# A study of the feculae of Orthoptera, their specificity, and the role which the insects'mouthparts, alimentary canal, and food-habits play in their formation

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(Láms. VII-VIII.)

Many physiological studies have been carried out on different aspects of the feculae ("feces") and their formation in Orthoptera *(sens. lat.)*. Among the more important of these researches are ones by Nenjukov and Parfentjev (1929), Nielsen (1943), and Snipes and Tauber (1937), who described for various species the speed of transit of food through the alimentary canal, *i. e.*, rate of formation of feculae; Chauvin (1946), the periodicity of defecation in four species; Brown (1937) and Chauvin (1941), the biochemistry of feculae; Brown (1937), their structure; and numerous authors, the general physiology of digestion and excretion in Orthoptera. Surprisingly, however, purely descriptive studies on feculae have lagged. Frost (1928; 1959) reviewed insect "scatology", but included scant material relative to Orthoptera; Weiss and Boyd (1950) described and figured the feculae of three species of Orthoptera, and Boldyrev (1928) did the same for a species of katydid; and Day (1950) described, but did not figure, those of a species of cockroach.

Nowhere, apparently, is there a study which elucidates the form and specificity, if any, of feculae in the major groups of Orthoptera, nor is there one which discusses satisfactorily the factors which influence their formation. It is in answer to these two questions that the present study was initiated and completed.

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## Methods.

Several different methods were used to obtain information on the form and specificity of feculae in the major groups of Orthoptera. First, many animals each of the common species of southeastern Michigan were collected in the field and placed immediately in individual, clean, foodless, screen-topped fruit jars, from which their feculae were gathered after 6 hours. Whenever possible, the sex of the defecating adults and the approximate instar of nymphs were recorded. The feculae gathered in this manner were stored dry in small cardboard boxes until use, when they were studied under a binocular dissecting microscope. Careful notations were made of their conformation, texture, size, and color. Drawings of one or more feculae regarded as typical of the series for each species were made with the aid of a camera lucida. Also, several typical feculae of each species were made into temporary slides and subjected to microscopic analysis to determine their food content [2].

Second, numerous Michigan Orthoptera were caged in the laboratory during the course of studies other than the present one, and their feculae were collected regularly for comparison with those of field-captured individuals. These "laboratory" feculae, unlike the above "wild" ones, were products of a known food suply. The pellets were maintained and studied in the same manner as were the foregoing ones.

Third, on the occasion of the author's assignment to the Instituto Español de Entomología, Madrid, Spain, as a Senior Fulbright Lecturer, he was enabled to compare the feculae of certain European species with those of the species of southeastern Michigan, on which the present paper is based. The collections of the Instituto were examined carefully to locate specimens with well-formed, extruded or partly extruded feculae. These pellets were removed gently with forceps, or were freed after relaxation of the insect. They were maintained and studied as before.

Fourth, experimentation was employed to test the importance of food selection in formation of feculae. Individuals of three species of Acrididae, each belonging to a different subfamily and characterized by different food-habits, were divided into two groups each: those in

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[2] For the technique used see Gangwere (1961).

the first (control) group were given food of the type they select in nature; those in the second (experimental) group food they do not normally eat. The feculae defecated by individuals of the two groups were then studied, compared, and drawn.

## Results.

### *The Study of Field-Collected Feculae.*

An average of twenty faculae each of forty-seven species of Michigan Orthoptera *(sens. lat.)* newly captured from nature were studied, compared, and drawn in the laboratory. These groups and species of known food-habit (Gangwere, 1961), the feculae of which reflect field conditions, included:

*Dermaptera (Earwigs).*

Doru a. aculeatum (Scudder) [3].

*Blattidae (Cockroaches).*

Blattella germanica (Linnaeus).
Parcoblatta pensylvanica (DeGeer).
Parcoblatta uhleriana (Saussure).

*Phasmidae (Walking-Sticks).*

Diapheromera femorata (Say) [4].

*Acrididae: Acridinae (Slant-Faced Locusts).*

Chloealtis conspersa Harris.
Chorthippus longicornis (Latreille).
Orphulella speciosa (Scudder).
Pseudopomala brachyptera (Scudder).
Syrbula admirabilis (Uhler).

