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AN INVESTIGATION OF THE FEMALE GENITALIA AS
TAXONOMIC CHARACTERS IN THE
MIRIDAE (HEMIPTERA)¹

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This investigation originated as an attempt to discover structures in the genitalia of female *Miridae* that might be used for taxonomic purposes. The great family *Miridae* includes a large number of very important economic forms, and the complexity and size of the family makes it imperative that definitive characters be found to properly differentiate the species. The works of Reuter, Van Duzee, and particularly Knight have established differentiating characters in the claspers, or harpagones of the males. However, no parallel studies of the females have been made, with the result that determinations of species in some of the larger genera, which contain many closely related species, such as *Lygus*, *Neolygus*, *Lopidea*, and *Orthotylus*, often have been tentative and sometimes impossible. This paper has been an effort, not so much to work out specific differences for all species within given genera, as to disclose whether or not such characters do exist in the females.

A second important aspect of the problem has been an attempt to establish on the basis of the female genital structures some conclusions concerning the phylogenetic relationships between the various mirid genera and higher groups. The generic classification of the *Miridae*, perhaps more than any other heteropterous family, is in a somewhat unsatisfactory condition. Numerous genera have been founded upon superficial characters. Therefore, it was felt that a study of the female genital structures might throw light upon some of these generic relationships, and indicate where more intensive future work is needed. Perhaps from the "long view" this has been the most important aspect of the problem.

The size of the family *Miridae* has made it impossible to cover more than a very small percentage of the species and only a portion of the genera. It has been the intent of the author to open new lines of investigation rather than to attempt to work out in detail any single group. Major emphasis has been placed upon the subfamily *Capsinae*

¹A dissertation submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

as restricted by J. Sahlb. (23), Bergroth (1), and Knight (11), with lesser attention being given to some of the other subfamilies.

Fortunately, the recent series of excellent papers by Dr. Bertil Kullenberg of Sweden has furnished terminology for some of the structures under investigation. Kullenberg's work is of the highest merit, and without it this investigation could hardly have been brought to its present form. However, a number of Kullenberg's names are essentially descriptive and rather lengthy for taxonomic usage. Therefore, letters have been used frequently during this investigation to designate the various morphological parts involved. This use of letters rather than names has seemed advisable in view of the almost complete lack of knowledge of the functions of the various parts. At the present time to assign names to the parts would add new terminology to an already unwieldy mass of morphological terms, and the terminology would almost certainly be superseded as the functions of the structural parts became known.

Two areas of the bursa copulatrix have been used in the present study: first, the sclerotized rings found on the dorsal wall of the bursa, and second, the sclerotized portions of the posterior wall with its attendant sclerites. These structures appear to be of the highest taxonomic and phylogenetic value. In most cases investigated not only do they seem to be of great value in establishing generic, tribal, and subfamily relationships, but they are often of great value in specific separation. Frequently the female parts show more striking differences than do the harpagones of the males (see *Lygus* discussion).

Primary attention was given to the two structures mentioned above for several reasons. First, structures to be of general taxonomic value should be as readily available for study as possible and not require special and difficult techniques in preparation. Because of their relatively strong sclerotization, the sclerotized rings and the posterior wall can be dissected for study in a very short time with only a little practice. Secondly, they appeared upon preliminary investigation to show considerable differentiation even within closely related groups. Thirdly, to cover even the limited ground surveyed in this study, it was necessary to limit the number of characters used. Since one of the essential premises in undertaking the study was to determine whether or not taxonomically useful characters are present, the adoption of two readily usable structures seemed the most practical approach, and the one to most effectively answer the unknowns for which the study was initiated. Undoubtedly good characters exist in the vulvar area of the female genitalia, and it would be most interesting to see if the ovipositor blades could be used to define species and higher groups in this family.

It is the hope of the author that this preliminary study will serve as the impetus whereby more detailed studies upon genera and generic-complexes will be made, with the result that the phylogeny of the *Miridae* may be more adequately known and the correct determination

of the species may be as readily accomplished by use of the female sex as is possible today by use of the male.

MATERIALS AND METHODS

The methods, materials, and techniques used during the course of this investigation have not been extensive or complicated, nor have they differed appreciably from those used in other genitalic studies.

When the abdomen had been removed from the body of the insect it was placed in a 5 per cent solution of hot potassium hydroxide, which in a short period of time cleared away extraneous material and left the sclerotized portions readily discernible. Hot potassium hydroxide was found preferable to a cold solution due to the great variation in the degree of sclerotization found in the various species of the family. Teneral specimens are entirely unsatisfactory material for study purposes. With a hot solution specimens could be checked several times during the clearing process within a relatively short period of time. However, once the time necessary for clearing a given species is known, the cold preparation is perfectly satisfactory.

Species cleared in potassium hydroxide were then removed to a Syracuse watch glass containing water and dissected. The holders used by the watch repair trade have proven to be excellent for holding dissection needles. These instruments give good leverage and hand control while firmly holding minuten nadeln pins which serve nicely for dissecting needles.

The dorsal wall of the abdomen was first dissected away and then the sclerites of the ventral wall. It was found necessary to dissect away various membranous portions in order to clearly expose the sclerotized rings of the bursa copulatrix and the posterior wall, particularly for purposes of making drawings. After the external abdominal sclerites had been removed the next step was to separate the anterior ovipositor blades, with their attendant structures, from one another. This was found to be most easily accomplished by placing the specimen with the ventral surface uppermost and then inserting a dissecting needle between the first and second fibulae at the point where they make an abrupt caudad turn near the base of the ovipositor blades. The needle was then pulled firmly and carefully in an anterior direction and the process repeated upon the opposite side. This freed the anterior ovipositor blades, the sclerotized rings of the bursa, and attendant structures from the posterior ovipositor blades, the ovipositor sheath and the posterior wall of the bursa that lies between the bases of the above structures. For purposes of illustration it was necessary to dissect the posterior wall away from the posterior ovipositor blades and the ovipositor sheath.

After dissection and study the parts were placed in a small vial containing 70 per cent ethyl alcohol together with a code number

which corresponded to a duplicate number placed upon the pin holding the specimen from which the abdomen had been removed. Later the genitalic parts were placed in tiny vials containing glycerine, and attached by their corks upon the pin holding the specimen.

For making drawings the genitalic portions were oriented upon cellulocotton in water or alcohol. The illustrations were made with use of a squared ocular under a Spencer dissecting microscope using eighty-five magnifications. Dissection was accomplished with a Spencer dissecting microscope using twenty-nine magnifications.

DISCUSSION OF THE FEMALE ABDOMEN

The following brief discussion is taken primarily from Snodgrass (24 and 25) and Kullenberg (16 and 17) and is intended merely to orient the reader as to the location of the parts involved in the taxonomic discussion. A rather complete morphological discussion of the segmentation of the abdomen and the parts involved in the abdomen of the *Miridae* may be found in the above-mentioned works of Kullenberg.

The heteropterous abdomen is composed of eleven segments with a telson present embryonically, but absent in the adult insect (9). The genital segments of the female are the eighth and ninth (24 and 17), however, adjacent segments are also somewhat modified to accommodate the great specialization of the genitalia.

The shaft of the ovipositor is composed of four blades, or *valvulae* (24). Two of these, the posterior pair, have a dorsal and internal position and are united at the base (Plate I, Fig. 2). The other two, the anterior pair, have an external and ventral position (Plate I, Figs. 1 and 3). The posterior *valvulae* belong to the ninth abdominal segment, while the anterior ones are part of the eighth segment. Distally the *valvulae* are expanded into "spear-shaped" tips armed with strong teeth on their margins for cutting into plant tissues at the time of egg deposition. The anterior *valvulae* are usually less heavily sclerotized than the posterior pair. For a discussion of the functional movements of the *valvulae* see Kullenberg (16).

From the proximal end of each *valvula* proceeds a slender sclerotized band. These bands are the fibulae of Verhoeff (29), shanks of Ekblom (5a), and *rami* of Snodgrass (24) (Plate I, Figs. 1, 2, 3). The *rami* of the anterior *valvulae* curve sharply along the anterior margins of the posterior *rami* and become attached by sclerotized rods, the *connecting pieces* (Plate I, Figs. 1 and 3), to the upper end of the transverse ridge of the ninth tergum. The posterior *rami* are attached to the anterior ends of the second *valvifers* (Snodgrass, 24), or *ovipositor sheath* (Kullenberg, 16), (Plate I, Fig. 2). The first *valvifers* are rather indistinct and poorly developed in the *Miridae*.

The *bursa copulatrix* (Plate I, Fig. 3) is an invagination between the eighth and ninth segments on the ventral side of the body. It is fastened to the *rami* and the proximal ends of the *connecting pieces*.

The first structures used in the study have been the sclerotized parts of the posterior wall of the bursa (17), which lies between the posterior *rami* and is attached laterally to them and to the bases of the posterior *valvulae* (Plate I, Fig. 2). This posterior wall is considered by Kullenberg to pertain to the ninth segment.

The second structures used have been the sclerotized rings found on the dorsal wall, or roof, of the bursa (Plate I, Fig. 1). They may be flat ellipses, circles, etc., formed by strongly sclerotized rings of the integument, or they may be curved and twisted in various manners. The rings are paired and bilaterally symmetrical in most of the species studied. The area in which these rings occur is considered by Kullenberg to pertain to the eighth abdominal segment.

GENERAL TAXONOMIC DISCUSSION

The family name *Miridae* has been the subject of considerable controversy. This resulted from a basic difference in nomenclatorial concepts regarding whether a family name should be derived from the name of the oldest included genus, or from a priority standpoint involving the first use of the name. Parshley (20) has pointed out, however, that the family name *Miridae* has precedence on both points, *Miris* Fabr. 1794 being the oldest included genus, and *Mirides* Hahn 1831 being the earliest name given to the family. In view of this, the author is unable to account for the use of *Capsidae* as the family name by Kullenberg in his recent papers, other than the fact that the name *Capsidae* has been in general use among European workers.

Several of the older authors, notably Fieber (6 and 7), Thomson (25a), and Douglas and Scott (5) have suggested schemes of classification of the family *Miridae*. However, the present groupings within the family originate in the works of O. M. Reuter, particularly in his treatise of 1910. In this contribution Reuter recognizes nine subfamilies of *Miridae* from the world.

In 1916, Van Duzee changed Reuter's *Heterotomaria* to *Orthotylinae* and his *Macrolopharia* to *Dicyphinae* and changed the nomenclature of several tribal names.

J. Sahlberg (23), Bergroth (1), and Knight (11) have raised Reuter's tribe *Mirini* of the subfamily *Capsinae* to subfamily rank. Knight (15) erected the subfamily *Hyaliodinae* to include the genus *Hyaliodes* and several Neotropical genera.

The characters used in separating the *Miridae* into subfamilies have been primarily the nature of the arolia, the condition of the hamus of the wing, and the male genital structures. These last have been introduced particularly by Knight (11). In that paper Knight mentions the fundamental nature of the genitalia in the phylogeny of the *Miridae*, but does not indicate what characteristics of the genitalia serve to place a given species in a particular subfamily.

Kullenberg (18) discusses the philosophical implications of struc-

tures used to establish phylogenetic relationships. His conclusions are based upon what to the writer seem to be very solid grounds. Kullenberg believes that structures which are highly plastic, in being influenced by mutations, are not reliable criteria upon which to establish phylogenetic systems. Conversely, those structural areas which are relatively resistant to adaptational change are to be considered as of the highest value. For example, Kullenberg believes that the male copulatory structures, which have the single function of inseminating the female, are likely to respond readily to mutations without impairment of their function, whereas the female genitalia which have a threefold function, the coupling of the male penis, the receipt and retention on the male products, and service in the process of egg-laying, are less likely to undergo rapid and extreme modifications, because of the equilibrium set up by the functional needs of the three activities. For this reason, Kullenberg concludes that the forms of the female genitalia are of extreme importance for the establishment of phylogenetic relationships.

Kullenberg indicates that *Bothynotus pilosus* and *Dicyphus constrictus* appear to be closely related and rejects the subfamily *Bothynotinae*, established for *Bothynotus*. He believes that the vestiture of the wing membrane constitutes a very superficial character upon which to found a subfamily group. Further, he considers that the *Mirinae* do not constitute a distinct subfamily, but only a tribe of the *Capsinae*.

Another viewpoint elucidated by Kullenberg is his rejection of the tarsal arolia as structures of high phylogenetic value. He feels that these structures are highly adaptable and functional and that they are not nearly so basic for establishing relationships as are the genitalia of the females.

TERMINOLOGY AND METHOD OF DESCRIPTION

The structures of the bursa copulatrix used in this study have hitherto been named only in part. Kullenberg (17) gives descriptive names to a number of the parts, and some of his names have been adopted in the present paper. In other cases, length of the names or inappropriateness has caused the writer to use other symbols to replace the Kullenberg terminology. With regard to the small parts that form the posterior wall of the bursa no terminology has been available. Since the functions of these minute structures are unknown the author has hesitated to arbitrarily assign descriptive names to them and further complicate the already unwieldy terminology of entomological morphology. Therefore, a system of letters has been adopted and used where the part under discussion does not possess a name, or where the name has appeared to the writer to be inappropriate.

The rings found on the dorsal wall of the bursa copulatrix are called throughout this paper the sclerotized rings. Kullenberg (17) designates these rings *chitinschlinge*. Adjacent to these sclerotized rings

one can often observe differentiated areas that are more heavily sclerotized than the surrounding membrane. This condition is particularly well developed in the subfamily *Capsinae*. The sclerotized region lying immediately anterior to the rings is designated as structure *F* (Plate III, Fig. 11). This region assumes various shapes and degrees of sclerotization, and often appears undifferentiated from the adjacent membranes. A second adjacent sclerotization is often present laterad of the rings. This sclerotization curves below them and appears to lie at an angle. This sclerotization has been designated as structure *G* (Plate III, Fig. 11), and perhaps represents the anterior margin of the *dorsal sac* (see Kullenberg, 17). Like structure *F*, this *G* sclerotization may be variously differentiated. Where the sclerotization around and near the rings is undifferentiated it has been designated under the general term, adjacent sclerotization.

The posterior wall of the bursa copulatrix appears to be very important taxonomically. The position of this posterior wall in relation to the adjacent structures is somewhat variable. It may lie dorso-ventrad, or cephalo-caudad, or, very often, it assumes a position somewhat intermediate between these two planes. For purposes of uniformity and clarity of description it has been necessary to arbitrarily consider each species as having the posterior wall lying in a dorso-ventral plane. This orientation has been followed throughout this paper. In the *Capsinae*, in particular, the posterior wall possesses a number of unnamed parts. In the majority of species studied the most conspicuous element consists of a pair of wing-like sclerites that diverge from the midline, generally curve in a dorso-lateral direction, and taper to the dorsal tips. In certain species these wing-like structures are the only features present on the posterior wall. Often they are fused into a single piece on the median line, but primitively they probably were paired (see *Phylinae* discussion). These wing-like structures are designated as the *A* structures in this paper (Plate II, Fig. 24).

In the *Capsinae* and *Mirinae* a prominent mesal thickening occurs on the posterior surface of the posterior wall. This thickening may be in the form of a simple bar, or rod, or it may assume a variety of twists and curves. It has been designated structure *B* (Plate II, Fig. 24). Frequently structure *B* extends considerably dorsad of the dorsal margins of the *A* structures and is recurved cephalad to terminate in a wide, button-like flange. This wide terminal flange has been designated as structure *C* (Plate II, Fig. 24). Structures *B* and *C* are equivalent to the *chitinknopfschen* of Kullenberg. The letter *D* has been given to an area lying dorsad of the dorsal margins of the *A* structures and between the tips of *A*. Usually the *D* area is membranous but may present various foldings and thickenings that are occasionally useful for purposes of description (Plate II, Fig. 24). Two thin flaps, or folds, often arise from the dorsal margin of the *A* structures and extend as broad rounded lobes in an antero-ventral direction. These lobes are designated as the *E* structures (Plate II, Fig. 24). In certain of Kullen-

berg's figures these lobes are designated as the *weiche falte*. In some species of *Capsinae* a pair of variously shaped lobes arise near the dorso-lateral tips of the *A* structures and extend mesad. These lobes are designated as the *H* structures (Plate II, Fig. 24).

In the subfamily *Orthotylinae* the posterior wall is so greatly modified that it has seemed necessary to adopt different letter designations even though the various structures are probably, in some cases, homologous to already designated structures in other subfamilies. The posterior wall in this subfamily sometimes lies nearly cephalo-caudad, but, for the sake of uniformity, the descriptions have been written with the posterior wall oriented on a dorso-ventral plane. In contrast to the *Capsinae*, the anterior surface of the posterior wall appears to offer the best taxonomic characters in this subfamily. Two large rounded lateral lobes are present that are perhaps homologous to the *A* structures found in other subfamilies. These paired lateral lobes have been designated the *J* structures (Plate VI, Fig. 15). Arising from the dorsal margin of each *J* structure and extending ventrad is a flange usually with one or two finger-like projections. These flanges may be homologous to the *E* structures of the *Capsinae*. They are designated as the *K* structures in the present paper (Plate VI, Fig. 15). These *K* structures are equivalent to the *sklerotisierte Falte* of Kullenberg. Between the *J* structures there is usually present a more or less prominent single sclerite, or median lobe, that here is designated structure *L* (Plate VI, Fig. 15).

In the individual descriptions to follow, the sclerotized rings and adjacent structures have been described first. Measurements for their maximum lengths have been from the anterior edge of the adjacent sclerotization to the posterior edge of the ring margin. This method of measurement is somewhat unsatisfactory for comparative purposes, as the adjacent sclerotization is sometimes rather indistinct. Furthermore, it gives no real idea as to the actual size of the ring. Maximum width of the sclerotized ring area has been considered to be from the lateral edge of one ring margin to the lateral edge of the other ring margin. This measurement is perhaps of more comparative value than the maximum length figures.

In all cases the description of the posterior wall follows that of the sclerotized rings. Measurements have been as follows: Maximum length is considered to be from the most ventral point along the ventral margin to the most dorsal point along the median line; the maximum width measurements have been made across the dorso-lateral tips of the *A* structures (*J* structures of the *Orthotylinae*). All measurements are given in millimeters or fractions thereof.

GENERAL DISCUSSION OF THE SUBFAMILIES

The present study includes material from eighteen tribes in nine subfamilies. The subfamily *Capsinae* has been subjected to the most intensive investigation. The other subfamilies have been studied less

intensively, but a selective attempt has been made to study species representing as many tribal groups as practicable.

The evidence at hand suggests that the subfamily distinctions recognized by Reuter and Knight are generally in agreement with the relationships indicated in the female genital parts studied. However, in a number of cases, the amount of material studied has not been sufficient to draw more than the most tentative conclusions. In other cases, certain genera show characters that indicate an intermediate position between two subfamilies. In a few genera the present taxonomic position does not appear to be in accord with the evidence offered by the genital structures studied.

The question of what constitutes a primitive or generalized condition in the female genital structures of the *Miridae* is, of course, rather hypothetical at the present stage of knowledge.

The subfamily *Bryocorinae* is considered here to show the most primitive type of genitalia (sclerotized rings and posterior wall). In this subfamily the rings are absent and the posterior wall is entirely membranous. The *Phylinae* and *Dicyphinae* likewise present a rather generalized picture. The sclerotized rings, in most cases, are simple ellipses with generalized, poorly differentiated adjacent sclerotization (Plate V, Fig. 16). The condition of the posterior wall in these two subfamilies is most significant. It consists of a pair of simple sclerites, which are considered to be homologous to the A structures of the more specialized subfamilies (Plate V, Fig. 7). In the *Phylinae* and *Dicyphinae* the sclerites are usually surrounded by undifferentiated membrane. These sclerites taper dorsad to end in a blunt point. In a number of the phyline genera the lateral margins of the sclerotized rings plus the adjacent lateral sclerotizations are somewhat curved dorso-mesad and appear to presage the greatly infolded condition so characteristic of what are considered the typical orthotyline genera. The relationship of the *Phylinae* to the *Orthotylinae* is further evidenced by the seemingly annectant position of the orthotyline species *Semium hirtum* Reuter. This species possesses a posterior wall very similar to the type possessed by the *Phylinae*. It consists of two simple diverging and tapering A structures (Plate VI, Fig. 11). The sclerotized rings of *S. hirtum*, while more infolded on the lateral margins than are those of any of the *Phylinae*, nevertheless present a much less specialized condition than do the other *Orthotylinae*.

The recently erected subfamily *Hyaliodinae* has sclerotized rings rather different from those of any other species studied, but suggestive of the twisted condition of the *Deraeocorinae* (Plate V, Fig. 8). The posterior wall, however, is of the same type as that found in the *Phylinae* and *Dicyphinae*. Only one species of this subfamily has been investigated so that considerably more study must be undertaken before any real statements can be made of the subfamily relationships.

The *Deraeocorinae* is a somewhat anomalous group that seems to present conditions more specialized than the preceding subfamilies.

In this subfamily the sclerotized rings (Plate V, Fig. 13) are considerably twisted and curved. The posterior wall (Plate VI, Fig. 10) is one simple sclerite rather than consisting of two distinct sclerites as in the preceding subfamilies. In *Deraeocoris histrio* Reut. (Plate VI, Fig. 8) the ventro-mesal area of this plate possesses a thickening. This thickening is suggestive in a generalized way of the *B* structures found in the *Capsinae* and *Mirinae*. One may suggest that possibly the posterior wall of the *Deraeocorinae* is the type from which the more specialized walls of the *Capsinae* have arisen. On the other hand, the rather complicated nature of the sclerotized rings suggests the possibility that the *Deraeocorinae* represent extremely specialized forms in which the posterior wall illustrates a secondarily simplified condition.

Extremely close relationships between the *Clivineminae* and the *Deraeocorinae* are indicated by the appearance of both the posterior wall and the sclerotized rings. Indeed, it is doubtful whether these groups should be considered distinct subfamilies. However, here again a study of more genera and species is needed before definite conclusions can be drawn. Certain of the *Orthotylinae* in the tribe *Halticini* show affinities relating them to the *Deraeocorinae* and *Clivineminae*. *Orthocephalus mutabilis* Fall., in particular, has a posterior wall very similar to that present in *Largidea rubida* (Uhl.) (Plate VI, Fig. 2), and the sclerotized rings show twisting and looping quite unlike those of the other *Orthotylinae*.

The subfamily *Orthotylinae* is probably not a *homogeneous* phyletic group. As mentioned above, the subfamily shows relationship to the *Phylinae* and *Dicyphinae* on the one hand and to the *Deraeocorinae* and *Clivineminae* on the other. The more characteristic genera show a highly infolded condition of the lateral margins of the sclerotized rings, so much so that in some genera it is difficult to see the ring margins. In these genera the posterior wall is exceedingly specialized and of a quite different nature than that found in any other subfamily. Two large lateral lobes are present (*J* structures) and each of these bears on its anterior surface a large appendage-like flange (*K* structure). This *K* structure is not present in any other subfamily studied and appears to the writer to be of great importance in defining this subfamily. Often a median lobe (*L* structure) is present between the large *J* structures. Probably these *J* structures represent the *A* structures of other subfamilies. The extreme specialization of the posterior wall in the *Orthotylinae* makes conclusions as to the homologies necessarily tentative at the present time. However, the characters found in the family genitalia indicate that the *Orthotylinae* and *Capsinae* represent the most specialized of the *Miridae* and that they are related through other subfamilies rather than directly to one another. The apparent heterogeneity of certain genera at present included in the *Orthotylinae* makes conclusions on their taxonomic position extremely difficult to understand.

The remaining two subfamilies, the *Capsinae* and *Mirinae*, undoubt-

edly are very closely related. Various of the older authors have considered them as representing a single subfamily group, and recently Kullenberg (18), after a study of the female genitalia, has regarded them as a single subfamily. The present author is inclined to agree with the viewpoint that a single subfamily is involved, although certain differences can be noted between the species of *Mirinae* and *Capsinae* studied. However, these differences are no greater than differences between groups of genera within the subfamily *Capsinae*, and therefore it is impossible on the basis of these studies to contribute evidence in favor of maintaining the two groups as separate subfamilies.

The female genital parts studied indicate that the *Capsinae* represent a very specialized group. This is particularly true of the posterior wall which is composed of wing-like divergent, dorsally tapering *A* structures that mesally have a strongly sclerotized area. Dorsally this area is usually strongly looped and twisted (Plate II, Fig. 24). The tips of the *A* structures often show mesally curving sclerites (*H* structures). In general, the posterior wall presents a wealth of taxonomic characters and is of a highly complex nature (see discussion under subfamily heading). The sclerotized rings are rather simple and consist of ovoid elliptical lobes. The adjacent sclerotization is considerably differentiated, and at least two distinct areas of sclerotization can be traced from genus to genus. Since this subfamily has been much more intensively studied than any of the other subfamilies it is perhaps impossible to compare the results with those noted above for other groups. Nevertheless, the fact that a basic morphological pattern has been found to be present through the subfamily certainly strengthens the admittedly fragmentary evidence obtained for the preceding subfamilies.

In conclusion, one may say that the female genital structures used in this study appear to have real worth in attempting to understand the phylogenetic relationships of the higher categories in this family. While the present study is only an introduction to the problem, it seems possible to interpret certain relationships and degrees of specialization that throw considerable light upon these higher categories.

A tremendous amount of future work will be needed upon these structures before the validity of the generalizations proposed here can be evaluated. Also, it will be necessary to test the evidence derived from these genital structures against other morphological, biological, and physiological criteria.

SUBFAMILY CAPSINAE REUTER 1883

This is a very large subfamily containing thousands of species in many genera. It includes some of the largest and most spectacular of the *Miridae*, as well as a number of genera of great economic importance.

Particular attention has been paid to this subfamily in the present study for a number of reasons. First, the subfamily contains a sufficiently large number of genera and species to make the availability of

material a matter of secondary importance, and to allow for sufficient diversity to enable one to evaluate the potential importance of these female parts as taxonomic criteria. Secondly, the *Capsinae*, at the outset, appeared to represent a more homogeneous group than any of the other large subfamilies. Therefore, one might reduce to a minimum the possibility of becoming involved in the problem of the correct disposition of a given species in regard to its present subfamily position. Finally, and by no means of lesser importance, was the fact that the majority of the species were of relatively large size and heavy sclerotization. This condition allowed dissection to be accomplished more readily, and considerably facilitated the interpretation and study of the genitalic parts used in this investigation.

The present investigation has included the study of fifty-eight species of *Capsinae*. These species represent thirty-three genera and two of the three tribes comprising the subfamily. Material representing the tribe *Myrmecorini* has not been available to the author for dissection purposes.

In general, the *Capsinae* appear to constitute a fairly compact group. With only a few exceptions the species follow a general pattern. As might be expected, a few species illustrate questionable situations where the affinities cannot be determined without considerably more material at hand.

The sclerotized rings (Plate III, Fig. 11) consist, in most cases, of a pair of more or less ellipsoidal, or ovoid, rings that have strongly sclerotized margins and are not infolded on the lateral margins as in some of the other subfamilies. In *Garganus fusiformis* (Plate IV, Fig. 10) the rings are represented only by a pair of bars, or rods, with no central area. This is considered to be a secondary specialization resulting from a fusion of the anterior and posterior ring margins. The posterior wall of the bursa of this species is of a conventional type for the subfamily. In *Polymerus basalis* (Plate V, Fig. 4) the rings have joined on the midline and become a single structure rather than a pair of rings. This species is also very interesting in that the posterior wall (Plate III, Fig. 5) is composed of a pair of narrow diverging A structures fused on the midline, but lacking the B, C, and E structures so characteristic of the other *Capsinae*. With the exception of these two species all the other species studied present paired rings, although in a few genera a sclerotized mesal connection exists across the midline (Plate IV, Fig. 1). The sclerotized rings are sometimes very valuable in separating species and genera, but, in general, they appear to be less useful for distinguishing the groups within the subfamily than are the characters found on the posterior wall.

The posterior wall of most of the *Capsinae* is a highly differentiated and specialized structure. It appears to offer excellent characters for subdividing the subfamily into natural groups. This wall consists of a pair of wing-like A structures usually meeting on the meson, where the posterior surface possesses a very strongly sclerotized area (struc-

ture *B*). This *B* structure usually extends dorsad and curves anteriorly to end in a widened flange, or *C* structure. Two semi-membranous folds arise from the dorsal margins of the *A* structures and extend ventrocephalad of them. These are designated the *E* structures and are possibly homologous to the *K* structures of the *Orthotylinae*. From the dorso-lateral tips of the *A* structures variously shaped sclerites arise and extend mesad. These are designated as the *H* structures and are lacking or entirely membranous in many genera. In *Neolygus* (Plate II, Fig. 9), these *H* structures are greatly enlarged and exceed the *A* structures in size.

The majority of genera of *Capsinae* investigated fall into five main groups on the basis of the appearance of the posterior wall. These five groups are not equal in rank and certainly not equal in homogeneity. Several of them can certainly further be broken down, and at least in one case the group is probably an assemblage of genera having no truly close relationship. They are placed together in this paper primarily as a matter of convenience.

The first of these groups includes the genera *Neoborus*, *Xenoborus*, and *Tropidosteptes*. These three genera are very closely related and probably represent a single genus (see generic discussion). The complex is quite distinct from any of the other capsines studied. It possesses large *H* structures that bear tubular evaginations that arise from the anterior surface and extend ventrad. The ventral margin is very deeply emarginate mesad. The *B* structure is absent or represented only by a minute thickening placed on a median extrusion of the *A* structures (Plate I, Fig. 7).

A second group includes the genera *Neurocolpus*, *Paracalocoris*, *Lampethusa*, and *Poeas*. Like the preceding, this complex is a very compact and well defined unit. The posterior wall has the *B* structure reduced to a small plate that does not reach the dorsal margin of the *A* structures. The *A* structures themselves are produced dorso-mesad and probably serve the functions of the *B* and *C* structures in other genera. The *H* structures are absent (Plate I, Fig. 17). As in the preceding group the relationships of the various genera to one another are so close as to make it doubtful whether separate generic recognition should be accorded the species. *Stittocapsus franseriae* Kngt. has a posterior wall that shows some resemblance to this group. However, it is of somewhat different composition, and the sclerotized rings are of a different nature, whereas in the other four genera the shape of these rings is nearly identical. Both of the above groups are discussed more fully later in this paper.

A third group of species includes the genera *Bolteria* and *Dichrooscytus*, and perhaps *Capsus*. This group is characterized by having the *A* structures separated from the *B* structure by a delicate membrane rather than being fused to it as in most of the other genera of the subfamily (Plate II, Fig. 3). In *Bolteria* and *Dichrooscytus*, and perhaps *Capsus*, this group is characterized by having the *A* structures separated

from the *B* structure by a delicate membrane rather than being fused to it as in most of the other genera of the subfamily (Plate II, Fig. 3). In *Bolteria* and *Dichrooscytus* the *B* structure is narrow and tapers to a ventral point (Plate II, Fig. 1). In *Capsus ater* a broad mesal area is present that possesses a narrow, dorsally projecting rod (Plate II, Fig. 2). It is not clear whether this entire mesal area represents the *B* structure, or whether the latter is represented only by the dorsally projecting rod. *Capsus* also possesses a different type of sclerotized ring from that shown by the other two genera. In *Dichrooscytus* and *Bolteria* the sclerotized rings are connected mesally by a sclerotized bar that is connected to the mesal margin of each ring (Plate IV, Fig. 3). In *Capsus* the rings (Plate IV, Fig. 6) are not connected by a mesal bar but are of the conventional type.

