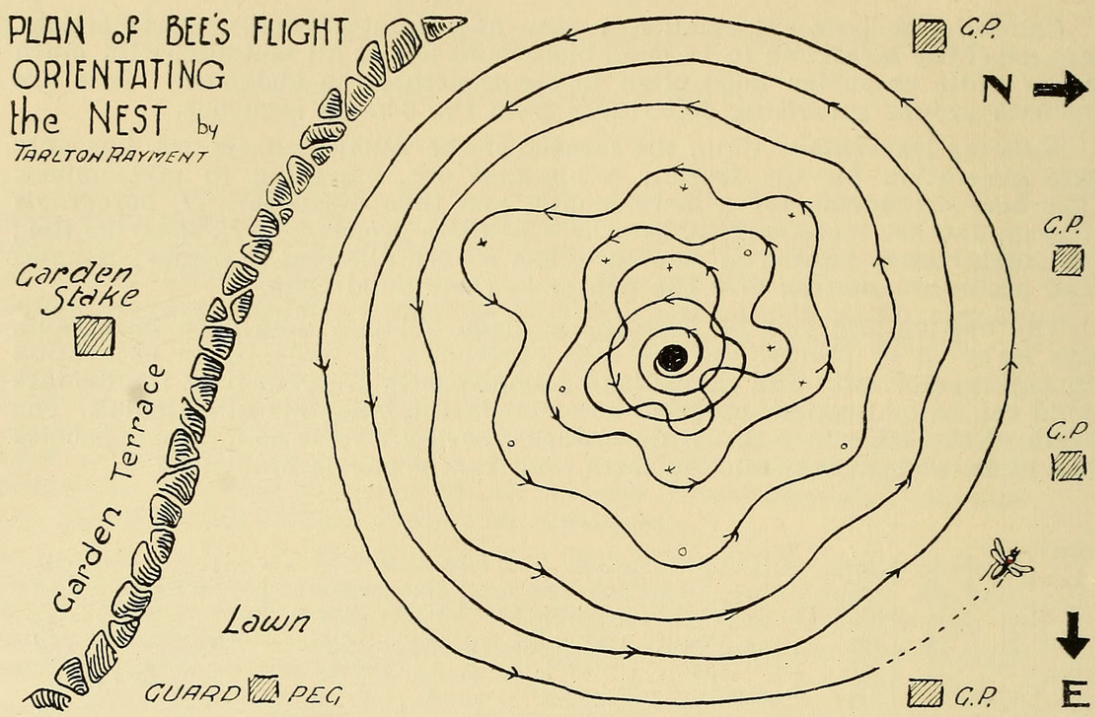

Fig. 2: Flight of red Primarius female, *Halictus dimorphus* when orientating the "nest."

Thereafter the shaft is seldom left unattended. A female's head usually closes the "doorway," and when one sister leaves for the harvest-field, another female comes up from below to close the aperture, and there awaits her turn to depart. The "watch" is assuredly maintained as a co-operative operation.

Should the investigator move ever so cautiously, the bee will instantly drop out of sight. She can do this simply by holding the legs "akimbo," and bringing the patellae or knee-plates to bear against the walls of the shaft; on the principle used in man's safety-chocks on city elevators.

During cold and windy "weather," which may continue over several days, the mouth of the shaft is sealed with a plug of cement; three or four arcs are first attached to the periphery, and then the central aperture is finally closed with a single pellet. The cement is composed of saliva and the finest particles of soil removed during the construction of the cells. Only once, during many years, was a pebble observed to close the shaft.

When the sun is bright enough, a female will emerge, bask in the warmth for a minute or two, and then take wing on a circular flight of orientation; always with her head towards the shaft, which is approximately 3 millimetres in diameter, and level with the ground.

During this initial flight she will plot the land-marks of the locality. If any one of these be moved during her absence, she will experience some difficulty on her return in locating her own particular shaft.

In *H. emeraldensis* Raym., the shafts are often only a few millimetres apart, and a dozen or more lie within a square foot, yet the bees will not be confused until some change in the "landscape" is effected by man or other agent.

A number of females, eight or so, emerge from each natal shaft, and continue to use it as the main "gang-way" to the numerous brood-cells

situated some 13 centimetres below. Microscopical examination of several hundreds of bees in the vernal brood demonstrated that all were virgin females. Not one male was present.