*Acrididae: Oedipodinae (Band-Winged Locusts).*

Arphia p. pseudonietana (Thomas).
Arphia sulphurea (Fabricius).
Camnula pellucida (Scudder).
Chortophaga viridifasciata (DeGeer).
Dissosteira carolina (Linnaeus).
Encoptolophus s. sordidus (Burmeister).
Pardalophora apiculata (Harris).
Spharagemon b. bolli Scudder.
Spharagemon collare (Scudder).

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[3] The earwigs, though they belong to the Dermaptera, an order separate from the Orthoptera, are conventionally studied by orthopterists, thus justifying the inclusion of *Doru* in this report.

[4] The feculae of this species have been described and figured previously by Weiss and Boyd (1950: plate XIV) and by Frost (1959: fig. 118), which descriptions are in general agreement with the one given in this paper.

*Acrididae: Cyrtacanthacridinae (Spine-Breasted Locusts)* [5].

Melanoplus b. bilituratus (Walker).
Melanoplus bivittatus (Say).
Melanoplus confusus Scudder.
Melanoplus f.-r. femur-rubrum (DeGeer).
Melanoplus keeleri luridus (Dodge).
Melanoplus s. scudderi (Uhler).
Paroxya hoosieri (Blatchley).
Schistocerca lineata Scudder.

*Tetrigidae (Grouse Locusts).*

Tetrix ornata (Say).
Tettigidea l. lateralis (Say).

*Gryllacrididae: Rhaphidophorinae (Cave and Camel Crickets).*

Ceuthophilus meridionalis Scudder.

*Tettigoniidae: Phaneropterinae (Bush and Round-Headed Katydids)* [5].

Amblycorypha oblongifolia (DeGeer).
Amblycorypha rotundifolia (Scudder).
Scudderia c. curvicauda (DeGeer).
Scudderia f. furcata Brunner.
Scudderia septentrionalis (Serville).

*Tettigoniidae: Copiphorinae (Cone-Headed Katydids).*

Neoconocephalus ensiger (Harris).

*Tettigoniidae: Conocephalinae (Meadow Grasshoppers).*

Conocephalus f. fasciatus (DeGeer).
Conocephalus nigropleurum (Bruner).
Orchelimum gladiator (Bruner).
Orchelimum volantum McNeill.
Orchelimum vulgare Harris.

*Tettigoniidae: Decticinae (Shield-Backed Katydids).*

Atlanticus testaceus (Scudder).

*Gryllidae: Gryllinae (Field Crickets).*

Acheta pennsylvanicus (Burmeister).

*Gryllidae: Nemobiinae (Ground Crickets).*

Nemobius allardi Alexander and Thomas.

*Gryllidae: Oecanthinae (White Tree Crickets).*

Neoxabea bipunctata (DeGeer).
Oecanthus angustipennis Fitch.
Oecanthus nigricornis quadripunctatus Beutenmüller.

Some specificity of feculae was noted. It was often possible, on the basis of pellet size, texture, color, and conformation, to identify the feculae of various families or subfamilies, but the method was found seldom, if ever, useful at the species level. The following types of feculae, all subject to considerable variation, were recognized:

*Type I.* The Acrididae (grasshoppers and allies) were found to have elongate feculae. Their green or brown-yellow pellets are of three subtypes:

*Type IA.* Those of the Acridinae (Lám. VII: 1, 6), which are

[5] The feculae of an insect of this group, though a genus not studied here, were described and figured previously by Weiss and Boyd (1950: plate XIV), which description accords generally with information given here.

elongate, spindle-shaped structures composed of numerous obliquely aligned grass fibers.

*Type IB.* Those of the Oedipodinae (Lám. VII: 3), which resemble the feculae of acridines, but tend to be less attenuate and sometimes have rather poorly aligned fibers.

*Type IC.* Those of the Cyrtacanthacridinae (Lám. VII: 7, 8), which are wrinkled, asymmetrical pellets best characterized by a lack of fibers, hence, lack of alignment. Nevertheless, much variation was displayed in all three subfamilies; for example, the feculae of cyrtacanthacridines occasionally are aligned (Lám. VII: 9), like those of acridines or oedipodines.