The fourth group of genera within the subfamily is a large one and is a more heterogeneous assemblage than are the three preceding groups. This fourth group is composed of the following genera: *Phytocoris*, *Lygus*, *Platylygus*, *Calocorisca*, *Poecilocapsus*, *Lygidea*, *Garganus*, *Horcias*, *Coccobaphes*, and possibly *Neolygus*. This group is characterized by having the portion of the *B* structure that lies between the *A* structures form a flattened disc, (Plate II, Fig. 26). This disc is usually tilted caudad from the ventral to the dorsal margin. In the majority of these genera the *H* structures are prominently developed, although they are apparently absent in *Phytocoris* and the subgenus *Apolygus*. The size and relationship of the disc of structure *B* to the margins of the *A* structures has proved very useful in the preparation of the generic key that follows this discussion.

The fifth group recognizable within the subfamily almost certainly does not represent a natural group of species. When more material has been investigated this group of genera will probably be separable into two or more sections. This aggregation is not in the same category as the preceding four groups, and perhaps the most one can say by way of definition is that it includes species with rather conventional types of posterior walls and sclerotized rings that do not fall within the preceding categories. This group at present is considered to include the following genera: *Adelphocoris*, *Pantilius*, *Calocoris*, *Euchilocoris*, *Irbisia*, *Thyrillus*, *Platytylellus*, and *Opistheuria*. The group may be characterized as having the *B* structure always extending dorsad of the dorsal margin of the *A* structures, and this *B* structure always lacking a true disc such as is present in the preceding group. *Irbisia* and *Thyrillus* probably represent a distinct group. The peculiar characteristics of these two genera are discussed in the descriptive section of this paper.

The genus *Neolygus* has rather conventionally shaped sclerotized rings (Plate III, Fig. 9), but the posterior wall is very greatly modified (Plate II, Fig. 9). The *H* structures are tremendously developed and are much larger than the *A* structures. A small disc-like *B* structure is present near the dorsal margin of the *A* structures. This disc-like *B*

structure probably shows a definite relationship to group four above. However, the genus shows such great modifications that much more information must accumulate before its true position can be ascertained.

The genus *Stenotus* appears to be quite distinct from any of the other capsine genera. Both the posterior wall and the sclerotized rings are of distinct types. If this genus has any close relatives within the subfamily they have not been represented among the genera studied during this investigation.

The species studied do not illustrate any characters that will serve to separate the *Resthenini* from the *Capsini*. The three genera of *Resthenini* observed have genital characters that are much more similar to some of the genera of *Capsini* than are several genera of *Capsini* to one another.

The phylogenetic position of the *Capsinae* within the family *Miridae* is extremely interesting. The female genitalia, as mentioned in the general subfamily discussion, indicate a highly specialized condition. Together with the *Orthotylinae* this subfamily is probably the most highly developed of any of the mirid groups. The *Deraeocorinae* are possibly the group from which the *Capsinae* have developed. This is suggested by the condition of the posterior wall which is a simple plate in the deraeocorines, but in a generalized way in some species shows a condition from which the more specialized *Capsinae* could easily have developed.

The following key is prepared to indicate characters that appear to be of value in separating the *Capsinae* into groups. It is extremely incomplete in that only a small portion of the genera are included, and of these only a few species of each have been studied. The intent has been to use this for future work, and workers, to test, change, clarify, or corroborate, as the case may be, when more studies have been made of the important characters found in the genitalia of the female *Miridae*.

1. Sclerotized rings connected with one another mesally by a sclerotized bar formed by the coalescence of the margins of the rings.
(Plate IV, Fig. 3) 2
- Sclerotized rings not connected mesad by a bar formed from the margins of the rings.
(Plate IV, Fig. 6) 4
2. A structures composed of two distinct sclerites with a membranous area between.
(Plate II, Fig. 1) 3
- A structure composed of a single sclerite that fuses solidly with structure B mesally and has no membranous median portion.
(Plate II, Fig. 6) PLATYTYLELLUS
3. Length of connecting bar between rings greater than length of a ring; rings tapering to a point laterad.
(Plate IV, Fig. 3) BOLTERIA
- Length of connecting bar between rings less than length of a ring; rings broadly truncate laterad.
(Plate IV, Fig. 2) DICHROSCYTUS

- Structure *B* possessing a flattened disc on posterior face, usually near ventral part of *B* and tilted posteriorly from base to apex.
(Plate II, Fig. 26) 19
15. Structure *B* branching near dorsal margin of structure *A* to form a large U-shaped apex to *B*.
(Plate II, Fig. 4) STENOTUS
Structure *B* of various shapes, but not forming a pair of large divergent arms. 16
16. Lateral extremities of rings terminating in a sharp point.
(Plate III, Fig. 10) 17
Lateral extremities of rings rounded, not terminating in a sharp point.
(Plate IV, Fig. 6) 18
17. *H* structures very prominent, structure *B* widening at dorsal apex to form a broad spreading flange.
(Plate III, Fig. 2) PANTILIUS
H structures lacking, or evident only as delicate membranes, structure *B* simple, lacking a spreading dorsal flange.
(Plate II, Fig. 25) ADELPHOCORIS
18. Posterior wall possessing a prominent central sclerite that is separated by a thin membrane from the true *A* structures.
(Plate II, Fig. 2) CAPSUS
Posterior wall conventional, the *A* structures directly in contact with structure *B*.
(Plate II, Fig. 10) OPISTHEURIA
19. Disc of structure *B* extending dorsad of the dorsal margin of structure *A*.
(Plate II, Fig. 14) 20
Disc of structure *B* not extending dorsad of the dorsal margin of structure *A*.
(Plate II, Fig. 27) 27
20. Disc of structure *B* reaching or surpassing the ventral margin of structure *A*.
(Plate II, Fig. 14) 21
Disc of structure *B* not reaching ventrad to the ventral margin of structure *A*.
(Plate II, Fig. 22) 24
21. Rings represented by a closed rod of sclerotin, at most with a small sub-oval opening near lateral margin.
(Plate IV, Fig. 11) 22
Rings normal, with typically narrow marginal sclerotization and wide interior. 23
22. Structure *E* not extending laterad of lateral margins of structure *A*.
(Plate II, Fig. 23) GARGANUS
Structure *E* extending considerably laterad of *A*.
(Plate II, Fig. 26) PHYTOCORIS
23. Structure *E* very large, extending laterad of structure *A* for most of the lateral margin of *A*; structure *C* broad and rounding at apex.
(Plate II, Fig. 30) LYGIDEA
Structure *E* small, extending laterad of *A* for only a short distance near the dorsal margin; structure *C* tapering to a narrowly rounded dorsal apex.
(Plate II, Fig. 14) Subgenus APOLYGUS

24. *H* structures represented by large twisting flanges, the area of the *H* structures greater than area of structure *A* which is reduced to a narrow band.
(Plate II, Fig. 22) CALOCORISCA
H Structures never with as great an area as structure *A*, and not twisted... 25
25. Structure *F* coalescing at the mesal margin to form a simple united sclerite.
(Plate IV, Fig. 15) POECILOCAPSUS
Structure *F* coalescing at median line, well separated mesad. 26
26. *F* structures extending anteriorly from the antero-mesal angle of the rings; rings separated mesad by more than one-half the length of a ring.
(Plate III, Fig. 8) PLATYLYGUS
F structures not extending anteriorly from antero-mesal angle of ring, lying in contact with anterior margin of ring for entire length; rings separated mesad by less than one-half the length of a ring.
(Plate V, Fig. 5) Subgenus AGNOCORIS
27. Structure *B* extending dorsad of structure *A* in the form of a two-pronged forceps-like structure.
(Plate II, Fig. 28) HORCIAS
Structure *B* lacking a two-pronged, forceps-like dorsal extension. 28
28. *H* structures possessing recurved tips, the *A* structures separated, with membrane between them.
(Plate II, Fig. 18) Subgenus LYGUS
H structures reduced or absent, never twisted at the tip, *A* structures contacting *B* for entire breadth, no mesal membrane between the *A* structures.
(Plate II, Fig. 27) COCCOBAPHES

THE NEOBORUS-TROPIDOSTEPTES-XENOBORUS COMPLEX

These three genera form a distinctive, closely related and very interesting group of species. The female genitalia fail to indicate any generic differentiation, yet the group illustrates structural peculiarities not found in any other genera investigated. The sclerotized rings are of a rather general type and show little to distinguish them from a number of other genera. The posterior wall, however, is most distinctive.

The female genital structures of the complex may be characterized as follows: Sclerotized rings (Plate I, Fig. 10): relatively small, sub-elliptical, tapering from lateral margin to meson; posterior margin slightly concave, rings widely separated mesad, adjacent sclerotization forming a thumb-like projection at latero-anterior margin, strongest sclerotization laterad of rings. Posterior wall (Plate I, Fig. 7): ventral margin of *A* structures curving strongly dorsad, very deeply emarginate. Dorsal margin of *A* structures extending dorsad mesally, curving anteriorly and again ventrad at the dorsal margin, and broadening into a wide knob (structure *C*?) at extreme anterior end. Structure *B* represented at most only by a slender inconspicuous transverse bar. *E* structures well developed and usually very conspicuous. *H* structures well developed, arising from extremities of *A* structures and extending

inward to meson or near it, these *H* structures each bearing a tubular evagination that arises near dorsal margin on anterior side and extends ventrad and cephalad in a pouch-like tube that appears usually to be open along the anterior surface and formed of an infolding of the evaginated walls. In *Neoborus palmeri*, however, a true "tube" is present (Plate I, Fig. 6), and in *Neoborus pacificus* (Plate I, Fig. 8), only a low evagination is present to suggest the long tubular structure of the other species. This evagination is the most striking feature common to the three genera and immediately sets them apart from any other genus of *Capsinae* investigated.

As with *Neurocolpus* and its allies we are dealing here with a very homogeneous group and one which, as before mentioned, is quite distinct from any other genera studied. Probably these groups do not represent genera but rather subgenera at the most. Certainly all available species must be studied before definite taxonomic conclusions can be drawn.

Further evidence to support the viewpoint that a single generic component is involved may be obtained from a glance at the characters used to separate the three genera. *Xenoborus* is separated from the others by the carinate margins of the pronotum, a somewhat ephemeral character at best in this group. *Neoborus* and *Tropidosteptes* are separated by the relative thickness of the antennal segments and the color.

The biological situation is also extremely interesting. The majority of species of all three breed on species of *Fraxinus*. For example, Knight (13) lists one species of *Tropidosteptes*, ten of *Neoborus*, and four of *Xenoborus* from Illinois. Of these the host plants are listed for fourteen, and of these only one, *Neoborus populi* Knigt., is not recorded as a phytophage of *Fraxinus*.

If the three genera eventually come to be regarded as a single genus, *Tropidosteptes* described by Uhler in 1878 will become the generic name.

NEOBORUS DISTANT 1884

This genus contains thirty described species, confined in distribution to North and Central America. The characters of the female genitalia used in this study are those discussed under the complex above.

Neoborus palmeri Reuter, 1908

Sclerotized rings: Typical for complex. Maximum length .32 mm., maximum width 1.18mm. (Plate I, Fig. 10).

Posterior wall: Large for the group and strongly sclerotized, mesal emargination of *A* structures deep, sides sinuate; evaginations of *H* structures large, and apparently closed tubes; anterior expansions (may be synonymous with structure *C*) of meso-dorsal extension of *A* structures elliptical; *E* structures large, narrowing strongly laterad. Maximum length .65 mm., maximum width .76 mm. (Plate I, Fig. 6). Hypotype: Newell, S. D. June 28, 1923. H. C. Severin.

Neoborus glaber Knight, 1923

Sclerotized rings: Typical. Maximum length .14 mm., maximum width .65 mm. Posterior wall: Meso-ventral emargination deep, somewhat V-shaped meso-dorsal extension of *A* structures broad, nearly parallel-sided; *H* structures pos-

sessing a broad finger-like extension that protrudes conspicuously in a dorso-mesal direction; anterior expansion (C?), sub-elliptical, ventral margin flattened. Maximum length .30 mm., maximum width .51 mm. (Plate I, Fig. 4). Hypotype: Navasota, Tex. May 2, 1948. M. Polhemus.

Neoborus pacificus Van Duzee, 1921

Sclerotized rings: Typical

Posterior wall: Meso-ventral emargination deep and widely V-shaped; E structures widening laterad; H structures very narrow, curving ventro-mesad, tubular evaginations represented only by a short broad protrusion from surface of sclerite; anterior mesal expansion narrow (poorly seen and exact shape somewhat problematic). Maximum length .31 mm., maximum width .43 mm. (Plate I, Fig. 8). Hypotype: McMinneville, Ore. October 5, 1946. K. M. Fender.

TROPIDOSTEPTES UHLER 1878

This genus at present contains only the type species, *T. cardinalis* Uhl., from North America. Eleven species have been at one time or another placed in the genus; of these seven are now placed in *Neoborus*, two in *Xenoborus* and one in *Neocapsus*. The genitalic characters are as in the discussion of the complex above.

Tropidosteptes cardinalis Uhler, 1878

Sclerotized rings: Rather typical, but with mesal margin of rings somewhat more rounded than in related species studied. Maximum length .24 mm., maximum width .91 mm. (Plate I, Fig. 9).

Posterior wall: Ventro-mesal emargination deep and broadly rounded, anterior mesal expansion deep, very shallowly emarginate on dorsal and ventral margins, H structures large and broad for group, tubular evaginations elongate, large and deeply grooved along posterior surfaces; E structures slender. Maximum length .35 mm., maximum width .68 mm. (Plate I, Fig. 7). Hypotype: Rock City, N. Y., Cattaraugus Co. July 5, 1915. H. H. Knight.

XENOBORUS REUTER 1908

This is a small genus of six described species, confined in distribution to North America. The characters are discussed under the complex above.

Xenoborus commissuralis Reuter, 1908

Sclerotized rings: Typical. Maximum length .13 mm., maximum width .71 mm. (Plate I, Fig. 11).

Posterior wall: Ventro-mesal emargination broad, narrowing dorsally; E structures broad mesally, tapering laterad; H structures slender with a narrow finger-like process that protrudes dorso-mesad from the dorso-mesal angle; tubular evagination short, thick, deeply grooved. Maximum length .35 mm., maximum width .59 mm. (Plate I, Fig. 5). Hypotype: Batavia, N. Y. July 30, 1916. H. H. Knight.

THE NEUROCOLPUS-PARACALOCORIS-LAMPETHUSA-POEAS COMPLEX

These four genera comprise a closely related group that has female genitalia very distinct from any other capsine genera investigated. The species studied all agree in possessing the following characteristics: The posterior wall (Plate I, Fig. 15), has strongly curving, lunate A structures. Structure B is very much reduced and does not reach the dorsal margin of the wings. Its place appears to be taken by a mesal

extension of the dorsal margin of the wall that projects dorsally and curves anteriorly at the apex and forms a small structure *C* (?) as does structure *B* in other *Capsinae*. The *E* structures are well developed and extend laterad of the lateral extremity of the *A* structures (Plate I, Fig. 17). There is considerable variation in the minute details of these structures, yet all maintain a very similar basic pattern, and species within a given genus may appear more similar to species in other genera than to related species within their own genus.

The appearance of the sclerotized rings (Plate I, Fig. 21), is also distinctive and again illustrates the extremely close relationship between species that exists within the complex. The rings are large with an evenly rounded median margin and a truncate lateral margin. The sclerotization around the rings is rather strong and projects anteriorly in an increasing arc from the lateral extremity of the rings to near the meson where it curves posteriorly in a deep emargination. Nothing has been found of generic value in these rings to separate one of these genera from the other, and very little of taxonomic value from species to species.

The question at once confronts one as to the advisability of generic separation for the species within the four genera. It is not the purpose of this dissertation to change in any way existing nomenclature; however, it is pertinent to suggest that here we are dealing with genera that are apparently not so distinct from one another as are other groups recognized as genera within the subfamily. It is the writer's opinion that these groups of species do not represent separate genera as the term is now used within the subfamily. It will of course be necessary to examine specimens of all available species before a final conclusion is reached. Whether one considers these species separate genera, subgenera, or does not separate them nomenclaturally is of course of lesser importance than the morphological fact that they do represent a distinct, closely related type. However, in view of the considerable degree of difference found between other recognized genera within the subfamily it seems that if the female genitalia are to be considered at all basic in the separation of genera, these four "genera" probably should be designated under a single generic name. Further support is given this viewpoint when one reviews the characters that have been used to separate the genera in the original descriptions and subsequently. The oldest included genus is *Neurocolpus* Reuter 1876: *Paracalocoris* was described by Distant in 1883, *Lampethusa* and *Poeas* by the same author in 1884 and 1893, respectively. *Neurocolpus* has been separated from the others by the apical dilation of the hairs on the first antennal segment, *Paracalocoris* by the excavated black spots on the pronotum, the others by relative antennal lengths and other minor structural and color differences. While these characters may be perfectly valid it seems to this writer that they do not constitute nearly as basic characters as do the female genital parts, and consequently it is concluded that a single generic type is represented.

The accompanying plates illustrate examples of all genera and show more clearly than any discussion the close affinity of the four groups.

NEUROCOLPUS REUTER 1876

This is a Nearctic genus composed at present of eight nominal species. The various species are very closely related to one another. Knight (12) separates them on the basis of the relative lengths of the first and second antennal segments, the length of the rostrum, and several color differences. Apparently the male genitalia are of no taxonomic value in the group. A number of species have been examined during this study and little has been found in the female genitalia that might not be a condition of individual variation. *Neurocolpus tiliae* Kngt. is quite distinct, but *mexicanus*, *simplex*, *arizonae*, and *jessiae* are extremely close to *nubilus* in the conformation of the posterior wall of the bursa as well as that of the sclerotized rings. Slight differences are present that may or may not prove to be of specific value when large series have been examined. It seems a strong possibility that several of these species will prove to be geographic races (subspecies) when a sufficiently detailed study has been made of the group.

Neurocolpus nubilus (Say), 1832

Sclerotized rings: Typical for complex; adjacent uniformly sclerotized wall with a marked invagination at antero-mesal margin, this wall does not appear to extend posteriorly below the rings as in other members of the complex, but to stop posteriorly at its junction with the anterior margins of the rings. Other than the above-mentioned character the rings are of very typical shape and form. Maximum length .53 mm., maximum width 1.17 mm. (Plate I, Fig. 16).

Posterior wall: A structures relatively narrow for complex, strongly curved, dorsal margin with a cut-in area adjacent to each side of base of a dorsal extension; structure B with a widened lance-like dorsal end; E structures well developed; dorso-mesal extension of A rather distinctive with a median depressed area and rounded margins. Maximum length .32 mm., maximum width .79 mm., length dorsal extension .17 mm. (Plate I, Fig. 15). Hypotype: Richmond, Ill. August 29, 1948. J. A. Slater.

Neurocolpus tiliae Knight, 1934

Posterior wall: Very distinct from *N nubilus*; the A structures much thicker, more strongly curving, dorsal margin lacking depressions near base of dorso-mesal extension, this latter broad and narrowing regularly from base to apex; structure B small with widened central area; E structures well developed. Maximum length .47 mm., maximum width .79 mm., length dorsal extension .16 mm. (Plate I, Fig. 17). Hypotype: St. Paul, Minn., University Farm. July 12, 1922. Clayton Johnson (Paratype).

PARACALOCORIS DISTANT 1883

This genus at present contains approximately forty-seven species with a rather large number of named varieties. The species are confined in distribution to the Nearctic and Neotropical regions. The species are diverse in color and habitus, some closely resemble members of the other three genera within this complex. Two species of the genus have been investigated; they differ from one another in a number of specific characters as mentioned below. The writer has been unable to find any

characters in the female genitalia that appear to be of generic value in separating this from the other three genera involved in the complex.

Paracalocoris scrupeus (Say), 1832

Sclerotized rings: Large, typical for complex with rounded median margin and truncate lateral margins; adjacent sclerotized dorsal wall uniformly and heavily sclerotized, concave dorsad, with a deep antero-mesal invagination. Maximum length .72 mm., maximum width 1.18 mm. (Plate I, Fig. 20).

Posterior wall: A structures wide, strongly curving, dorsal extension widening from the base, then narrowing to apex, but of considerable width throughout; structure B slender, margins undulating. Maximum length .52 mm., maximum width .72 mm., length dorsal extension .20 mm. (Plate I, Fig. 13). Hypotype: Ithaca, N. Y. June 23, 1920. H. H. Knight.

Paracalocoris johnstoni Knight, 1930

Sclerotized rings: Very similar to *P. scrupeus*. Maximum length .89 mm., maximum width 1.34 mm.

Posterior wall: A structures narrower than in *scrupeus*, less strongly curved, dorsal extension more slender, narrowing evenly from base to apex; structure B very small, lacking the undulate margins of *scrupeus*. Maximum length .39 mm., maximum width .79 mm., length dorsal extension .17 mm. (Plate I, Fig. 18). Hypotype: Navasota, Tex. April 10, 1948. M. Polhemus.

POEAS DISTANT 1893

This is a monotypic genus erected for the South American species *P. reuteri* Dist. This species definitely falls into the same group of species as *Neurocolpus*, *Paracalocoris* and *Lampethusa*.

Poeas reuteri Distant, 1893

Sclerotized rings: Very typical of complex, antero-mesal invagination very deep and narrow. Maximum length .58 mm., maximum width 1.44 mm. (Plate I, Fig. 21).

Posterior wall: Essentially of type found within complex, but offering some interesting differences. A structures strongly curving dorsad, ventral margin of A structures broadly emarginate mesally, dorsal extension flaring into a widely lobed apex; structure B composed of a strongly sclerotized elliptical central area bordered by a pair of less strongly sclerotized flanges on each side; E structures very well developed. Maximum length .52 mm., maximum width .72 mm., length dorsal extension .28 mm. (Plate I, Fig. 14). Hypotype; D. Federal, Brazil, Rio D'Ouro (?). May 1946. J. C. M. Carvalho.

LAMPETHUSA DISTANT 1884

This genus is composed of four species, one found in the Southwestern United States and three Neotropical in distribution. One species, *L. collaris* Reut., has been examined and found to be closely related to the three genera discussed above.

Lampethusa collaris Reuter, 1909

Sclerotized rings: Typical, median margin rounded and somewhat narrowed as in *Neurocolpus nubilus* (Say), but with sclerotization of dorsal wall uniform below rings, median emargination very slight and broad. Maximum length .59 mm., maximum width 1.22 mm. (Plate I, Fig. 19).

Posterior wall: A structures thick and strongly, lunately curving, the dorsal extension nearly straight-sided for apical one-half of length and broad throughout; structure B composed of a lightly sclerotized ventral base that widens abruptly to

a broad, rounded hoe-like apical region; E structures present (these latter somewhat mutilated and not shown in Plate I, Fig. 12. Maximum length .37 mm., maximum width .72 mm., length dorsal extension .18 mm. (Plate I, Fig. 12). Hypotype: Santarem, Brazil. Acc. No. 2966. J. C. M. Carvalho.

STITTOCAPSUS KNIGHT 1942

This is a recently described monotypic genus found in the southwestern part of the United States. The female genitalia appear to be generically distinct from any other genus investigated. Knight (14) in the original description placed the genus near *Adelphocoris*. The structures considered here show no closer relationship to *Adelphocoris* than to a number of other genera. The sclerotized rings have rather more in common with the species of *Calocoris* studied.

Stittocapsus franseriae Knight, 1942

Sclerotized rings: Small for size of species, relatively weakly sclerotized; rings very widely separated mesad, subelliptical, with ring broadened irregularly at lateral margin; structure G well developed, curving below rings, extending strongly mesad in a curving arc to near median line. Maximum length .26 mm., maximum width .76 mm. (Plate V, Fig. 2).

Posterior wall: A structures moderately curving dorsad, a broad, very shallow median emargination on ventral margin; structure B prominent, not reaching the dorsal margin of a broad, short, median dorsal extension, B highest at center, sloping gradually in all directions; apex of meso-dorsal extension slightly concave, curving anteriorly and widening into a typical structure C; dorsal margins of A structures irregular; E structures not evident. Maximum length .22 mm., maximum width 1.11 mm. (Plate II, Fig. 15). Hypotype: Mohawk, Ariz. April 1, 1941. L. L. Stitt.

CAPSUS FABR. 1803

This genus is now considered to contain approximately fifteen species. The species are found in the Oriental, Palearctic, Nearctic, and perhaps Neotropical regions.

One species, *Capsus ater* (L.) has been studied. The posterior wall of this species is quite distinctive. The A structures are separated from a large mesal plate by thin membrane, instead of being fused to structure B (Plate II, Fig. 2). This feature is found only in *Dichrooscytus* and *Bolteria* (Plate II, Figs. 1 and 3), in addition to the present genus. However, these genera lack the broad mesal plate. The sclerotized rings are of a much different type in *Capsus* than they are in *Dichrooscytus* and *Bolteria*.

Capsus ater (L.), 1758

Sclerotized rings: Prominent, semi-elliptical, posterior margin concave, ring thickest at lateral extremity; structure F prominent along anterior margin of each ring, widening near meson, its mesal margin bluntly and irregularly rounded, not in contact with opposite side. Maximum length .54 mm., maximum width 1.21 mm. (Plate IV, Fig. 6).

Posterior wall: Very distinctive, a large median plate present possessing a pair of prominent, posteriorly curving projections on its ventro-lateral margin; A structures sloping strongly dorsad, connected to median plate only by a very delicate membrane; structure B arising from near dorsal margin of median plate, widening dorsad; structure C represented by a pair of wing-like processes and a delicate elliptical membranous margin; E structures very prominent, projecting considerably laterad of A structures, surface covered with short projecting spines. Maximum

length .48 mm., maximum width .78 mm. (Plate II, Fig. 2). Hypotype: Park Ridge, Ill. June 5, 1942. J. A. Slater.

DICHROOSCYTUS FIEBER 1858

This small genus is at present composed of fourteen species. The various species are found in the Palearctic and Nearctic regions. Only one species, the genero-type, *D. rufipennis* (Fall.), has been examined.

The affinities of this genus are clearly with *Bolteria*, to which it is very closely related in the structure of the female genital parts investigated. In both genera the margins of the sclerotized rings (Plate IV, Fig. 2) coalesce mesally and form a connecting bar, or ridge between the two rings. The B structure area of the posterior wall of the bursa is similar, composed of a long slender rod that widens dorsally and curves anteriorly to form a broad structure C. The A structures of both genera appear to be composed of two parts with a membranous mesal portion between them.

Dichrooscytus rufipennis (Fall.), 1807

Sclerotized rings: (See generic discussion above.) Rings tapering mesad from a broad subtruncate lateral margin; adjacent sclerotization undifferentiated and weakly sclerotized. Maximum length .22 mm., maximum width .86 mm. (Plate IV, Fig. 2).

Posterior wall: A structures with a mesal membranous area between the two sides, ventral margin straight with slightly produced corners, A structures sub-rectangular rather than lunately curving, widening dorsad; structure B composed of a tapering sclerite that broadens dorsad and curves anteriorly at apex to form a broad elliptical structure C; a pair of poorly differentiated H structures present at extremities of A; E structures prominent, broad and subrectangular. Maximum length .47 mm., maximum width .62 mm. (Plate II, Fig. 3). Hypotype: Neida, Oberlausitz: Germany. June 27, 1943. Coll. K. H. C. Jordan.

BOLTERIA UHLER 1887

This is a small genus composed of seven species, the members of which are confined in distribution to the Nearctic region. One species, *B. luteifrons* Kngt., has been examined. The genus is very close to *Dichrooscytus* Fieber and has certain features in common with *Platytyl-ellus* (see discussion under the above-mentioned genera). A study of all the species of *Bolteria* and *Dichrooscytus* to determine the generic limits would be of considerable interest.

Bolteria luteifrons Knight, 1922

Sclerotized rings: Elliptical, widely separated mesad, connected mesally by a long slender sclerotized band formed by coalescence of margins of sclerotized rings; adjacent sclerotization undifferentiated. Maximum length .14 mm., maximum width .41 mm. (Plate IV, Fig. 3).

Posterior wall: A structures separated into two sclerites by a membranous mesal area, the sclerites curving strongly dorsad and narrowing from meson to lateral tips, dorsal margin more strongly sclerotized than ventral; structure B elongate, widening dorsally to a broad knob, an abrupt expansion of rod about two-thirds distance from its ventral point; structure C concave on dorsal side, with a distinct anteriorly directed ridge arising from dorsal margin, anterior surface strongly concave, form reniform. Maximum length .29 mm., maximum width .58 mm., length structure C .09 m., width structure C .20 mm. (Plate II, Fig. 1). Hypotype: Gray Summit, Mo. May 16, 1943. R. C. Froeschner.

PHYTOCORIS FALLEN 1814

This is probably the largest single genus of the *Miridae*. Approximately 266 species are considered to be present within the generic limits. The distribution is predominately Nearctic and Palearctic. Such a tremendous assemblage of species from every major faunal area of the world would require a study more extensive than the present one for itself alone. The female genitalia of only a single species have been examined, and, if this species is at all indicative, the genitalia seem to indicate a distinct group with relationship to the fourth group of genera (see subfamily discussion).

Phytocoris osborni Knight, 1928

Sclerotized rings: Very distinctive, rings reduced to a small round opening near lateral margin, marginal sclerotization thick, extending mesad in a distinct bar to near median line, not in contact mesad. Maximum length .14 mm., maximum width .72 mm. (Plate IV, Fig. 11).

Posterior wall: *A* structures slightly concave near meson on ventral margin, curving conventionally dorsad; structure *B* consisting of a flat disc with a more heavily sclerotized central line apparent, this disc tilted strongly posteriorly from its ventral base to dorsal apex, the dorsal extension of *B* running almost at right angles in this species, actually extending more anteriorly than dorsally; *E* structures prominent, nearly the size of the *A* structures. Maximum length .27 mm., maximum width .72 mm. (Plate II, Fig. 26). Hypotype: Sioux City, Iowa. July 5, 1948. J. L. Laffoon.

LYGUS HAHN 1833

This is an enormous genus containing upwards of 300 species, various ones of which are found in all the major faunal regions of the world. Many of the species are quite variable, and a large number of varieties and synonyms have been described in the literature. Apparently many of the species will prove to be polytypic, and a large-scale study using detailed population analyses is badly needed and offers an excellent field of study.

The present study is much too limited in scope to present a completely clear picture of the group. However, the few species examined do show some most interesting situations.

The genus *Lygus* has been considered to be composed of the following subgenera: *Lygus* Hahn 1833, *Orthops* Fieber 1858, *Lygocoris* Reuter 1875, *Agnocoris* Reuter 1875, *Paralygus* Reuter 1906 and *Neolygus* Knight 1917.

However, China (2) points out that the first valid type fixation for *Lygus* Hahn 1833 is that of Distant (4), who names *L. pabulinus* as type. The subgeneric name *Lygocoris* Reuter 1875 therefore becomes a synonym of *Lygus*. China proposes the subgenus *Apolygus* for those species formerly included under the subgenus *Lygus*.

Material has been studied from five of these subgenera, and the characters of the female genitalia indicate that the subgenera, at least in some cases, will ultimately prove not to be congeneric. Knight (13) has already accorded generic rank to his *Neolygus*, a conclusion that the female genitalia corroborate to a marked degree. Indeed, the species

of *Neolygus* studied do not appear to be even closely related to the *Apolygus* complex, and their former position within the same genus appears to have been based upon a superficial resemblance rather than any true phylogenetic relationship. (See *Neolygus* for discussion.) The subgenus *Lygus* containing the single included species *L. pabulinus* (L.) also has female genitalia very dissimilar from *Apolygus* and probably should be considered a distinct genus. The posterior wall of the bursa in this species is very unique among the species studied (Plate II, Fig. 18). Unfortunately, were this subgenus to be raised to generic rank, all of the economically important "Lygus" bugs of North America would take a different generic name.

The subgenus *Agnocoris* Reuter also appears to be rather distinct from the other *Lygus* species studied.