This virgin brood of spring is also present in *H. emeraldensis* Raym.; *H. raymenti* Ckll.; *H. demissus* Ckll., and *H. cyclurus* Ckll. It is probably true of *H. leai* Ckll.; *H. peraustralis* Ckll. and *H. goraeensis* Raym. It does not exist in *H. lanarius* Sm., where both males and females hibernate in their natal cells over winter, and both sexes emerge in early spring. *H. seductus* Ckll. has the same sequence.

Nevertheless, in spite of this divergence from the typical pattern, there are yet two forms of females in *H. lanarius* Sm. Armbruster (1916) and Legewie (1922) agree on the three discrete generations for the European *H. malarchurus*, but maintain that the over-wintering generation is bisexual. This is true of the Australian *H. lanarius*, but it is certainly not the case in *H. dimorphus*.

The vernal virgins have a blackish-green head; a lighter metallic-green thorax, and the abdomen is of a clear apricot-colour. Excavation of over 100 shafts demonstrated that each vernal virgin had merely extended a tunnel from her natal cell, and had constructed for herself a group of eight or so cells.

The cluster of cells built by *H. cyclurus* Ckll. is much more compact, and may be lifted out in one lump, with the cells more or less contiguous and cemented together. The cluster of mud cells is even tighter, and arranged in the more orderly design of the Nomiine bee, *Nomia australica* Sm.

The subearthen colony may now contain over 60 cells in various stages of construction, but all the females will continue to use the main shaft. There is not any "mother" bee present as Fabre maintained, for not one individual field-bee of the autumnal brood survives the winter. This state

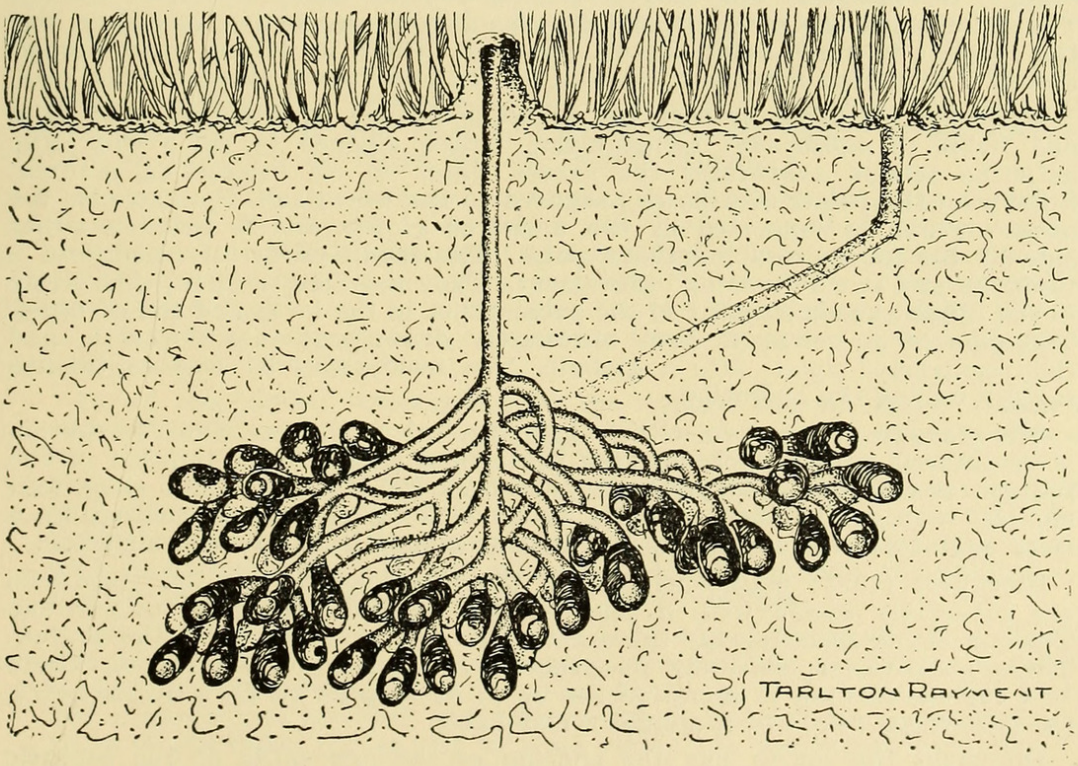

Fig. 3: Graphic section of "nest" of colony of *Halictus dimorphus* with brood at all stages.

also persists in the seven species mentioned above. In *H. leucorhinus* Ckll., and *H. eboracensis* Ckll. there is only one generation, of both sexes, which emerge in midsummer; the smaller males a few days before the females, as in all bees.