*Type II. Diapheromera femorata* (Lám. VIII: 13), a representative of the Phasmidae (walking-sticks and allies), like the Acrididae, has elongate feculae, but there is little likelihood of confusion. Feculae of Type II, characteristic of *Diapheromera,* are highly asymmetrical and irregularly ridged, which ridging results from the prominent veins of the leaves of woody plants which the insect eats. Thus, the feculae of *Diapheromera* may be distinguished from those of the grass-feeding acridines and oedipodines by their lack of symmetry and alignment, and from those of the forbivorous [6] cyrtacanthacridines by their ridging.

*Type III.* Non-elongate, granular feculae are defecated by the earwig *Doru a. aculeatum,* the pellets of which (Lám. VIII: 11) are minute, golden brown in color, cylindrical, and homogeneous in texture, being composed of numerous fine pollen grains enclosed in a delicate peritrophic membrane and showing neither projections nor plates.

*Type IV.* The feculae of Orthoptera other than the above were found to be non-elongate and non-granular. Though less readily classified than the preceding because of their variability, they fit into several loose subtypes outlined below:

*Type IVA.* The non-elongate, non-granular feculae of the Tetrigidae (grouse locusts) (Lám. VIII: 17) are small, dark brown pellets of variable texture, usually fine and homogeneous, but sometimes fibrous.

*Type IVB.* A second kind of non-elongate, non-granular feculae occurs in the Copiphorinae (cone-headed katydids) (Lám. VIII: 10) and sometimes in the Conocephalinae (meadow grasshoppers). The color of these pellets is light, usually gray-white, yellow, or tan, and

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[6] Forbs are broad-leaved herbs, and stand in contrast to grasses, narrow-leaved herbs.

their outline somewhat irregular. Their characteristic plated appearance is caused by glumes and other fruit coats of grasses, which incrust their twisted surface; in absence of these incrustations the pellets are indistinguishable externally from those of Type IVC, below.

*Type IVC.* A third kind of non-elongate, non-granular feculae occurs in the Phaneropterinae (bush and round-headed katydids) (Lámina VIII: 15) and sometimes in the Conocephalinae (Lám. VIII: 19). These moderate-sized, ovoid, cylindrical, or irregular pellets are black, fuscous, or light brown in color and of wrinkled and sometimes bristly texture. They are similar to the following type, Type IVD, but differ in lacking sand grains or insect sclerites.

*Type IVD.* The last of the non-elongate, non-granular feculae are those of most scavengers and predators, including the Blattidae (cockroaches) (Lám. VIII: 16), Decticinae (shield-backed katydids) (Lámina VIII: 18), Gryllidae (crickets and allies) (Lám. VIII: 14), and Rhaphidophorinae (camel crickets). Sclerites and insect appendages, fibers of plants, and sand grains are common components, which often jut out from the pellet and lend a broken appearance to its already wrinkled and irregular surface; in their absence the pellets are indistinguishable from those of Type IVC, above. The color of the feculae is black, dark brown, or light brown. The feculae of the Oecanthinae (white tree crickets) (Lám. VIII: 12) also belong in this category, but are readily separated from the others by their comparatively minute size and nicely elliptical or ovoid outline.

The color of the above types of feculae was found to vary, which proved to be a function of the food residues as well as their incrustations of excrement. A content of grasses and sedges, as determined by microscopic analysis, yields green, light brown, or tan feculae; one of floral materials or succulent leaves of forbs black feculae; one of animal remains dark brown feculae. The basic color of the feculae, as determined by the food residues, was found to be modified to varying degrees by the products of the Malpighian tubules spread over their surfaces. These crystalline waste materials exhibit a wide variety of dull colors, mostly orange, red, or purple. Sometimes they lend their color to an entire pellet, but usually only to parts.

There proved to be a size disparity in feculae. Comparatively small species, *e. g., Doru a. aculeatum,* produce small feculae, while large ones, *e. g., Syrbula admirabilis,* large feculae. It was found also that

females produce feculae approximately twice the size of those of males of the same species, and that the size of feculae increases regularly with each nymphal stage, though their form remains approximately the same.

### *The Study of Laboratory-Collected Feculae.*

Large numbers of feculae of almost fifty species of Michigan Orthoptera caged in the laboratory and maintained on a known supply of food proved similar to feculae obtained from "wild" individuals newly brought into the laboratory from nature. The identity of these laboratory species is here omitted because study of their feculae yielded nothing new, merely corroborating "wild" data given above.