Within the subgenus *Apolygus* the following species have been studied: *oblineatus*, *elisus*, *hesperus*, *vanduzeei*, *plagiatus* and *atriflavus*. The evidence obtained from a study of these species indicates that the posterior wall is rather constant throughout the various species. Certain small differences can be ascertained, but whether these represent actual specific characters or will indicate only individual variation can only be established by the study of large series of all the species from various parts of their respective ranges. For the present, the differences appear to be doubtful as aids to specific identification. The character of the posterior wall therefore constitutes, on present evidence, a generic character. The sclerotized rings show a basic pattern throughout the species studied. Nevertheless, they vary considerably from species to species and appear to offer good characters for specific differentiation. Only in the case of *L. elisus* and *L. hesperus* has the writer been unable to satisfactorily separate the species upon this character.

The subgenus *Apolygus*, upon the evidence of the species studied, may be characterized as follows: Sclerotized rings (Plate III, Fig. 18), subrectangular, not noticeably narrowed either mesad or laterad, a prominent structure *F* extending from anterior margin of rings in an antero-mesal direction, but not in contact on median line, lateral margin of this adjacent sclerite protruded at anterior angle into a more or less hooked process which may be of some value in specific determination; structure *G* poorly developed, indistinct, or lacking. Posterior wall (Plate II, Fig. 14); as mentioned above, this structure is very constant within the subgenus and appears to be unquestionably of generic importance. The *A* structures curve normally; *H* structures absent; structure *B* from a posterior view consisting of a flat disc between *A* structures, tipped posteriorly from ventral to dorsal ends, a median extension proceeds from below this disc, curves strongly cephalad at its dorsal margin and possesses a strongly sclerotized, distinctively shaped structure *C*.

Lygus vanduzeei Knight, 1917

Sclerotized rings: Very small, widely separated, a distinct angle from posterior to anterior margin along mesal margin; *F* structures prominent, curving very

strongly cephalad from their origin to mesal extremity. Maximum length .53 mm., maximum width 1.08 mm. (Plate III, Fig. 18).

Posterior wall: As in generic discussion. Maximum length .42 mm., maximum width .85 mm. (Plate II, Figs. 8 and 14). Hypotype: Black Mts., N. C. (?)—21—30, 1912. Beutenmuller.

Lygus plagiatus Uhler, 1895

Sclerotized rings: Rings short and wide from anterior to posterior margin, considerably larger than *vanduzeei*, median margin rounded; *F* structures bordering anterior margin of rings for nearly entire length, not strongly produced anteriorly, widely separated mesad, lateral margin produced in a thick blunt hook. Maximum length .43 mm., maximum width 1.12 mm. (Plate III, Fig. 13).

Posterior wall: As in generic discussion. Maximum length .40 mm., maximum width .72 mm. Hypotype: Urbana, Ill. October 16, 1945.

Lygus atriflavus Knight, 1917

Sclerotized rings: Small, very widely separated mesad, rings narrower and more elongate than in preceding species; *F* structures prominent, extending strongly cephalad in a wide arc to terminate near midline, prominent hook at lateral margin of *F* structure. Maximum length .46 mm., maximum width 1.01 mm. (Plate III, Fig. 12).

Posterior wall: As in generic discussion. Maximum length .30 mm., maximum width .75 mm. Hypotype: Williams, Ariz. August 4, 1917. H. H. Knight.

Lygus oblineatus (Say), 1832

Sclerotized rings: Relatively elongate and slender, more of a type with *elिसus*, *hesperus* and *atriflavus* than with *vanduzeei* and *plagiatus*; rings considerably longer than the above; *F* structures weakly developed, not extending anteriorly away from anterior margin of rings, a prominent lateral hook present. Maximum length .19 mm., maximum width 1.08 mm. (Plate III, Fig. 19).

Posterior wall: As in generic discussion. Maximum length .29 mm., maximum width .76 mm. Hypotype: Champaign, Ill. June 22, 1946. J. and W. Rapp.

Lygus hesperus Knight, 1917 and *Lygus elिसus* V. D., 1914

Sclerotized rings: The writer has been unable to distinguish between these two forms on the conformation of the rings. In both species the rings resemble *oblineatus*, but are noticeably less elongate and the *F* structures curve moderately cephalad from the anterior margin of the rings. The shape of the lateral projection of structure *F* differs in the two species as shown in Plate III, Figs. 16 and 17, but whether this will prove to be of specific value must await the study of a series of both species. Maximum length .35 mm., maximum width 1.01 mm. (from *L. hesperus*).

Posterior wall: As in generic discussion. Maximum length .31 mm., maximum width .68 mm. (from *L. elिसus*). *Lygus hesperus*—Hypotype: Emery Co. Utah. August 10, 1921. G. O. Wiley. *Lygus elिसus*—Hypotype: Oroville, Wash. August 2, 1918. A. C. Burrill.

The subgenus *Agnocoris* is perhaps generically distinct from *Apolygus*, at least the type species *L. rubicundus* does not appear to be closely allied to the species of *Apolygus* studied. Both the sclerotized rings and the posterior wall offer characters at variance with the type shown by the *Apolygus* species. Chief among these may be mentioned the shape of the rings, which are ovate or cordiform rather than rectangular, with the mesal end tapering to a sharp point; further, the comparative lack of differentiation of structure *F* is informative (Plate V, Fig. 5). In the posterior wall the *H* structures that arise from the lateral extremities of the *A* structures and curve mesad and ventrad to near structure

B are not found in *Apolygus* species. Further, structure *C* is of a different nature than in the preceding forms (Plate II, Fig. 19).

Lygus rubicundus (Fall.), 1829

For structural characteristics see subgeneric discussion above.

Sclerotized rings: Maximum length .12 mm., maximum width .40 mm.

Posterior wall: Maximum length .19 mm., maximum width .53 mm. Hypotype: Sioux City, Iowa. July 4, 1948. J. L. Laffoon.

The monotypic subgenus *Lygus* appears to be rather distantly related to the species of *Apolygus* studied. Certainly unless subsequent studies show a merging of characters not apparent from the material observed, this subgenus will be recognized as of distinct generic rank. In certain respects the relationships appear to be with *Neolygus* rather than any of the other subgenera.

Lygus pabulinus (L.), 1761

Sclerotized rings: Small for size of species, subtriangular, tapering strongly from broad lateral margin to a pointed mesal end, posterior margin concave, nearly in contact mesad, no apparently well-differentiated adjacent sclerotization present, some resemblance to *Coccobaphes sanguinarius* in contour of the rings. Maximum length .12 mm., maximum width .55 mm. (Plate V, Fig. 3).

Posterior wall: Structure complicated; *A* structures only moderately curving with concave dorsal margin; a small structure *B* in form of a flat disc with a short dorsal extension; structure *C* apparently absent; *H* structures arising from extremities of *A* structures, extending as wide, straight, bar-like sclerites to near meson where the sclerites twist ventrally and anteriorly and terminate in a pair of anterior points; *E* structures prominent, narrow, their basal connection not approaching lateral margin of *A* structures; a pair of large spreading folds extending anteriorly from the dorsal margin of the paired sclerites (not visible in figure), these folds nearly as large and prominent as the *A* structures. Maximum length .27 mm., maximum width .62 mm. (Plate II, Fig. 18). Hypotype: Gatlinburg, Tenn. July 20, 1947. R. H. Whittaker.

Kullenberg (17) illustrates the female genitalia of *Lygus campestris* (L.). From his fine illustration it appears that the subgenus *Orthops* also may prove to be distinct. In this species, the sclerotized rings are apparently not differentiated from the surrounding membranes.

The writer has been able to examine one teneral specimen of *Lygus sallei* Stal, 1862, a species that belongs to the subgenus *Paralygus*. The sclerotized rings are somewhat similar to those of *Lygus rubicundus* and appear to have little in common with the type found in the subgenus *Apolygus*.

PLATYLYGUS VAN DUZEE 1915

This is a small Nearctic genus of six nominal species. Five of the species are western and southwestern in distribution in the United States. The generotype, *P. luridus* Reut., is found in the northeastern states. One species, *P. grandis* Kngt., has been investigated.

Platylygus grandis Knight, 1919

Sclerotized rings: Large even for size of species, slenderly elliptical, lying at a markedly divergent angle from anterior to posterior end; *F* structures extending in an antero-mesal direction from the anterior margin of the rings, not in contact

mesad; G structures weakly developed, broadly in contact mesad. Maximum length .81 mm., maximum width 1.58 mm. (Plate III, Fig. 8).

Posterior wall: Suggestive of *Poecilocapsus lineatus* (Fabr.); meso-ventral margin of A structures broadly and shallowly emarginate; structure B curving caudad and recurved strongly anteriorly at dorsal margin; a delicate membranous structure C present; H structures curving from dorso-lateral extremities of "rod-like" extension of A structures, as in *Pantilius*, *Calocoris*, and *Poecilocapsus*; E structures prominent with a conspicuous ventral projection of ventro-lateral angle. Maximum length .42 mm., maximum width 1.22 mm. (Plate II, Fig. 24). Hypotype: Trinidad, Colo. (Stonewall 8,500 ft.) August 7, 1925. H. H. Knight.

CALOCORISCA DISTANT 1884

This is a small genus of nine described species, the members of which are found in Central America, Mexico, and the southwestern part of the United States. One species of the genus has been studied. The appearance of the posterior wall of the bursa is most interesting and distinctive (Plate II, Fig. 22). Relationship with *Calocoris*, *Pantilius*, *Poecilocapsus*, and *Platylygus* is suggested, both in the appearance of structure B and especially in the tremendous development of the H structures that arise from the extremities of the A structures. The narrow bar-like condition of structure A has not been discovered in any other genera studied.

Calocorisca sticticollis (Stal), 1860

Sclerotized rings: Rather small for size of species, tapering strongly from wide lateral end to a blunt point at mesal end; adjacent sclerotization nearly uniform over entire surface, no prominent F structures evident. Maximum length .20 mm., maximum width .84 mm.

Posterior wall: Very distinctive; A structures very narrow and bar-like, curving strongly dorsad; H structures developed into large, strongly twisted expansions that are recurved ventrally and terminate in a wide curving expanded plate; structure B suggestive of *Calocoris*, but with a disc-like ventral plate, not approaching ventral margin of A structures and tilted posteriorly from base to apex, dorsal extension recurving anteriorly, terminating in a membranous extension that broadens to apex; E structures prominent. Maximum length .40 mm., maximum width .79 mm. (Plate II, Fig. 22). Hypotype: Parque Nacional, Da Serra Dos Orgaos (?), Teresopolis. April 14-22, 1947. P. Wygodzinsky.

POECILOCAPSUS REUTER 1876

This is a small genus containing ten nominal species; all but one, the generotype, *P. lineatus* (F.), confined in distribution to Mexico and Central America.

The female genital affinities seem to point toward *Calocoris* and *Pantilius*, insofar as these three genera possess large H structures attached near the lateral extremities of the A structures of the posterior wall of the bursa copulatrix.

Poecilocapsus lineatus (Fabricius), 1798

Sclerotized rings: Subelliptical, strongly sclerotized, widely separated mesad, postero-lateral angle very strongly sclerotized and thickened; F structures prominent along entire anterior margin of rings, curving mesad, broadly in contact mesally. Maximum length .45 mm., maximum width 1.22 mm. (Plate IV, Fig. 15).

Posterior wall: A structures moderately curving, latero-dorsal extension very strongly sclerotized, forming a bar-like structure that extends mesad along dorsal margin of A structures, ventral margin of A structures undulate mesally; structure B

prominent, not approaching ventral margin of *A*, consisting of an elliptical plate tilted dorso-caudad, with dorsal extension that curves anteriorly and widens into a broad membranous structure *C*; extremities of *A* structures with paired, anteriorly twisting *H* structures somewhat as in *Calocoris* and *Pantilius*, these sclerites produced mesad half way to midline; *E* structures prominent. Maximum length .32 mm., maximum width .89 mm. (Plate II, Fig. 29). Hypotype: Great Swamp, Chatham Twp., N. J. July 9, 1944. J. & W. Rapp.

LYGIDEA REUTER 1879

This is a small genus composed of twelve species, all but the type species being found in the Nearctic region. The generotype, *illota* Stal, was described from Siberia. One species in the genus, *L. rosacea* Reuter, has been examined. This species is a very typical member of the fourth group of genera within the subfamily (see subfamily discussion).

Lygidea rosacea Reuter, 1909

Sclerotized rings: Large and strongly sclerotized, subelliptical, tapering mesad, posterior margin slightly concave, moderately separated mesad; adjacent sclerotization well developed, *F* structures arising just laterad of center of anterior margin of rings, broadening mesad to terminate at mesal tip of rings in a broad truncate margin; *G* structures broadly curving below the rings, lateral margin with a blunt lateral projection. Maximum length .49 mm., maximum width 1.08 mm. (Plate V, Fig. 1).

Posterior wall: *A* structures curving moderately dorsad; structure *B* in form of flattened disc tilted posteriorly from ventral to dorsal extremities, dorsal extension broadening and flaring dorsad with lateral margin sloping anteriorly from meson; *H* structures prominent, curving ventrad from lateral origin toward meson, tapering to a blunt point mesad, dorsal margin with a projection near center that curves anteriorly and forms a curving bend anterior to the sclerite proper; *E* structures very large, produced laterad of *A* structures for nearly entire length. Maximum length .30 mm., maximum width .75 mm. (Plate II Fig. 30). Hypotype: Ames, Iowa. June 17, 1949. J. A. Slater.

GARGANUS STAL 1862

This is a small genus composed of six species. The members of the genus are confined in distribution to the Western Hemisphere. One species, *Garganus fusiformis* (Say), has been studied. The posterior wall is of a rather generalized nature (Plate II, Fig. 23), but the sclerotized rings are very distinctive in that the rings are reduced to a single elongate bar (Plate IV, Fig. 10). This bar-like condition of the rings is probably generically distinctive. Despite the peculiar nature of the rings, the posterior wall indicates that the genus belongs with the fourth group of species in the subfamily (see subfamily discussion).

Garganus fusiformis (Say), 1832

Sclerotized rings: Rings absent, represented only by an undulate bar that extends in a cephalo-caudal direction from meson to lateral extremity. This bar may represent either a coalescence of the rings or either the anterior or posterior margin of the ring, the other margin being absent, adjacent sclerotization present laterad and extending anterior to the "ring"; no indication of *G* structure sclerotization. Maximum length .21 mm., maximum width .58 mm. (Plate IV, Fig. 10).

Posterior wall: *A* structures curving normally dorsad, ventral margin straight for considerable distance from meson; structure *B* area with a flat, indistinct disc and a heavily sclerotized median bar that widens dorsad; weak *H* structures present, arising from lateral extremities of *A* structures; *E* structures large, but not project-

ing laterad of *A* structures. Maximum length .14 mm., maximum width .40 mm. (Plate II, Fig. 23). Hypotype: Bath, Ill. July 31, 1946. J. A. Slater.

HORCIAS DISTANT 1884

The genus *Horcias* is composed of twenty-seven nominal species confined in distribution to the Western Hemisphere. Three species of the genus have been examined, *dislocatus*, *fallax*, and *signoreti*. The female genital parts reveal that *signoreti* is probably not congeneric with the other two species examined. A study is needed of the genitalia of all the species to determine the generic limits of this group.

Horcias dislocatus (Say), 1832

Sclerotized rings: Rings lunate, very elongate and slender, in close approximation along median line, not narrowing perceptibly mesad or laterad; *F* structures weakly developed, lying close along anterior margin of rings; *G* structures prominent, tapering from a broad lateral margin to a blunt point one-third distance from mesad extension of rings, a prominent thumb-like lateral protrusion present. Maximum length .58 mm., maximum width 1.26 mm. (Plate IV, Fig. 8).

Posterior wall: Structure distinctive; *A* structures curving normally dorsad; *H* structures curving broadly mesad to terminate one-fourth way from median line; structure *B* composed of a flat disc tilted posteriorly from ventral to dorsal margins, a dorsal extension proceeding from this and anterior to it that is bifurcate and forms a forceps-like structure; membranous extensions from tips of paired *H* structures curve ventrad and divide near this forceps formation into a pair of lateral prongs; *E* structures prominent. Maximum length .39 mm., maximum width .91 mm. (Plate II, Fig. 28). Hypotype: Locality unknown. X429 J. A. Slater collection.

Horcias fallax Reuter, 1909

Sclerotized rings: Rings considerably less elongate than in *dislocatus*, more subelliptical than lunate, area within rings conspicuously broader in comparison with length; condition of adjacent sclerotization indefinite in specimen examined, but a prominent thumb-like lateral protrusion present. Maximum length .32 mm., maximum width .89 mm.

Posterior wall: General facies similar to *dislocatus*; structure *B* flattened, disc area absent, but perhaps lost in dissection, forceps-like dorso-mesal extension with prongs continued dorsad to form a closed circular area with a strong membrane within, this perhaps homologous to structure *C* of other genera; *H* structures broader and proportionately less heavily sclerotized than in *dislocatus*. Maximum length .30 mm., maximum width .72 mm. Hypotype: 4 mi. E. Gilbert, Iowa. May 24, 1949. J. A. Slater.

Horcias signoreti (Stal), 1859

This species is certainly not congeneric with the above if the female genitalia serve at all as indicators of relationships. The sclerotized rings (Plate IV, Fig. 14) are of quite a different type, having the anterior-mesal angles of the rings produced very strongly cephalad as prominent horn-like extensions. Of more significance perhaps is the fact that the posterior wall is of an entirely different type. The forceps-like dorsal extension of structure *B* is lacking, and *B* is of a more conventional nature. The *H* structures are absent and the *A* structures are much less prominently produced and tapering laterad, and the area of the *A* structures is much greater proportionate to its size (Plate III, Fig. 4). Hypotype: M. Gerais, Brazil. C. R. Claro 1945. J. C. M. Carvalho.

COCCOBAPHES UHLER 1878

This is a monotypic genus; the lone species, *C. sanguinarius* Uhl., is confined in distribution to the eastern United States.

Coccobaphes sanguinarius Uhler, 1878

Sclerotized rings: Rings elongate, widening laterad, strongly sclerotized with posterior and lateral margins thickest; *F* structures curving mesad; a definite thumb-like projection laterad on *G* structures; rings moderately wide apart mesad. Maximum length .32 mm., maximum width 1.04 mm. (Plate IV, Fig. 12).

Posterior wall: *A* structures moderately curving; structure *B* strongly developed, a subcircular strongly sclerotized area midway from ventral margin; median extension bearing pair of very prominent lateral elongations that form a conspicuous dorsal margin to the entire structure, these lateral elongations slope antero-ventrad from the dorsal margin and form the most conspicuously distinct portion of the wall; *E* structures prominent. Maximum length .25 mm., maximum width .94 mm. (Plate II, Fig. 27). Hypotype: Rock City, N. Y., Cattaraugus Co. July 4, 1915. H. H. Knight.

ADELPHOCORIS REUTER 1896

This is a genus of large mirids containing approximately forty-three described species and a number of varieties. The species are most numerous in the eastern part of the Palearctic region, but members are found in all the major faunal areas of the world with the exception of the Neotropical. In the three species studied the posterior wall is nearly identical in all three species, but the sclerotized rings indicate certain small specific differences.

Adelphocoris rapidus (Say), 1832

Sclerotized rings: Very large and broad, rings nearly meeting on meson, mesal margin broad and running along median line for a considerable distance, tapering strongly to a point laterad; *F* structures appear absent; *G* structures weakly developed and indistinct. Maximum length .54 mm., maximum width 1.09 mm. (Plate V, Fig. 6).

Posterior wall: See *A. lineolatus* (Goeze). Maximum length .19 mm., maximum width .94 mm. Hypotype: Urbana, Ill. June 27, 1941. J. A. Slater.

Adelphocoris superbus (Uhler), 1875

Sclerotized rings: Very similar in shape and form to *A. rapidus*. In the specimen examined the rings are somewhat more elongate in this species than in the preceding. In view of the opinion of some authors that these species represent races rather than distinct species, examination of a series will be necessary to determine whether or not the above distinction will prove to be of specific value. Maximum length .62 mm., maximum width 1.22 mm.

Posterior wall: See *A. lineolatus* (Goeze). Maximum length .18 mm., maximum width 1.00 mm. Hypotype: Sheridan, Wyo. August 2, 1927. H. H. Knight.

Adelphocoris lineolatus (Goeze), 1778

Sclerotized rings: Less obovate than preceding two species, more narrowed at median line, forming a noticeably less broad median margin along midline; *G* structures more prominently developed and broadly in contact mesad. Maximum length .54 mm., maximum width 1.08 mm.

Posterior wall: Structure simple; *A* structures narrow, ventral margin straight for a considerable distance and curving only moderately dorsad; structure *B* curving posteriorly from ventral to dorsal margins, dorsal margin strongly recurved anteriorly and widened into a simple *C* structure from whence membranous connectives connect with the lateral extremities of the *A* structures; *E* structures prominent. Maximum length .19 mm., maximum width .86 mm. (Plate II, Fig. 25). Hypotype: Bath, Ill. July 31, 1946. J. A. Slater.

PANTILIUS CURTIS 1833

This is a small genus composed of four species confined in distribution to the Eastern Hemisphere. Of the four, one species, the generotype,

Pantilius tunicatus (Fabr.), has been studied. The female genitalia of this species indicate some relationship to *Calocoris* but show some rather remarkable characteristics.

Pantilius tunicatus (Fabr.), 1781

Sclerotized rings: Large and strongly sclerotized, median margin broadly rounded, lateral margin tapering to an elongate point, posterior margin concave; structure *F* produced considerably cephalad of rings, with a very wide, deeply sinuate median emargination, which terminates mesad of rings at a strongly sclerotized, elliptical button-like sclerotized area; structure *G* lies ventrad of the rings, widest at lateral margins, possessing a lateral thumb-like protrusion at antero-lateral angle, whole sclerite tapering mesad and concave dorsally. Maximum length .47 mm., maximum width 1.15 mm. (Plate III, Fig. 10).

Posterior wall: Very distinctive, *A* structures only slightly curving on ventral margin, elliptical; structure *H* large, composed of posteriorly curving lateral extensions with lobed distal ends; structure *B* large, heavily sclerotized, narrowing near middle, widening dorsad, with dorsal margin extended strongly caudad to form a shelf-like ledge; *E* structures small and inconspicuous. Maximum length .34 mm., maximum width .98 mm. (Plate III, Fig. 2). Hypotype: Bautzen, Oberlausitz, Germany. October 14, 1939. K. H. C. Jordan.

CALOCORIS FIEBER 1858

This is a large genus containing approximately eighty-four described species, several of these with a number of varietal names. The various species are found in all the faunal regions of the world, but the center of distribution lies in the Palearctic region.

It is difficult in a genus of this size to draw conclusions as to its affinities on the basis of a few species. However, the female genitalia appear to illustrate a distinct generic group with a relationship to *Pantilius*.

The generic characters of the female parts studied are as follows: Structure *F* arises from anterior margin of rings, and curves antero-mesad to median line, where a thin mesal connection is present. Below rings structure *G* likewise curves antero-mesad to meet at the median line. This sclerotized piece is very suggestive of *Pantilius*. The sclerotized rings are widely separated mesad and strongly sclerotized. The posterior margin is produced into a narrow ridge on its internal side (Plate III, Fig. 11).

The posterior wall is rather suggestive of *Pantilius*. Structure *B* reaches the ventral margin, or close to the margin of the *A* structures, and dorsally curves strongly cephalad to widen into a broad, distinct *C* structure. Most suggestive of *Pantilius* are the *H* structures attached near the dorso-lateral tips of *A* structures. These *H* structures curve strongly cephalad and are somewhat twisted (Plate III, Fig. 3).

Calocoris norvegicus (Gmelin), 1788

Sclerotized rings: Typical of the genus; rings moderately subelliptical. Maximum length .61 mm., maximum width 1.21 mm. (Plate III, Fig. 11).

Posterior wall: Structure *B* narrowed one-half way from ventral margin, widening dorsad; structure *C* broad, basal sclerotization much the thickest, sloping posteriorly both dorsad and ventrad of a transverse median ridge; *H* structures arising from tips of *A* structures, broad, curving strongly antero-ventrad, surface sloping

in several directions; dorsal margins of *A* structures sharply emarginate near meson, forming a narrow connection with structure *B*. Maximum length .35 mm., maximum width .73 mm. (Plate III, Fig. 3). Hypotype: Maspeth, L. I., N. Y. June 13, 1908. C. E. Olsen.

Calocoris biclavatus (H.S.), 1835

Sclerotized rings: Rings very slender and elongate, sloping caudo-laterad from mesal margin; *F* structures very slender forming a fine mesal connection; *G* structures typical with a very distinct lateral thumb-like protrusion on lateral margin. Maximum length .42 mm., maximum width 1.18 mm. (Plate III, Fig. 14).

Posterior wall: Very similar to *C. norvegicus*; structure *B* appearing not to reach ventral margin of *A* structures; *A* structures themselves much thicker dorso-ventrally than in *C. norvegicus*. Maximum length .36 mm., maximum width .81 mm. Hypotype: Lausche, Oberlausitz, Germany. August 11, 1942. K. H. C. Jordan.

Calocoris fulvomaculatus (De Geer), 1773

Sclerotized rings: Rings short, irregularly ovoid, much wider and less elliptical than in two species above; *F* structures thicker than in *C. biclavatus*. Maximum length .56 mm., maximum width 1.04 mm. (Plate III, Fig. 15).

Posterior wall: Not available. Hypotype: Casslau (?), Oberlausitz, Germany. June 23, 1940. K. H. C. Jordan.

EUCHILOCORIS REUTER 1909

This is a South American genus composed of two species. The affinities of the genus are with *Calocoris* and its allies (see *Calocoris*), particularly in the development of the *H* structures that arise from the extremities of the *A* structures.

Euchilocoris rufinasus (Stal), 1860

Sclerotized rings: Rings short and oval, flattened along posterior margin, mesal end somewhat narrowed; *F* structures narrow, nearly uniform in width throughout, broadly in contact mesad, curving posteriorly from connection with rings to meson and dropping ventrad toward median line. Maximum length .30 mm., maximum width 1.08 mm. (Plate IV, Fig. 16).

Posterior wall: Ventral margin of *A* structures with a short median emargination, *A* structures rather thick dorso-ventrally; *H* structures present at dorso-lateral extremities of *A* structures, the former with a very narrow connection, widening to a broad, truncate distal end, the sclerotization weak; structure *B* reaching ventral margin of *A* structures by virtue of a relatively weakly sclerotized ventral piece that widens ventrad and appears somewhat lobed; *B* structure proper, curving posteriorly with dorsal extension typically recurved at apex, bearing an elongate-elliptical membranous structure *C*; *E* structures prominent. Maximum length .40 mm., maximum width .84 mm. (Plate II, Fig. 5). Hypotype: M. Gerais, Brazil, C. R. Claro, 1947. J. Carvalho.

IRBISIA-THYRILLUS COMPLEX

These two genera are certainly very closely related in regard to the female genital structures used in this study. The two genera have been recognized as very close in relationship by all workers on the *Miridae*. However, whether *Thyrillus pacificus* Uhler should be considered congeneric with the various species of *Irbisia* remains an open question. The female genital structures considered here indicate very close relationship, but *Thyrillus pacificus* shows some characteristics that tend to place it somewhat apart from *Irbisia shulli* Kngt. and *Irbisia sericans* Stal, the two species of *Irbisia* studied.

The complex may be recognized by the following characteristics: The sclerotized rings are strongly sclerotized, small in size and widely separated from one another mesally. A rather marked degree of differentiation is present in the marginal sclerotization of the rings (Plate IV, Fig. 7). The posterior wall has *A* structures that are concave on the ventral margin, structure *B* is strongly developed and possesses a prominent posterior protrusion (Plate II, Fig. 17) that appears to be of specific importance. Structure *B* dorsad of the posterior protrusion expands noticeably and has an anteriorly recurved dorsal margin.

Thyrellus pacificus Uhler, 1894

Sclerotized rings: Margins of rings very thick and closely appressed, leaving little or no central area present, appearing more like an irregular sclerotized bar than a ringed structure, rings widely separated mesally, dorsal wall sclerotization weak, not extending anteriorly any appreciable distance from the rings. Maximum width 1.15 mm. (Plate IV, Fig. 9).

Posterior wall: *A* structures strongly curving, deeply concave on ventral margin; structure *B* with a characteristic posterior protrusion, dorsad of protrusion median process is of uniform width for some distance then widens dorsally. Maximum length .25 mm., maximum width .94 mm. (Plate II, Figs. 20 and 21). Hypotype: Rexburg, Idaho. June 22, 1935. C. F. Smith.

Irbisia sericans (Stal), 1858

Sclerotized rings: Heavily sclerotized, appearing somewhat intermediate between *T. pacificus* and *I. shulli*, area within rings narrow, postero-lateral region of rings with an apparently additional sclerotized partial ring, dorsal wall extending anterior a considerable distance beyond rings, possessing a strongly concave mesal margin. Maximum width 1.15 mm. (Plate IV, Fig. 7).

Posterior wall: *A* structures narrower and less strongly curved than in *I. shulli* and *T. pacificus*, ventral margin broadly and shallowly emarginate, posterior protrusion of structure *B* characteristic, median process expanding broadly dorsad. Maximum length .20 mm., maximum width .79 mm. (Plate II, Figs. 16 and 17). Hypotype: Corvallis, Ore. May 24, 1932.

Irbisia shulli Knight, 1941

Sclerotized rings: Rings less heavily sclerotized than in preceding species, presenting a more elliptical, typical ring-like appearance with a much wider central area; and apparently accessory thickening present in postero-lateral region of ring margin; dorsal wall produced anteriorly, but less prominently than in *I. sericans*, weakly concave mesally. Maximum width 1.05 mm. (Plate IV, Fig. 5).

Posterior wall: Ventral margin of *A* structures very shallowly emarginate mesad; structure *B* widening apically, but less markedly than in *sericans*, posterior protrusion appears characteristic. Maximum length .19 mm., maximum width .82 mm. (Plate II, Figs. 11, 12 and 13). Hypotype: Lenore, Idaho. May 7, 1938. W. E. Shull.

PLATYTYLELLUS REUTER 1908

This is a large genus containing approximately seventy-nine described species, the members of which are confined in distribution to the Western Hemisphere. The largest number of species are known from the Neotropical region.

The outstanding generic feature of the species studied is the median bar formed by the sclerotized rings. This bar extends between the two rings and fuses them together into a single united structure

(Plate IV, Fig. 1). The rings themselves are strongly sclerotized. In *insitivus*, *crucifer*, and *costalis* the rings are large, widest at the lateral ends and tapering to the meson. In *circummaculatus* and *flavicostus* the rings are relatively smaller, not so tapering from meson to lateral extremity and with less of a "tear drop" effect than in the preceding three species.

The posterior wall (Plate II, Fig. 6) is well developed, heavily sclerotized and of a complicated nature. The A structures are of a fairly conventional type. A strongly developed structure B is present that widens dorsad and curves antero-ventrad and then anteriorly again. Structure C is large, variously shaped and offers good specific differences between the various species. As mentioned in the subfamily discussion, nothing has been found in this genus to warrant tribal distinction from the *Capsini*; indeed the female structures investigated place *Platytylellus* rather closer to some capsines than many of them appear to be to one another.

Platytylellus insitivus (Say), 1832

Sclerotized rings: Large and heavily sclerotized, much widened laterad, the rings curving posteriorly from meson to lateral extremity. Maximum length .30 mm., maximum width 1.29 mm.