Each oval cell measures 7 mm. approx. at the long axis, and 3.5 mm. at the short, and there is an impalpable thin lining of a colloidal silvery skin, a secretion of the salivary glands of the mother. When provisioned and supplied with an egg, each cell is sealed off from the tunnel with a wad or plug of masticated "mud." The cell-walls are made of the finest pebbles cemented together with the salivary secretion. At a casual examination, they would be said to consist of refined mud. There is not a trace of the thick white porcelain described by Fabre.

The subearthen cells and galleries are maintained in a perfect sanitary condition, for every scrap of biological debris is quickly disposed of by a horde of milk-white acarine mites in the genus *Caloglyphus*. The mites literally cover the walls, and when a bee dies the symbiotes soon attack the body. They eject a drop of clear liquid onto the material, which is dissolved and then ingested.

The mites have not been observed on the field-bees, which could not, of course, be a factor in dispersal, since the female bee returns to the one colony. The mites have, however, been observed to cluster about the apical, segments of female mutillid wasps, which are parasitic on the bees, and consequently haunt many shafts when seeking a suitable host to receive an egg. The parasitic mutillids, and *not* the bees, are the chief agents in the dispersal of the mites.

The store of food for the larval bee is a perfectly smooth sphere of pollen, 3 mm. in diameter, and the colour varies according to the botanical source of the grains, and ranges from ivory-colour to olive; from russet to brightest orange, for halictine bees are polylectic, visiting many botanical species. The exterior of the pudding contains the largest proportion of nectar, but the interior is much drier, almost powdery. There is, too, a small proportion of a biological substance secreted by the pharyngeal glands of the head.

When first gathered by bees, the nectar of flowers is, of course, very thin, and liable to subsequent fermentation unless ripened in some way. The halictine female evaporates the excess water in an interesting manner. Sitting on the petals of a flower, exposed to the warm sun, she extrudes the nectar, which is supported by the upcurved glossa, and is held on either side by the galeae and maxillary palpi. The mouth-parts then maintain a rapid up and down "beating" movement. They are able to effect this owing to the hinge-like attachment of the submentum to the lorae and the cardines. The globule of nectar is thus alternately drawn out into a thread, and then contracted again into a globule. The nectar can be seen to thicken rapidly during the operation.

The elongate-oval centrolecithal egg is typical of all bees, and the chorion is sculptured with a more or less pentagonal pattern, the imprint of the follicle cells lining the ovariole. It measured 250 microns at the short axis and 450 microns at the long, and is attached to the pollen-pudding by a clear agglutinative secreted by the mucous glands in the female abdomen.

Stockhert (1923) maintains that in the European species the brood-cells are invariably sealed with a plug of mud immediately after oviposition. That is established for all the Australian species studied by the author. There is, however, certainly no progressive feeding of the larvae. There is a copious feeding of secretion for up to as long as 20 days in *Exoneura*, an Australian genus of a simple social habit.

On about the fourth day the chorion of the egg splits at the cephalic pole, and the young larva soon begins to feed on the pudding, which it does by sweeping its head to and fro as the mandibles pare off thin slices clear across the store. The larval mandibles have a molar area for the grinding

