The biology and behaviour of *Poekilocerus bufonius* Klug, with special reference to the repellent gland (Orth. Acrididae)

BY

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The genus *Poekilocerus* Serville is distributed throughout East and North Africa, Arabia and S.-W. Asia (Chopard 1943). The range of *P. bufonius* Klug includes N. Africa (Egypt), E. Africa (Sudan) and S.-W. Asia (Johnston 1956); in Israel it is found in the desert areas south of Wadi Raman, extending to the North along the Araba Valley and the Dead Sea depression. The Dead Sea population is probably the most northern one in Asia.

BIOLOGY AND BEHAVIOUR.

P. bufonius is not uncommon throughout its range but occurs rather sporadically. For instance, on July 17, 1957, a great number (30 males and 17 females) were collected on a single plant of *Daemia tomentosa* (Asclepiadaceae). It is always found near plants of the family Asclepiadaceae. In the areas inhabited by it, there are hardly any places containing these plants without some individuals to be found. On isolated plants of the Asclepiadaceae one may encounter several specimens, while at the same time it is rarely found on other plants which abound in the neighbourhood. Throughout this study (1952-1958) several hundreds were collected, all of them on Asclepiadaceae or in their vicinity.

The species is rarely met with in the open, but is usually hiding among branches in the centre of a bush. In summer its activity is limited to the morning and afternoon, when the temperature is between 26-30° C. During the hot hours of the middle of the day, every form of activity ceases.

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When one approaches this insect up to a distance of 2-3 meters, it moves to the other side of a branch, always keeping the branch between itself and the observer, to whom only parts of the antennae, eyes and tarsi are visible. When the observer moves around the bush, the grasshopper will move slowly in the same direction. When more closely approached, they drop to the ground, hiding, if possible, in dense vegetation. When driven out into the open, the males, which have relatively large wings (see table I), tend to fly, while the

TABLE 1.

Measurements of adults.

Sex	Weight in gr.	Length in mm.		
		body	Elytra	hind femur
male	0,930-1,180	33,4-40,3	22,0-27,6	11,7-15,0
female	2,385-5,080	43,5-68,0	24,0-37,0	16,1-24,5

larger and heavier females, with the comparatively small wings, do not use them and try to escape by jumping.

Adults may be collected throughout the year, but they are most common during May-July, this period, apparently, being their main mating season, since most of the specimens were in copulation at this time. During this season the abdomina of the females are distended and only 3-4 segments are covered by the wings. Hoppers were collected in nature during March-April. Younger hoppers are dark-grey with a pattern of yellow spots; in the fourth and fifth stages they are very dark and similar to the adults. Their behaviour on shrubs is like that of the adults, but in the open they remain motionless and, owing to their protective colouring, may be overlooked.

Egg-laying females were observed twice in nature: in April in Wadi Menaye (South Negeb) and in July at Ein-Gedi (N.-Dead Sea). In both cases the connection between oviposition-place and moisture conditions was obvious. In the W. Menaye the female dug in the sand at the foot of a rock, where the sand was as dry and hot, but a depth of 3-4 centimetres the sand was markedly cooler to the hand and moisture was felt at a depth of 8-10 cm.; still deeper, at the tip of the abdomen, the sand was quite wet. The intersegmental membranes were extended 4-5 cm. each, and the yellow eggs were clearly visible through the transparent skin.

At Ein-Gedi, in July, the egg-laying female was found under a *Calotropis procera* shrub, in a dry river bed; humid sand was reached at that spot at a depth of a few centimetres.

Breeding in the laboratory.

The terraria used for breeding had the size of 50 × 30 × 30 cm., the floor was covered with 20 cm. of wet sand. Fresh food *(Calotropis procera, Asclepias curasavica, Cryptostegia* sp.) was given daily. For continuous normal breeding the temperature was 30° C (± 2).

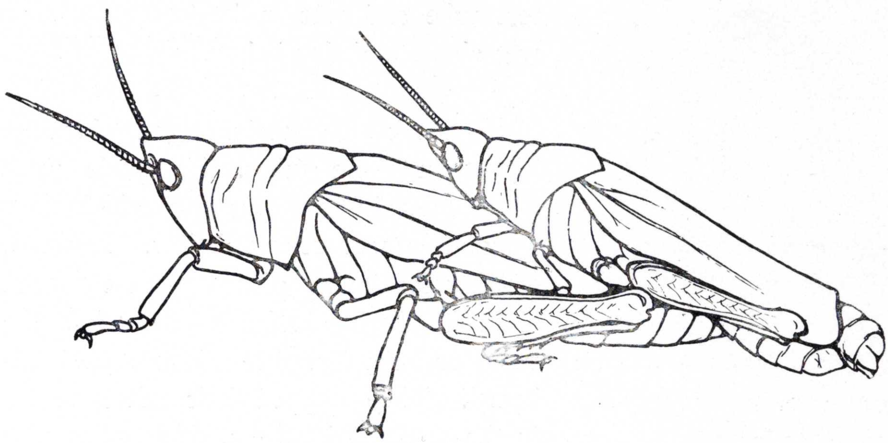

Fig. 1.—The copulation (according to a fotograph).

Copulation: The male approaches the female from the side and touches her with his quickly moving antennae. If the female does not move, the male mounts, grasping her pronotum with his forelegs. Unresponsive female reacts to the soliciting male by repelling movements of all her legs and will try to throw him off, especially with her hind legs. After the male is securely settled on the female's back, male and female may sit without further movements for some time. From time to time the male pushes his abdomen downwards alongside the abdomen of the female. Copulation begins only when the female responds to the movements of the males abdomen by upward movements of the end of her body.

The antennae of the aroused male move in all directions. He then draws backwards along the female's back giving up his position on the pronotum (fig. 1). The copulating pair sits motionless for 12-18 hours.

Copulation between *Poekilocerus* males and *Schistocerca gregaria* females was observed in captivity where both species were kept together.