Posterior wall: Structure B well differentiated; structure C very large, rectangular, posterior face concave, ventro-lateral margin produced into short sharp processes, dorsal margin irregularly rounded; A structures narrow and slender. Maximum length .40 mm., maximum width .99 mm.; maximum length structure C .25 mm., maximum width structure C .21 mm. Hypotype: Traer, Iowa. June 30, 1931. G. C. D. and H. M. H.

Platytylellus costalis (Stal), 1858

Sclerotized rings: Form and shape very similar to *insitivus*, but considerably larger. Maximum length .55 mm., maximum width 1.73 mm. (Plate IV, Fig. 1).

Posterior wall: A structures proportionately broader than in the preceding species, more lunately curved; structure B widened dorsad; structure C very broad with a wide dorsal margin, anterior surface deeply concave mesad, ventro-lateral angles produced into acute anteriorly directed processes. Maximum length .50 mm., maximum width 1.04 mm.; maximum length structure C .25 mm., maximum width structure C .56 mm. (Plate II, Figs. 6 and 7). Hypotype: Itatiaya-1100 M. Maromba E. do Rio-Brazil. October 12, 1926. J. F. Zikan.

Platytylellus circummaculatus (Stal), 1854

Sclerotized rings: Less elongate than in the preceding species, laterally not curving so strongly caudad, lacking "tear drop" effect, lateral portion of ring not considerably wider than mesal portion.

This species appears in regard to this structure to represent a distinct group within the genus and yet to retain the basic generic character of the connecting bridge (or bar) between the two rings. Maximum length .14 mm., maximum width .86 mm. (Plate IV, Fig. 4).

Posterior wall: A structures of rather normal shape, structure B widest near center of A structures narrowing dorsally and ventrally; structure C lying at an angle to A structures, irregular at its wide dorsal margin, narrowing evenly ventrally to a bluntly rounded ventral end, acute ventro-lateral processes of two preceding species lacking. Maximum length .23 mm., maximum width .65 mm. Hypotype: M. Gerais, Brazil. C. R. Claro 1941. J. C. M. Carvalho.

Platytylellus flavicostus Berg. 1884

The only available specimen of this species is somewhat teneral. The affinities appear to lie with *insitivus* and *costalis* in that the sclerotized rings are widened laterally and structure C possesses very sharp prominent processes on the ventrolateral margins. Hypotype: Goias, Brazil. J. C. M. Carvalho.

Platytylellus atroluteus (Dist.), 1883

It appears questionable whether this species is congeneric with the above. The specimen studied has no connecting bar between the sclerotized rings, and the appearance of the A structures on the posterior wall is quite distinctive. Hypotype: M. Gerais, Brazil. Vicosa June 1944. J. C. M. Carvalho.

OPISTHEURIA REUTER 1908

This genus contains only two described species, both found in the Nearctic region. *Opistheuria* is often considered closely related to *Platytylellus*. However, the female genitalia do not support this relationship. In this genus the sclerotized rings (Plate V, Fig. 9) are widely separated and have no mesal connecting bar between them.

As in *Platytylellus*, no characters of the female genitalia aid in substantiating the present tribal distinction for this genus.

Opistheuria clandestina var. *dorsalis* Knight, 1918

Sclerotized rings: Prominent, irregularly elliptical, a strongly marked concavity near center of posterior margin; adjacent sclerotization weak and nearly uniform; rings widely separated mesad. Maximum length .31 mm., maximum width .88 mm. (Plate V, Fig. 9).

Posterior wall: A structures narrow, widely diverging laterad; structure B widened ventrad, a prominent enlargement ventrad of antero-ventral curvature; structure C weakly sclerotized, composed of a twisted ring of membrane, emarginate along dorsal margin; structure D with ridge-like transverse thickenings of surface; structure E not visible posteriorly, but well developed. Maximum length .34 mm., maximum width .72 mm.; maximum length structure C .17 mm., maximum width structure C .25 mm. (Plate II, Fig. 10). Hypotype; Harahan, La. August 17, 1944. R. Alrutz.

ONCEROMETOPUS REUTER 1876

This is a small Nearctic genus containing nine described species, all of which are found in the southwestern United States and Mexico. As in the other genera of this tribe, no characters appear to be present in the female genitalia to warrant tribal distinction.

Oncerometopus nigriclavus Reuter, 1876

Sclerotized rings: Rather short and relatively wide, broadest at lateral end, tapering to a blunt point near meson; no connecting bar between the rings as in *Platytylellus*, a rather well sclerotized plate (adjacent sclerotization) arising from the connecting piece, extending anteriorly under entire area of rings, this plate concave dorsad and appearing to act as support for the rings. Maximum length .20 mm., maximum width .86 mm. (Plate III, Fig. 7).

Posterior wall: Generalized, structure B well developed, curving anteriorly at its most dorsal extension; structure C membranous, difficult to distinguish from surrounding membrane; structure E conspicuous, covered with short spines. Maximum length .32 mm., maximum width .61 mm. Hypotype: Label illegible. X485 (Author's collection).

CREONTIADES DISTANT 1883

This is a moderately large genus of about forty-seven described species. The members of the genus are found in all the major faunal regions, but the greater number of species are Ethiopian and Oriental in distribution.

Only a single member of the genus has been studied. The female genitalia are somewhat suggestive of *Adelphocoris*. However, the closest relationship is with *Horcias signoreti* (Stal) to which it is related by the prominent antero-mesad projection of the sclerotized rings, and the relatively simple posterior wall with the dorsal margin of the *A* structures nearly straight. Much more material will need to be studied before any conclusions can be drawn as to the generic position of *Creontiades*.

Creontiades debilis Van Duzee, 1915

Sclerotized rings: Rings large, nearly meeting one another mesad, posterior margin concave; a delicate adjacent sclerotization arising near antero-mesal angle of rings and curving strongly cephalad (specimen teneral and thus difficult to see). Maximum length .32 mm., maximum width .94 mm. (Plate IV, Fig. 13).

Posterior wall: Simple, *A* structures broad dorso-ventrally, ventral margin moderately curving, dorsal margin nearly straight; structure *B* simple; *E* structures well developed. Maximum length .17 mm., maximum width .65 mm. Hypotype: Port Laraca, Tex. 1933. R. L. McGars (?).

NEOLYGUS KNIGHT 1917

This genus, formerly considered a subgenus of *Lygus*, contains thirty-one described species, all but two of which are confined to eastern and central North America in distribution; the other two species are European. Knight (13) raises *Neolygus* to generic rank. As mentioned under the *Lygus* discussion, the female genital structures investigated lend much evidence to this view and indicate that the *Neolygus* group is not even closely allied to *Apolygus* in its affinities. Further evidence for the generic entity of *Neolygus* may be obtained from the very different nature of the male parameres (see Knight 10, 13) and some very interesting biological differences, such as restriction to single host plant versus general feeding habits, and overwintering as eggs versus overwintering as adults. The morphological and biological evidence therefore seems to substantiate the fact that superficial resemblance has been the sole reason for placing *Neolygus* with the *Lygus* complex.

The female genitalia are quite distinctive and apparently represent highly specialized types. The sclerotized rings show almost no specific distinctions in the three species examined, and the description of *Neolygus communis* Knigt. below will serve for all the species studied. The posterior wall is quite unique (Plate II, Fig. 9); the *A* structures are narrow, rather undulate in appearance, with structure *B* represented by a small round button near the dorso-mesal margin. The most striking feature of the wall is the tremendous development of what appear to be the *H* structures that arise from the extremities of the *A* structures.

These sclerites may or may not be homologous to the sclerites found in other genera. They are enormously enlarged, considerably larger than the *A* structures and apparently fused along the median line. They lie with the free ventral margin tilted anteriorly from the dorsal more posterior margin; on the posterior face a secondary plate may arise and likewise another on the anterior face near the apex. The *E* structures are small, but extend prominently laterad of the *A* structures (Plate II, Fig. 9).

Although the genus is certainly distinct, its affinities are obviously with *Lygus pabulinus* (considered in this paper as probably a distinct genus from *Apolygus*), the latter having the large plate-like structures present and possessing the same complicated series of plates present on the posterior wall (Plate II, Fig. 18).

Neolygus communis Knight, 1917

Sclerotized rings: Large and prominent, subelliptical, narrowing mesad, posterior margin strongly concave, ring margins strongly produced anteriorly at antero-mesal margin into a horn-like sclerotized projection; margin of rings prominently folded for nearly its entire length; adjacent sclerotization very weakly developed. Maximum length .61 mm., maximum width 1.15 mm. (Plate III, Fig. 9).

Posterior wall: As in generic discussion, with a prominent secondary plate arising near the dorsal margin of *H* structures on the posterior face and extending ventrad and laterad; *H* structures fused weakly and evenly along median line. Maximum length .47 mm., maximum width .72 mm. (Plate II, Fig. 9). Hypotype: Rock City, N. Y. Cattaraugus Co. July 5, 1915. H. H. Knight.

Neolygus omnivagus Knight, 1917

Sclerotized rings: As in *N. communis* Kngt. Maximum length .53 mm., maximum width 1.18 mm.

Posterior wall: *A* structures as in *communis*; *H* structures distinctive, large and ovoid, with right sclerite lying over left one on meson (posterior view), to give a layered appearance, dorsal margin strongly emarginate as is the secondary plate (see *N. communis*); this curving of the margin together with the secondary folding gives an invaginated appearance and may indicate the origin of the condition found in the *Neoborus* complex. In any case, the condition here apparently represents a more specialized condition than in the other species studied. Maximum length .51 mm., maximum width .72 mm. Hypotype: Gatlinburg, Tenn. (5,500 ft.). July 2, 1947. R. H. Whittaker.

Neolygus fagi Knight, 1917

Sclerotized rings: Similar to *N. communis*. Maximum length .50 mm., maximum width .98 mm.

Posterior wall: *A* structures as in above species; *H* structures very large, extending ventrad anterior to *A* structures, mesal connection consisting of only thin membrane to give appearance of two very distinct sclerites, posterior secondary fold very weakly developed and inconspicuous, dorsal margin only slightly emarginate and not appearing invaginated as in *N. omnivagus*. Maximum length .39 mm., maximum width .73 mm. Hypotype: Gatlinburg, Tenn. (3,000 ft.). July 20, 1947. R. H. Whittaker.

STENOTUS JAKOVLEV 1877

This genus is composed at present of approximately thirty-five described species found in all the faunal regions of the world with the exception of the Neotropical. The majority of the species are African. Only one species, *Stenotus binotatus* (Fabr.), has been studied. The

female genital parts indicate the genus to be very distinct and not closely allied to any other genera studied.

Stenotus binotatus (Fabricius), 1794

Sclerotized rings: Rings subelliptical, widely separated mesad, lying in an antero-mesal angle from posterior to anterior end; ring sclerotization strong, particularly inner margin; rings tapering strongly both caudad and cephalad, the cephalic tapering with tips not in contact; no apparent adjacent sclerotization. Maximum length .45 mm., maximum width .90 mm. (Plate V, Fig. 7).

Posterior wall: Wide *A* structures present with a short *B* structure on posterior face; *B* structure not reaching ventral margin, widening dorsad and forking to form a wide lunate dorsal projection; *E* structures prominent; *A* structures strongly curving, nearly straight along ventral margin. Maximum length .43 mm., maximum width .69 mm. (Plate II, Fig. 4). Hypotype: Ledges St. Pk. Iowa, Boone Co. June 27, 1948. J. A. Slater.

POLYMERUS WESTWOOD 1839

This is a large genus composed of approximately seventy-six named species from all the major faunal regions of the world. Only a single species, *Polymerus basalis* Reut., has been examined. The affinities do not appear to be close to any other genus of the *Capsinae* studied. The posterior wall is of a very different type.

Polymerus basalis Reuter, 1876

Sclerotized rings: Small and delicate for size of species, rings open at mesal margin to form one open area between ring margins rather than forming two distinct and separate rings; "rings" tapering laterad; adjacent sclerotization present laterad of "rings", but poorly differentiated. Maximum length .12 mm., maximum width .40 mm. (Plate V, Fig. 4).

Posterior wall: *A* structures reduced to narrow, strongly curving bands forming a lunate-appearing structure, ventral margin strongly emarginate mesad; structure *B* absent, all dorsal parts membranous; *E* structures large, delicately sclerotized. Maximum length .20 mm., maximum width .37 mm. (Plate III, Fig. 5). Hypotype: Ruthven, Iowa, 5 mi. N. W. June 16, 1949. J. A. Slater.

SUBFAMILY MIRINAE REUTER 1910

Three species of this subfamily have been investigated during the present study. These species represent the genera *Miris*, *Stenodema*, and *Collaria*. In addition, Kullenberg (17) has illustrated and described the female genitalia of certain species of *Pithanus*, *Trigonotylus*, *Notostira*, *Teratocoris*, *Miris*, and *Stenodema*.

Kullenberg (18) concludes that this group of genera is not worthy of subfamily status, but should at most be accorded tribal status in the *Capsinae*. The few species that have been examined by the author tend to confirm this view.

The sclerotized rings are simple and relatively reduced in size, yet they show no greater divergence from the type found in the *Capsinae* than do some of the capsine genera from one another. The appearance of the posterior wall is of the greatest importance in evaluating the affinities of the group. This posterior wall (Plate III, Fig. 6) is of essentially the same type as that found in the *Capsinae*. The *A*, *B*, *C*, and *E* structures are very evident and as far as can be determined at present cannot be separated from the appearance of these structures

in the *Capsinae*. When it is realized that the tarsal arolia, are of the same type in the two subfamilies, the very close relationship of these two groups is at once evident.

MIRIS FABRICIUS 1794

As limited at the present time the genus contains eight species. The female genitalia of one species, the generotype *Miris dolabratus* (L.), have been examined during the present study.

Miris dolabratus (L.), 1758

Sclerotized rings: Very small, weakly sclerotized and inconspicuous for size of species; rings irregularly ovoid, widely separated mesad; well developed sclerotization present laterad of rings extending ventrad of them toward midline and considerably cephalad of ring margin, this sclerotization not differentiated into F and G areas. Maximum length .19 mm., maximum width .43 mm. (Plate V, Fig. 21).

Posterior wall: A structures narrow, forming a shallow median emargination along ventral margin, structure B with a dorsally directed flap rising from ventral margin, main shaft of B extended considerably dorsad of dorsal margin of A, strongly recurved cephalad; structure C well developed; E structures narrow and inconspicuous, extending laterad of lateral margin of structure A only at the dorso-lateral extremity of A. Maximum length .19 mm., maximum width 1.04 mm. (Plate III, Fig. 1). Hypotype: 5 mi. N. W. Ruthven, Iowa. June 16, 1949. J. A. Slater.

STENODEMA LAPORTE 1832

This genus contains approximately twenty-seven species. The various species are found in all the major faunal regions of the world with the exception of the Australian.

The female genitalia of one species, *S. vicinum* (Prov.), have been examined. In addition, Kullenberg (17) described and figured *S. laevigatum* (L.).

The genus belongs to the *Mirinae* group, whether considered as a distinct subfamily or as a tribe of the *Capsinae*, in the possession of very small inconspicuous sclerotized rings (Plate V, Fig. 15), and in having the posterior wall strongly fused with the posterior ovipositor blades and lying mostly anterior to them rather than semi-dorsal as in most of the *Capsinae*. It is not however particularly closely related to *Miris*, the other genus of *Mirinae* studied, although the posterior wall is rather similar.

Stenodema vicinum (Provancher), 1872

Sclerotized rings: Rings very small, weakly sclerotized and inconspicuous for size of species, subrectangular with rounded mesal margin and subtruncate lateral margins, not widely separated mesad; adjacent sclerotization present at caudo-lateral margin of rings, tapering posteriorly, not extending anterior to rings. Maximum length .10 mm., maximum width .68 mm. (Plate V, Fig. 15).

Posterior wall: Similar in form to *Miris dolabratus* with narrow strongly curving A structures; structure B prominent, concave on posterior face, widening dorsad and possessing a small round, button-like C structure; E structures small, narrow, and apparently not extending laterad of lateral edge of structure A. Maximum length .11 mm., maximum width .68 mm. Hypotype: McMinnville, Ore. August 20, 1946. K. M. Fender.

COLLARIA PROVANCHER 1872

This small genus contains seven named species, with the various species distributed in the *Nearctic*, *Neotropical*, and *Ethiopian* regions of the world. The female genitalia of the generotype, *C. meilleurii* Prov., have been examined. The sclerotized rings were not revealed by the dissection and may be absent or so delicately sclerotized as to be lost upon clearing. The posterior wall (Plate III, Fig. 6) possesses the slender *A* structures found in *Miris* and *Stenodema*, and if this character is to be given much consideration *Collaria* must be grouped with the above-mentioned genera.

Collaria meilleurii Provancher, 1872

Sclerotized rings: Not evident.

Posterior wall: *A* structures slender, strongly curving dorsad, forming a very strikingly lunate arc; structure *B* prominent, ventrally forming a concave disc with the ventro-lateral angles produced ventrad as curving prongs, this disc tapering to a dorsal point somewhat dorsad of the dorso-mesal margin of the *A* structures; shaft of *B* extended dorsad and strongly recurved anteriorly at its apex; structure *C* very prominent, composed of two irregular lobes; *E* structures exceeding lateral margins of *A* structures, but not approaching midline. Maximum length .25 mm., maximum width .65 mm. (Plate III, Fig. 6). Hypotype: Urbana, Ill. June 25, 1942. J. A. Slater.

SUBFAMILY ORTHOTYLINAE VAN DUZEE 1916

This is a tremendous subfamily composed of many hundreds of species and a great number of genera. The subfamily at the present time is separated into nine tribes. During the present study twenty-five species, representing fourteen genera and seven tribes have been examined.

The majority of the *Orthotylinae* appear to represent a very specialized and highly differentiated condition. The tribes *Semiini*, *Labopini* and *Halticini* apparently have only a distant relationship to the other tribes. This is true also of the one species of *Pilophorus* studied. The more "typical" members of the subfamily may be characterized as possessing sclerotized rings (Plate VII, Fig. 3), in which the lateral margin of the ring, together with the adjacent lateral sclerotization, is strongly folded dorso-mesad, so that the fold projects a considerable distance into the interior of the ring, and, in some cases, extends across the ring to the mesal margin. As mentioned in the general subfamily discussion, this condition is suggested in the *Phylinae* and perhaps in a modified sense in the *Deraeocorinae*, but it reaches a tremendous development in this subfamily.

The most distinctive feature of this group of species is the development of an anterior flange, or appendage (*K* structure) (Plate VI, Fig. 15), on the lateral lobes (*J* structures) of the posterior wall of the bursa. These highly developed *K* structures are not present in any of the other subfamilies of the *Miridae*. These structures offer very good characters for the differentiation of species in all cases investigated, as well as being important in the recognition of relationships in the

higher groups. K structures are present in all the species studied in the *Lopidini*, *Orthotylini*, and *Ceratocapsini*. It has been impossible with the present amount of material to separate the above-mentioned three tribes satisfactorily upon the female genitalia. While certain differences exist between the tribes, these differences are no greater than those found between different genera within the same tribe. Until the range of variation within any given tribe is fairly accurately known it will be impossible to know whether these genital structures have value in the definition of tribal limits.

In the *Pilophorini* representatives of two genera, *Pilophorus* and *Pseudoxenetus*, have been examined. These two genera differ greatly in the composition of the posterior wall. *Pseudoxenetus* possesses very large and well-developed K structures, very like those found in the species of *Lopidini* and *Orthotylini* (Plate VI, Fig. 17). *Pilophorus*, on the other hand, possesses a posterior wall that completely lacks the K structures and is rather unlike any other species of mirid studied (Plate VI, Fig. 12). It seems obvious that *Pseudoxenetus* is considerably more closely related to the two tribes mentioned above than it is to the genus *Pilophorus*.

The tribe *Halticini* presents a very perplexing picture. Representatives of three genera of this tribe, *Halticus*, *Strongylocoris*, and *Orthocephalus* have been studied. *Strongylocoris* is the only genus of the three that possesses the K structures (Plate VI, Fig. 18), and, as discussed under the generic description, the two species of this genus studied are certainly not congeneric. The species *Orthocephalus mutabilis* (Fall.) is one of the most interesting of all the *Miridae* studied. The posterior wall of this species (Plate VI, Fig. 4), is of the same type as that found in the *Deraeocorinae* and *Clivineminae*, and is very similar to the posterior wall of *Largidea rubida* (Plate VI, Fig. 2). The sclerotized rings of *mutabilis* are more similar to the type found in the *Deraeocorinae* than they are to the majority of the species of *Orthotylinae* (Plate VII, Fig. 6). It seems most questionable to the author whether this species really belongs with the *Orthotylinae*. If forms are found that more closely relate *mutabilis* to the *Orthotylinae*, then it certainly represents a connecting link between the *Orthotylinae* on the one hand and the *Deraeocorinae* and *Clivineminae* on the other.

Halticus intermedius is another species that presents an anomalous situation. The sclerotized rings (Plate VII, Fig. 1), are large and as closely related to the *Capsinae* as to any other group. These rings lack the tremendous infolded lateral margins of the majority of the *orthotylinae*, although a very slight indication of this condition is present. The posterior wall of *intermedius* (Plate VI, Fig. 9) is rather simple and unlike any other species studied. This wall offers no clue to the affinities of the species in relation to the other species studied.

The genus *Labops*, belonging to the tribe *Labopini*, illustrates another perplexing situation. Two species of *Labops* have been studied. The sclerotized rings (Plate VII, Fig. 4) are infolded on the lateral

margin, although less so than in the majority of the *Orthotylinae*. However, the posterior wall is completely unique (Plate VI, Fig. 14). It consists of two lateral lobes (*J* structures ?) with large, strongly sclerotized developments along the lateral and mesal margins of these lateral lobes. These sclerotized areas may be homologous to the *K* structures of the other orthotylinae, but they appear to be fused with the *J* structures rather than to proceed away from them as do the usual flange-like appendages.

The other species worthy of special note in this section is *Semium hirtum* Reut. In the general subfamily discussion this species has been discussed as an annectant form between the *Orthotylinae* and the *Phylinae*. It is possible the species is actually referable to the *Phylinae* by virtue of its simple posterior wall (Plate VI, Fig. 11). However, the sclerotized rings are considerably more infolded than in any of the *Phylinae* studied (Plate VII, Fig. 8). Therefore, it appears that in this species one is dealing with a type showing an intermediate position between two divergent groups.

Present evidence strongly indicates that the *Orthotylinae*, as limited at present, are not a homogeneous group. It is probable that as knowledge expands some of the genera will be removed to other subfamilies, or raised to the status of independent subfamilies. On the other hand, it is always possible that increased knowledge will show intergrading forms that will retain the subfamily in its present condition, although this is not considered likely by the present writer.

The evidence from this study would place those species with prominent *K* structures in one subfamily and reject from the subfamily limits the following genera: *Semium*, *Labops*, *Orthocephalus*, *Halticus*, and *Pilophorus*.

The *Orthotylinae* offer a most fruitful field for further investigation of the female genitalia, both in respect to higher group relationships and to specific differences.

In addition to the genital parts studied, the vulvar area appears to offer a good potential field for profitable taxonomic investigation.

HALTICUS HAHN 1831

This genus contains approximately eighteen species. The various species are distributed in the Palearctic, Nearctic, Neotropical, and Oriental regions and the oceanic Pacific islands. One species of the genus, *H. intermedius* Uhl., has been studied.

The relationships are obscure. Together with *Orthocephalus*, *Labops*, and *Semium* this genus shows little affinity to the remainder of the *Orthotylinae* studied. The rings (Plate VII, Fig. 1), and even the posterior wall to a degree, show a similarity to the condition found in the *Capsinae*. This posterior wall (Plate VI, Fig. 9) also shows a rather definite relationship to *Labops*, but probably represents a less extremely specialized type.

Halticus intermedius Uhler, 1904

Sclerotized rings: Relatively large and strongly sclerotized, narrowly separated mesad, mesal margin rounded, ring abruptly widening laterad, curving in an arc latero-caudad from meson to lateral angles, causing the meso-caudal margin to be strongly concave, this margin also forming a flange produced slightly dorso-laterad; lateral margin together with adjacent sclerotization curving dorsad, but not folded over onto the ring as in most *Orthotylinae*; adjacent sclerotization large, covering the entire area ventrad of the rings, broadly joined to the connecting piece; mesal angle of rings with short, broad mesal projections that appear to fuse on the meson; a delicate semicircle of sclerotized tissue curving mesad from posterior edge of meso-caudal flange to midline, giving a circular appearance to the area between the rings; adjacent sclerotization not differentiated into *F* and *G* structures. Maximum length .43 mm., maximum width .94 mm. (Plate VII, Fig. 1).

Posterior wall: Small and simple, composed of two dorsally tapering and divergent sclerites, suddenly narrowed almost at right angles near center of dorsal margin, ventral one-half thus only half breadth of apical half; a tumid mesal area bordered by a narrow, indistinct, more heavily sclerotized ring. Maximum length .29 mm., maximum width .43 mm. (Plate VI, Fig. 9). Hypotype: Trail Co., N. D. August 14, 1923. A. A. Nichol.

HETEROTOMA LATREILLE 1825

This is a small Palearctic genus containing three described species. The female genitalia of the generotype, *H. meriopterum* (Scop.), have been examined. The female genitalia of this species have been described and figured by Kullenberg (17). However, since several authors have considered this the type genus of the subfamily it has been considered advisable to redescribe the female genitalia in this paper.

The species is typically orthotyline due to the presence of prominent *K* structures on the posterior wall and in the possession of strongly infolded lateral margins of the sclerotized rings and adjacent sclerotization.

Heterotoma meriopterum (Scopoli), 1763

Sclerotized rings: Rings with lateral margin together with adjacent lateral sclerotization strongly infolded, nearly reaching mesal margin of ring; ring subelliptical and strongly concave dorsally. Maximum length .22 mm., maximum width .36 mm.

Posterior wall: *L* structure apparently absent; *J* structures large, almost in contact mesally at dorsal margin, diverging and tapering ventrad, terminating in a broadly rounded apex; *K* structures large and prominent with a deep central concavity, prominent lateral projection present that extends in an arc ventromesad, mesally with a large bulge that reaches to mesal margin of *J* structures. Length *K* structure .27 mm., width *K* structure .26 mm. Hypotype: Oberlausitz, Germany. July 12, 1936. K. H. C. Jordan.

ORTHOCEPHALUS FIEBER 1858

This is a small Palearctic genus composed of eighteen described species, with one species, *mutabilis* (Fall.), common to the Palearctic and Nearctic regions. The genitalia of one species, *O. mutabilis* (Fall.), has been examined. The subfamily position of this genus is very puzzling, it appears to be rather closely related to the *Deraeocorinae* and *Clivineminae*, both in the twisted formation of the sclerotized rings (Plate VII, Fig. 2) and in the simple, flattened, lobed condition of the posterior wall (Plate VI, Fig. 4) of the bursa. Certainly *Orthocephalus* has little in common with such "typical" orthotyline genera as *Orthoty-*

lus, *Lopidea*, *Ilnacora*, etc. The posterior wall completely lacks the large prominent K structures so characteristic of these genera, and the formation of the sclerotized rings is much more suggestive of *Deraeocoris* and *Largidea* than any of the other *Orthotylinae* studied.

Orthocephalus mutabilis (Fallen), 1807

Sclerotized rings: Very large for the species, strongly twisted, tapering antero-mesad to a blunt point, lateral margin curving strongly dorsad to a high point at the antero-lateral angle, anterior margin of ring lying ventrad of posterior margin and curving dorsad laterally; formation basically very much as in *Deraeocoris quercicola* Knight, but lying in a somewhat different plane; connecting sclerotization broad, short, and strongly sclerotized, mesal margin produced into an elongate curving tongue-like fold that curves dorsad over mesal margin of rings and extends as a long tongue to near median line. This development may well prove to be diagnostic for the genus. A moderately sclerotized subtriangular F structure present along anterior margin of rings; rings very widely separated mesad and definitely of a deraeocorine type. Maximum length .24 mm., maximum width 1.01 mm. (Plate VII, Fig. 6).

Posterior wall: A simple sclerite, composed of two lobes (A structures) broadly fused mesad; A structures produced only slightly dorsad, forming a broad, shallowly concave dorsal margin to the structure; ventrad sclerite produced into a pair of blunt hook-like projections that curve mesad to nearly come into contact at the midline, forming an oval opening within their mesal margins, median area slightly more heavily sclerotized on each side of midline, but without a definite structure B. Maximum length .39 mm., maximum width .65 mm. (Plate VI, Fig. 4). Hypotype: Ithaca, N. Y. June 19, 1918. H. H. Knight.

SEMIUM REUTER 1876

This genus contains two species, both confined in distribution to the Nearctic region. The female genitalia of the generotype, *S. hirtum* Reut., have been examined.

This genus appears to be an annectant type, between the *Orthotylinae* and *Phylinae*. The interesting position of the genus is discussed under the subfamily and general discussion sections.

Semium hirtum Reuter, 1876

Sclerotized rings: Strongly sclerotized, subtriangular, tapering to a short blunt point antero-mesad; connecting sclerotization strongly developed, broad and short, widely in contact with connecting piece; this sclerotization folded dorsad, lateral to rings and curving over lateral ring margin, a short central area of this fold more strongly sclerotized, remainder semi-membranous; rings widely separated mesally. Maximum length .12 mm., maximum width .42 mm. (Plate VII, Fig. 8).

Posterior wall: Simple, consisting of a pair of A structures that curve dorsad and diverge from ventral to dorsal extremities and taper dorsad, a membranous ventral area present. Maximum length .19 mm., maximum width .29 mm. (Plate VI, Fig. 11). Hypotype: Tilden, Ill. September 14, 1948. J. A. Slater.

ORTHOTYLUS FIEBER 1858

This is a very large genus containing upwards of 108 described species. The genus appears to be absent from the Neotropical region. The majority of the species are found in the Palearctic and Nearctic regions. Four species, *modestus*, *dorsalis*, *ornatus*, and *viridis*, have been examined.

Orthotylus, the type genus of the subfamily, is very typical of those

genera considered by the author to be "orthotyline" in the characters found in the female genitalia. The sclerotized rings have the characteristic folding over, of the lateral margin and adjacent sclerotization (see subfamily discussion) (Plate VII, Fig. 2). The posterior wall (Plate VI, Fig. 28) possesses the characteristic *J* structures and these contain prominent *K* structures. These *K* structures bear a prominent lateral projection at the apical end and a bulging mesal margin. Sometimes this bulge may be produced, as in *modestus* (Plate VI, Fig. 27), to form a blunt projection apically, in which case the tip of the *K* structure appears bifid. The *L* area is small, relatively undifferentiated, and sometimes appears entirely membranous.

Orthotylus modestus Van Duzee, 1916

Sclerotized rings: Ring margin weakly sclerotized, rings elongate cephalocaudad; lateral margin of rings together with lateral margin of adjacent sclerotization curving mesad as a bluntly triangular fold, extending into interior of ring proper; adjacent sclerotization prominent, concave, a prominent fold overlapping the caudo-mesal angle of the rings; connecting sclerotization deeply concave, broadly joined to the connecting piece. Maximum length .43 mm., maximum width .86 mm. (Plate VII, Fig. 2).

Posterior wall: *J* structures characteristic for genus; *L* structure not visible in specimen examined; *K* structures prominent, covered with hairs or spines, a median bulge strongly produced to form a bifid tip to *K* structure. Length *K* structure .31 mm., width *K* structure .19 mm. (Plate VI, Fig. 27). Hypotype: Muscatine, Iowa. July 8, 1927. Harris & Johnston.

Orthotylus dorsalis (Provancher), 1872

Sclerotized rings: See *modestus*.

Posterior wall: *J* structures as in *modestus*; *K* structures with a short thick apical projection, median bulge strongly rounded and prominent, attachment of *K* to *J* appearing sinuate. Length *K* structure .31 mm., width *K* structure .19 mm. (Plate VI, Fig. 29). Hypotype: Elkader, Iowa. July 28, 1927. Harris and Johnston.