### *The Study of Feculae of European Species.*

A total of five or less feculae were obtained from each of thirty-three species of European Orthoptera, distributed among the families Acridinae (6 spp.), Copiphorinae (1 sp.), Cyrtacanthacridinae (5 spp.), Decticinae (5 spp.), Gryllinae (2 spp.), Nemobiinae (1 sp.), Oedipodinae (9 spp.), Pamphaginae (3 spp.), and Pycnogastrinae (1 sp.). Two of the genera, *Chorthippus* and *Nemobius,* were among those studied in the United States, but all species were new to this investigation. The data obtained agreed closely with those from the Michigan field study, for which reason no additional information will be given concerning them.

### *Experimentation.*

A series of experiments tested the importance of food selection in formation of feculae. Five individuals of *Chorthippus longicornis* were fed the forb lettuce *(Lactuca)* exclusively, and five others were given their normal grass diet. The former produced wrinkled, twisted feculae (Lám. VII: 2), while the latter produced well-aligned feculae (Lámina VII: 1).

Five individuals of *Chortophaga viridifasciata* were restricted to grass; five to the spiny forb thistle *(Cirsium);* and five to lettuce.

Grass-fed *Chortophaga* yielded aligned feculae (Lám. VII: 3), lettuce-fed ones wrinkled, unaligned feculae (Lám. VII: 4); and thistle-fed ones partly aligned feculae (Lám. VII: 5).

Five individuals of *Melanoplus s. scudderi* were fed only grass; five the forb dandelion *(Taraxacum);* and five lettuce. They produced, under these respective diets, aligned feculae (Lám. VII: 9); unaligned feculae (Lám. VII: 8); and unaligned, twisted feculae (Lám. VII: 7).

## Discussion.

It has long been appreciated that the feculae of Orthoptera are necessarily something more than feces or food residues, for the Malpighian tubules empty into the intestine around its periphery, and, therefore, must coat the feces in some manner with their excretions. Physiological studies by a number of authors have been carried out on the chemical nature of these excretions and food residues, on their mode of formation, and on the feculae themselves. It would serve no point to discuss these findings here, but Brown's research on feculae is pertinent. He found (1937) that feculae are composed largely of undigested food particles, which are encapsulated by a delicate peritrophic membrane, the outer surface of which is incrusted with crystalline excretions, derived principally or entirely from the Malpighian tubules.

The present study on purely descriptive aspects of feculae recognizes a number of types and subtypes among Michigan Orthoptera, including aligned and unaligned ones; non-elongate granular ones; and non-elongate, non-granular ones. These types are delineated on a somewhat arbitrary basis according to variations in size, form, texture, and color. They are not to be construed as anything more than a convenient way of describing certain tendencies in feculae of different Orthoptera. There is too much variation among them for any other interpretation; for example, consecutive feculae from a single animal occasionally may be of diferent types, in response to varying influences, particularly food.

It is clear, on the basis of the present study, that feculae of Orthoptera usually do not differ among related species; indeed, they do not always differ among the major groups, families and subfamilies, though they exhibit tendencies toward specificity. In view of the foregoing,

it would appear that feculae should not be used as characters in taxonomic separation. This conclusion verifies the statement by Weiss and Boyd (1952) that "the use of feculae in the identification of species has only a very limited and by no means positive value". The present author agrees wholeheartedly, and, because of the great danger of gross misdetermination, is not even sure that he condones the limited use of fecal keys in the case of certain economically important species (Hodson and Brooks, 1956; Morris, 1942; *et al).*

Food selection is, in good part, responsible for the form, texture, size, color, and alignment, if any, which characterize feculae. The more succulent, softer, and less fibrous the food, the smaller, more irregular, and more twisted the feculae. This relationship is well illustrated by the Acrididae. In the Michigan Acridinae, a group of exclusively graminivorous (grass-feeding) Acrididae, the feculae are invariably well-aligned; in the Oedipodinae, which are usually graminivorous but sometimes forbivorous, the feculae are usually aligned but occasionally poorly aligned or even twisted; and in the Cyrtacanthacridinae, which are largely forbivorous, the feculae are usually poorly aligned and twisted.