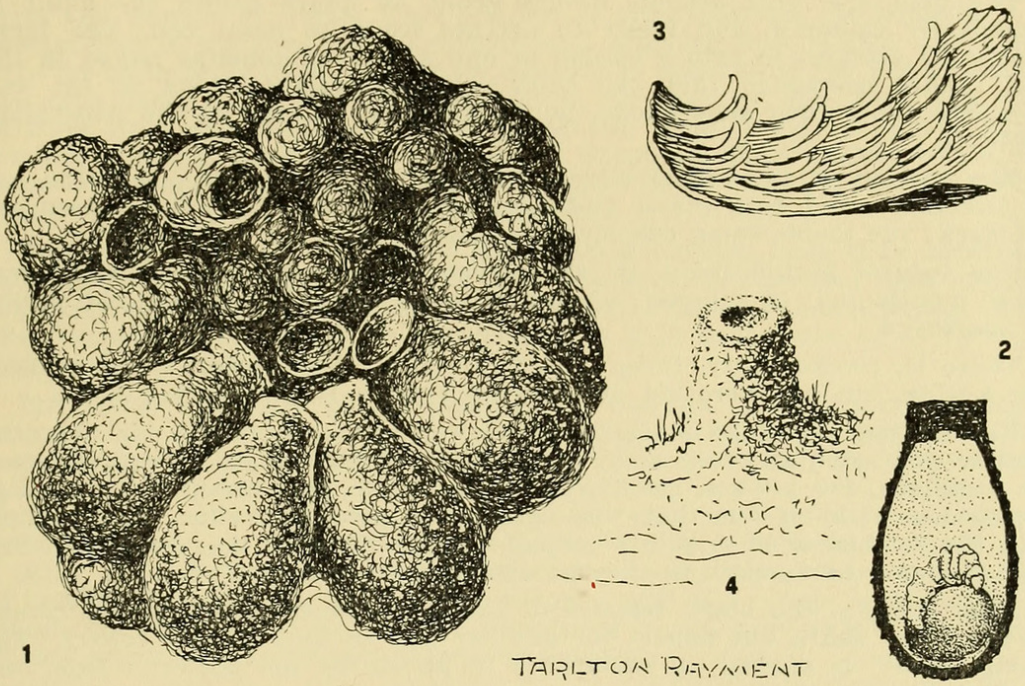

Fig. 4: Details of *Halictus cyclurus* and *leai* Cockerell.

1. A group of the small earthen cells of *Halictus cyclurus* Ckll.
2. A section of the cell showing a larva feeding on the pollen-store.
3. The old pollen-mat of *H. leai* Ckll. breaks down into a number of salivary flakes, and reveals the method of construction.
4. The tiny chimney-stack over the entrance to the shaft.

of the pollen-grains, and some eight to ten days are spent in consuming the "pudding." The soft exterior containing more nectar is not consumed first as described by Fabre for his French species.

Hymenopterists are almost unanimous in agreeing that the larval food of wild-bees consists solely of pollen and honey, but that is mere opinion, unsupported by either experiment or analytical chemistry. Indeed, Snodgrass (1925) goes so far as to assert that only the hive-bee *Apis* secretes the predigested "pap" that is fed to the larvae. The author (1951) was able to demonstrate that *Exoneura* continues the progressive feeding of pap for weeks longer than the hive-bee.

In all the genera investigated by the author, the six rectal glands are excessively large in species, such as *Halictus*, that supply only a pollen-ball for the larvae, but they are exceedingly small in other species, such as *Trigona* and *Apis*, which continues with progressive feeding of the larvae with the pharyngeal secretion over a lengthy period. Pavlovsky and Zarin (1922) concluded that the function of the glands is production of a catalase with oxidising action. In any case, the halictine glands are covered with a close network of tracheal tubules to supply oxygen.

The fully grown halictine larva measures 5 mm. in length, but when the compound eyes begin to colour, about 11 weeks later, the length is reduced to 4.5 mm. The white crystaline pupa has a very large head and thorax, and a somewhat "prickly" appearance, due to numbers of nodes on various parts of the body, but chiefly in rows round the abdominal segments.

The pollen residues are retained in the mesenteron until its junction with the proctodaeum is effected. The faeces are then voided, just prior to the onset of metamorphosis as a series of moniliform "threads."

The fifth and final ecdysis occurs about 36 hours before the adult is completely coloured, and ready to emerge from its natal cell. The larva makes no attempt to spin a cocoon of any kind, and remains naked in the cell. Fabre concluded that the thick white porcelain lining of the cell rendered the cocoon superfluous, but this cannot be true of the Australian *Halicti.*

The progeny of the vernal virgins emerges in midsummer, about the end of December, and both males and females are present, but both sexes are jet-black; the males being considerably smaller than the females.

The longest period taken by the larvae to reach full development was three months, but in summer, when the temperatures are higher, the period is shortened.

There is, consequently, three months, covering the winter, when no bees are a-wing, but a generation of coloured virgins is hibernating below.

The mating may take place on the flowers, or even in the air over the shafts, and copulation is only momentary. Vision must supersede scent on occasions, for a black male, *H. raymenti* Ckll., was observed to attempt copulation with an ant that was carrying a piece of yellow leaf, and so had the semblance of a yellow-bodied female. None of the species studied was observed to copulate in the burrows as described by Fabre.