The selection of oviposition sites: In some of the terraria the sand on the floor was replaced by a cardboard lifted 20 cm. above the floor, in which holes were made, several test tubes 20 cm. long and 3.5 cm. wide were inserted, with the openings on the same level with the carboard. The tubes were filled with sand, which was either dry or wet, or dry in the upper part of the test tube and wet in ist lower part, or wet above and dry below.

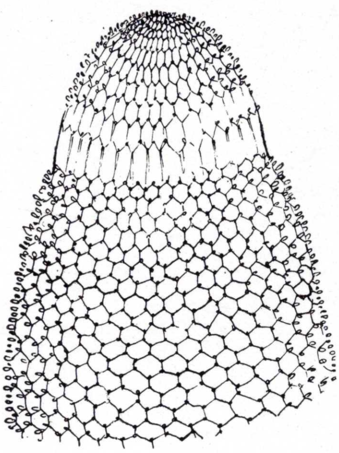

Fig. 2. — Structure of the egg shell.

Between June 1954 and December 1956 about 60 females were observed laying in these tubes. Egg-pods were deposited only in those tubes which were completely wet or wet-below. Females, looking for laying places, were observed to begin digging indiscriminately into the tubes or even trying to dig into the cardboard. They stopped their efforts to dig in the cardboard 0.5 cm. thick, once they passed through it.

In the dry tube and in the wet-top, dry-below tube, they stopped digging at a depth of 6-8 cm., withdrawing their abdomens and began the search for a better oviposition place. That depth seems, therefore, to be a critical zone for the determination of the fitness of the oviposition site. Only when they find this critical zone wet, they continue digging to the depth of 16-19 cm. and then start to deposit their egg-pods.

During oviposition the whole abdomen, and part of the thorax, to the base of the hind legs, is buried in the ground. The wings are held close to the ground, and sometimes are somewhat spread.

The eggs, numbering 112-254 (Table 2) are 6-8 mm. long. and 1-2 - 1.5 mm. wide. The structure of the lower end of the egg shell is shown in fig. 2.

TABLE 2.

Egg-pods.

No. of pod	No. of eggs	Weight in mg.	
		Total	average per egg
1	254	1841	7,2
2	193	1012	5,2
3	112	694	6,2
4	158	1295	8,2
5	172	1049	6,1
6	212	1378	6,5
7	132	730	5,5
8	196	1156	5,9
9	206	1194	5,8
10	195	1125	5,7
11	160	1180	7,3
12	145	1060	7,3

The upper part of a pod (7-10 cm.), is a hollow tube of foam with a thin partition. The fresh egg-pod is light yellow, turning into brown a few hours later.

The laying depth (17-19 cm.), compared with other grasshoppers, is remarkable, but similar deep layings were observed in related Ethiopian grasshoppers (*Phymateus aegrotus* Gerst., *Poekilocerus vittatus* Klug, and *P. hieroglyphicus* Klug).

The increase in the length of the abdomen, during oviposition is due to stretching of five intersegmental membranes, which after the oviposition contract to normal size. Many females, in which the abdomen did not completely contract after oviposition, died later (observation in laboratory).

Nine females kept between June and August 1954 in a terrarium laid 35 egg-pods, making an average of 3.8 pods per female.

Development period: The development of eggs kept continuously in wet sand, at a temperature of 30° C (± 2°), lasted 30 days, while those kept in the same humidity at 26° C hatched after 45-48 days. Hatching success wass generally 100 %.

Hatching was delayed in egg-pods kept in tubes which were allowed to dry slowly. Examination of these eggs, within the second month after oviposition and later, revealed fully developed embryos. When moisture was added, hoppers emerger two hours later. The hatching percentage diminishes with time, and from egg-pods kept dry for a whole year, only 30-40 hoppers were hatched. Further examination of the egg-pods which were kept dry for a year showed that only the eggs in the central part of the pods hatched, while those on the periphery were completely desicate.

The process of hatching is similar to that of other Acrididae. In few cases, in which the egg-pods were not straight but more or less curved, the hoppers dug their way up straight through the sand and not along the curvature of the egg-pod, and many died on their way through the sand.

The development of hoppers: Two batches were reared under different conditions for a whole year (from 4.7.1955 to 10.7.1956): group A was kept indoors at 30° C (± 2). This group produced four generations during the year.

Group B kept aoutdoors, getting several hours of insolation almost each day, in the climatic condition of Tel-Aviv, has given tise to only one generation during the year. Similar results were obtained during 1957 and 1958.

Measurements of the different hopper stages are given in Table 3.

TABLE 3.

Measurements of hoppers in mm.

Stage	Length of	
	body	hind femur
I	6,9 - 9,3	3,0 - 3,6
II	11,0 - 16,0	4,2 - 6,5
III	16,0 - 22,2	7,0 - 10,0
IV	25,0 - 34,2	10,2 - 12,2
V	35,0 - 44,5	12,0 - 16,2

Under optimal conditions, 12-16 days elapse between the last moult and maturity. Egg laying occurs 3-4 weeks after the last moult. The males develop faster than the females and they mature 8-10 days earlier.

Young hoppers begin to eat on their second day. During stages I and II they will eat almost only Asclepiadaceae plants, which they invariably picked out of 30 different species offered to them. Stages III and IV, on the other hand, though preferring Asclepiadaceae, in the absence of them ate also other plants (Table 4).

TABLE 4.

Plants that were eaten by hoppers

(from 30 various species).

Portulaca oleracea	Portulacaceae
Nicotiana glauca	Solanaceae
Atriplex halimus	Chenopodiaceae
Artemisia monosperma	Compositae
Urospermum picroides	"
Lactuca scariola	"
Crepis aspera	"

Out of some 700 hoppers of all stages were offered food other than their preferred food. Only 8 developed into adults (Table 5). Development success on Asclepiadaceae averaged 90 %. The extreme dependence of the younger stages on Asclepiad-plants necessitates the location of the oviposition site in the proximity of these plants.