Notwithstanding the above, when *Chorthippus longicornis,* one of the few Michigan acridines capable of eating forbs, is forced to eat lettuce, it yields poorly aligned, twisted feculae like those of cyrtacanthacridines; and the latter, in turn, egest aligned feculae when fed grasses excusively. More compelling evidence yet is furnished by feeding thistle *(Cirsium),* a plant with numerous, stiff, elongate bristles, to acridids. Thistle, a succulent forb, would be expected to result in unaligned, twisted feculae, but, to the contrary, it forms partly aligned feculae (Lám. VII: 5); this latter can only be explained by the plant's bristles, which must act as do fibers of grasses in producing alignment in feculae.

The above is an oversimplification, as is pointed out by the fact that the feculae of grass-fed cyrtacanthacridines are not as well-aligned as those of grass-fed acridines. The cause of this variation lies in the shape of the pieces removed by the insects' mouthparts during feeding and also the way in which they are mechanically handled by the digestive tract. As shown by Gangwere (1961a), acridines remove slender, elongate, fibrous pieces from the grass leaves on which they feed, and these morsels, by virtue of their length, which is sometimes greater

than the diameter of the insects' gut, cannot assume a position other than a linear or obliquely aligned one, which they maintain as they pass along the length of the tract. Once in the midgut, the semicontinuous food mass becomes enveloped by the peritrophic membrane, and is coated by excretory materials from the Malpighian tubules as it passes the pyloric valve. Then, individual elongate feculae composed of numerous aligned fibers are pinched off from the food column by the valve at the anterior end of the rectum and are extruded during defecation.

Cyrtacanthacridines, in contrast, ingest shorter, more irregular pieces from their foods. These morsels often require no particular orientation within the digestive tract, which fact results in irregular, twisted feculae. Thus, when spine-breasts feed on grass, they feed in much the same manner as they do on forbs, which results in a somewhat less regular pellet than would be eliminated by a grass-fed acridine. Much the same may be said for the non-acridid Orthoptera, particularly katydids and crickets. It is noted that their morsels tend to be even smaller, shorter, and more irregular than is the case with those in the Cyrtacanthacridinae, which conditions result inevitably in non-elongate, twisted feculae. Furthermore, most of them seldom eat grass, and could not be expected to yield aligned feculae.

The texture of feculae is directly dependent on the nature of the food and the way in which it is mechanically handled by the mouthparts and mechanically and physiologically handled by the digestive tract. The texture is necessarily fine and homogeneous when the content is largely of pollen, as in *Doru;* it is irregular and plate-like when it includes grass fruit coats, as in *Neoconocephalus;* it is irregular and bristly when of animal remains, as often in *Atlanticus;* and it is fibrous and aligned when of grass leaves, as in *Syrbula.*

The color of feculae varies somewhat with food selection, for feculae composed of grasses and sedges tend to be green or light brown; those of floral materials and soft, succulent leaves black; and those of insect remains dark brown. Some color is dependent on the excretions of the Malpighian tubules, which crystalline materials are highly variable but tend to be dull shades of orange, red, and purple. One would expect also that the color of feculae varies with the bleaching effect of light, but no evidence to this effect was uncovered.

The size of feculae is largely a function of the size of defecator.

This obvious relationship is a direct function of the insects' behavior during feeding, their food selection, the size and form of their mouthparts, and their age. Small species produce small feculae, while large ones large feculae. Some figures relative to this relationship are given by Day (1950), who found that the feculae of the large cockroach *Macropanesthia* have over 300 times the volume of those of the smaller cockroach *Blattella,* a ratio in proportion to the weight relationship between these two insects. There comes to mind immediately the question of whether there is a similar size disparity between the feculae of different-sized individuals of the same species. The present study shows that the form of the feculae remains the same, but that the size differs according to the size of the defecator. Thus, the expected disparity between the feculae of males and females is obtained, in conformity with the females' much greater body size; and that between feculae of nymphs of diferent stages, therefore, sizes is also realized.

The size of feculae may be subject to another variable, age, for Boldyrev (1928) found that senescent individuals of the katydid *Bradyporus* produce smaller feculae than do other adult individuals of the same sex and species. This effect is undoubtedly a result of the decreased feeding activities that characterize senescent individuals of any species of Orthoptera.