After mating, the black females of the midsummer brood do not return to the natal shaft, but depart for another site to form a new colony. The damp "spoil" is pushed up backwards in pellets by the posterior legs, and at first forms a tiny tumulus, or mound, at the entrance; later, some of it will be built into a short rough-cast turret a few millimetres tall. It is, however, soon dispersed by rain and wind, and only a discoloured patch of subsoil remains to indicate the position.

This foundation of a new colony by a lone mated female has been observed over many years, and was confirmed in 1952 by Clifford Beauglehole, of Portland, Victoria, who was co-operating with the author in the study of *H. cyclurus* Ckll. and *H. demissus* Ckll.

It can be assumed, then, that the sexual urge is the determining factor in driving forth the mated female from the parental home to found a new colony. The virgin *Halicti*, lacking such an urge, merely extend the natal

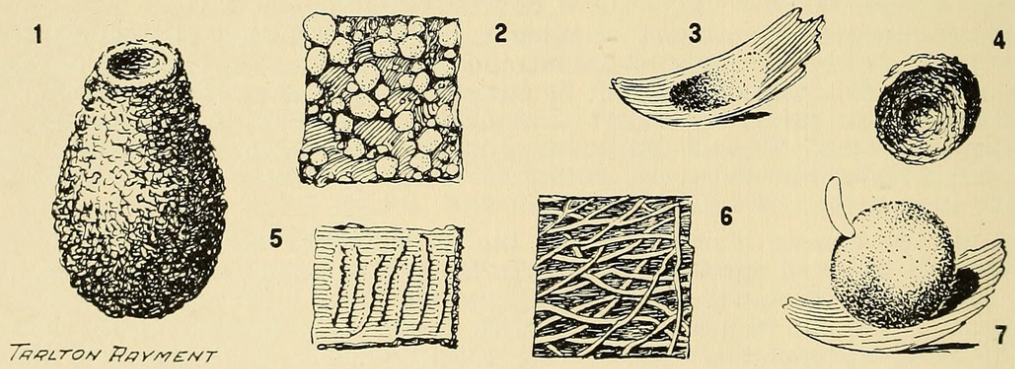

Fig. 5: Details of *Halictus emeraldensis* Rayment and *H. leai* Cockerell.

1. Earthen cells of *Halictus emeraldensis* Raym.
2. Exterior wall highly magnified to show the grains of sand.
3. Scale or mat of *H. leai* to receive the pollen-pudding.
4. The earthen plug for closing the cell.
5. Streaks of pollen regurgitated by the larva.
6. Interior wall of cell showing the strands of silk.
7. Pollen-mat, with pudding and egg of *H. leai* Ckll.

cells and remain at home. This concept is supported by the behaviour of worker-bees of the hive for, as undeveloped females, they remain inside the hive for 14 or more days before they venture to issue from the hive, whereas the true female, the "queen," flies forth in four or five days and will produce only drones, or males, if prevented from doing so. Fully sexed females in many other genera of bees and wasps die quickly when restrained from emerging to the nuptial flight. Virgins have, however, survived long confinement, up to 8 weeks, by the author.

Numerous "nests" of the mated midsummer females have been excavated in January, and without exception, only one black mother has been present, together with six or eight cells in various stages of construction. This observation was confirmed by Beauglehole in 1952 in the case of *H. cyclurus* Ckll. and *H. demissus* Ckll.

The author succeeded in establishing new colonies of *H. dimorphus* Raym. at a distance of 22 miles from the parent shafts. Hibernating virgin females were dug out of the cells in late winter; at the end of July. Knitting-needles 3 mm. in diameter were thrust down for 12 centimetres into similar soil. Two females were held over each shaft and they hastily descended, for at that stage the bees are positively geotropic. The shaft was then closed with a pellet of clay. However, after the bees have once flown, there is a change of tropism, for then the bees are heliotropic, and will refuse to descend, but simply fly off and are lost. These introduced virgin females did not depart in any way from the typical behaviour pattern.

The progeny of the black bisexual generation of midsummer emerges in autumn, and is comprised exclusively of jet-black virgins. Several hundreds of shafts have been investigated, and five others were under daily observation from 2nd Aug. 1948 to 25th Mar. 1950, and not one male was taken in spring throughout that long period.

Stockhert (1923) concluded that the old females of the autumnal generation of *H. malachurus* survive through the following spring and summer. That is most certainly not the case in any Australian *Halictus* studied by the author. Not one female lived to see her daughters emerge.