TABLE 5.

The success of development on various plants.

Date of exper.	No. of hoppers		No. of adults	
	Asclepiad plants	various plants	Asclepiad plants	other plants
15.11.1955	100	100	70	—
2. 4.1956	60	100	50	5
25. 5.1956	50	300	42	1
10. 7.1958		200		2

Moulting individuals and fresh exuviae are often devoured by others; they especially selected the region with the poison gland.

In nature the general colour of hoppers is dark grey, with a pattern of yellow spots, becoming dark-blue in the adult.

In hoppers bred under artificial light, the background colour was light yellow-grey in the hoppers, and various shades of grey in the adult. Those bred in sunlight attained the normal dark coloration. The darkening process was arrived only with hoppers of the 1st and 3rd stage, whereas later stages remained light coloured when transfered to sunlight. When kept under artificial ligth and given photoprediodic changes, no darkening of their coloration was observed. Thus the quality of the light seems to be the determining factor in background coloration.

The repellent gland.

A number of Acrididae are known to secrete repellent liquids that will afford a certain degree of protection from predators.

This phenomenon is usually as a purposeful action, produced under direct stimulus, mostly mechanical and, rarely, optical. In most cases a body liquid is secreter through small apertures located in various parts of the body. Vosseler mentions (1902) that in *Oedaleus senegalensis* Kr. and *Acrotylus insubricus* Scop. the appearance of a vesicle that protrudes under the pronotum. In *Aularchus miliaris* (Hingston 1927) there are two apertures in the pronotum, two in the metanotum and one in each leg. The best developed gland is found in the Pyrgomorphid genera *Zonocerus* Stäl, *Phymateus* Thunberg (Lotto 1950, Pawlowsky 1916), and *Poekilocerus* Serville (Ebner 1914).

The opinion prevalent amongst all authors up to now was that the repellent properties of the secretion are derived directly from the juices of the food plants, which ar in all cases poisonous weeds.

This assumption seems to have been in apriori one, it will be later shown that repellent qualities of the secretion are independent of the feeding habits of the insect and that the venom is a product of its metabolism.

Morphology and histology of the glands: The repellent gland is found in the first abdominal tergite, connected to the inside of the *musculus dorsalis intersegmentalis,* inside a special cavity of the tergum (fig. 3.).

The first traces of the gland could be detected in embryos; even at the oligopod stage one can detect clusters of granular cells connected dorsally with the hypodermis.

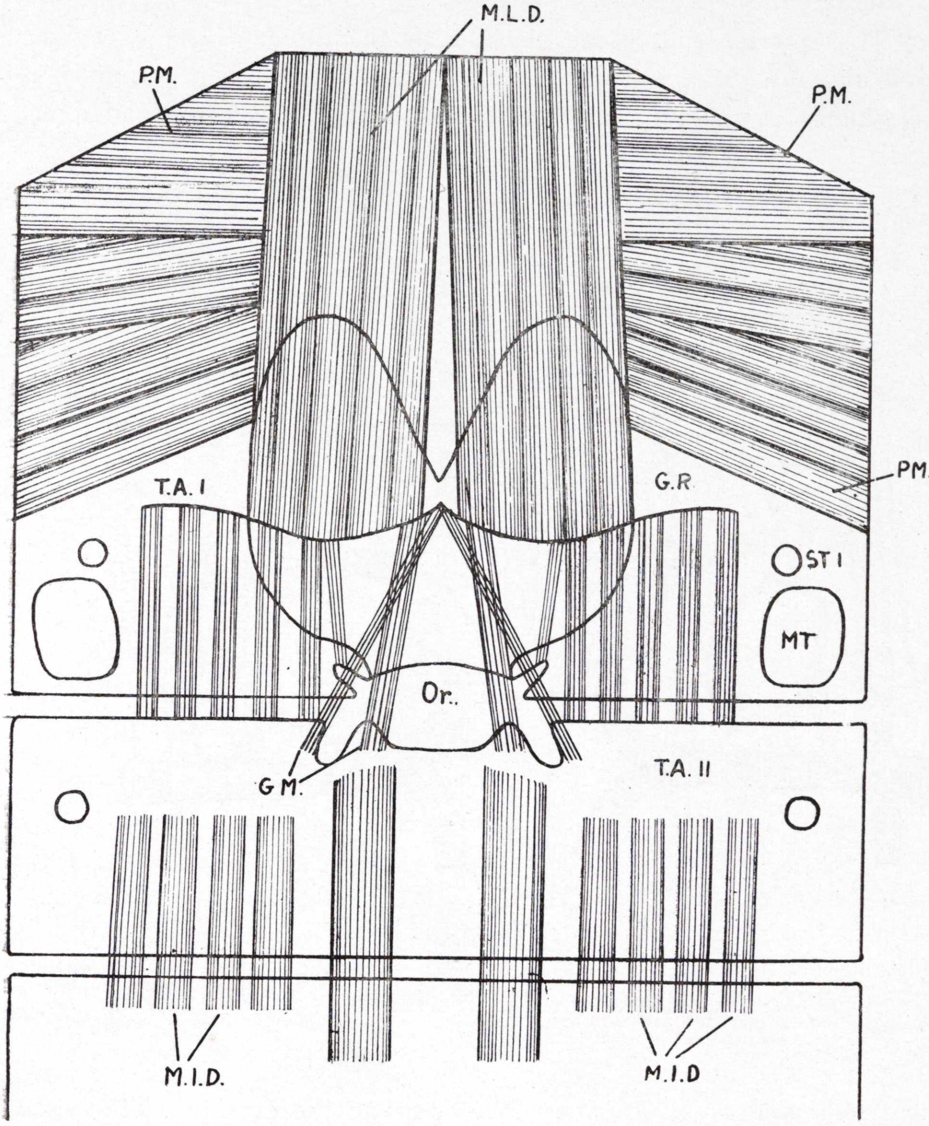

Fig. 3.—Diagram of the thoracical muscles and Repellent Gland: M.L.D., Dorsal longitudinal muscles.—P.M., Muscles of leg.—T.A. I., T.A. II., First and second abdominal tergites.—M.I.D., Dorsal intersegmental muscles.—G.M., Glandular musclefibers.—G.R., Repellent Gland.—ST. I., Stigma of the first abdominal segment.—MT., Tympanum.—Or., Orifice of the gland.