It would appear that much can be learned from a careful study of the feculae of Orthoptera and other insects. Often it is possible to identify feculae to the major group of insect from which they come, or, if one is working with a very limited economic fauna, *e. g.,* the insects which infest oak trees, it may even be possible to make determinations to species, using a fecal key like that prepared by Hodson and Brooks (1956), though the efficacy of the latter is questioned by this author. One perhaps can determine the age of defecating individuals, particularly in outbreak situations, providing he is sure of the species involved; and, on the basis of drop, he may even gain a rough idea of population size. Without question it is feasible to analyze feculae to determine their food composition. Thus, many aspects of the biology of Orthoptera can be studied indirectly through feculae, though it must be emphasized that discretion is necessary in interpretation of data obtained in this manner.

## Summary and conclusions.

The feculae of forty-seven species of Michigan Orthoptera *(sens. lat.)* were examined to determine whether they are specific, and the results were checked against those obtained from a more limited study of feculae of thirty-three species from a different fauna, that of Spain. Some specificity was found, making possible recognition of a number of types and subtypes, including *elongate feculae, ridged* in the Phasmidae and *non-ridged, aligned* to *unaligned* in the Acrididae; *non-elongate, granular feculae* in the earwig *Doru;* and *non-elongate, non-granular feculae* of several subtypes. Among the latter is a subtype found in the Copiphorinae; another in the Phaneropterinae; another in the Tetrigidae; and one in various scavengers and predators of the Blattidae, Decticinae, Gryllidae, and Rhaphidophorinae. It is emphasized that these so-called types represent nothing more than an arbitrary classification of certain tendencies in feculae.

The size disparity of feculae defecated, respectively, by males and by females was noted, those of females being almost twice as large as those of males, in conformity with the greater body size of the former; however, the form of the feculae remains the same. A similar disparity was noted between feculae of nymphs of different life stages.

The importance of food in determining the conformation of feculae was demonstrated by experiments in which different types of foods were given to three species of grasshoppers, causing corresponding changes in form of their feculae. Data from two of the species, *Chorthippus longicornis* and *Melanoplus s. scudderi,* are particularly significant. The acridine *Chorthippus,* a grass-feeder, produced feculae like those of cyrtacanthacridines when forced to eat forbs; the cyrtacanthacridine *Melanoplus,* largely a forb-feeder, produced feculae similar to those of acridines when restricted to grasses.

The nature of feculae, including their color, size, configuration, and texture, is shown, therefore, to depend on many variables, among which are the insects' behavior, their structure, both mouthpart and gut, and their food.

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## EXPLANATION OF LAM. VII

Fig. 1.—Aligned fecula (Type IA) of a grass-fed *Chorthippus longicornis* (Acridinae).

Fig. 2.—Unaligned fecula (Type IC) of a lettuce-fed *Chorthippus longicornis.*

Fig. 3.—Aligned fecula (Type IB) of a grass-fed *Chortophaga viridifasciata* (Oedipodinae).

Fig. 4.—Unaligned fecula (Type IC) of a lettuce-fed *Chortophaga viridifasciata.*

Fig. 5.—Poorly aligned fecula of a thistle-fed *Chortophaga viridifasciata.*

Fig. 6.—Aligned fecula (Type IA) of the graminivore *Syrbula admirabilis* (Acridinae).

Fig. 7.—Unaligned fecula (Type IC) of a lettuce-fed *Melanoplus s. scudderi* (Cyrtacanthacridinae).

Fig. 8.—Unaligned fecula (Type IC) of a dandelion-fed *Melanoplus s. scudderi.*

Fig. 9.—Aligned fecula (Type IB) of a grass-fed *Melanoplus s. scudderi*

## EXPLANATION OF LAM. VIII

Fig. 10.—Fecula (Type IVB) of the seminivore (grass "seed"-feeder) *Neoconocephalus ensiger* (Copiphorinae).

Fig. 11.—Fecula (Type III) of the pollen-feeder *Doru a. aculeatum* (Dermaptera).

Fig. 12.—Fecula (Type IVD) of the predator-omnivore *Oecanthus nigricornis quadripunctatus* (Oecanthinae).

Fig. 13.—Fecula (Type II) of the dendrophagous (tree- and shrub-feeder) *Diapheromera femorata* (Phasmidae).

Fig. 14.—Fecula (Type IVD) of the scavenger *Acheta pennsylvanicus* (Gryllinae).