The progeny of the black autumnal virgins are fully developed before the winter, but the individuals will all be green, with the abdomen of a lively apricot-colour. They do not come out to fly, but semi-hibernate in their natal cells throughout the winter entirely without food; they are nevertheless strong enough on the wing when they emerge in spring.

There are critical differences in the gross morphology and anatomy of the vernal, summer and autumnal halictines, but they are all microscopic in character. The results of a long series of micrometer measurements are equally interesting, but are beyond the ambit of this nota previa. The triangular appendage of the labrum differs in the three females, not only in *H. dimorphus*, but in several other species having three discrete broods.

In the author's collection the specimens are distinguished by green labels for the vernal (primarius) virgins; yellow for the bisexual or summer (secondarius) brood, and blue for the autumnal (tertianus) virgins.

It has been demonstrated, then, that the new colony is undoubtedly founded by the mated female of midsummer and the population is then at its lowest ebb, but her six or eight virgin daughters of the autumn may rear 36 or more red virgins, consequently the colonies are most populous during spring and autumn.

An investigation of the chromosomes is in progress, in the hope that some light will be shed on the genetical mechanism controlling the phenomenon, but it teems with difficulties—the small size; the mere finding of such minute cells; the problem of determining to which brood the larvae belong, since the latest of any one brood may overlap the earliest of the succeeding one—the difficulties encountered in tracing any individual of a populous colony in a subearthen "nest" are almost insuperable.

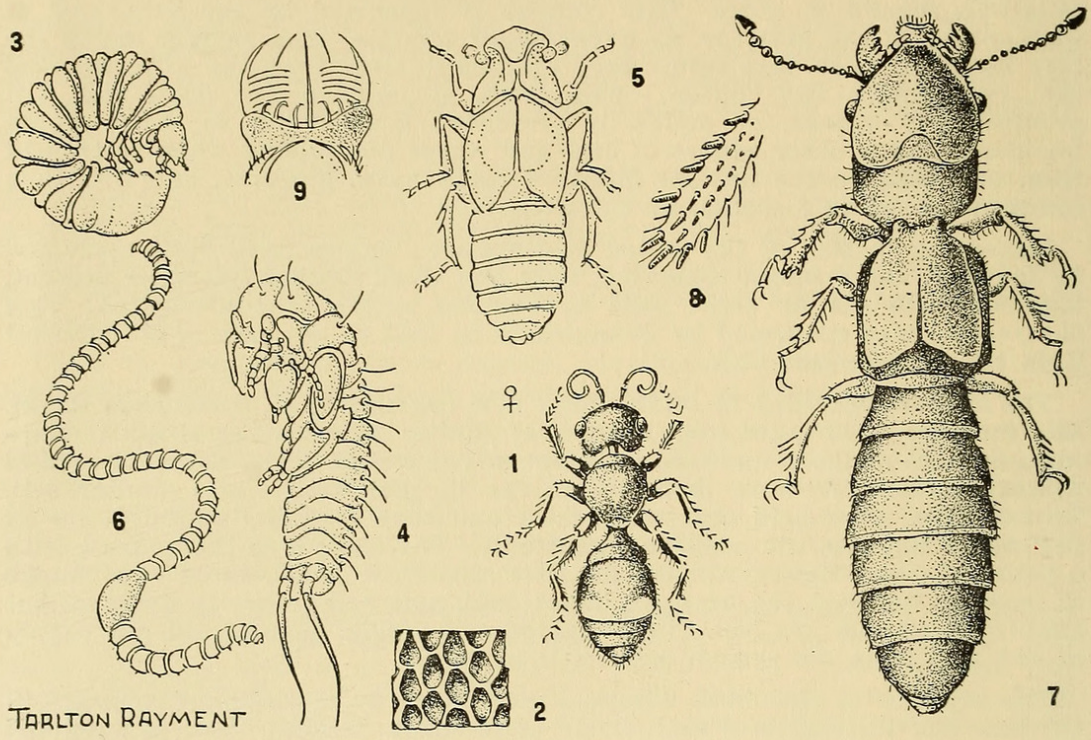

Fig. 6: The biological associates of *Halictus dimorphus* Rayment.

1. A small mutillid parasite, *Ephutomorpha gondennda*, Raym.
2. The pyriform sculpture of the mesothorax.
3. Minute larva of a beetle.
4. The white pupa of a beetle, sp. unknown, measures only 2 mm. in length.
5. A small immature beetle.
6. A small white segmented worm has a number of chaetae, and many had a "cocoon" or egg-case (Oligochaeta).
7. The largest beetle, *Oephronistus australicus* Bl., measured 5.5 mm. approx. in length.
8. Tibia of anterior leg more highly magnified.
9. Setae of mouth-parts more highly magnified.