In adults the gland attains a size of 4.5-6.5 mm. Its shape is that of a whitish anterior bladder with two lobes. When the gland is congested with liquid, it becomes spherical.

Close under the gland lies the heart and a great number of branches of the tracheal system. Laterally the gland reaches to the base of the leg muscle (fig. 3.).

The anterior end of the gland, near the thorax, rests under the base of *musculus longitudinalis dorsalis*. At the other extremity it terminates at the thin intersegmental membrane between abdominal

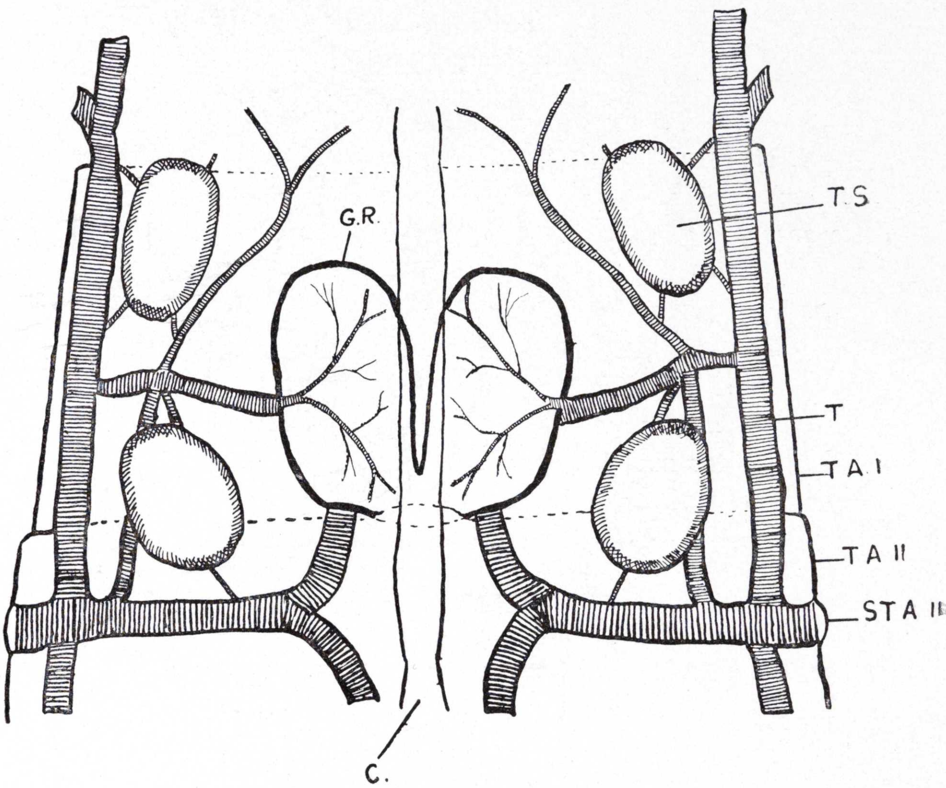

Fig. 4.—Tracheal tubes and sacs surrounding of the gland: G.R., Repellent Gland.—T.S., Tracheal sac.—T., Stigmal trachea.—S.T.A. II., Stigma of the second abdominal tergite.—C., The dorsal vessel.

tergites I and II, where its orifice opens to the outside. The edges of those tergites have peculiarly different, wavy outlines, and as a result, a narrow pore between the two rings is formed, which serves as an orifice to the gland.

The adaptive specialization of this structure is further emphasized at the anterior edge of tergite II, where, in addition to the little orifice and laterally to it, can be seen two tiny apodemata to which are attached special muscle fibers, which are connected to the inside of the first abdominal tergite, and by contracting, will narrow the slit, thus serving to control the intensity and direction of the squirting fluid (fig. 3.).