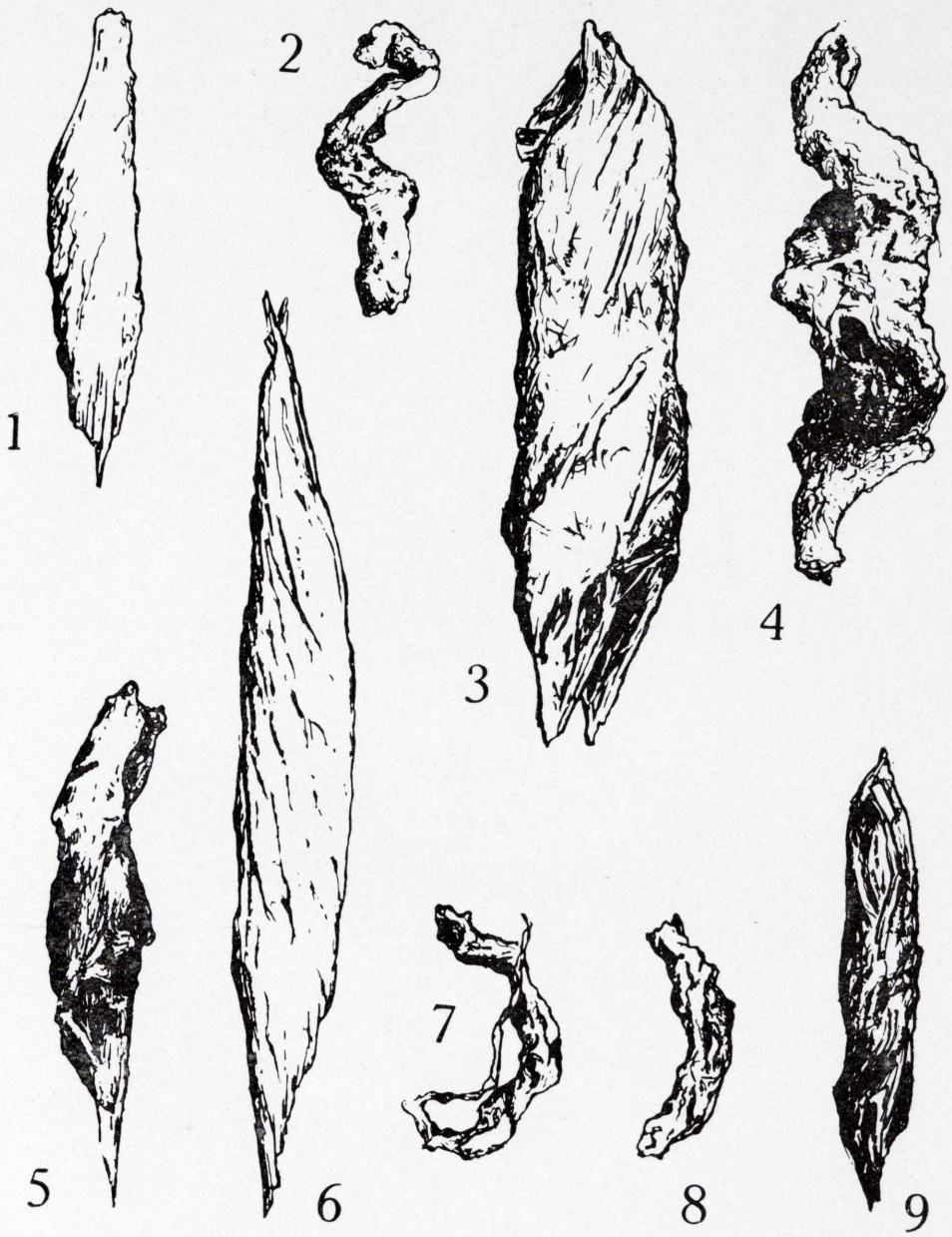
Fig. 15.—Fecula (Type IVC) of the forb-feeder *Scudderia c. curvicauda* (Phaneropterinae).

Fig. 16.—Fecula (Type IVD) of the scavenger *Parcoblatta pensylvanica* (Blattidae).