The author's researches confirm the claim of Armbruster (1916) and Legewie (1922) that there are in certain *Halicti* three discrete broods and that the virgins produce both males and *females;* the males appearing in only one of the three broods. Prof. W. M. Wheeler (1933) concluded: "If Armbruster's and Legewie's interpretation is correct, then the Dzierzon rule has been 'shot to pieces'."

Translocation of Genes ?

The discovery in 1954 by Clifford Beauglehole of a large colony of the bee, *Halictus* (*Chloralictus*) *erythrurus* Ckll. at Gorae West, via Portland, Victoria, enabled the author to shed additional light on the genetical inheritance of these remarkable bees. The collector estimated that the colony contained over 1,000 shafts.

Excavating portion of the sub-earthen colony at crucial intervals revealed three discrete generations similar to those of *H. dimorphus* Raym., but with one fundamental departure. There is a like vernal (September) brood of virgin females (Primarius), with green head and thorax, and apricot-coloured abdomen.

Then there is a bisexual mid-summer (December) brood, the Secondarius females of which are coloured exactly like the vernal virgins, although the males with which they mate are again jet-black.

The progeny of these mated pairs are all virgin (Tertianus) females of green and apricot colour, emerging about the end of March. It is the over-wintered progeny of these Tertianus females that emerges in September.

Since the males are invariably jet-black throughout the chloralictine cluster studied in this research, the author postulates that the metallic colours are sex-linked with femaleness, so that the unique black Secondarius females of *H. dimorphus* Raym. present a tantalizing problem to the investigator. The males of ten or so species are all small, jet-black, and exceedingly difficult for the taxonomist to determine.

The mid-summer or bisexual brood contained a number of extraordinary mutations of black males with monstrous heads, and often with only the stubs of wings, suggesting those of certain mutations obtained by Morgan in his experiments with *Drosophila melanogaster*. The huge heads at once suggest parallels with Wheeler's dinergates in ants.

The author has already described (Victorian Naturalist, Ap. 1950, pp. 233-238), a number of mutations in bees, and which appear to be parallels with many of those recorded by Morgan for fruit-flies; there were white-eyed, and even totally blind drones. It would appear, then, that if the difficulties of obtaining authentic larvae from specific females were not insuperable, the genetical investigation of the chromosomes of halictine bees would produce results even more startling than those presented by the flies. Notwithstanding the difficulties involved, investigation of the larvae is being continued at every available opportunity.

The author postulates that the widest distribution connotes the oldest species, and since *H. erythrurus* Ckll. ranges down the coastal areas from Queensland to Western Australia, and even to Tasmania, he suggests that it is probably the original root from which so many of the chloralictine bees have branched.

A graphic comparison of the extraordinary and the normal head is presented by the drawings, but the insects were carefully measured, and comparisons are given below in microns.

HEAD.

	Length of	Width of	Thickness of
Normal male	1,300	1,500	700
Mutation male ..	2,000	1,900	1,500

COMPOUND EYES.

900	400
800	200

MANDIBULAE.

1,000	450 at base
1,500	700

Mutation Male:—Length 5.5 mm. Polished black, some amber colour on legs.

Head almost hairless; supraclypeal area fused with amber clypeus, which has two lateral teeth on anterior margin; mandibles large, with a conspicuous tooth on the lower margin near base; antenna filiform, black above, ferruginous beneath; labrum ferruginous; two large red maculae laterad of insertion of scapes; articles of the flagellum bear an amber flange. The basal segment of the labial palpus is expanded and dark; genae largely red, and excessively developed, thus creating a huge fossa.

Prothorax laterally reddish; scutellum smooth, dull, impunctate; abdomen broad and robust; the sterna with only dark lateral patches suffused with black (they are almost wholly suffused in the allotype, and partly so in male of *H. paradimorphus* Raym.).

Legs, especially anterior coxae, trochanters, femora and tibiae are yellow, and very large and robust (see No. 7 in Plate XXII). Wings exceedingly short, and in some specimens, reduced to mere stubs.

It is impossible to include in this nota previa the complete account of the anatomy and biology of these remarkable bees, but they are dealt with exhaustively in the author's large monograph of the subgenus which is awaiting publication.

REFERENCES.