These muscles are part of the dorsal intersegmental musculature,

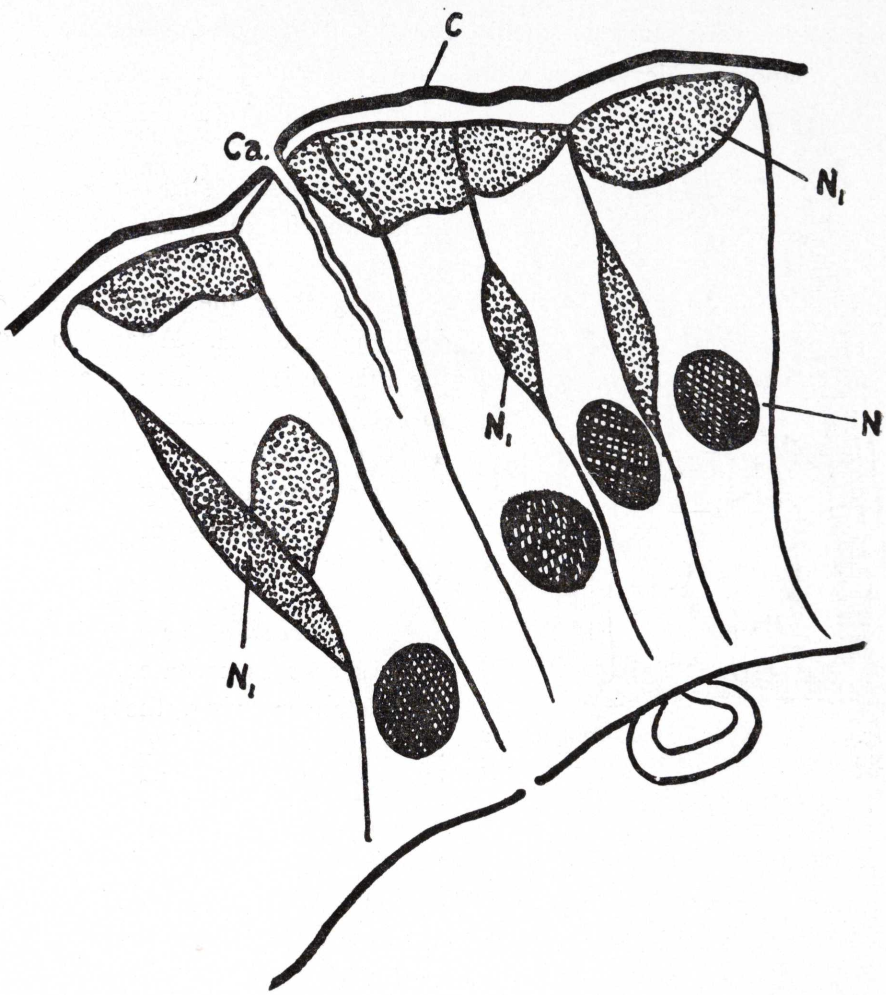

Fig. 5.—Diagram of the histological structure of the gland: N., Nucleus of a secreting cell.—N_1, Nucleus of the matrix cells.—C., Cuticle.—Ca., Canaliculi of a secreting cell.

and there are some very thin fibers that are connected with the membrane which envelops the gland.

For the network of tracheal tubes and sacs see fig. 4.

The histological structure of the gland (fig. 5.) is the same as of the glands of *Phymateus* spp. (Pawlowsky, Lotto). Beginning from the orifice of the gland the epithelium changes gradually, secretory cells replacing epithelial cells, which become cylindrical, their nuclei change globular to oval and lay closer to the base of the cell.

The watery liquid that fills the gland has a greyish to whitish colour, and a very pungent smell. The liquid part of the secretion rapidly evaporates, leaving a white dust, consisting of small particles of varying shapes and mostly rounded edges.

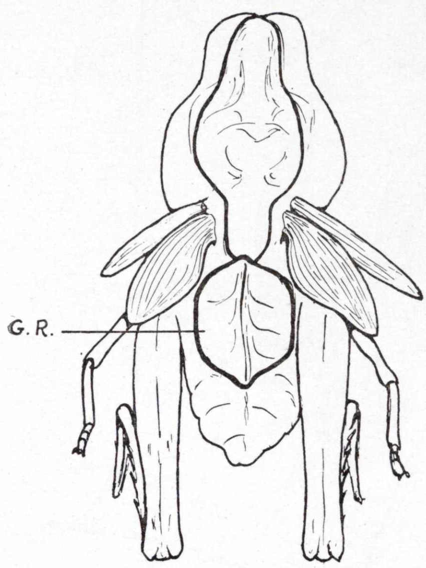

Fig. 6. — Exuviae (according to a fotograph): G.R., The cuticle of the gland.

The general structure of the gland was found to be identical in all stages. The gland functions immediately after the larvae are hatched and hardened. After moulting, the thin cuticule, which is attached to the glandular tissue is thrown off, and the discarded skin carries in its inside a very thin bag filled with the liquid contents of the gland (fig. 6.).

The function of the gland: When *Poekilocerus* is irritated, its body contracts somewhat, the head and the posterior end of the abdomen turning downward, the legs being held close to the body the antennae poiting straight ahead, parallel to each other. This position will be taken whenever pressure is exerted on the insect, or when it reacts to any strange object or approaching animal by means of optical stimulus (fig. 7.). If the irritation continues and the animal cannot escape, or when it is caught by hand, the repellent gland is activated. The curvature of the body increases and may sometimes attain a half-circle. The volume of the body is reduced in this way and consequently the internal pressure of the hemolympha rises. At the same time the intersegmental muscles of the back contract, the orifice of the gland is opened and the liquid is squirted out. Thus the actual ejection of the liquid is the result of the combined action of muscles causing internal pressure, chiefly on the hemolymph.

During secretion, the behaviour of the hoppers differs from that of the adults and it seems to be especially noteworthy, that the ejection of repellent fluid is more efficient in the hoppers than in the