Orthotylus ornatus Van Duzee, 1916

Sclerotized rings. See *modestus*

Posterior wall: *J* structures as in *modestus*; *K* structures with an elongate blunt, thick apical projection, median bulge nearer base than in other species studied, curving evenly from the apical tip, widest near base, attachment to *J* structures narrow and laterad. Length *K* structure .28 mm., width *K* structure .16 mm. (Plate VI, Fig. 26). Hypotype: Ames, Iowa. June 15, 1929. H. A. Stabe.

Orthotylus viridis Van Duzee, 1916

Sclerotized rings: See *modestus*.

Posterior wall: *J* structures as in *modestus*; *K* structures similar to *dorsalis*, apical projection proportionately more elongate, median bulge less produced, giving *K* a less broadened aspect, attachment to *J* not appearing sinuate. Length *K* structure .26 mm., width *K* structure .14 mm. (Plate VI, Fig. 28). Hypotype: Ft. Madison, Iowa. July 12-13, 1927. Harris and Johnston.

LOPIDEA UHLER 1872

This is a large homogeneous genus containing sixty-two described species. The various species are confined in distribution to North and Central America with the greater number of species Nearctic in distribution.

The female genitalia studied are of a definite orthotyline type, with the sclerotized rings strongly twisted, the lateral margins forming an overlapping flap much as described for *Orthotylus*. The posterior wall (Plate VI, Fig. 22) is also orthotyline in the possession of a median and two lateral sclerites or lobes (*L* and *J* structures), these latter each with a prominent *K* structure. This *K* structure is generically distinct from that of any other genera studied. It is composed of two narrow elongate projections curving ventrad with a very deep, broad concavity between them. The lateral projection appears to be always more elongate than the median and to possess a sharp angle along the lateral margin. The median projection possesses short hairs or setae that are reduced or absent on the lateral projection. Specific differences appear to be present in the conformation of these *K* structures, but it seems doubtful to the author if they will prove adequate to separate all the species of the genus from one another.

The following species of the genus have been examined: *media*, *incurva*, *teton*, *staphyleae*, *robiniae*, and *heidemanni*.

Lopidea staphyleae Knight, 1917

Posterior wall: *L* structure elongate, rectangular (torn in dissection); *J* structures typical for genus with dorso-mesal corner curving below *L* structure and forming a narrow connecting band between *J* structures; *K* structures prominent, lateral and mesal projections relatively very slender forming a very broad U-shaped concavity within their margins. Length *K* structure .43 mm., width *K* structure .25 mm. (Plate VI, Fig. 21). Hypotype: Strawberry Point, Iowa. July 27-29, 1927. Harris & Johnston.

Lopidea teton Knight, 1923

Posterior wall: *L* structure broad, its dorso-lateral angles curved laterad into connecting bands that appear to connect with *J* structures, ventral margin broad and truncate, slightly swollen, mesal area bearing a more strongly sclerotized patch or knob that may represent a primitive, or vestigial *B* structure; *K* structures with projections rather stout, median projection tapering gradually to apex, lateral projection with a sharply angled bend on its lateral margin, apex very faintly hooked, extending considerably further ventrad than mesal projection. Length *K* structure .36 mm., width *K* structure .23 mm. (Plate VI, Fig. 22). Hypotype: Cherokee, Iowa. July 1, 1897. H. Osborn.

Lopidea incurva Knight, 1918

Posterior wall: *L* structure narrowing ventrad to terminate in a truncate slightly expanded apex; *J* structures normal for genus; *K* structures with lateral projection strongly tapered to a blunt point, median projection short, blunt and thick with bluntly rounded apex. Length *K* structure .23 mm., width *K* structure .22 mm. (Plate VI, Fig. 23). Hypotype: Donnelson, Iowa. July 13, 1927. Harris & Johnston.

Lopidea heidemanni Knight, 1917

Posterior wall: *L* structure subtriangular, tapering ventrad to a blunt rounded apex; *J* structures prominent, extending ventrad of projection of *K* structures, broadly truncate at apex; *K* structures relatively short and stout, lateral projection only slightly longer than mesal, with a short taper to apex. Length *K* structure .23 mm., width *K* structure .18 mm. (Plate VI, Fig. 25). Hypotype: Iowa City, Iowa. July 9, 1927. Harris & Johnston.

Lopidea robiniae (Uhler), 1861

Posterior wall: Very similar to *incurva*, particularly in form of K structures, median projection thickened, but less so than *incurva* and proportionately longer. Length K structure .29 mm., width K structure .19 mm. Hypotype: Wyoming Co., N. Y. September 14, 1915. H. H. Knight.

Lopidea media (Say), 1832

Posterior wall: L structure somewhat as in *incurva*, dorsal margin less convex; J structures longer than K structures, lateral projection of K elongate distad of the angle, L structure elongate, strongly tapered to apex. Length K structure .23 mm., width K structure .18 mm. Hypotype: 1 mi. S. Amana, Iowa. June 23, 1928. G. O. Hendrickson.

ILNACORA REUTER 1876

This is a small genus composed of six species, all of which are confined in distribution to the Nearctic region. One species, *I. malina* Uhl., has been examined.

Ilnacora is a definite orthotyline type. The sclerotized rings are similar to those of *Lopidea* and *Orthotylus*, with the overlapping flap, composed of the lateral margin of the rings plus the adjacent lateral sclerotization prominent. The posterior wall has well developed K structures. In the species studied the K structures lack a mesal projection and appear to be rather closer to *Orthotylus* than to *Lopidea* (Plate VI, Fig. 16).

Ilnacora malina Uhler, 1877

Posterior wall: L structure present as a wide sclerite, tapering to a blunt point ventrad, dorsal margin nearly straight, very slightly concave; J structures large, extending considerably ventrad of lateral projection of K structure, its meso-ventral margin shallowly emarginate, median margin recurved laterad in a prominent flap that reaches laterally to mesal margin of K structure; K structures connecting with J structures near dorso-mesal angle of latter, K structure short with a right angle bend along lateral margin, a short stout lateral projection present, but no indication of a median projection. Length K structure .22 mm., width K structure .14 mm. (Plate VI, Fig. 16). Hypotype: Des Moines, Iowa. July 3, 1948. J. LaRue.

PILOPHORUS HAHN 1829

This is a moderately large genus composed of approximately forty-four species, the members of which are apparently absent from the Ethiopian, Australian, and Neotropical regions. The female genitalia of *Pilophorus strobicola* Knegt. have been examined.

The sclerotized rings indicate that *Pilophorus* is only distantly related to the other *Orthotylinae*. The rings are quite prominent and large for the size of the insect, and the ring margins are not obscure and indistinct as they are in *Orthotylus*, *Lopidea*, and *Ilnacora*, etc. However, the mesal folding of the lateral margin of the rings and the adjacent lateral sclerotization is of the same type as that found in other orthotyline forms (Plate VII, Fig. 7). The condition of the posterior wall of the bursa copulatrix (Plate VI, Fig. 12) is rather different from that of the more "typical" orthotylines. The wall resembles the above mentioned genera in being composed of three lobes or sclerites, but differs primarily in apparently completely lacking the K structures that form such a conspicuous feature of the posterior wall of many of the *Orthotylinae* studied.

Pilophorus strobicola Knight, 1926

Sclerotized rings: Conspicuous, lying almost dorsal to *connecting piece* that curves antero-mesad below rings; rings subelliptical lying with long axis nearly cephalo-caudad, tapering dorso-mesad; lateral margin of ring together with adjacent lateral sclerotization folded dorso-mesad over ring and extending into interior of ring; adjacent sclerotization prominent but relatively undifferentiated. Maximum length .22 mm., maximum width .55 mm. (Plate VII, Fig. 7). Hypotype: Grundy Center, Iowa. August 23, 1927. H. G. Johnston.

The sclerotized rings of *Pilophorus walshii* Uhler 1887 have been examined and found to be of the same type as those of *strobicola* except that the posterior margin is somewhat wider due to the expansion of the caudo-mesal angle of the ring.

Posterior wall: *L* structure very weakly sclerotized, almost membranous, tapering to a blunt point at its dorsal apex; *J* structures strongly curved dorsad and divergent, tapering to a point at dorsal extremities, ventral margin consisting of a narrow band of strongly sclerotized tissue, emarginate mesally, appearing to connect the *L* and *J* structures; median area of this band with dorsal margin folded ventrad in a tiny flange or flap; between posterior wall and shanks apparently lies a slender accessory sclerite which is rather prominent in this species. Maximum length .17 mm., maximum width .23 mm. (Plate VI, Fig. 12). Hypotype: Grundy Center, Iowa. August 23, 1927. H. G. Johnston.

LABOPS BURMEISTER 1835

This is a small genus of approximately eight species, the members of which are found in the Nearctic and Palearctic regions. The female genitalia of two species, *L. hirtus* Knegt. and *L. hesperius* Uhler, have been examined. The genitalia of the members of this genus constitute a very unique type and the affinities are obscure. The sclerotized rings (Plate VII, Fig. 4) show a small folding of the lateral margin of the rings, somewhat as in the typical *Orthotylinae*. Perhaps this character is sufficient to place the genus with the subfamily *Orthotylinae*. The posterior wall of the bursa (Plate VI, Fig. 14), however, is a very unique structure. It consists of a pair of *J* structures whose margins are heavily sclerotized and appear to be of a different composition from the interior of the lobe. It is possible this bordering sclerotization represents a *K* structure. The mesal margin possesses spines and hooks that are in approximation on the median line.

It seems very possible that *Labops* may represent a primitive orthotyline type from which the more specialized members of the subfamily have arisen.

Labops hirtus Knight, 1922

Sclerotized rings: Very large for the species, rings elongate, lying mesocephalad from lateral to mesal margins, tapering to a sharp point at antero-mesal angle, lateral margin possessing small dorsal fold that curves mesad into interior of ring; a semi-membranous sheet of tissue connecting with apex of this infolded margin, extending over lateral ring margin and anteriorly along adjacent lateral sclerotization; meso-caudal margin of ring possessing a folded-over flange near center of margin; adjacent sclerotization strongly sclerotized, surrounding rings in a subelliptical concave form. Maximum length .52 mm., maximum width 1.01 mm. (Plate VII, Fig. 4).

Posterior wall: Composed of a pair of convex *J* structures with delicate membrane between, no indication of an *L* structure; *J* structures possessing a U-shaped sclerotization along lateral and mesal margin, this sclerotization appearing somewhat as a *K* structure with two elongate projections, but apparently firmly attached to lobes for entire length, mesal projection with an irregular row of teeth near middle and a deeply bifid apex; dorsally entire structure broadly rounded, lateral

projections, tapering ventrad to a pointed apex; *J* structure between marginal sclerotization strongly convex (from a posterior view), laterally more heavily sclerotized, this area twisting below strongly arched central portion of lobe. Maximum length .47 mm., maximum width .72 mm. (Plate VI, Fig. 14). Hypotype: Afton, Wyo. July 20, 1946. G. F. Knowlton. (Posterior wall). Pingree Park, Colo. August 15-22, 1924. Drake and Hottes. (Sclerotized rings).

Labops hesperius Uhler, 1872

One teneral specimen of this species has been examined. The sclerotized rings seem generally similar to those of *L. hirtus*, but are difficult to see. The mesal projection of the posterior wall (see *L. hirtus* above) is well developed and shows some excellent specific differences from *hirtus* (Plate VI, Fig. 13). The apex of the mesal projection is not bifid and is spined along the latero-ventral margin; the median spines are differently arranged, and the dorso-mesal angle is projected in a spinous process toward the midline, rather than being evenly rounded as in *hirtus*. The entire posterior wall is smaller than in the specimens of *hirtus* examined. Maximum length .34 mm., maximum width .58 mm. (Plate VI, Fig. 13). Hypotype: Maligne Lake, Alberta, Canada. July 1-3, 1915. E. L. Diven.

MECOMMA FIEBER 1858

This is a small genus containing five species, the members of which are found in the Palearctic and Nearctic regions, with the exception of *madagascariensis* Reut. from the island of Madagascar. The female genitalia of one species, *M. gilvipes* (Stal), have been examined.

The genus is a rather generalized orthotyline type, with the typical infolding of the lateral margin of the sclerotized rings, *J* structures that form the posterior wall of the bursa copulatrix, and with these *J* structures possessing well developed, simple *K* structures.

Mecomma gilvipes (Stal), 1858

Sclerotized rings: Small, orthotyline in character with strongly infolded lateral margins that extend mesad into interior of rings; ring margins indistinct, lying with long axis meso-laterad; rings very widely separated on median line. Maximum length .16 mm., maximum width .48 mm.

Posterior wall: *J* structures prominent, *L* structure reduced or absent; *J* structures short and broad, dorsal margin thickened throughout its width; a prominent pair of *K* structures present, apex considerably ventrad of *J* structures proper, tapering evenly to apex, no differentiation into lateral and median projections, lateral margin curving posteriorly and much more lightly sclerotized than the evenly tapering central area of flange. Maximum length .19 mm., maximum width .35 mm. (Plate VI, Fig. 19). Hypotype: McMinneville, Ore. August 26, 1947. K. M. Fender.

STRONGYLOCORIS BLANCHARD 1840

This is a small Holarctic genus composed of approximately twenty-two species. The female genitalia of two species, the generotype *leucocephalus* (L.) and *stygicus* (Say), have been examined.

It is interesting to discover that the type species of the genus, *leucocephalus*, is apparently not congeneric with the North American *stygicus*. Unfortunately, both of the available females of *leucocephalus* proved to be slightly teneral, or the posterior wall of the bursa is very lightly and delicately sclerotized. In any case, it has been impossible for the writer to clearly see the various parts of the posterior wall. However, enough can be ascertained to show that the structure lacks the well-developed *K* structures and characteristic tri-lobed con-

dition found in *stygius*. Indeed, *leucocephalus* appears to approach the *Capsinae* in the general appearance of the posterior wall. The sclerotized rings are also very different in the two species. In *stygius* a very characteristic orthotyline type is present, while in *leucocephalus* the rings are very complicated and twisted (Plate VII, Fig. 5). A study of this genus appears to be necessary to ascertain the actual generic limits and to correctly place the *leucocephalus* type of female genitalia in relation to other mirids.

For the present all that can be said is that *stygius* is a typical orthotyline with the usual infolding of the lateral margin of the sclerotized rings and prominent K structures arising from the J structures of the posterior wall of the bursa copulatrix, whereas *leucocephalus* illustrates a unique and highly differentiated condition.

Strongylocoris stygius (Say), 1832

Sclerotized rings: Typically orthotyline in possessing a large infolding of lateral margin of ring together with adjacent lateral sclerotization; form and shape very much as in *Orthotylus modestus* (Plate VII, Fig. 2). Maximum length .15 mm., maximum width .72 mm.

Posterior wall: Composed of an L and two J structures; L structure broad and conspicuous, widening from dorsal base to a broad, truncate ventral apex, ventrally lying anterior to meso-ventral angle of J structures at margins; J structures large, extending ventrad of K structures, convex posteriorly, ventro-mesal margin shallowly emarginate, dorsal margin deeply incised mesad of base of K structures in a meso-ventral direction from the base; K structures much more heavily sclerotized than J structures, broad, with a prominent median bulge near base and a single apical projection that is twisted near apex; form of K structures suggestive of *Orthotylus ornatus* Length K structure .26 mm., width K structure .17 mm. (Plate VI, Fig. 18). Hypotype: Dolliver State Park, Iowa. July 1, 1927. Harris and Johnston.

Strongylocoris leucocephalus (L.), 1758

Sclerotized rings: Form complicated; rings with broad projecting lateral protrusions, posterior margin much curved and twisted, possessing a short flange that extends caudo-laterad and together with mesal portion of posterior margin of rings forms the anterior lip of a broad scoop-shaped structure that lies posterior to ring; mesad rings extend anteriorly in a broad bulge with median margins in very close approximation, a delicate adjacent sclerotization lies ventrad of rings and extends considerably cephalad of them; this adjacent sclerotization bearing a pair of irregular transverse plates directly cephalad of anterior margin of rings.

This type of ring unique among species of *Miridae* investigated during course of this study. Maximum length .38 mm., maximum width .78 mm. (Plate VII, Fig. 5).

Posterior wall: As mentioned above, the posterior wall in the specimens available has been unsuitable for illustration or description, and for this reason the affinities of this species cannot be determined at the present time. Hypotype: Moravia merid. Czechoslovakia, Straznica. June 7, 1942. Dr. Hoffer.

CERATOCAPSUS REUTER 1876

This is a large genus that contains approximately sixty species, the members of which are confined in distribution to the Western Hemisphere. By far the greater number of described species are found in North America. The female genitalia of two species, *fasciatus* Uhl. and *modestus* Uhl., have been examined.

Ceratocapsus represents a rather typical orthotyline type in the possession of sclerotized rings that have the lateral margins strongly

infolded and the remainder of the ring margin depressed and inconspicuous. The posterior wall possesses paired *J* structures with prominent *K* structures present on the anterior surface. The *J* structures are broad and short and in both species studied have a noticeable median bulge near the base. The *L* structure appears to be absent, or little differentiated from the adjoining membranes (Plate VI, Fig. 20).

The posterior wall shows excellent specific differences in the two species examined, but relatively little conformity to indicate generic characters.

Ceratocapsus modestus Uhler, 1887

Sclerotized rings: Typical orthotyline type.

Posterior wall: *J* structures very broad along dorsal margin, margin straight, lobes narrowing to a broad rounded apex, extending ventrad of *K* structures, median margin sinuate with a prominent basal bulge; *K* structures leaflike, ovate, lying nearly transversely across *J* structures, attached near latero-dorsal angle of *J* structures, covered with short hairs or setae. Length *K* structure .18 mm., width *K* structure .10 mm. (Plate VI, Fig. 20). Hypotype: Braddyville, Iowa. July 31, 1927. Harris and Johnston.

Ceratocapsus fasciatus Uhler, 1877

Sclerotized rings: Typical orthotyline type.

Posterior wall: *J* structures broad and short, only slightly narrowed ventrad, ventral margin truncate, dorsal margin thickened into a calloused ridge, mesal margin sinuate, with a prominent basal bulge; *K* structures prominent, extending ventrad of *J* structures, of simple form in being composed of a single extension that tapers to a broad round apex, covered with short hairs or setae. Length *K* structure .17 mm., width *K* structure .11 mm. (Plate VI, Fig. 24). Hypotype: Braddyville, Iowa. July 21, 1927. Harris and Johnson.

HETEROCORDYLUS FIEBER 1858

This is a small genus of thirteen described species, limited in distribution to the Palearctic and Nearctic regions. The female genitalia of one Nearctic species, *H. malinus* Reut., has been examined.

The genitalia are of the very typical orthotyline character, with prominent infolding of the lateral wall of the sclerotized rings and the trilobed posterior wall that possesses a pair of prominent *K* structures, arising on the caudal surfaces of the *J* structures.

Heterocordylus malinus Reuter, 1909

Sclerotized rings: Typically orthotyline with lateral margin of rings strongly infolded, ring itself weakly sclerotized, strongly concave on dorsal side, mesal margin also curved to give ring a compressed and enveloped appearance, lateral infolding with a short spur present, projecting ventrad from base of fold. Maximum length .36 mm., maximum width 1.35 mm.

Posterior wall: *L* structure very small, much shorter than large *J* structures, centrally located between them; *J* structures large, subrectangular, ventral margin truncate, dorsal margin calloused, tapering slightly ventrad, mesal margin nearly straight; *K* structures large, with a very broad base containing a prominent mesal bulge, a well developed lateral projection, hook shaped, entire flange covered with short hairs or setae. Length *K* structure .40 mm., width *K* structure .36 mm. (Plate VI, Fig. 15). Hypotype: Ames, Iowa. June 12, 1897.

PSEUDOXENETUS REUTER 1909

This is a North American genus containing only two species. The female genitalia of one species, *P. scutellatus* (Uhl.), have been examined.

The female genitalia are of the usual orthotyline type with exceptionally large infoldings of the lateral wall of the rings and adjacent tissue, and prominent K structures on the anterior face of the trilobed posterior wall of the bursa copulatrix.

This genus is certainly very closely related to the European species of the genus *Cyllocoris*, if not congeneric with them. The sclerotized rings of *P. scutellatus* appear to be almost identical to those illustrated by Kullenberg (17), for *Cyllocoris flavoquadrimaculatus* (De G.). The posterior wall of the two species also is of the same type although exhibiting some specific differences. A study of all the species of these two genera to ascertain the degree of generic differentiation would seem to be very desirable.

Pseudoxenetus scutellatus (Uhler), 1890

Sclerotized rings: Large and prominent, typically orthotyline in having an infolding of lateral margin of ring plus adjacent lateral sclerotization, this infolding very broad and large, extending entirely over interior of ring and covering a portion of the mesal margin; a central sclerotized shaft formed from the lateral sclerotization is prominent in center of fold; ring margin prominent, not weakly developed and enveloped by the margins as in many *Orthotylineae*; rings widely separated mesad. Maximum length .36 mm., maximum width 1.01 mm. (Plate VII, Fig. 3).

Posterior wall: Composed of three lobes, L structure short, tapering to both dorsal and ventral extremities with a prominent widening in the center; J structures large, straight along dorsal margin, narrowing to a broadly rounded ventral apex, mesal margin broadly bulging mesad along basal one-third of margin; K structures large and broad, not reaching ventrad to apex of J structures, a deep emargination present, that produces a long, broad, blunt lateral projection and a short, stout mesal one, this mesal projection less than one-half length of lateral projection, covered with short, stout setae or hairs. Length K structure .39 mm., width K structure .27 mm. (Plate VI, Fig. 17).

SUBFAMILY DERAECORINAE DOUGLAS AND SCOTT 1865

This subfamily has been recently separated from the *Capsinae* because of the simple, hair-like condition of the tarsal arolia.

Two genera and six species of the subfamily have been studied during the present investigation. The female genitalia confirm the validity of separating the group from the capsines, although it appears to be very closely related to the *Clivineminae*.

The sclerotized rings are strongly looped and twisted and show considerable variation among the species studied. It seems probable that the large genus *Deraeocoris* can be separated into several subgroups on the basis of these female structures, as of the five species of the genus studied, three fall into one group while the other two are rather distinct in the appearance of these rings.

The posterior wall in all the species studied is simple and composed of a single plate. This plate is, in most cases, deeply emarginate on the

ventral margin and usually produced dorsad as a pair of diverging lobes (Plate VI, Fig. 3). While this posterior wall is quite simple it suggests an advance over the two separate sclerites found in the *Dicyphinae*, *Phylinae*, and *Hyaliodinae*. This simple plated condition may very well have come about through a mesal fusion of the separate *A* structures of the above-mentioned subfamilies. It seems quite probable that this type of posterior wall illustrates the generalized condition from which the specialized structures found in the *Capsinae* and *Mirinae* have developed. Indeed, as mentioned in the discussion of subfamilies, *Deraeocoris histrio* (Reut.) shows a mesal thickening not unlike the small *B* structures found in such capsine genera as *Neurocolpus* and its allies (Plate VI, Fig. 8).

Similarities to some of the orthotyline genera can also be detected. The incurving of the lateral margins of the rings bears evident relationship to the infolding of the margin of the rings in the majority of *Orthotylineae*. Of more importance is the close similarity of the posterior wall in such a species as *Orthocephalus mutabilis* to the conditions found in the *Deraeocorinae*.

DERAEOCORIS KIRSCHBAUM 1855

This is a very large genus of approximately 180 species, the members of which are found in all the major faunal areas of the world. Five species of *Deraeocoris* have been investigated, and all present a basically similar aspect in the female genital structures involved. All of the species agree in possessing well-developed sclerotized rings that are strongly twisted and often looped and connected with the "connecting piece" by a relatively slender band, or arm of sclerotized tissue. In all cases, the posterior wall is a simple plate with a pair of dorsally extended lobes that probably represent the ventral wings of the *Capsinae*. The ventral area of this plate is usually a thin membrane contrasting strongly with the more heavily sclerotized dorsal two-thirds. This ventral portion is easily overlooked or lost in dissection. Structure *B* is either absent or represented by a very small knob on the meson. Specific differences appear to be present in the formation of the posterior wall.

In a genus of this size it is impossible to ascertain the possible criteria for generic entity without a detailed study of many species from various parts of the world.

Deraeocoris quercicola Knight, 1921

Sclerotized rings: Strongly sclerotized, narrowing mesad, posterior margin depressed near lateral end where rings make a right angle bend and extend antero-dorsad, anterior margin of rings lying more ventral than posterior margin and curving dorsad from mesal to lateral ends so that most dorsal portion of ring is where posterior and anterior ring margins appear to coalesce, from this point margin of connecting sclerite joins, this sclerite runs caudad to coalesce with the "connecting piece" which tapers from anterior to posterior ends and is strongly concave dorsad; anterior adjacent sclerotization present (probably homologous to *F* structures of *Capsinae*), curving caudo-mesad along anterior margin of ring and

possessing a sharp point at antero-lateral angle. Maximum length .36 mm., maximum width .86 mm. (Plate V, Fig. 10).

Posterior wall: Consisting of a pair of simple *A* structures, narrowly fused mesad, extending dorsad as two large lobes; ventral portion of sclerite membranous, ventral margin strongly emarginate; more heavily sclerotized dorsal two-thirds sloping posteriorly from lateral to mesal margin, broadly rounded, with deep central emargination between the two lobes. Maximum length .63 mm., maximum width .75 mm. (Plate VI, Fig. 3). Hypotype: Ames, Iowa. June 18, 1949. J. A. Slater.

Deraeocoris nitentatus Knight, 1921

Sclerotized rings: Similar in form to *quercicola*, rings narrower, mesal margin square cut, appearing truncate rather than tapering to a blunt point; *F* structures weakly developed, bearing a distinct point at antero-lateral margin. Maximum length .25 mm., maximum width .79 mm.

Posterior wall: Similar to *quercicola*, *A* structures more broadly in contact mesally, their dorsal margins forming a broad, shallow emargination rather than a deep one as in the above species; a small knob present on meson. Other features as in *quercicola*. Maximum length .50 mm., maximum width .65 mm. (Plate VI, Fig. 10). Hypotype: Braddyville, Iowa. July 21, 1927. Harris & Johnston.

Deraeocoris nigrutilus Knight, 1921

Sclerotized rings: Ring formation appears identical with that of *quercicola*, but slightly smaller. Maximum length .30 mm., maximum width .78 mm.

Posterior wall: Similar to *quercicola*. A definite knob of sclerotized tissue present on meson (structure *B*); dorsal emargination deep and V-shaped rather than broad at maximum indentation. Maximum length .56 mm., maximum width .72 mm. Hypotype: Vienna, Va. July 7, 1926. H. H. Knight.

Deraeocoris sayi Reuter, 1876

Sclerotized rings: Basic pattern as in the above species, rings very strongly looped and twisted forming a figure eight when viewed from dorsal aspect, secondary flange present on connecting sclerotization; adjacent sclerotization weakly sclerotized coming to a blunt point mesad. Maximum length .25 mm., maximum width .91 mm. (Plate V, Fig. 13).

Posterior wall: *A* structures very broad, widely divergent, with a broad, shallow meso-dorsal emargination, mesal connection narrow, the ventral membranous portion much reduced; indication of a minute weak *B* structure present. Maximum length .65 mm., maximum width 1.37 mm. Hypotype: Navasota, Texas. April 19, 1948. M. Polhemus.

Deraeocoris histrio (Reuter), 1876

Sclerotized rings: Appearance as in *quercicola*, relatively much smaller, rings shorter and proportionately wider, tapering to a blunt point mesally. Maximum length .19 mm., maximum width .46 mm.

Posterior wall: *A* structures very widely divergent, little projected dorsally, forming a very shallow concavity on dorsal margin, ventral margin sinuate, depressed mesad, lobes evenly rounded; small *B* structure near ventral margin on meson, ventral membranous portion either lost in dissection, or naturally absent. Maximum length .22 mm., maximum width .53 mm. (Plate VI, Fig. 8). Hypotype: Ames, Iowa.

ALLOEOTOMUS FIEBER 1858

This is a small Palearctic genus containing three species. Of these, the type, *A. gothicus* (Fallen), has been examined. The genital structures place it beyond doubt in the subfamily *Deraeocorinae*. This relationship is borne out by the condition of the arolia. The affinities of the genus are clearly with *Deraeocoris*, both in the curving and

twisting of the sclerotized rings and in the simple form of the posterior wall of the bursa copulatrix. Although it differs from any *Deraeocoris* studied it will be impossible to ascertain the generic characters of the female genitalia in this subfamily until an intensive study of *Deraeocoris* has been accomplished.

Alloeotomus gothicus (Fallen), 1829

Sclerotized rings: Twisted, posterior margin curving ventrad at both ends, produced to form a flange-like lip, lateral margin produced dorsad almost at right angles near dorso-lateral angle; whole ring tapering mesad, general plan much as in *Deraeocoris*; adjacent sclerotization very large and prominent for size of rings, extending ventrad of rings to form a prominent ventral adjacent sclerotization; F structure present, thinly membranous and indistinct; rings relatively very small for size of species. Maximum length .14 mm., maximum width .48 mm. (Plate V, Fig. 20).

Posterior wall: Composed of a simple sclerite forming a pair of dorsally directed A structures, mesal connection moderately narrow, lobes broad and short forming a very broad, shallow dorsal emargination, ventral area of sclerite membranous, deeply emarginate mesad. This structure very much the type of *Deraeocoris*. Maximum length .31 mm., maximum width .61 mm. (Plate VI, Fig. 1). Hypotype: Neschwitz, Oberlausitz, Germany. August 1, 1942. K. H. C. Jordan.

SUBFAMILY CLIVINEMINAE REUTER 1875

Of this small subfamily a single species, *Largidea rubida* (Uhl.), has been studied. In addition, Kullenberg (17) gives excellent illustrations of the sclerotized rings and posterior wall of *Bothynotus pilosus* Boheman. These two genera represent different tribes of the subfamily, and differ greatly in the appearance of the sclerotized rings. In *Largidea* the rings are ovoid, and while somewhat curved are essentially simple in appearance (Plate V, Fig. 22). In *Bothynotus* the rings are apparently rather similar to the type found in several members of the genus *Deraeocoris*, being infolded laterally and subtriangular in shape. These rings are also rather suggestive of *Orthocephalus mutabilis* (Fall.).

The posterior wall in both these species is very similar to the type found in the *Deraeocorinae*. Kullenberg's figure of *Bothynotus pilosus* shows the wall to be composed of two wide wing-like sclerites not fused along the median line. However, the general form and shape is very similar to the appearance of the posterior wall in the species of the *Deraeocorinae* and in *Largidea*.

The *Clivineminae* are certainly very closely related to the *Deraeocorinae*, and it seems very possible that future investigation will show them to represent a single subfamily group.

LARGIDEA VAN DUZEE 1812

This is a small Nearctic genus composed of four species. The simple condition of the posterior wall places this genus near the *Deraeocorinae* and certain of the anomalous *Orthotylinae*, such as *Orthocephalus*. Indeed, the posterior wall is more nearly like that of *Orthocephalus mutabilis* (Fallen) than any other species studied.

Largidea rubida (Uhler), 1904

Sclerotized rings: Small, widely separated mesad, tapering from lateral to mesal margins, mesal margin rounded, lateral margin subtruncate, ring margins relatively thick becoming more so laterad, lateral margin produced dorsad; adjacent sclerotization represented by a narrow irregular bar that reaches just cephalad of posterior angle of rings and slopes ventrad from lateral to mesal margins; a narrow membranous area surrounding rings and adjacent sclerotization, this membranous area rather uniform in composition. Maximum length .22 mm., maximum width .61 mm. (Plate V, Fig. 22).