Armbruster, L.—Zur Phylogenie der Geochlechts-bestimmungsweise bei Bienen. Zool Jahrb. Abt. Syst., 40: pp. 323-386. 1916.

Legewie, H.—Beitrage zur Biologie der Bienengattung Halictus. Mitteil, Badisch. Landesver, F. Naturk. U. Natur-schutz in Freiburg, i, B. I, pp. 235-257. 1922.

Pavlovsky, E. N. and Zarin, E. J. Quart. Journ. Micro. Sc. new ser. p. 15-17, 1922.

Rayment, Tarlton:—A Cluster of Bees, pp. 236-333, 1935.

Rayment, Tarlton.—Australian Zoologist, xi, 4, pp. 285-313, 1951.

Rayment, Tarlton.—Bees of the Portland District, p. 13-26, 1953 .

Snodgrass, R. E.—Anatomy and Physiology of the Honeybee, pp. 171-173, 1925.

Stockhert, E.—Ueber Entwicklung und Lebensweise der Bienengattung Halictus und ihrer Schmarotzer zugleich ein Beitrag zur Stammesgeschichte des Bienenstaates, Konowia, 2, 1923.

Wheeler, W. M.—Colony-Founding Among Ants, pp. 121-145, 1933.

EXPLANATION OF PLATE XX.

The colourful females of the spring brood are all virgins; the males and mated females of the summer brood are entirely black (see plate for details).

[The grateful thanks of the President and members of the Society are tendered to the "Argus" newspaper, Melbourne, for generously supplying, free of cost, the coloured plate which illustrates this paper.—Ed.]

EXPLANATION OF PLATE XXI.

1. Tumulus and crater of "spoil" from shaft is soon dispersed by the wind.
2. The mound "heaves" and tumbles as fresh material is thrust up from below.
3. A pebble is sometimes used to close the aperture.
4. A fillet of "cement" is first attached to one side of the pit-mouth.
5. A second fillet is added.
6. A third is joined to the periphery.
7. The fourth leaves only an opening in the centre.
8. A final pellet closes the aperture.
9. Pellets of "cement" are brought up in the bee's mandibles, and built round the aperture to make the friable rim hard enough to resist the wear of traffic.
10. A pebble wedged in the calcar of a Primarius female.
11. The cement rim of the periphery is finally smoothed with the tip of the abdomen.
12. The dentate hind calcar is used to pare off the "spoil" by a thrust downwards.
13. Patella or knee-plate (basitibial plate) of female.
14. The position of the bee descending the shaft, with the patellae pressed against the wall.
15. The finely serrated calcar is used to open the pollen-sacs of the flowers, and pollen-grains often fill the serrations.
16. Some of the black Secondarius females have tridentate mandibles.
17. When a "chimney" impinged on a leaf of *Hypochaeris*, the bees cut a neat round entrance through the leaf.
18. The abdomen of the female often has a few pebbles attached to the tip after she has completed the cementing of the rim about the "door."

EXPLANATION OF PLATE XXII.

Nos. 1-10.—Mutation male, *Halictus erythrurus* Ckll.

Nos. 11-18.—Allotype male.

Nos. 19-26.—Secondarius female *H. erythrurus* Ckll.

1. Front view of the large quadrate head of mutation. (Hairs not included in any diagram.)
2. Lateral view showing excessive development of the genae to a tooth.
3. Clypeus with its dentate margin viewed by transmitted light.
4. Genitalia at same magnification as No. 16.
5. Mandible, with tooth, at same magnification as No. 13.
6. Labrum.
7. Anterior leg at same magnification as No. 18.
8. Strigilis of anterior leg is alike in both males.

9-10. Two abdominal sterna at same magnification as Nos. 11 and 12.

11-12. Corresponding abdominal sterna of allotype.

13. Acute mandible.
14. Front view of head-capsule of allotype.
15. Lateral view.
16. Genitalia of allotype male.
17. Labrum.
18. Anterior leg; compare with No. 7.
19. Anterior coxae of female with prioperceptive pore-organs—Marked with an arrow.
20. Bidentate mandible of female.
21. Ventral view of prosternum of female at articulation of anterior coxae.
22. Hind calcar has one large tooth.
23. Anterior wing of Secondarius female.
24. Punctation of mesothorax is alike in both males.
25. Labial palpus of mutation with its enlarged dark basal segment.
26. Appendage of labrum of female.
27. Four apical segments of flagellum of mutation.