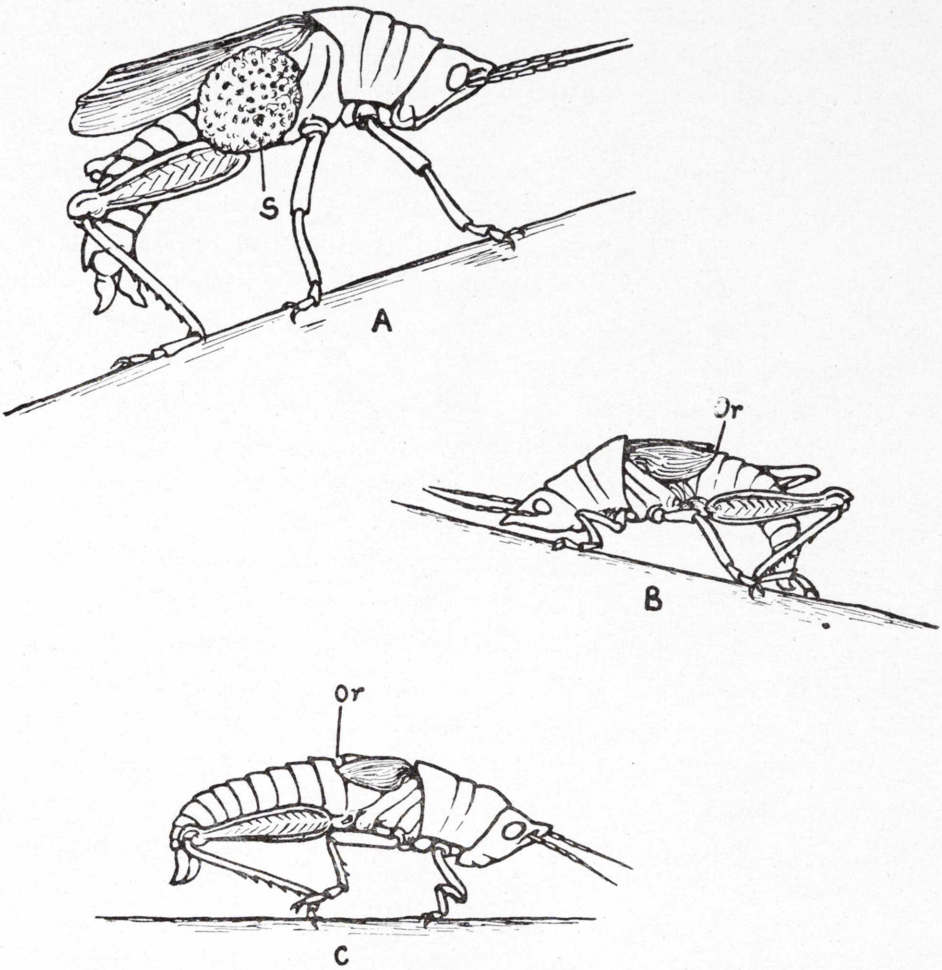

Fig. 7.—The defense positions (according to fotographs): A., Adult with bubbles of excretion (S).—B., C., Hoppers in two different positions.—Or., Orifice of the gland.

adults. The dorsum of the hopper is not covered with wings which impede the squirting of fluid. The fluid is sprayed with considerable force in a double jet over and beyond the head of the hopper to a distance of up 50 or 60 cm. Both the tiny droplets and the pungent smell of the fluid are spread all around the insect. The narrowing and widening of the slit between the tergites, determines the direction, angle and distance of squirting. The action may be repeated five to six times at short intervals. Most of the secreted material will fall upon the object that provoked the squirting. Often, when the hopper approaches maximum stimulation, its antennae will vibrate. This vibration is so fast that the antennae can no longer be seen clearly. At this stage all the muscles of the insect's body are in a state approaching a spasm and the hopper may turn on its back and roll around without its trying to escape. This catalepsy during which it will remain motionless, may last as long as ten minutes. Also hoppers just after moulting, when the internal body pressure is insufficient to produce ejection, and those that have spent the whole contents of their glands, will react to additional stimulation by becoming motionless.

In the adult the back is covered by the wings. The fluid from the adults gland is secreted under the wings and flows on both sides of the body, in the shallow groove between abdominal tergites I and II. On its way the fluid reaches the tracheal stigma of the second abdominal segment. At the same time, air is released through this stigma under pressure. Liquid that flows over the stigma mixes with the air and forms bubbles of foam, coverting the opening (Fig. 7 A.). The bubble which may grow as large as 1 ½ cm., dries after a few minutes, leaving a dusty white material.

Effects of the secretion upon animals: The effect of the secreted material on different animals was tested by external application and by injection.

To obtain a sufficient quantity of the liquid, the insects were induced to squirt into Petri dishes. The material collected was tested immediately after secretion as well as after desication, so that in the latter case, quantities and concentration could be controlled.

Effects of the secretion on mammals: When a single drop of fresh liquid was administered to the rigth eye of a mouse, *Acomys cahirinus* (Murine) by pipette, its eyelids closed at once; the mouse rubbed its head with the forepaws; slowly, the eyelids opened again, but the mouse began to shake its head nervously. When a strong beam of light was directed towards the eye, it did not react, but when the same light was turned to the other eye, the mouse closed it and ran away. The mouse recovered after an hour and did not touch food until the next day.

Injections were given subsutaneously or intramuscularly into the muscles of the hind leg of white laboratory mice of 20-28 gr. weight. There were 3-5 mice in each experimental series and a same number of controls received injections of physiological salt solution of equal volume.

Tested were: 1. The gland secretion. 2. The hemolympha. 3. The secretion of specimens that had not been feeding on Asclepiadaceae.

At the very first experimental injection it became evident that the tested substance was a potent poison of obvious neurotoxic effect. The leg that received the injection was immediately paralysed; immobility spread very soon also to the other leg, and the mouse ceased to move, its fur bristled and the manner of breathing changed, the inhalations becoming deeper and slower. The animal tried to move, dragging the hind legs behind, mostly with the soles upturned. The anterior part of the body became paralysed: the mouse fell on its abdomen trembling now and then. The eyes closed no longer reacted to irritation; the frequency of respiration was reduced, the thoracic movements of the muscles became spasmodic. Sometimes there was a jerking movemente or two and death followed.

The contents of two glands or 0.25-0.30 mg. dried venom suffices to kill a mouse within 7-15 minutes. When the injected dosage was below the lethal treshold, the phenomena observed were essentially similar, except for the ultimate spasms. In all cases the mouse became totally apathetic, a condition which persisted for up to 10 minutes. After this it would recover gradually, begin to preen itself, lick its forepaws and within 30-40 minutes it usually had fully recuperated and begun to feed once again.

In all autopsies which were subsequently performed, nothing unusual was found internally.

Toxicity of the hemolymph: The abdomens of four hoppers in the II and III stages were opened with sharp scissors and the exuding drops of hemolymph were caught in a Petri dish. In the same manner the fluid of four hoppers of *Schistocerca gregaria* was obtained. Three albino mice received injections of 0.3 cc. of the hemolymph of *Poekilocerus,* while three others at the same time were injected with an equal volume of the hemolymph of *Schistocerca.* Those mice which had received the hemolymph of *Poekilocerus* began at once to show symptoms of poisoning and death ensued at about 14-25 minutes. The *Schistocerca* injection did not produce any visible effect.

The experiments were repeated twice with identical results.

The independence of poison production from the food plant: As alrady stated, previous investigators tended to assume that poisonous properties of the secretion were derived from the plant on which the insect feeds, these being normally specis of the Asclepiadaceae.