Posterior wall: Simple, consisting of a single plate, narrowing dorso-laterad, deeply cleft or emarginate mesally on the ventral margin. Suggestive of *Orthocephalus mutabilis* (Fallen). Maximum length .19 mm., maximum width .49 mm. (Plate VI, Fig. 2). Hypotype: Salida, Colo. July 24, 1900. E. D. Ball (?).

SUBFAMILY HYALIODINAE KNIGHT 1943

This small subfamily formerly was included in the *Dicyphinae*. Only one species has been studied, *Hyaliodes harti* Knight. This species shows a close relationship to the *Dicyphinae* and *Phylinae* by reason of the simple paired sclerites that comprise the posterior wall. The sclerotized rings, however, are considerably twisted and bear little relation to the simple elliptical aspect of the rings shown in the two tribes mentioned above (Plate V, Fig. 8). In fact, the twisted condition is slightly suggestive of the *Deraeocorinae*. While this twisting possibly represents an independent variation, it is entirely possible that *Hyaliodes* may illustrate an intermediate condition between the *Deraeocorinae* on the one hand and the *Phylinae* and *Dicyphinae* on the other.

HYALIODES REUTER 1876

This is a small genus containing approximately seven species. The members of the genus are confined in distribution to the Nearctic and Neotropical regions of the world. The female genitalia of a single species, *Hyaliodes harti* Kngt., have been examined. The relationships are discussed under the subfamily heading above.

Hyaliodes harti Knight, 1941

Sclerotized rings: Relatively large for size of species, transverse, rings strongly twisted and looped-over at lateral margin, elongate laterally and narrow cephalo-caudad, narrowly connecting by a sclerotized rod mesad, anterior margins possessing an anteriorly directed fold unattached along mesal two-thirds of margin; surrounding areas membranous and undifferentiated. Maximum length .13 mm., maximum width .56 mm. (Plate V, Fig. 8).

Posterior wall: Simple and much like *Dicyphus discrepans* and the various species of the *Phylinae* investigated. Hypotype: Urbana, Ill. V. E. Shelford.

SUBFAMILY PHYLINAE REUTER 1910

Of this large subfamily nine species have been studied, each representing a different genus. The material studied represents three tribes. *Chlamydatus*, *Gerhardiella*, *Plagiognathus*, *Psallus*, and *Reuteroscopus* belong to the *Phylini*; *Oncotylus* and *Lopus* to the *Oncotylini*, and *Coquillettia* to the *Hallodapini*.

As mentioned in the general discussion of the subfamilies, the genital characters studied indicate that this subfamily is rather generalized and that the species probably represent relatively primitive forms.

The *Phylinae* may be characterized as possessing ovoid or subelliptical sclerotized rings, although these are sometimes modified considerably. The sclerotization adjacent to these rings is sometimes differentiated into various areas, but on the whole does not illustrate the definite regions present in such subfamilies as the specialized *Capsinae*.

The condition of the posterior wall has been considered very important in evaluating the phylogenetic position of this subfamily. The sclerotized parts of this wall consist of a pair of bilaterally symmetrical sclerites that are in close approximation ventrally, but diverge and taper dorsad to end in blunt points (Plate VI, Fig. 7). These are considered as probably homologous to the *A* structures of the more specialized groups. In one species, *Reuteroscopus ornatus*, an additional differentiated area is present dorsad of these *A* structures, but this is considered for the present as merely a secondary acquisition, (Plate VI, Fig. 5).

With the relatively small amount of material studied it has been impossible to discover structures of value in separating the tribal groups on the basis of the female genitalia. The species studied do fall into three groups. The first, represented by *Gerhardiella*, *Plagiognathus*, and *Psallus*, has the semimembranous areas about the sclerotized rings broken up into a number of more or less poorly defined subdivisions (Plate V, Fig. 18). This entire area is relatively much larger than in other species, causing the sclerotized rings to be very widely separated mesad (see discussion under the genera involved).

The other species present a much simpler picture in regard to the sclerotized ring areas than is the case with the preceding three species. Here a definitely ascertainable adjacent sclerotization is evident laterad of the rings and usually curving to a greater or lesser extent ventrad of them. The remainder of the area about the rings and particularly mesad of them appears to consist of a simple undifferentiated membrane (Plate V, Fig. 17).

Reuteroscopus ornatus is a somewhat anomalous species, insofar as its relationship to the other species of the subfamily are concerned. The adjacent sclerotization is large and shows some indistinct areas of differentiation, but is of a type wholly unlike that found in *Psallus*, *Plagiognathus*, and *Gerhardiella* (Plate V, Fig. 19). Further, the additional lobed areas of the posterior wall in *ornatus* indicate that this species is not closely related to the other species studied.

The relationship of the *Phylinae* to the more specialized *Orthotylinae* has been discussed previously. The slight infolding of the lateral margins of the rings, together with the lateral adjacent sclerotization, in some of the species is very indicative of the more advanced infolding found in the orthotylinae. Of the greatest importance in this respect is the discovery of the apparently annectant species, *Semium hirtum*, that shows at least as much relationship in the genital parts studied to the *Phylinae* as it does to the majority of the *Orthotylinae*.

In summary, the female genital parts studied indicate that the

Phylinae are a generalized, primitive group with simple sclerotized rings and a posterior wall consisting of two simple paired sclerites. A relationship to the *Orthotylinae* is indicated by reason of the infolding of the lateral margins of the rings, and the existence of a species that appears to be intermediate between the two subfamilies.

GERHARDIELLA POPPIUS 1911

This is a monotypic Nearctic genus erected by Poppius for his *G. rubida*.

The genital parts investigated indicate that this genus is a rather typical phyline type, with a simple posterior wall consisting of paired *A* structures surrounded by undifferentiated membrane. The sclerotized rings indicate a relationship to *Psallus* and *Plagiognathus* in that the rings lie a delicately sclerotized semimembranous plate that is subdivided into several poorly differentiated areas. The lateral margins of the rings together with the lateral margins of the sclerotized plates of these three genera are recurved slightly dorso-mesad and are in this respect suggestive of the condition found in the *Orthotylinae*.

Gerhardiella rubida Poppius, 1911

Sclerotized rings: Rings large, marginal sclerotization narrow throughout, shape irregularly subrectangular, mesal margin sinuate, posterior margin nearly straight, lateral margin rounded, with caudo-lateral angle together with adjacent sclerotized area slightly dorsally infolded; surrounding sclerotization broadly connected to *connecting piece*, greatly subdivided mesad of rings, a more heavily sclerotized bar arising from cephalo-mesal angle of rings and extending cephalo-mesad to midline, a Y-shaped structure posterior to these bars with base of Y lying on midline and arms extending cephalo-laterad to cephalo-mesal angle of rings, remainder of area between rings composed of two lobes that extend posteriorly some distance caudad of posterior margin of rings. Maximum length .44 mm., maximum width 1.01 mm. (Plate V, Fig. 18).

Posterior wall: Typically phyline; consisting of a pair of simple sclerites (*A* structures), diverging and tapering dorsad; surrounding membranes undifferentiated. Maximum length .14 mm., maximum width .42 mm. (Plate VI, Fig. 7). Hypotype: Ft. Collins, Colo. July 9, 1902. E. D. Ball (?).

PSALLUS FIEBER 1858

This is a very large genus containing approximately 127 species and numerous named varieties. The various species of the genus are found in all the major faunal areas of the world, with the possible exception of the Neotropical region proper. However, the great bulk of the species are confined in distribution to the Nearctic and Palearctic regions.

The female genital parts have been studied for only one species, *P. ancorifer* (Fieb.). This species indicates that a close relationship exists between *Psallus* and *Plagiognathus*. This relationship has, of course, long been evident using various external parts as criteria. Until a large number of species of both genera have been studied it will be impossible to ascertain whether or not the genitalia substantiate the present generic concepts.

Psallus ancorifer shows its phylene character by the simple paired sclerites that make up the posterior wall. The sclerotized rings are surrounded by a broad, semimembranous plate that is differentiated into several more or less distinct areas as is true for *Plagiognathus* and *Gerhardiella*, but not for the other genera of *Phylinae* studied.

Psallus ancorifer (Fieber), 1858

Sclerotized rings: Rings delicately sclerotized, widely separated mesad, sub-oval, lying on a semimembranous platelike structure that is somewhat differentiated into definite areas; rings and adjacent tissue placed further caudad than in most *Miridae*, so that *connecting piece* passes ventrad of anterior region of ring rather than posterior to rings as in most species; lateral margins of rings together with adjacent sclerotization extending considerably cephalad of rings and appearing creased or folded transversely near its anterior margin. Maximum length .50 mm., maximum width .79 mm. (Plate V, Fig. 16).

Posterior wall: Simple phylene type, composed of two simple *A* sclerites that taper dorsad. Hypotype: Washington, D. C. June 30, 1926. H. H. Knight.

PLAGIOGNATHUS FIEBER 1858

This is a large genus containing approximately ninety-two species and a considerable number of named varieties. The species are found in the Nearctic and Palearctic regions, with a single species described from Chile.

The genital parts of one species, *P. politus* Uhl., have been examined. *Plagiognathus* is apparently rather closely related to *Psallus*, as both genera have ovoid sclerotized rings placed on a large semimembranous plate. The genus, in addition to its close approximation of the type of ring area found in *Psallus*, shows its phylene character by the simple *A* structures that form two dorsally tapering sclerites as in the other *Phylinae*.

Plagiognathus politus Uhler, 1895

Sclerotized rings: Rings small, irregularly ovoid, widely separated mesad, lateral margin together with adjacent sclerotization slightly folded dorso-mesad, a delicate but distinct sclerite present laterad and ventrad of ring proper, this sclerotization broad and extending mesad and cephalad of ring; mesal semimembranous portion differentiated by light folds or creases in anterior region; general conformation suggestive of *Gerhardiella* and *Psallus*. Maximum length .43 mm., maximum width .79 mm. (Plate V, Fig. 14).

Posterior wall: Typical phylene type. Hypotype: Belvidere, Ill. September 1, 1948. J. A. Slater.

REUTEROSCOPIUS KIRKALDY 1905

This is a Nearctic genus composed of three species. The female genitalia of the generotype, *R. ornatus* (Reut.), have been examined during the course of this study.

Reuteroscopus is allied to the other *Phylinae* studied in the possession of a posterior wall composed of two simple dorsally tapering sclerites. However, a pair of large semimembranous lobes (Plate VI, Fig. 5) are present dorsad of the *A* structures, which probably represents a specialization of the rather uniform membranous area found in other *Phylinae*. The sclerotized rings are simple, but the adjacent

sclerotization is large and of somewhat different conformation than in the other *Phylinae* studied.

Reuteroscopus ornatus (Reuter), 1876

Sclerotized rings: Rings relatively small, transverse, tapering to a point mesad, slightly twisted so that the anterior margin is somewhat depressed below the posterior and lateral margins, ring widening laterad, lateral margin broad and subtruncate, adjacent sclerotization large and conspicuous, curving mesad below rings, terminating mesad of mesal angle of rings and near the midline, widened anteriorly with several folds in the sclerite, caudo-laterally narrowing to fuse with connecting piece by an elongate narrow stalk. Maximum length .23 mm., maximum width .55 mm. (Plate V, Fig. 19).

Posterior wall: Composed of two simple dorsally tapering A sclerites as in other *Phylinae*; a pair of dorsally expanding lobes lying in membrane dorsad of A sclerites and narrowly connected mesally. (Plate VI, Fig. 5). Hypotype: Glen Carbon, Ill. September 12, 1948. J. A. Slater.

CHLAMYDATUS CURTIS 1838

This is a moderate-sized genus of approximately twenty-three species. The various species are distributed in the Nearctic, Palearctic and Neotropical regions. The female genitalia of one species, *C. associatus* Uhl., have been examined.

The genital parts studied appear to be rather typically phylina in character. The species possesses simple, ovoid rings and a posterior wall consisting of paired A structures as in the other *Phylinae*.

Chlamydatius associatus Uhler, 1872

Sclerotized rings: Very delicately sclerotized, ring margin so thin as to be difficult to discern for its entire margin, rings ovoid, closely approaching one another at midline; conspicuous adjacent sclerotization lying laterad and partially ventrad of rings. Maximum length .18 mm., maximum width .50 mm.

Posterior wall: Composed of two simple sclerites (A structures), tapering dorsad as in other *Phylinae*. Hypotype: 4 mi. E. Gilbert, Iowa. May 24, 1949. J. A. Slater.

LOPUS HAHN 1832

This genus is composed of three species, all three Palearctic in distribution, but the generotype, *L. decolor* (Fall.), is also found in North America. The female genitalia of the generotype have been examined during the present study.

The relationship of the genus is with the other *Phylinae* in that the posterior wall is composed of two simple sclerites with undifferentiated adjacent membranes. The sclerotized rings are simple and show very close relationship to *Oncotylus* and a somewhat more distant relationship to *Coquillettia*.

Lopus decolor (Fallen), 1807

Sclerotized rings: Transverse, subtriangular, posterior margin flattened, anterior margin strongly rounded, lateral angle raised and together with laterally adjacent sclerotization slightly folded; adjacent sclerotization tapering posteriorly to connect to connecting piece by a narrow stalk, the sclerite sloping strongly ventrad below the rings from lateral to mesal margin, mesal margin only one-third of distance mesad of lateral angle of rings; adjacent sclerotization undifferentiated into F and G structures. Maximum length .16 mm., maximum width .65 mm. (Plate V, Fig. 12). Hypotype: McLean, N. Y. July 27, 1916. H. H. Knight.

COQUILLETIA UHLER 1890

This is a Nearctic genus containing eleven described species. The female genitalia of one species, the genotype *C. insignis* Uhl., have been examined.

The affinities of the genus are apparently with the other *Phylinae* studied. The posterior wall consists of simple paired *A* structures while the sclerotized rings are simple and slightly infolded at the lateral angle. This folding over which is noticeable in several *Phylinae* probably shows some relationship to the condition found in the more specialized *Orthotylinae*.

Coquilletia insignis Uhler, 1890

Sclerotized rings: Large and strongly sclerotized, rings diverging laterad from antero-mesal angle, subelliptical, antero-lateral margin flattened, posterior margin broadly rounded, antero-mesal angle produced into a point, caudo-lateral angle produced dorsad and slightly folded mesad, together with margin of adjacent sclerotization lateral adjacent sclerotization conspicuous lateral to and slightly ventrad of margin of ring, extending cephalad of ring margin for most of length of ring, not differentiated into *F* and *G* structures. Maximum length .38 mm., maximum width .112 mm. (Plate V, Fig. 17).

Posterior wall: Typical phyline type, consisting of a pair of simple sclerites (*A* structures) tapering dorsad, membranous portion of posterior wall appears to show a slight degree of differentiation, perhaps presaging the more complicated conditions found in the *Capsinae*. Hypotype: Trinidad, Colo. Stonewall 8,500 ft. August 7, 1925. H. H. Knight.

HARPOCERA CURTIS 1838

This Palearctic genus contains two species. The genotype, *H. thoracica* (Fallen) 1807, has been examined. The female parts studied in this investigation are figured by Kullenberg (17). His figures agree in all respects with the specimen examined. The rings are simple and strongly sclerotized; the posterior wall is composed of typical paired *A* structures that taper dorsad.

ONCOTYLUS FIEBER 1858

The author has examined a somewhat teneral specimen of *Oncotylus guttulatus* Uhler 1894. The sclerotized rings appear transverse and subtriangular and are very suggestive of *Lopus decolor*. The condition of the posterior wall is difficult to ascertain, but it appears to be a typical phyline condition with simple paired *A* structures that taper dorsad.

SUBFAMILY DICYPHINAE OSHANIN 1912

Of this small subfamily only one species, *Dicyphus discrepans* Knight, has been studied. As judged by the female genitalia, this species indicates the subfamily is very closely related to the *Phylinae*. The sclerotized rings are simple ellipses without evident differentiation of the adjacent sclerotization (Plate V, Fig. 11). The posterior wall is composed of two distinct sclerites (*A* structures) diverging and tapering dorsad (Plate VI, Fig. 6). This posterior wall is the same type as that found in the *Phylinae*. It is interesting to note that Van

Duzee in his 1917 Catalogue places the tribe *Hallodapini* in the subfamily *Dicyphinae*, whereas it is now considered as a tribe of the *Phylinae*.

While it appears evident that the group is closely related to the *Phylinae*, considerable work will be necessary to ascertain the actual systematic position of *Dicyphus* and its allies.

DICYPHUS FIEBER 1858

This is a moderately large genus of approximately fifty-four described species. The various species are present in all the major faunal areas of the world. The female genitalia of one species, *Dicyphus discrepans* Kngt., have been examined.

Dicyphus discrepans Knight, 1923

Sclerotized rings: Simple, consisting of a symmetrical ellipse that diverges laterad from anterior to posterior end; rings appear surrounded by simple membrane, not differentiated into *F* and *G* structures. Maximum length .19 mm., maximum width .30 mm. (Plate V, Fig. 11).

Posterior wall: Very simple, composed of a pair of simple sclerites, probably homologous to structure *A*, that taper from a thick blunt ventral area to a narrow point dorsad and are not in contact on meson; area between structures a simple membrane. Maximum length .15 mm., maximum width .22 mm. (Plate VI, Fig. 6).
Hypotype: McMinneville, Ore. May 23, 1947. K. M. Fender.

SUBFAMILY BRYOCORINAE DOUGLAS AND SCOTT 1865

This subfamily appears to lack completely the sclerotized rings that form such a prominent feature of the bursa copulatrix in other subfamilies. This situation is true for the three species, representing three genera, examined, and is apparently true also for *Bryocoris pteridis* Fallen described and figured by Kullenberg (17). As mentioned above, the female genitalia of three species have been examined. These species are: *Monalocoris filicis* (L.), *Pycnoderes quadrimaculatus* Guerin and *Halticotoma valida* Reuter. The first of these, *M. filicis* (L.), belongs to the tribe *Bryocorini* Reuter 1910. In this species both the posterior wall and the ring area appear to be entirely membranous, the vulvar area also shows little differentiation. The female genitalia of this species have been described and figured by Kullenberg (17). *P. quadrimaculatus* Guer. and *H. valida* Reut. belong to the tribe *Pycnoderini* Reuter 1910. Here also no sclerotization of rings or posterior wall could be ascertained. However, what is taken as the vulvar area is highly developed and strongly sclerotized. It appears likely that this region will reveal good taxonomic characters in this tribe.

The question at once arises as to the phylogenetic significance, if any, of the absence of differentiated structures in the genitalia of the species of this subfamily. It seems possible that one is dealing here with a primitive group wherein the complex conditions found in other subfamilies have not appeared. This hypothesis is strengthened by the fact that the subfamily is relatively small in number of genera and species, yet some of the species are of rather wide distribution.

Also, the fact that *Monalocoris filicis* (L.) feeds upon pteridophytes seems rather significant. In any case, the ring and posterior wall obviously are not able to be used in this subfamily, although their absence may be of considerable phylogenetic importance.

ACKNOWLEDGMENTS

My sincere thanks are due to Dr. Harry Hazelton Knight who originally suggested this problem, directed its course, and made many helpful suggestions. I am further indebted to Dr. Knight for the use of many specimens from his extensive private collection.

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I also wish to extend my appreciation to Dr. H. M. Harris, Head of the Department of Zoology and Entomology of Iowa State College, for making facilities for study available and for helpful suggestions. Also I extend thanks to several members of the staff of the department for the gift of specimens and for suggestions during the course of the investigation. Sincere thanks are due Dr. W. H. Wellhouse for critically reading the manuscript and making a number of helpful suggestions.

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APPENDIX

PLATE I

- FIG. 1. Dorsal view of genital structure pertaining to eighth abdominal segment (partially dissected) of *Coquillettia insignis*; Uhler. X14. S, sclerotized ring; G, anterior ramus; C, connecting piece; W, body wall; N, anterior valvula.
- FIG. 2. Dorsal view of genital structures pertaining to ninth abdominal segment (partially dissected), of *Adelphocoris lineolatus* (Goeze). X14. E, E structures; B, B structure; C, C structure; F, posterior ramus; M, posterior valvula; O, ovipositor sheath.
- FIG. 3. Lateral view of the terminal segments of the abdomen of a female mirid, showing valvulae extruded. X16. C, connecting piece; U, bursa copulatrix; F, posterior ramus; G, anterior ramus; O, ovipositor sheath; M, posterior valvula; N, anterior valvula. (Adapted from Kullenberg 16).
- FIG. 4. *Neoborus glaber* Knight. Anterior view of posterior wall. X43.
- FIG. 5. *Xenoborus commissuralis* Reuter. Anterior view of posterior wall. X43.
- FIG. 6. *Neoborus palmeri* Reuter. Anterior view of posterior wall. X43.
- FIG. 7. *Tropidosteptes cardinalis* Uhler. Anterior view of posterior wall. X43. A, A structure; E, E structure; H, H structure; T, tubular evagination of the H structure.
- FIG. 8. *Neoborus pacificus* Van Duzee. Anterior view of posterior wall. X43.
- FIG. 9. *Tropidosteptes cardinalis* Uhler. Dorsal view of sclerotized rings. X43.
- FIG. 10. *Neoborus palmeri* Reuter. Dorsal view of sclerotized rings. X43.
- FIG. 11. *Xenoborus commissuralis* Reuter. Dorsal view of sclerotized rings. X43.
- FIG. 12. *Lampethusa collaris* Reuter. Posterior view of posterior wall. X43.
- FIG. 13. *Paracalocoris scrupeus* (Say). Posterior view of posterior wall. X43.
- FIG. 14. *Poeas reuteri* Distant. Posterior view of posterior wall. X43.
- FIG. 15. *Neurocolpus nubilus* (Say). Posterior view of posterior wall. X43.
- FIG. 16. *Neurocolpus nubilus* (Say). Dorsal view of sclerotized rings. X43.
- FIG. 17. *Neurocolpus tiliae* Knight. Posterior view of posterior wall. X43. A, A structure; B, B structure; E, E structure.
- FIG. 18. *Paracalocoris johnstoni* Knight. Posterior view of posterior wall. X43.
- FIG. 19. *Lampethusa collaris* Reuter. Dorsal view of sclerotized rings. X43.
- FIG. 20. *Paracalocoris scrupeus* (Say). Dorsal view of sclerotized rings. X43.
- FIG. 21. *Poeas reuteri* Distant. Dorsal view of sclerotized rings. X43.

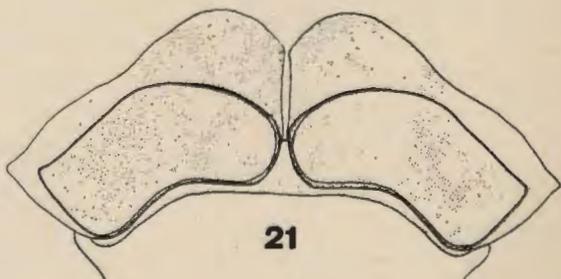
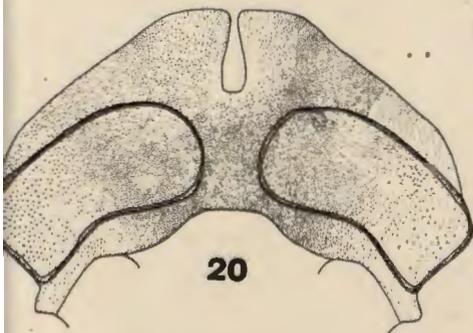
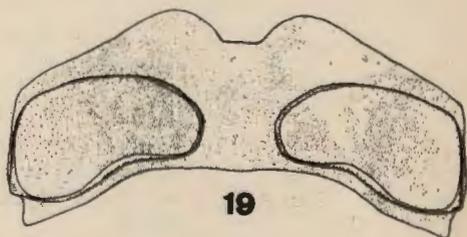
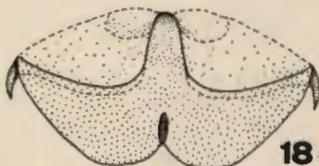
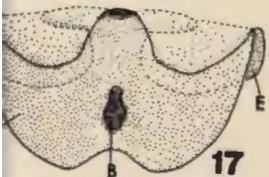
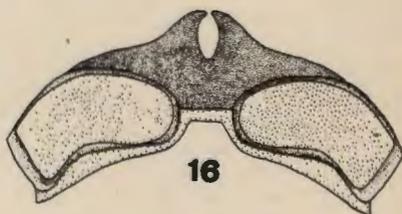
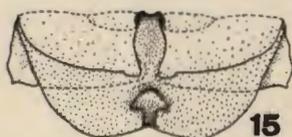
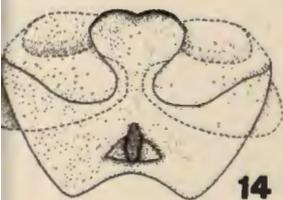
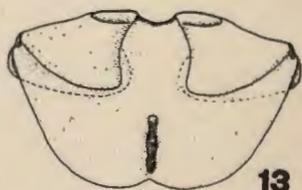
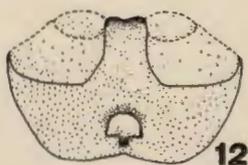
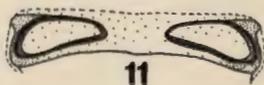
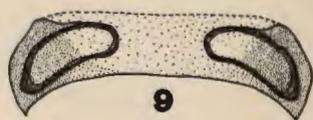
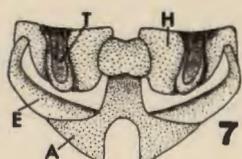
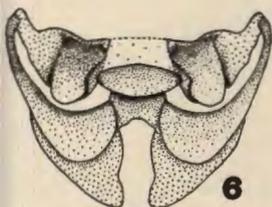
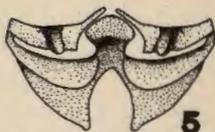
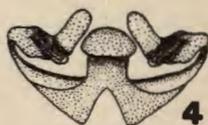
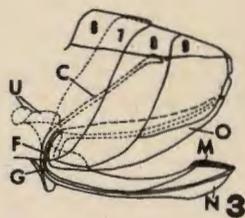
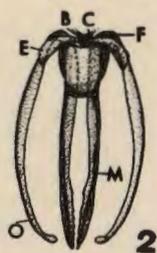
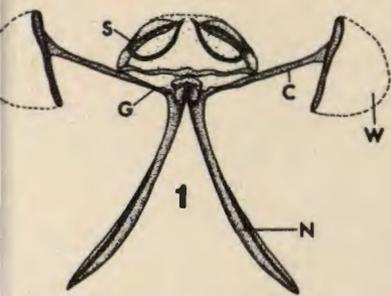


PLATE II

- FIG. 1. *Bolteria luteifrons* Knight. Anterior view of posterior wall. X 43.
 FIG. 2. *Capsus ater* (L.). Posterior view of posterior wall. X 43.
 FIG. 3. *Dichrooscytus rufipennis* (Fallen). Posterior view of wall. X 43.
 FIG. 4. *Stenotus binotatus* (Fabr.). Posterior view of posterior wall. X 43.
 FIG. 5. *Euchilocoris rufinasus* (Stal). Posterior view of posterior wall. X 43.
 FIG. 6. *Platytylellus costalis* (Stal). Posterior view of posterior wall. X 43.
 FIG. 7. *Platytylellus costalis* (Stal). B and C structures of posterior wall, anterior view. X 53.
 FIG. 8. *Lygus vanduzeei* Knight. B and C structures of posterior wall, anterior view. X 43.
 FIG. 9. *Neolygus communis* Knight. Posterior view of posterior wall. X 43.
 FIG. 10. *Opistheuria clandestina* var. *dorsalis* Knight. Posterior view of posterior wall. X 43. D, D structure.
 FIG. 11. *Irbisia shulli* Knight. Posterior view of posterior wall. X 43.
 FIG. 12. *Irbisia shulli* Knight. B and C structures of posterior wall, anterior view. X 43.
 FIG. 13. *Irbisia shulli* Knight. Lateral view of B structure of posterior wall. X 43.
 FIG. 14. *Lygus vanduzeei* Knight. Posterior view of posterior wall. X 43.
 FIG. 15. *Stittocapsus franseriae* Knight. Posterior view of posterior wall. X 43.
 FIG. 16. *Irbisia sericans* (Stal). Posterior view of posterior wall. X 43.
 FIG. 17. *Irbisia sericans* (Stal). Lateral view of B structure of posterior wall. X 43.
 FIG. 18. *Lygus pabulinus* (L.). Posterior view of posterior wall. X 43.
 FIG. 19. *Lygus rubicundus* (Fallen). Posterior view of posterior wall. X 43.
 FIG. 20. *Thyrillus pacificus* Uhler. Posterior view of posterior wall. X 43.
 FIG. 21. *Thyrillus pacificus* Uhler. Lateral view of B structure of posterior wall. X 43.
 FIG. 22. *Calocorisca sticticollis* (Stal). Posterior view of posterior wall. X 43.
 FIG. 23. *Garganus fusiformis* (Say). Posterior view of posterior wall. X 43.
 FIG. 24. *Platylygus grandis* Knight. Posterior view of posterior wall. X 43. A, A structure; B, B structure; C, C structure; E, E structure; H, H structure.
 FIG. 25. *Adelphocoris lineolatus* (Goeze). Posterior view of posterior wall. X 43.
 FIG. 26. *Phytocoris osborni* Knight. Posterior view of posterior wall. X 43.
 FIG. 27. *Coccobaphes sanguinarius* Uhler. Posterior view of posterior wall. X 43.
 FIG. 28. *Horcias dislocatus* (Say). Posterior view of posterior wall. X 43.
 FIG. 29. *Poecilocapsus lineatus* (Fabr.). Posterior view of posterior wall. X 43.
 FIG. 30. *Lygidea rosacea* Reuter. Posterior view of posterior wall. X 43.