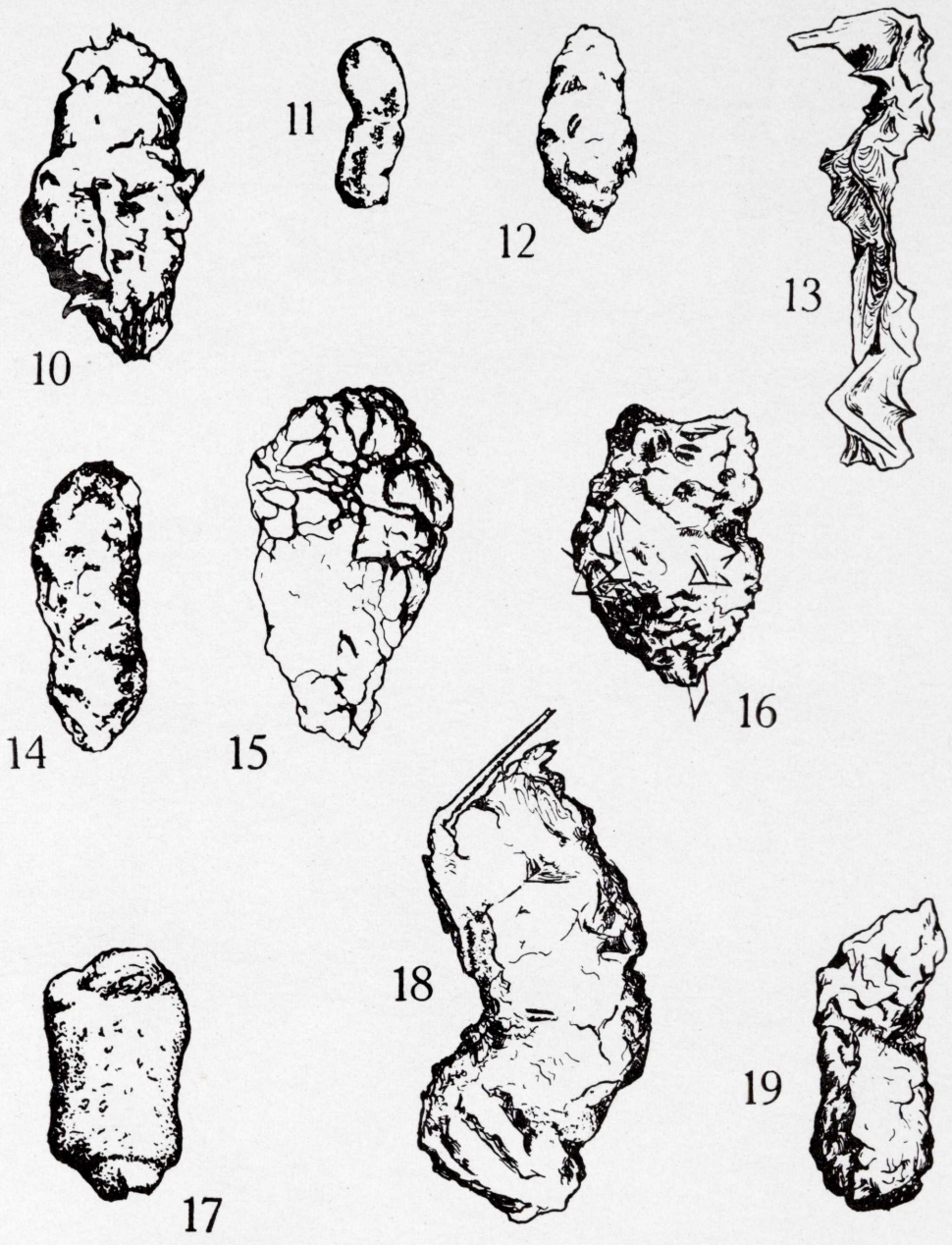
Fig. 17.—Fecula (Type IVA) of the modified omnivore *Tettigidea l. lateralis* (Tetrigidae).

Fig. 18.—Fecula (Type IVD) of the scavenger-predator *Atlanticus testaceus* (Decticinae).

Fig. 19.—Fecula (Type IVC) of a leaf-fed *Orchelimum vulgare* (Conocephalinae).




S. K. GANGWERE: A Study of the feculae of Orthoptera, their specificity, and the role wich the insects' mouthparts, alimentary canal, and food-habits play in their formation.

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