In order to test the presence or absence of such a correlation, an attempt was made to raise a generation of *Poekilocerus* on plants which are known to be harmless or even edible to man (see table 4), and the following experiments were made with hoppers of the III and IV stages.

Liquid secretion of the gland obtained in the manner described above did not differ, either in appearance or in smell, from the "normal" secretion. Secretion which had been allowed to desicate, when examined under the microscope, showed particles which were indistinguishable from those produced by ordinary, asclepiad-fed individuals. Fresh secretion was injected into the leg muscles of three mice in doses of 0.4 cc. of fluid each. The effect was typical and identical with earlier experiments. All mice died about 15 min. after injection. This experiment was repeated twice with the same result.

The experiments with hemolymph also showed no differente results other than typical.

Repellent Behaviour.

The repellent effects of Poekilocerini upon various animals are unknown. Experiments were made to confront our species with a number of other animals, especially insectivorous, which occur in the same region (Table 6.). Natural conditions were, as much as posible, imitated in arranging the meeting between *P. bufonius* and the other subjects. In many cases, however, forceful methods had to be used.

TABLE 6.

No. of animal species used to confront.

Arachnoidea	9 species
Insecta	5 species
Reptilia	6 species
Aves	3 species
Mammalia	5 species

The grasshoppers were introduced through a small opening in the roof of the terraria, in which the tested animals were kept, in order not to interfere with their ordinary behaviour. In experiments with the birds and hedgehog, the *Poekilocerus* were put into the cages. In the following a number of selected protocols is given, arranged to the systematic order of the used animals.

ARACHNOIDEA.

Paragaleodes sp.: 23.7.1954, temp. 28° C. A third stage hopper was introduced to a large (7 cm.) *Paragaleodes*. The solifug reared immediately on its legs, lifted the pedipalpi, the thorax began to move sideways with typical feeling movements. The chelicers were rubbed one against the other, opened and closed. The animal advanced slowly towards the hopper and lay motionless in the sand. As soon as the solifung was near the hopper it pounced upon it and seized it. Immediately, the whole body of the *Poekilocerus* was covered with secreted liquid. The solifugid retreated and the hopper remained motionless. The solifugid trembled, rubbed its chelicera and hid under a stone; when it was offered the hopper once mori it would not make another attack. On other insects *Paragaleodes* fed immediately.

Buthus judaicus: 24.7.1954, temp. 30° C. A third-stage hopper was introduced into a terrarium with *B. judaicus*. The scorpion seized the hopper with claws and passed it to the cheliceras, then suddenly it let go and withdrew. Prae- and postabdomen were bent upwards while the scorpion stood on its claws and forelegs, buried its head in the sand and rubbed it in the substratum. The body was swaying as in a "dance". Within 2 minutes the scorpion managed to clean the chelicera and then it pushed the pedipalps in the sand in order to rub and clean them.

The experiment was repeated with almost identical results, but this time the whole body of the scorpion was rubbed in the sand, after the attacked *Poekilocerus* had squirted its secretion on to the scorpion.

Buthus quinquestriatus, Scorpio maurus, Nebo hierochonticus: 6.3.1955, temp. 30° C.

Three second stage, four third stage and three fourth stage hoppers were introduced to them, in the terrarium. Next day, the hoppers were found uninjured. On 8.3.1955 *S. maurus* and *N. hierochonticus* were observed trying to seize several hoppers, but in every case they left them at once. On 10.3.55, ten hoppers of *Schistocerca gregaria* were introduced into the same terrarium, while the *Poekilocerus* were still in it. Next day four of *Schistocerca* had been eaten. After 5 days all the *Poekilocerus* were removed alive.

The same results were reached with *Latrodectes* sp., *Chaetopelma olivacea* and *Hogna* sp., these were kept in a glass container together with *Poekilocerus* for two weeks. During this time various other grasshoppers were offered and devoured.

Insecta.

Experiments in: 25.7, 27.7, 15.9.1954. Temp. 28°-30° C.

Anthia sexmaculata, Eremoplana infelix. Blepharopsis mendica and *Eremiaphila sacra.* Not a single *Poekilocerus* was eaten by one of these insects.

Reptilia.

Into each one of standard terraria one or more specimens of one species was introduced. The animals were given a week in order to get used to the new surroundings and to the observer. The animals also got accustomed to the opening and closing of the aperture in the roof of the terrarium. The floor was covered with a two cm. layer of sand. The temperature was 30°-33° C.

Mabuya vittata: In all experiments four adult specimens were used, kept in two separate terraria. *Poekilocerus* was introduced from above and an attempt was always made to drop it near the head of the skink, whose reaction we wanted to observe. The reaction of the skink was typical: at first a swift attack on the grasshopper that retaliated by squirting upon the aggressor. The skink dropped its victim that remained alive. The tail of the skink was lifted while it buried its head in the sand, moving swiftly to and fro to rub it clean.

All the specimens tried again and again to attack, but when the effect was the same, they gave up, lost interest, and retired into a corner of the terrarium.

For control, at the same time, other species of grasshoppers were offered and eaten.

Eumeces schneideri, Chalcides ocellata, Acanthodactylus pardalis and *A. schreiberi* gave the same reaction.

Agama sinaita: 13.9.1954. Temp. 28° C. When a hopper of *Poekilocerus* was shown to it through the glass front of the terrarium it made swallowing movements which may be interpreted as movements prior to the feeding. When the hoppers were introduced into the terrarium, the *Agama* approached, looked at them but made no attempt to seize them. When subsequently a hopper of *Schistocerca* was introduced, it was caught and eaten immediately. Again thereafter a hopper of *Poekilocerus* was offered and after the same hesitation caught and eaten. No more hoppers were touched, including the next day. Two other specimens of *A. sinaita* entirely refused hoppers and adults of *Poekilocerus,* but would accept readily those of *Sch. gregaria* and other grasshoppers.

Aves.