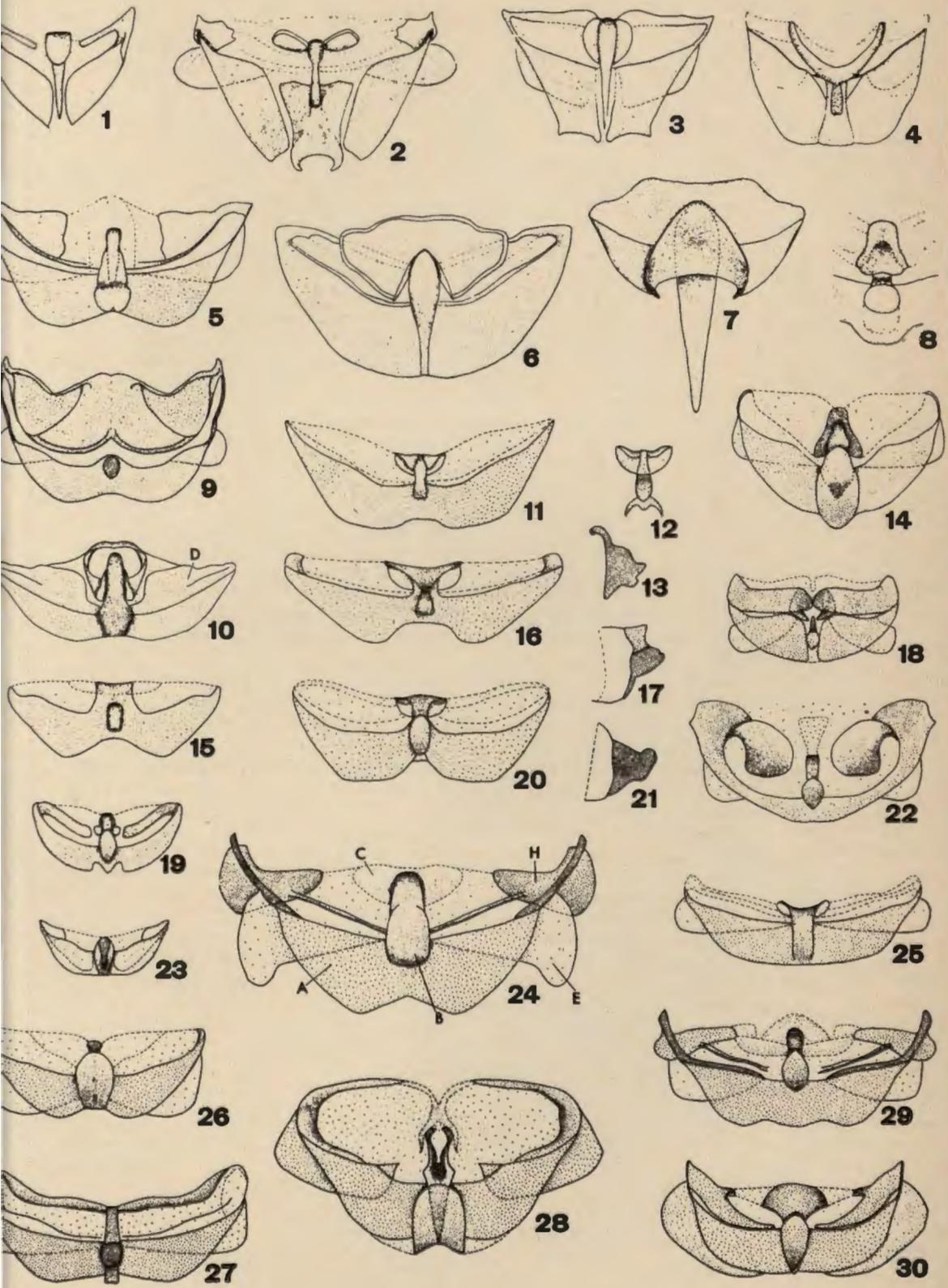
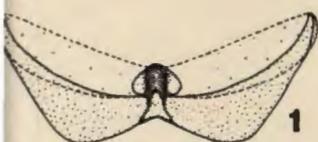
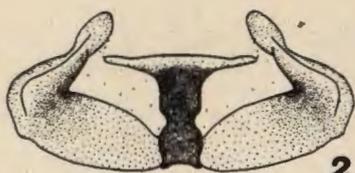


PLATE III

- FIG. 1. *Miris dolabratus* (L.). Posterior view of posterior wall. X43.
FIG. 2. *Pantilius tunicatus* (Fabr.). Posterior view of posterior wall. X 43.
FIG. 3. *Calocoris norvegicus* (Gmelin). Anterior view of posterior wall. X 43.
FIG. 4. *Horcias signoreti* (Stal). Posterior view of posterior wall. X 43.
FIG. 5. *Polymerus basalis* Reuter. Posterior view of posterior wall. X43.
FIG. 6. *Collaria meilieurii* Provancher. Posterior view of posterior wall. X 43.
FIG. 7. *Oncerometopus nigriclavus* Reuter. Dorsal view of sclerotized rings. X 43.
FIG. 8. *Platylygus grandis* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 9. *Neolygus communis* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 10. *Pantilius tunicatus* (Fabr.). Dorsal view of sclerotized rings. X 43.
FIG. 11. *Calocoris norvegicus* (Gmelin). Dorsal view of sclerotized rings. X43. F, F structure; G, G structure; S, sclerotized ring.
FIG. 12. *Lygus atriflavus* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 13. *Lygus plagiatus* Uhler. Dorsal view of sclerotized rings, X43.
FIG. 14. *Calocoris biclavatus* (H.S.). Dorsal view of sclerotized ring, right side. X 43.
FIG. 15. *Calocoris fulvomaculatus* (De Geer). Dorsal view of sclerotized ring, right side. X 43.
FIG. 16. *Lygus hesperus* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 17. *Lygus elisus* Van Duzee. Lateral projection of adjacent sclerotization of sclerotized ring area, right side. X 43.
FIG. 18. *Lygus vanduzeei* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 19. *Lygus oblineatus* (Say). Dorsal view of sclerotized rings. X 43.



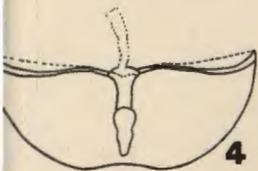
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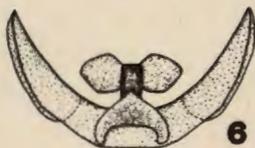
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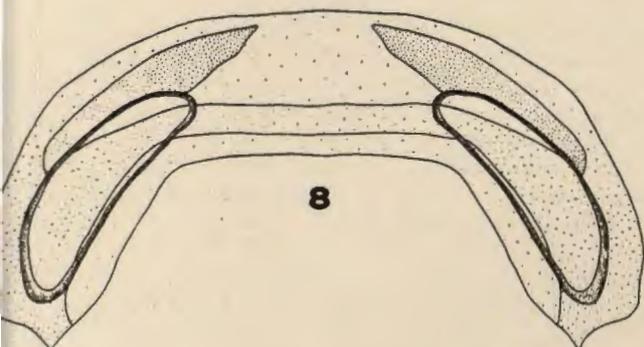
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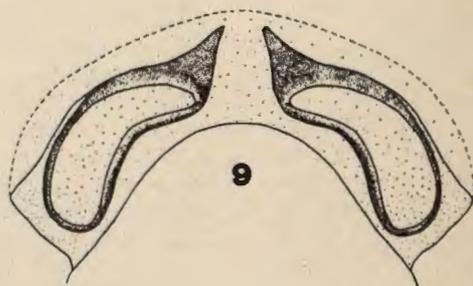
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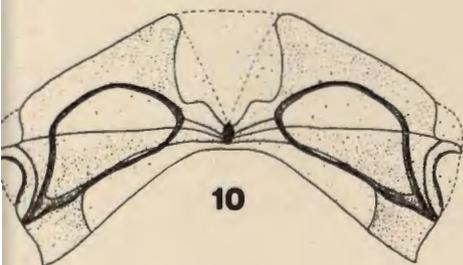
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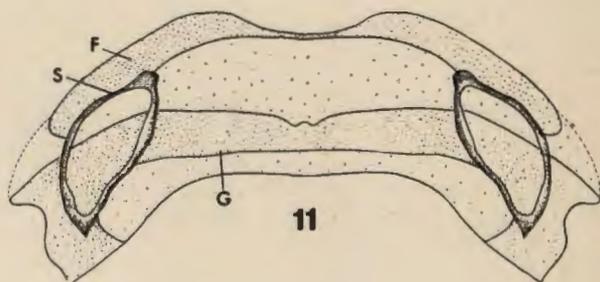
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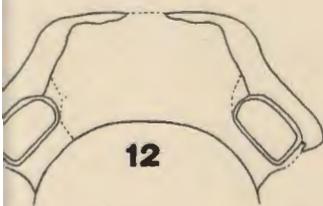
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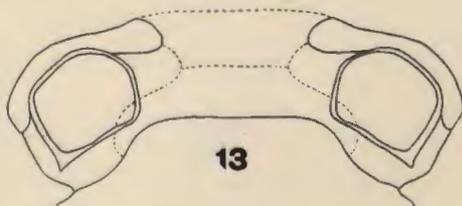
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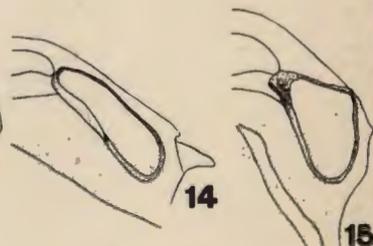
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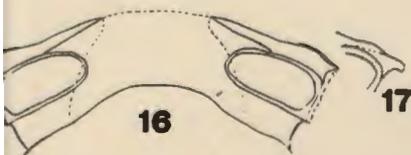


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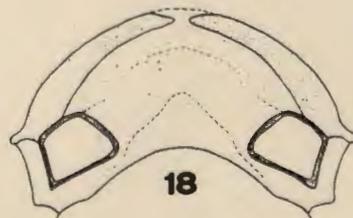


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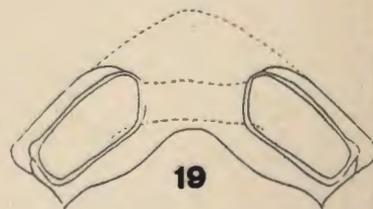


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PLATE IV

- FIG. 1. *Platytylellus costalis* (Stal). Dorsal view of sclerotized rings. X 43.
FIG. 2. *Dichrooscytus rufispennis* (Fallen). Dorsal view of sclerotized rings. X 43.
FIG. 3. *Bolteria luteifrons* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 4. *Platytylellus circummaculatus* (Stal). Dorsal view of sclerotized rings. X 43.
FIG. 5. *Irbisia shulli* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 6. *Capsus ater* (L.). Dorsal view of sclerotized rings. X 43.
FIG. 7. *Irbisia sericans* (Stal). Dorsal view of sclerotized rings. X 43.
FIG. 8. *Horcias dislocatus* (Say). Dorsal view of sclerotized rings. X 43.
FIG. 9. *Thyrillus pacificus* Uhler. Dorsal view of sclerotized rings. X 43.
FIG. 10. *Garganus fusiformis* (Say). Dorsal view of sclerotized rings. X 43.
FIG. 11. *Phytocoris osborni* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 12. *Coccobaphes sanguinarius* Uhler. Dorsal view of sclerotized rings. X 43.
FIG. 13. *Creontiades debilis* Van Duzee. Dorsal view of sclerotized rings. X 43.
FIG. 14. *Horcias signoreti* (Stal). Dorsal view of sclerotized rings. X 43.
FIG. 15. *Poecilocapsus lineatus* (Fabr.). Dorsal View of sclerotized rings. X 43.
FIG. 16. *Euchilocoris rufinasis* (Stal). Dorsal view of sclerotized rings. X 43.

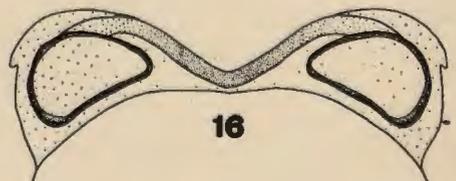
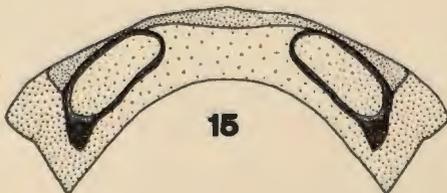
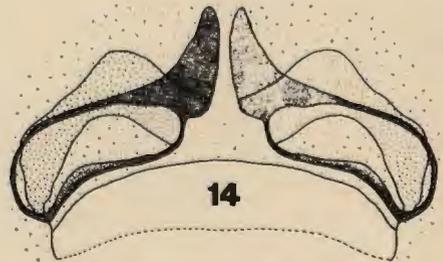
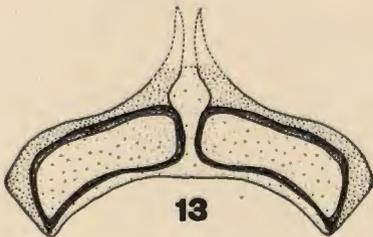
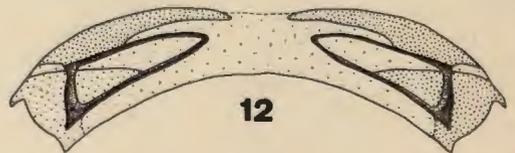
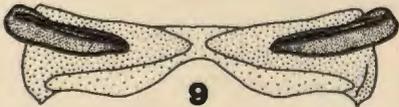
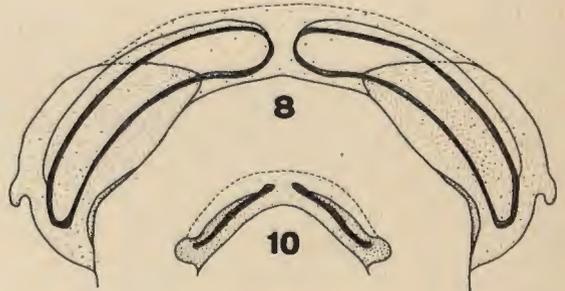
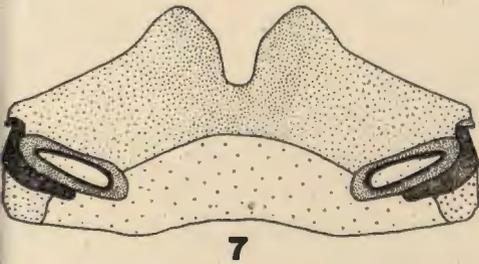
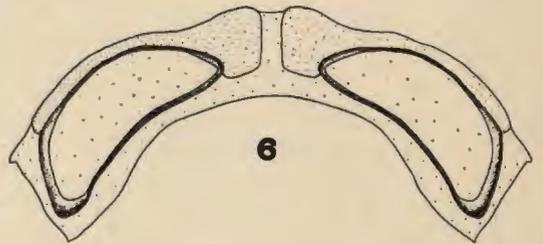
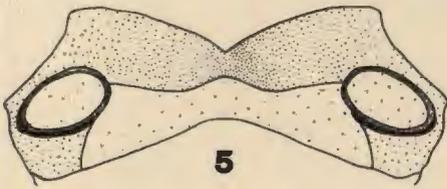
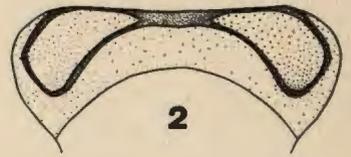
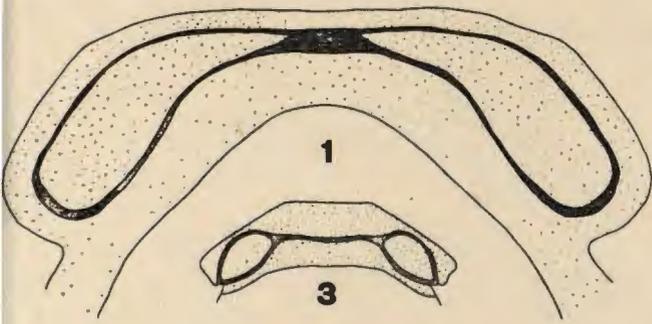


PLATE V

- FIG. 1. *Lygidea rosacea* Reuter. Dorsal view of sclerotized rings. X 43.
FIG. 2. *Stittocapsus franseriae* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 3. *Lygus pabulinus* (L.). Dorsal view of sclerotized rings. X 43.
FIG. 4. *Polymerus basalis* Reuter. Dorsal view of sclerotized rings. X 43.
FIG. 5. *Lygus rubicundus* (Fallen). Dorsal view of sclerotized rings. X 43.
FIG. 6. *Adelphocoris rapidus* (Say). Dorsal view of sclerotized rings. X 43.
FIG. 7. *Stenotus binotatus* (Fabr.). Dorsal view of sclerotized rings. X 43.
FIG. 8. *Hyaliodes harti* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 9. *Opistheuria clandestina* var. *dorsalis* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 10. *Deraeocoris quercicola* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 11. *Dicyphus discrepans* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 12. *Lopus decolor* (Fallen). Dorsal view of sclerotized rings. X 43.
FIG. 13. *Deraeocoris sayi* Reuter. Dorsal view of sclerotized rings. X 43.
FIG. 14. *Plagiognathus politus* Uhler. Dorsal view of sclerotized rings. X 43.
FIG. 15. *Stenodema vicinum* (Provancher). Dorsal view of sclerotized rings. X 43.
FIG. 16. *Psallus ancorifer* (Fieber). Dorsal view of sclerotized rings. X 43.
FIG. 17. *Coquillettia insignis* Uhler. Dorsal view of sclerotized rings. X 43.
FIG. 18. *Gerhardiella rubida* Poppius. Dorsal view of sclerotized rings. X 43.
FIG. 19. *Reuteroscopus ornatus* (Reuter). Dorsal view of sclerotized rings. X 43.
FIG. 20. *Alloetomus gothicus* (Fallen). Dorsal view of sclerotized rings. X 43.
FIG. 21. *Miris dolabratus* (L.). Dorsal view of sclerotized rings. X 43.
FIG. 22. *Largidea rubida* (Uhler). Dorsal view of sclerotized rings. X 43.

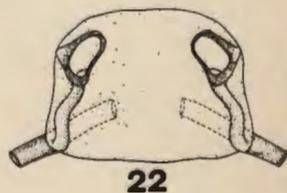
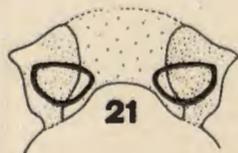
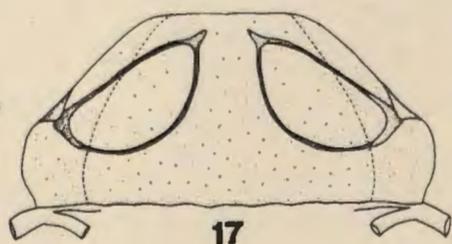
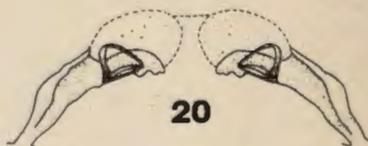
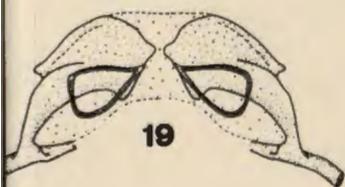
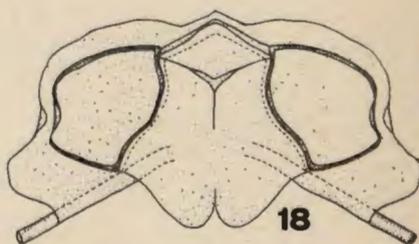
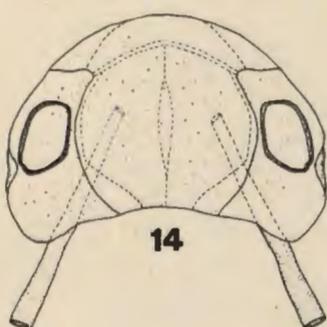
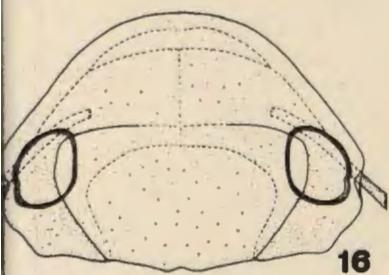
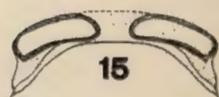
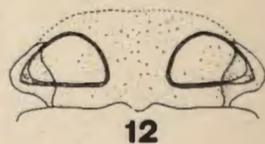
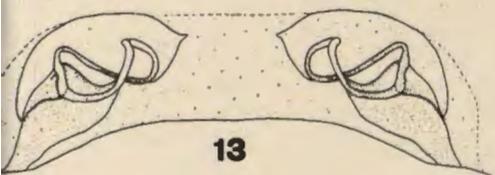
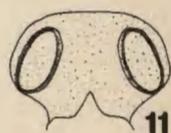
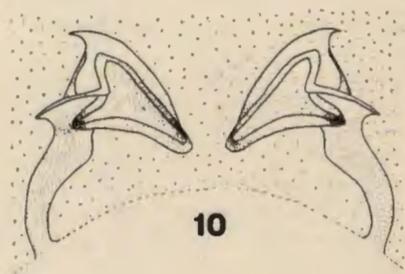
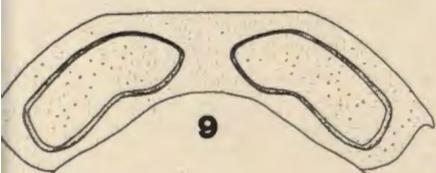
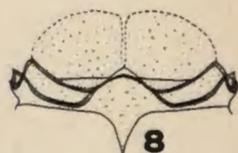
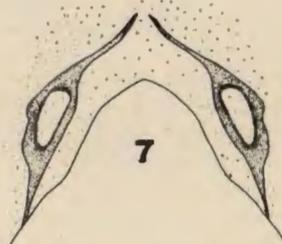
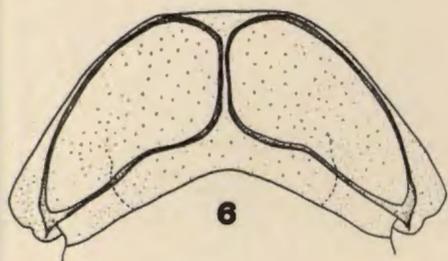
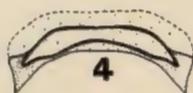
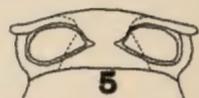
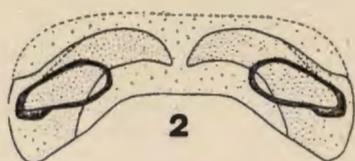
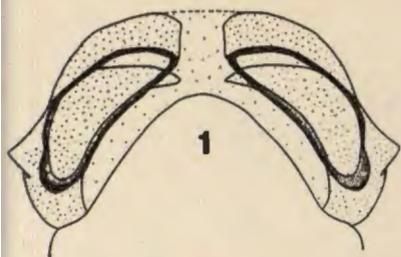
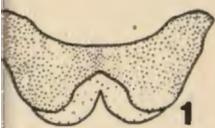
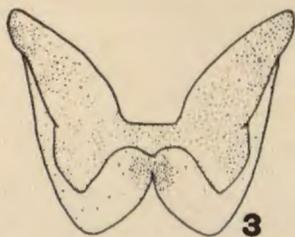


PLATE VI

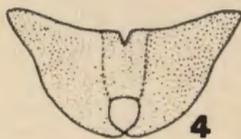
- FIG. 1. *Alloeotomus gothicus* (Fallen). Posterior view of posterior wall. X 43.
 FIG. 2. *Largidea rubida* (Uhler). Posterior view of posterior wall. X 43.
 FIG. 3. *Deraeocoris quercicola* Knight. Posterior view of posterior wall. X 43.
 FIG. 4. *Orthocephalus mutabilis* (Fallen). Posterior view of posterior wall. X 43.
 FIG. 5. *Reuteroscopus ornatus* (Reuter). Posterior view of posterior wall. X 43.
 FIG. 6. *Dicyphus discrepans* Knight. Posterior view of posterior wall. X 43.
 FIG. 7. *Gerhardiella rubida* Poppius. Posterior view of posterior wall. X 43. A, A structure.
 FIG. 8. *Deraeocoris histrio* (Reuter). Posterior view of posterior wall. X 43.
 FIG. 9. *Halticus intermedius* Uhler. Posterior view of posterior wall. X 43.
 FIG. 10. *Deraeocoris nitentatus* Knight. Posterior view of posterior wall. X 43.
 FIG. 11. *Semium hirtum* Reuter. Posterior view of posterior wall. X 43.
 FIG. 12. *Pilophorus strobicola* Knight. Anterior view of posterior wall. X 43.
 FIG. 13. *Labops hesperius* Uhler. Anterior view of mesal area of posterior wall. X 43.
 FIG. 14. *Labops hirtus* Knight. Anterior view of posterior wall. X 43.
 FIG. 15. *Heterocordylus malinus* Reuter. Anterior view of posterior wall. X 43. J, J structure; K, K structure; L, L structure.
 FIG. 16. *Ilnacora malina* Uhler. Anterior view of posterior wall. X 43.
 FIG. 17. *Pseudoxenetus scutellatus* (Uhler). Anterior view of posterior wall. X 43.
 FIG. 18. *Strongylocoris stygicus* (Say). Anterior view of posterior wall. X 43.
 FIG. 19. *Mecomma gilvipes* (Stal). Anterior view of posterior wall. X 43.
 FIG. 20. *Ceratocapsus modestus* Uhler. Anterior view of posterior wall. X 43.
 FIG. 21. *Lopidea staphyleae* Knight. Anterior view of posterior wall. X 43.
 FIG. 22. *Lopidea teton* Knight. Anterior view of posterior wall. X 43.
 FIG. 23. *Lopidea incurva* Knight. Anterior view of posterior wall. X 43.
 FIG. 24. *Ceratocapsus fasciatus* Uhler. Anterior view of posterior wall. X 43.
 FIG. 25. *Lopidea heidemanni* Knight. Anterior view of posterior wall. X 43.
 FIG. 26. *Orthotylus ornatus* Van Duzee. Anterior view of posterior wall. X 43.
 FIG. 27. *Orthotylus modestus* Van Duzee. Anterior view of posterior wall. X 43.
 FIG. 28. *Orthotylus viridis* Van Duzee. Anterior view of posterior wall. X 43.
 FIG. 29. *Orthotylus dorsalis* (Provancher). Anterior view of posterior wall. X 43.



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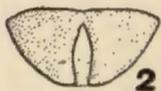
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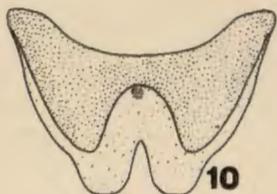
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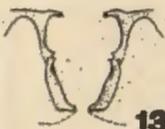
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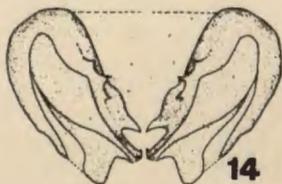
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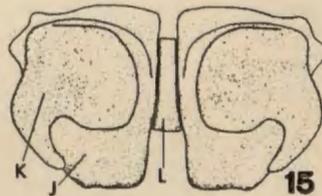
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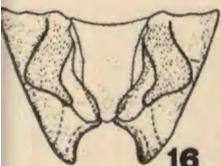
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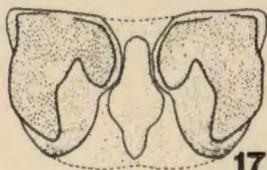
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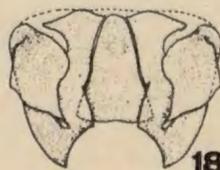
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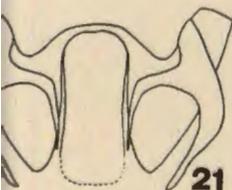
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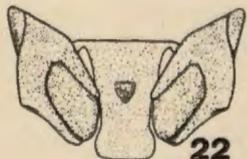
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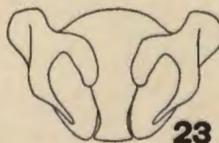
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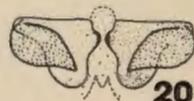
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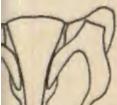
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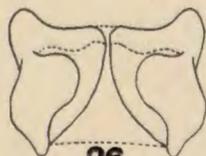
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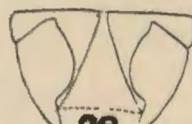
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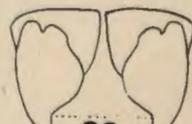
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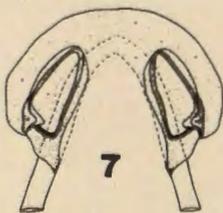
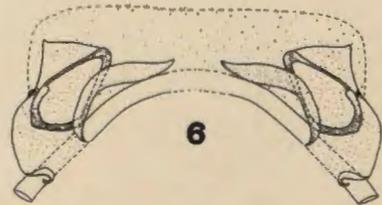
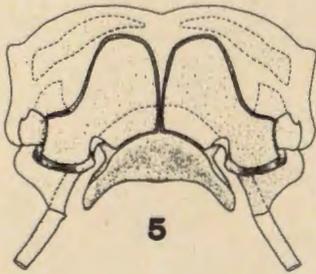
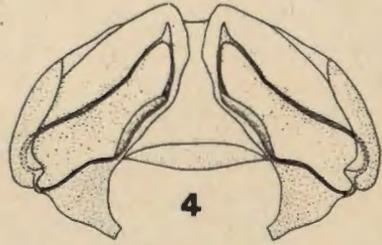
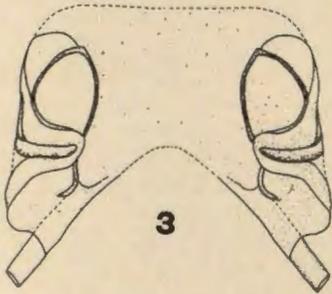
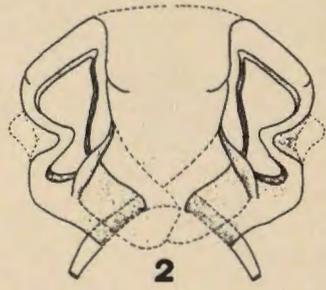
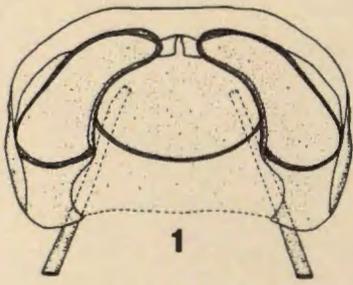
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PLATE VII

- FIG. 1. *Halticus intermedius* Uhler. Dorsal view of sclerotized rings. X 43.
FIG. 2. *Orthotylus modestus* Van Duzee. Dorsal view of sclerotized rings. X 43.
FIG. 3. *Pseudoxenetus scutellatus* (Uhler). Dorsal view of sclerotized rings. X 43.
FIG. 4. *Labops hirtus* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 5. *Strongylocoris leucocephalus* (L.). Dorsal view of sclerotized rings. X 43.
FIG. 6. *Orthocephalus mutabilis* (Fallen). Dorsal view of sclerotized rings. X 43.
FIG. 7. *Pilophorus strobicola* Knight. Dorsal view of sclerotized rings. X 43.
FIG. 8. *Semium hirtum* Reuter. Dorsal view of sclerotized rings. X 43.



LIFE HISTORY OF THE YELLOW PERCH, *PERCA FLAVESCENS*
(MITCHILL), OF CLEAR LAKE, IOWA¹

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The yellow perch, *Perca flavescens* (Mitchill), is a common and highly prized fish in Iowa although in some localities it does not reach a desirable size. This species finds favor with anglers since it is easy to catch and has excellent food quality. Its ability to withstand high fishing intensity is widely known, and in many waters the perch provide reliable fishing from year to year. Young yellow perch provide forage for predatory fish and often constitute much of their food early in the summer when most other species have yet to spawn.

This life history of the perch of Clear Lake is based upon fisheries investigations carried out during the years 1941, 1947, 1948, and 1949. Clear Lake, in Cerro Gordo County, is the third largest lake in Iowa and has an area of 3,643 acres. It is a rich eutrophic lake with a maximum depth of about twenty feet and an average depth of about twelve feet. The lake is exposed to strong wind action in the summer, and the water tends to be thoroughly mixed and non-stratified.

The mean water temperature in three feet of water for the last two weeks of June 1949 was 74°F., for July 82°F., and for August 78°F., with maxima of 86°F., 89°F., and 86°F., respectively. The water level was more than twelve inches lower on September 1 than in late June.

The following plants were collected during the summer of 1949. Verification and assistance in identification were received from Dr. Ada Hayden and Dr. Richard Pohl of the Department of Botany, Iowa State College.

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SUBMERGED

- Characeae (Chara Family)
Chara sp.
 Nymphaeaceae (Water Lily Family)
Nymphaea tuberosa Paine
Nuphar advena Ait.
 Najadaceae (Pondweed Family)
Potamogeton illinoensis Morong
Potamogeton nodosus Poiret
Potamogeton pectinatus L.
Potamogeton Richardsonii (Benn.) Rydb.
Potamogeton natans L.
Potamogeton praelongus Wulf.
Najas flexilis (Willd) Rotsk and Schmidt
 Hydrocharitaceae (Frogbit Family)
Vallisneria americana Michx.
 Polygonaceae (Buckwheat Family)
Polygonum coccineum Muhl.
Polygonum amphibium L.
 Haloragidaceae (Water Milfoil Family)
Myriophyllum exalbescens Fernald

FLOATING

- Lemnaceae (Duckweed Family)
Lemna minor L.
Spirodela polyrhiza (L.) Schleid

MARGINAL

- Sparganiaceae (Bur Reed Family)
Sparganium eurycarpum Engelm.
 Alismaceae (Water Plantain Family)
Sagittaria latifolia Willd
Sagittaria latifolia forma gracilis (Pursh) Robinson
Alisma Plantago-aquatica L.
Sagittaria heterophylla Pursh
 Polygonaceae (Buckwheat Family)
Polygonum punctatum Ell.
 Cyperaceae (Sedge Family)
Scirpus fluviatilis (Torr) Gray
Carex hystericina Muhl.