Turdoides squamiceps: 13.4.1954. Temp. 24° C. These experiments were carried out in the cages of the birds to be tested. A fourth-stage hopper was introduced into a cage with two birds. The bird approached, looked at the hopper from all sides and caught it. The bill at once was covered by the squirted secretion of the hopper. The *Turdoides* dropped the hopper and began violently to clean its bill. At the same time the other *Turdoides* approached and got a squirt of secretion even before it touched the hopper. The *Poekilocerus* had adapted the extreme defense posture and every time the bird approached, 6-7 times in all, the hopper squirted a double jet of secretion onto the head of the bird, wetting it considerably. Eventually the *Turdoides* left the hopper alone and began to clean themselves thoroughly.

MAMMALIA.

Acomys cahirinus: 28.8.1954. Temp. 30° C. Two fourth-stage hoppers were dropped into the terrarium through the aperture in the roof. The mouse turned its head immediately towards the *Poekilocerus,* began to smell in their direction and to approach them. Having approached a hopper, it seized it with its mouth and forepaws, and received a squirting on its head, neck and paws. The hopper, still alive, escaped and climbed up the wire netting. The mouse began, first of all, to clean its mouth most throughly with its forepaws, then legs and the face. Eventually it laid down and began to rub its belly in the sand by sideways movements. This took several minutes. When the mouse had cleaned itself, it began to search for the hopper, found the second one standing on the sand and attacked it, the results were identical. Four times the mouse repeated its attempts to catch the *P. bufonius,* but it gave up, hid in a corner of the terrarium and stood there. On the next day the *Poekilocerus* were found still alive in the terrarium. In parallel experiments with a *Mus musculus* the same results were obtained. When the same *A. cahirinus* were subjected to these experiments for a fortnight, they developed a conditioned reflex reaction. As soon as the aperture was opened ther mice bristled and when the *Poekilocerus* was dropped into the terrarium, the mouse fled into a corner. In a few cases they even began to rub their heads. When pebbles instead of hoppers were dropped, the mice displayed the same behaviour.

In a few cases hoppers were overpowered by mice, but this occurred only after moulting, when the gland is empty and the hoppers unable to squirt. Even very hungry mice would it only certain parts and never touched the thorax or the anterior part of the abdomen, where the gland is situated. Experienced mice ran away from the smell of *Poekilocerus.* This happened when a tube dipped in the liquid was brought near the nose of a mouse.

The reactions of *Meriones crassus* were similar to those of *A. cahirinus.*

Hemiechinus auritus: 4.9.1954. Temp. 26° C. Three fourth-stage hoppers were introduced into the terrarium. The hedgehog perceived them at once and began to smell them. It seized one but dropped it immediately. The hopper was dead but the hedgehog left it alone and rubbed its nose for a long time. After some ten minutes the hedgehog attacked the second hopper and let it go — this stime still alive. No inducemente could move the hedgehog to oblige and touch any more *Poekilocerus.* It rolled itself up and never even looked at the hoppers that were climbing over him.

Paraechinus aethiopicus: 6.4.1956. During an excursion in the Southern Negeb, this specimen, which is typical of this desert zone, was caught near Ein-Radian. In the same place adults of *Poekilocerus* were collected. We put two adults into the box, where the hedgehog was kept. It detected them, approached with his nose very cautiously and withdrew. We tried to offer him the grasshoppers but he would not touch them by any means. Other grasshoppers, such as *Cyclopternacris cincticolis* and *Sphingonotus rubescens,* when put into the box, were eaten without hesitation.

Glands in other pyrgomorphinae.

Anatomic and histologic examinations of *Pymgomorphella granosa* St. and *Pyrgomorpha conica* Ol. have shown that both these species have glands similar to that of *Poekilocerus,* but cells of the glands are much smaller and the secreting cells are scarttered singly among ordinary hypodermic cells. The fluid secreted by the two species is transparent, not sticky, and the maximum squirting distance is only a few centimetres. In both species the liquid has a distinct smell that has nothing to do with the plants they are feeding on. With *granosa* the smell reminds one of decaying meat. With *conica* the liquid has a smell like that of mouldy and spoilt cocoa.

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Bibliography.

BEIER, M.

1937. Eine neue Wehrdruse bei soltatoren Orthopteren. C. R. int. Congres Zool. (1935)2: 1458-1462.

CHOPARD, L.

1938. La Biologie des Orthopteres. Encyc. ent.

1943. Orthopteroides de l'Afrique du Nord. Faune Emp. franc.

EBNER, R.

1914. Ein Eigenthumliches Verteidigungsmittel bei *Poecilocerus hieroglyphicus* Klug. Anz. Akad. Wiss. Wien.

GRASSE, P. P.

1937. L'hemaphrorrhee, rejet-reflexe de sang et d'air par les Acridiens phymateides. C. R. Acad. Sci. Paris.

HINGSTON, R. W. G.

1927. The liquid-squirting habit of oriental grasshoppers. Trans. ent. Soc. London, LXXV.

JOHNSTON, H. B.

1956. Annotated Catalogue of African Grasshoppers. Camb. Univ. press.

KRAUS, H. A.

1900. Uber ein eigenthumliches Organ bei der Feldheuschrecke *Poecilocerus socotranus* Burr. Zool. Anz. 23.

LOTTO, G.

1950. Sulla presenta di una ghiandola ripugnatoria in due Ortotteri del genere *Phymateus*. Boll. Soc. ital. Med., 10, 195-201.

PAWLOWSKY, E.

1916. On the Anatomy of *Phymateus hildebrandti* (Orthoptera, Phymateidae) in connection with the peculiarities of the dermal secretion. In Sc. res. Zool. Exped. to British Eeast Africa and Uganda. 1914, I(3): I-28. (In Russian. English summary.)

UVAROV, B. P.

1948. Recent Advances in Acridology: Anatomy and Physiology of Acrididae. Trans. R. ent. Soc. Lond. Vol. 99, part I.