EMERGENT

- Cyperaceae (Sedge Family)
Scirpus validus var. *creber* Fern.

There has been a major change in the aquatic vegetation of Clear Lake during the last several years. According to Bailey and Harrison (1), extensive beds of emergent and submergent vegetation were present in the north and west littoral zones of Clear Lake in 1941, 1942, and 1943. At that time *Ceratophyllum demersum*, *Typha latifolia*, *Anacharis canadensis*, and *Wolffia columbiana* were considered common. These species were not found in 1949. *Potamogeton nodosus*, one of the most common plants in 1949, was not included in Bailey and Harrison's list. The large beds of bulrush³ described by them were still present, and seine samples in 1949 showed the majority of small fish in Clear Lake used these beds for foraging and shelter.

³ Identified by Bailey and Harrison as *Scirpus acutus*. Cleary (1947) and the author identified the specimens taken in 1947 and 1949 as *Scirpus validus* var. *creber* Fern. The 1949 specimens were verified at the Iowa State College Herbarium.

According to reliable residents of the Clear Lake area, submerged vegetation was so abundant during the summers of 1945 and 1946 that boating was nearly impossible in the water between McIntosh Woods and the Ventura grade. This water averages about five feet in depth and has large areas of shoals about two feet in depth. The situation became so acute that the boat liveries in this western part of the lake were threatened with failure.

During 1947 little submerged vegetation was in evidence in the area. In 1949 sparse, scattered plants were growing in shallow water near McIntosh Woods. Similar conditions were found in all other parts of Clear Lake, and no large beds of submerged vegetation were found. The species were represented only by scattered plants in the shallower waters among the bulrushes. *Potamogeton illinoensis* and *Potamogeton nodosus* washed in along shore with roots intact. This was thought to be the result of severe wave action or carp activity, but no direct evidence as to the cause was noticed. The changes in aquatic vegetation undoubtedly had an effect on the feeding, reproduction, and protective activities of the fish in Clear Lake. The bulrush beds probably minimized some of the effects of the disappearing submergents since the bulrushes grew in water up to five feet in depth. Gill netting indicated that the bulrushes greatly influenced the activities of the adult fish since most of the small fish, forage fish, and food organisms inhabited these areas.

MATERIALS AND METHODS

The growth study of the Clear Lake yellow perch is based upon scales from 738 perch collected from 1941 to 1949. In 1941, Harry M. Harrison, Jr., collected 69 yellow perch by angling, gill netting, and seining. Robert Cleary took 102 yellow perch in 1947, and James Sieh, 322 in 1948. In the latter two collections, most of the fish were caught in gill nets. In addition, samples of young-of-the-year perch were taken in 1943, 1947, 1948, and 1949.

The 1949 collection of 262 perch was taken from all habitats by various methods of capture from June 17 to September 1, and the size ranges varied considerably with the type of gear used for capture (Table 1). Gill netting selected the larger perch, seining the smaller perch, and angling the widest range of sizes. Since seining with a 30-foot or 500-foot seine showed little difference in selectivity, it is probable that few large perch inhabited the shore line area.

It was observed that the smallest mesh of the gill nets (1½ inch stretch) was too large to catch many of the one- and two-year-old perch. This was especially apparent when perch were caught easily on hook and line, while gill nets in the immediate vicinity showed practically no success. During the month of August, the author by angling 30 hours caught 99 perch for an average of 3.3 fish per hour.

In this study, standard length measurements were used. In addition, total and fork lengths were recorded. On the basis of the measure-

ments of 685 perch ranging from 74 to 216 millimeters in standard length, the following conversion factors were calculated:

$$\begin{aligned}\text{Fork length} &= 1.150 \text{ standard lengths} \\ \text{Total length} &= 1.210 \text{ standard lengths} \\ \text{Total length} &= 1.053 \text{ fork lengths}\end{aligned}$$

The scales were prepared for projection as described by Lewis and Carlander (17). The scales were easily read without cleaning, and no addition of water to the slides was necessary. A microprojector similar to that described by Van Oosten, Deason, and Jobs (20) was used to examine the scales at a magnification of 42 diameters.

TABLE 1
NUMBERS OF YELLOW PERCH TAKEN IN EACH 10-MILLIMETER SIZE GROUP BY
VARIOUS GEAR IN CLEAR LAKE, 1949

Standard Length in Millimeters	Experimental Gill Net*	30-Foot Seine	500-Foot Seine	Angling	Total
70-79.....	.....	2	2	.....	4
80-89.....	.....	10	2	5	17
90-99.....	.....	12	16	25	53
100-109.....	4	10	7	41	62
110-119.....	19	5	5	27	56
120-129.....	15	2	1	11	29
130-139.....	7	.....	.....	8	15
140-149.....	4	.....	.....	3	7
150-159.....	1	.....	.....	.....	1
160-169.....	.....	.....	.....	1	1

* With mesh sizes of 1.5, 2.0, 2.5, 3.0, and 4.0 inch, stretch measure.

The ages of the yellow perch were determined by counting the number of annuli on the scales. Fish having no annuli were placed in 0 age class, and the older fish were designated by Roman numerals representing the number of annuli present. No "false annuli" were detected on the scales of the Clear Lake perch. No perch were taken before June, and all perch showed considerable growth from the last annulus. Apparently the annuli are formed sometime in early spring before June in Clear Lake.

LENGTH-WEIGHT RELATIONSHIP

The mathematical relationship between standard length in millimeters (L) and weight in grams (W) of the Clear Lake perch can best be described by the following formula:

$$\text{Log } W = -5.6902 + 3.483 \text{ Log } L$$

(a) (b)

The values *a* and *b* were determined by the least squares method using the unweighted logarithms of the average lengths and weights of the combined 1947 and 1949 data. A comparison of the weights computed

with this formula with the actual weights indicates a fairly good fit (Table 2). Most of the 1947 fish were longer and also heavier for their length than the 1949 fish.

The relative plumpness of a fish may be represented by the coefficient of condition, K, where

$$K = \frac{W 10^5}{L^3}$$

W = weight in grams

L = standard length in millimeters.

The K values increase in length in both 1947 and 1949 (Table 2). The average K for 1947 was 2.37 and for 1949, 1.86. This difference is due partly to the number of larger fish in 1947; also, however, the average K for each size group in 1949 is less in all cases than the corresponding sizes in 1947.

TABLE 2
LENGTH-WEIGHT RELATIONSHIP OF YELLOW PERCH FROM CLEAR LAKE

Average Standard Length in Millimeters	Weight in Grams		Estimated Weight in Grams*	Total Length in Inches	Weight in Ounces	Average K	Number of Fish
	Mean	Range					
1949							
77.....	8	6-10	8	3.6	0.28	1.72	3
87.....	11	9-13	12	4.0	0.38	1.68	12
96.....	16	11-25	16	4.5	0.42	1.78	51
105.....	21	16-30	22	5.0	0.55	1.83	76
115.....	28	17-41	31	5.4	0.97	1.86	54
123.....	37	31-50	39	5.8	1.3	1.97	32
134.....	50	43-70	52	6.4	1.8	2.10	14
143.....	63	56-81	66	6.8	2.2	2.18	7
152.....	83	.....	81	7.3	2.9	2.36	1
165.....	101	.....	108	7.7	3.6	2.25	1
Av. K 1.86							
1947							
76.....	8	6-11	7	3.6	0.28	1.78	7
82.....	10	8-13	9	3.9	0.35	1.88	4
113.....	43	.....	29	5.3	1.5	2.49	1
127.....	70	.....	43	6.0	2.5	2.88	1
136.....	59	43-62	55	6.5	2.3	2.38	7
143.....	69	57-92	66	6.8	2.5	2.35	16
153.....	88	75-128	83	7.3	3.1	2.45	10
163.....	112	85-134	104	7.7	3.9	2.48	13
173.....	131	113-152	127	8.2	4.6	2.54	7
197.....	198	.....	200	9.4	6.9	2.85	1
201.....	227	.....	215	9.6	8.0	2.79	1
214.....	255	.....	267	10.2	9.0	2.62	2
Av. K 2.37							

* Log W = - 5.6902 + 3.483 Log L.

A comparison of the average K from various lakes showed that the Clear Lake perch were about median in position [Hile, (11); Beckman, (2); Lewis, (16); Carlander, (3); Eschmeyer, (9), (10); and Schneberger, (19)].

BODY-SCALE RELATIONSHIP

The body-scale relationship was determined by plotting the mean standard length of the fish for each 10-millimeter group against the mean anterior radius of the scales and fitting a line to the data by the least squares method. Measurements were taken from a total of 666 yellow perch, of which 100 were obtained in 1947, 319 in 1948, and 247 in 1949. Separate analysis of the various years' collections indicated that the same body-scale relationship could be used for all samples. Observations indicated that a straight line would satisfactorily describe the relationship. The line was found to have an intercept of 19.5 millimeters and a slope of 0.99. The growth calculations were made on a direct proportion basis using 19.5 millimeters as a base rather than zero on a nomograph [Carlander and Smith, (6)].

AGE AND GROWTH

Of the 738 yellow perch aged in this study, 21.0 per cent were one year old, 66.3 per cent were two years old, 12.6 per cent were three years old, and 0.03 per cent four years old. The sampling methods tended to select the larger perch, and the number of one-year-old fish collected was not representative of their abundance. The lack of older fish may be quite significant. Although yellow perch are not particularly long lived, in most populations perch live five to six years or even longer [Carlander, (5); Schneberger, (19); Hile and Jobes, (12), (13); Jobes, (14)]. Since there were many two-year-old perch caught in Clear Lake during the summer periods, it is not known whether the difference in numbers of the two- and three-year-old fish is caused by a high mortality of the two-year-old fish late in the year or of the three-year-old perch early in the year. In 1949 there were 23 three-year-old perch captured in June, 8 in July, and 4 in August. No evidence of large numbers of dead or dying perch was seen or reported during the time that the older fish disappeared.

It is possible that the decrease in perch between age groups II and III might be caused by migration to other parts of the lake rather than mortality, but larger perch were not located despite efforts to sample all areas of the lake in 1949.

The calculated growth increment for the perch was highest the first year in almost every case, and decreased with age thereafter (Table 3). The growth rates of male and of female perch were found to be not statistically different and therefore the data were combined. The calculated lengths and the average length at capture indicate a general decrease in growth rate from 1941 to 1949.

To test whether the changes in growth were significant, the standard

deviations were determined for the calculated lengths (in these cases the uncorrected lengths based upon direct proportion calculations were used) of the two-year fish collected in 1941, 1947, 1948, and 1949 (Table 4). Application of Student's *t* test indicated that the first year's growth was statistically greater in fish collected in 1941 than in any other year and in 1947 than in 1948 and 1949, but the difference between

TABLE 3
AVERAGE CALCULATED LENGTHS OF YELLOW PERCH IN EACH AGE GROUP FOR THE 1941, 1947, 1948, AND 1949 COLLECTIONS FROM CLEAR LAKE

Age Class and Year of Capture	Number Examined	Standard Length in mm. at Each Annulus				Standard Length at Capture*
		1	2	3	4	
1941						
II.....	69	76	133			168
Increment in mm.....		76	57			
Increment in gm.....		8	44			
1947						
I.....	15	57				86
II.....	79	59	122			151
III.....	8	66	134	170		192
Combined.....	102	59	123	170		
Increment in mm.....		59	63	36		
Increment in gm.....		3	36	69		
1948						
II.....	272	53	103			125
III.....	48	55	109	157		163
IV.....	2	65	137	176	206	210
Combined.....	322	53	104	157	206	
Increment in mm.....		53	51	48	30	
Increment in gm.....		2	21	64	99	
1949						
I.....	140	55				99
II.....	68	52	89			117
III.....	37	51	94	116		130
Combined.....	245	54	91	116		
Increment in mm.....		54	39	22		
Increment in gm.....		3	12	14		

* 1947, 1948, 1949, fish collected during June, July, and August. 1941 fish collected in September and October.

the first year's growth of the fish collected in 1948 and 1949 was not significant. By the end of the second year the fish collected in later years were all significantly smaller than those collected in previous years. The fact that the lengths were not corrected before making the comparisons would not materially change the results, since the differences would be similar if calculated on a corrected basis and the *t* values ranged from 6.1 to 19.2, all far beyond the 5 per cent level of significance.

The difference in growth is more marked when the weight rather than the length increments are studied. The weight increments were

estimated using the length-weight relationship: $\text{Log } W = -5.6902 + 3.483 \text{ Log } L$.

The average calculated standard lengths at the first annulus show the greatest decrease in growth from 1941 to 1947 with no further decrease in 1948 and 1949. The average increment during the second year shows the greatest decrease from 1947 to 1948, and the increment

TABLE 4
MEANS AND STANDARD DEVIATIONS OF THE LENGTHS CALCULATED BY DIRECT PROPORTION OF TWO-YEAR-OLD FISH COLLECTED IN 1941 TO 1949

Year Collected	Year Class	Number	Length at Each Annulus (Standard deviation in parenthesis)	
			1	2
1941.....	1939	69	64(15)	129(22)
1947.....	1945	79	46(6)	118(10)
1948.....	1946	272	40(7)	99(10)
1949.....	1947	68	39(7)	83(10)

during the third year has decreased the most from 1948 to 1949. These decreases in lengths are progressively greater from the first annulus to the third annulus at the periods mentioned above. It appears that first the young perch may have been affected by conditions for slow growth, and later the older perch, but the older the fish the more severely was the growth retarded.

If one follows a single year class collected in different years, the lengths at the same annulus are found to decrease with age (Table 3). This may indicate that faster growing fish die at an earlier age or that the sampling methods are selecting the larger sized perch of the younger age classes.

TABLE 5
AVERAGE GROWTH IN MILLIMETERS OF AGE CLASS II YELLOW PERCH IN CLEAR LAKE, BY TWO-WEEK PERIODS, 1948

Dates	Number of Fish	Growth From Last Annulus	Increment
June 12-25.....	45	21.15	.....
June 26-July 9.....	44	23.81	2.66
July 10-23.....	118	27.50	3.69
July 24-Aug. 6.....	38	28.21	.71
Aug. 7-20.....	26	30.96	2.75

The 1948 sample of perch was large enough so that seasonal growth beyond the second annulus could be analyzed by two-week periods from June 12 to August 20 (Table 5). Approximately two-thirds of the growth from the time of annulus formation to August 20 was completed by June 12.

Periodic samples of young-of-the-year perch were taken during the summers of 1947, 1948, and 1949 and the summer and fall of 1943 (Table 6). The growth of the perch through the first summer was quite similar for each year and the data were therefore combined.

The growth rate of the yellow perch in Clear Lake is fairly slow when compared to that in other lakes in the Midwest. The average calculated standard length at the end of the third year in Clear Lake was 125 millimeters, which may be compared with similar data for other lakes as follows:

Silver Lake, Wisconsin (Schneberger, 1935)	101 mm.
Weber Lake, Wisconsin (Schneberger, 1935)	138 mm.
East Lake, Iowa (Lewis, 1950)	150 mm.
Nebish Lake, Wisconsin (Schneberger, 1935)	154 mm.
Lake of the Woods, Minnesota (Carlander, 1950)	162 mm.
Red Haw Lake, Iowa (Lewis, 1950)	216 mm.

FOOD HABITS

An analysis was made of 283 perch stomachs taken from Clear Lake in 1949. All stomachs were inspected fresh except for the young-of-the-year which were preserved in formalin. No intestines were inspected. The analyses, not meant to be comprehensive, give a general idea of the perch food habits.

Table 7 shows the frequency of food items as they occurred in each age group. Perch a year or older were not studied for microscopic organisms since the smaller food items were not present in large enough numbers to be significant in the analysis.

The stomach analysis included no volume measurement although the size of a food organism and its frequency are an indication of

TABLE 6
GROWTH OF YOUNG-OF-THE-YEAR YELLOW PERCH, CLEAR LAKE, 1943-1949

Period	Number	Standard Length in mm.	
		Mean	Range
June 17-July 1	69	25.3	20-35
July 2-16	171	39.4	30-50
July 17-Aug. 1	307	44.8	35-58
Aug. 2-16	268	51.0	40-63
Aug. 17-Sept. 1	127	52.4	44-63
Sept. 15-29	10	55.5	50-65
Oct. 29	48	66.1	53-78

volume. The perch stomachs that were considered full or nearly so and were dominated by one type of food were found to occur with the caddis-fly larvae 36 times, midge larvae 7, midge pupae once, *Chara* once, and fish 23 times. Caddis-fly and midge larvae were the most important food during the period of study, June to August. Vegetative material occurred frequently but never in any quantity. *Chara* and

Hyalella were found in the stomachs only in June, for which no reason can be given.

In Lake Mendota, Pearse and Achtenberg (18) found that small crustacea (Entomostraca) constituted an important part of the young perch food during the summer, although insect larvae predominated as they grew older. The 1949 young perch fed mostly on insect larvae as early as July 8, and Entomostraca, although always present, con-

TABLE 7
PERCENTAGE OCCURRENCE OF FOOD FOR EACH AGE CLASS OF THE
CLEAR LAKE YELLOW PERCH, 1949*

	Age † Class 0	Age ‡ Class I	Age § Class II	Age || Class III
Number of stomachs examined.....	33	150	65	35
Number of stomachs containing food.....	30	101	56	28
Fish				
Fish eggs.....				7.1
Fish remains				
Bluegill.....		2.0		
Yellow bass.....		1.0		
Spottail shiner.....			1.8	
Unidentified.....	3.3	7.0	14.3	21.4
Insect larvae				
Midge.....	76.6	55.4	26.8	39.3
Crane fly.....				3.6
Midge (pupae).....	16.6		12.5	13.6
Damsel fly.....		1.0	1.8	
Dragonfly.....	16.6	5.0	1.8	10.7
Mayfly.....	33.3	23.8	12.5	25.0
Caddis fly.....	33.3	74.3	55.4	46.4
Adult insects.....				
<i>Buena</i> sp. (Hemiptera).....	6.6		1.8	
Crustaceae				
<i>Hyalella</i> sp.....		2.0	1.8	
Crayfish.....		1.0		
Bryozoa				
Statoblast.....			1.8	
Mollusca				
<i>Linna</i> sp.....		1.0	1.8	3.6
Plants				
Vegetative material.....	10.0	13.9	5.6	21.4
Plant seeds.....		3.0		3.6
<i>Chara</i> sp.....		4.0	5.6	17.9

* Figures given as the percentages of stomachs containing food which contained each item.

† 14 collected in July, 19 in August.

‡ 9 collected in June, 16 in July, 125 in August.

§ 24 collected in June, 16 in July, 25 in August.

|| 23 collected in June, 8 in July, 4 in August.

tributed little to the food volume. Other food of the young perch was similar to that of the older fish except that midge larvae appeared more frequently than caddis-fly larvae and *Chara* did not occur.

The older perch were found to have Entomostraca present in their stomachs in important numbers during the summer in Lake Mendota [Pearse and Achtenberg, (18)], in other Wisconsin lakes [Couey, (7)], and in Costello Lake, Ontario [Langford and Martin, (15)]. No Clear Lake perch over a year old fed on Entomostraca in significant numbers. Examination of Clear Lake plankton indicated a scarcity of Entomostraca.

The stomach analysis indicates that the amount of fish taken by the perch in Clear Lake increases with age. It appears however that fish were not taken under normal conditions by the Clear Lake perch. Many of the fish found in the perch stomachs apparently were dead minnows discarded from minnow boxes or from fishermen's hooks. Perch containing these fish were usually taken at a public dock where minnow boxes and fishermen were present, and some of the minnows in the perch stomachs carried hook marks. All identified species of food fish were taken from perch captured by seine. It was noted during the summer that many of the larger fish fed on young fish as they were concentrated by the seining process and that even young white bass fed on young bluegills. Such observations indicate that the perch take the young fish in the seine, especially since in these cases the fish in the stomachs were fresh and easily identifiable. It appears that the 1949 Clear Lake perch did not usually feed on fish.

DISEASES AND PARASITES

It was found that the 245 perch inspected from Clear Lake in 1949 were comparatively free of disease and parasites. The inspection included all external surfaces, the mouth, gills, stomach, intestines, liver, kidneys, ovaries, and mesenteries.

No diseases or parasites were found on 118 perch. Black grubs (Strigeid larvae) occurred in 125 specimens but the infections were light in every case. What appeared to be fin rot occurred at the base of the soft dorsal fin on five specimens but none of the fish seemed seriously affected. A "fish louse," *Argulus versicolor*, was found on one perch. Other fish may have been parasitized since observation of young-of-the-year perch indicated the occasional presence of black grub and leeches.

None of the perch observed were malformed. Slight injuries were found on three perch, one perch had an eye missing, and a pectoral and ventral fin were missing from two perch.

It has been reported that the growth rate of perch can be decreased by parasitism [Cross, (8)]. Internal parasites tended to be more responsible for the influence on growth while the black grub usually had no apparent effect. From the 1949 data, it would appear that

diseases, parasites or injury have no major effect on the growth or activities of the Clear Lake perch.

ABUNDANCE OF YELLOW PERCH

It was difficult to obtain perch older than young-of-the-year in Clear Lake during 1949. The gill net catches in 1947, 1948, and 1949 indicate a marked decrease in numbers in Clear Lake perch (Table 8). Although it is recognized that the catch per hour in gill nets may be subject to many errors as a method of estimating abundance, the decrease in catch was so great as to demonstrate a decrease in the abundance of the perch. The 1949 Clear Lake average catch of perch per hour is considerably lower than those from Lake of the Woods and Lake Mille Lacs, Minnesota.

A creel census was taken at Clear Lake by the Iowa State Conservation Commission from May 15 to July 1 in 1948 and 1949. The following data concerning the perch were obtained:

	1948	1949
Total number of perch caught	3,541	250
Total number of angling hours	30,463	17,523
Average number of perch per hour	0.116	0.014

Undoubtedly many perch were returned to the water by the fishermen because of their small size, but the decrease in abundance, as suggested by the creel census, is still of significance.

DISCUSSION

This study indicates that the Clear Lake perch are short lived and have decreased in growth rate, plumpness, and abundance from 1941 to 1949. It is believed that the environmental conditions are not now suitable for a desirable perch population in Clear Lake. Lewis (16) found that the perch were similarly short lived in Red Haw and East Lakes which are small, thermally stratified reservoirs in southern Iowa. His opinion was that a lake may provide for excellent habitat for small perch but have a very poor or unsuitable environment for the large ones. He further explained that in Red Haw and East Lake the deeper cooler waters normally inhabited by larger perch had an extremely low dissolved oxygen content although the shallow water frequented by the smaller perch had adequate dissolved oxygen.

Since Clear Lake is a comparatively large shallow lake with no thermal stratification and apparently has high dissolved oxygen content at all depths during the summer, oxygen supply does not seem to be a factor limiting the environment of the older and larger perch. It is possible that temperature conditions may not be suitable for larger perch since the maximum temperatures during the summer months at Clear Lake are high and fairly uniform at all depths. Since the range of the perch is confined mostly to southern Canada and north and northeastern United States, it appears that the cooler waters are

more favorable for the perch. If this is the case, the shallower lakes with high summer temperatures may not be favorable for large perch.

The decrease shown in growth rate, plumpness, and abundance is probably associated with a change of environmental conditions in the lake. Although not all changes in Clear Lake could be observed in the past few years, the decrease in abundance of submerged vegetation appears to be the most important. Perch are known to live in, and to feed on organisms living in, weed beds.

The reason for the pronounced decrease in vegetation in Clear Lake is not known, although it is possible that carp may have been

TABLE 8
COMPARISON OF THE AVERAGE NUMBER OF YELLOW PERCH TAKEN PER HOUR IN 625
SQUARE FEET OF EXPERIMENTAL GILL NET

Location	Hours	Number of Perch	Average Number of Perch per Hour
Lake of the Woods..... (Carlander, 1942)			0.4733
Lake Mille Lacs..... (Carlander, 1944)	2,412	1,189	0.4931
Clear Lake, 1947.....	272	346	1.2950
Clear Lake, 1948.....	1,084.5	337	0.3107
Clear Lake, 1949.....	1,497	50	0.0340

responsible. There are no comparative figures to indicate an increase in numbers of carp in Clear Lake during the decrease of vegetation, but the Iowa Conservation Commission rough fish removal crew stated in 1949 that the carp were present in large numbers in Clear Lake especially in the last few years.

SUMMARY

1. The water in Clear Lake is warm, non-stratified, turbid, and apparently well mixed during the summer months. The submerged vegetation in Clear Lake has decreased considerably in abundance since 1946.

2. The life history of the yellow perch was based upon 753 perch collected in 1941, 1947, 1948, and 1949 with experimental gill nets, 50-foot seines, a 500-foot seine, and angling equipment.

3. Gill nets proved inadequate in capturing the smaller perch although many yearlings were taken by angling.

4. The length conversion factors for the Clear Lake perch are: total length equals 1.210 standard lengths and 1.053 fork lengths; fork length equals 1.150 standard lengths.

5. Of the 738 perch aged in the study, 21.0 per cent were one year old, 66.3 per cent were two years old, 12.6 per cent were three years old, and 0.03 per cent four years old. Compared to perch in other lakes, the Clear Lake perch are relatively short lived.

6. The Clear Lake perch showed a general decrease in growth rate from 1941 to 1949. The young perch appear to have been affected by conditions for slow growth first and eventually the older perch, but the older the fish, the more severely was the growth retarded.

7. No statistical difference was found between the growth rates of the male and female perch in Clear Lake.

8. Comparative growth rates of the perch from various lakes indicated that the Clear Lake perch were relatively slow growing.

9. The mathematical relationship between standard length in millimeters and weight in grams of the Clear Lake perch is best described by the formula:

$$\text{Log } W = -5.6902 + 3.483 \text{ Log } L$$

10. The average K for the 1947 perch was 2.37, and for 1949, 1.86. The value of K increased with increase in age and in length.

11. Caddis-fly and midge larvae appeared to be the most common food items taken by the Clear Lake perch. The feeding habits of all ages of the Clear Lake perch were quite similar, and Entomostraca, usually a common perch food, were found in insignificant numbers.

12. Except for light infestations of black grub, the Clear Lake perch were practically free of those diseases and parasites which could be detected by gross examination.

13. Gill net and creel census catches indicate a decrease of abundance of perch in Clear Lake since 1947.

14. It is postulated that the decrease in growth rate, condition factor, and abundance is correlated with a decrease in aquatic vegetation.

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SURVEY OF LITERATURE ON INSECT LIPIDS¹

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Lipids, sometimes referred to as lipides, lipins, or lipoids, play an important role in animal metabolism. In a broad sense the term includes true fats, waxes, cerebrosides, sterols, and phospholipids such as lecithin and cephalin. Closely related to these compounds are others having a common solubility, such as higher hydrocarbons present in waxes, some pigments, and the fat-soluble vitamins A, D, E, and K.

With the exception of true fats, known functions of the different fractions in insects are vague. Fats serve as important energy reserves during periods of embryological development, metamorphosis, and food scarcity. Fat represents the storage of more combustible material gram for gram than does either carbohydrate or protein. Dietary and stored fats are sources of metabolic water which is of prime importance to species living in an environment containing only small amounts of moisture. A gram of fat, when completely metabolized, yields more than twice the amount of water produced by metabolism of a gram of non-fatty foodstuff.

The importance of phospholipids, sterols, and lipids in their entirety has become evident from experimental work with forms of animal life other than insect. The cytoplasm, Golgi apparatus, mitochondria, and limiting membrane of animal cells apparently contain lipids. Relatively large amounts of phospholipid and cholesterol are present in nuclei. Chromosomes of some dividing cells are completely dissolved by fat solvents. Active muscles seem to contain more phospholipid than inactive ones; and the phospholipid molecule serves as a transport vehicle for fatty acids [Heilbrunn (38)].

LIPID REQUIREMENTS OF INSECTS

The amount of lipids contained in the diets of insects differs considerably because of varied food habits. As noted below, a few insects have been reared in the laboratory on a fat-free diet or on one containing only traces of fat. Entomological literature includes numerous references indicating that some insects require fat or an ether-soluble factor for normal growth and reproduction. A number of these references offer experimental evidence that a factor present in the unsaponifi-

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able portion of the ether-soluble fraction is required and, in most cases, this growth factor has been identified as a sterol.

Cook and Scott (15) reported that fat was not an essential constituent of the diet of *Zootermopsis angusticollis*. Termites on a regimen not containing fat exhibited a slightly greater increase in weight than when fat was included. Fat-soluble vitamins A and D were required, and were supplied in the unsaponified portion of cod-liver oil. High concentrations of cod-liver oil were harmful, and the authors postulated that this might be due to the toxic action of large amounts of cholesterol present in the unsaponified fraction or to the occlusion of the tracheae by the oil.

Nutritional requirements of the mosquito, *Theobaldia incidens*, have been investigated by Frost *et al.* (27). They concluded that if fats were required at all, the amounts were very small. A factor present in the non-lipid fraction of dried brewer's yeast was required. Addition of butter, vitamin D concentrate, carotene solution, or olive oil was non-beneficial.

Parkin (65) stated that *Lyctus* powder-post beetles developed normally on a diet of ether-extracted oak sapwood.

Smith (78) reared *Camponotus* ants on a medium containing casein, sucrose, fat, linoleic acid, cholesterol, salt mixture, and brewer's yeast. Omission of fat from the diet of nurse ants did not appreciably affect development of the young. Smith was aware that small amounts of lipid may have remained in the yeast after washing with ethyl ether.

According to Martin and Hare (55), fats were not required by larvae of the mealworm, *Tenebrio molitor*; actually, growth was inhibited when fats were present in the diet in excess of three per cent.

Bacot and Harden (4), reporting on vitamin requirements of *Drosophila*, indicated that either a fat or fat-soluble factor, or both, were required for development.

Richardson (69) reared the Mediterranean flour moth, *Ephestia kuehniella*, on wheat flour extracted with various fat solvents. Extraction removed a growth-promoting substance which was not completely restored by return of the extract to the extracted flour. The growth factor could be replaced by an ether extract of egg yolk but not by the ether or alcohol-soluble fraction of butter. Richardson believed that the failure of *Ephestia* larvae to grow in extracted media was due to removal of vitamin A.

Sweetman and Palmer (83) stated that the flour beetle, *Tribolium confusum*, did not require a fat-soluble factor for growth and reproduction of one generation. However, the rate of development was accelerated by addition of a fat. This insect did not require vitamin A.

The nutrition of flesh fly larvae, *Lucilia sericata*, has been investigated by Michelbacher *et al.* (60). Rapid growth was obtained on a medium of casein, yeast, mineral salts, cystine, butter, and cod-liver oil.

Moskalenko (61) reported that cockroaches did not grow on a vitamin-free diet. Since a combination of supplements was necessary,

he concluded that vitamins A and B were required. Ether extract of wheat germ was the most potent source of the fat-soluble factor. MacCay (53) stated that the German roach, *Blattella germanica*, required growth factors present in yeast. Both fat-soluble and water-soluble factors were essential. There was no specific indication that the fat-soluble requirements included vitamins A and D.

From results of chemical analyses of sugar beet webworm, *Loxostege sticticalis*, Pepper and Hastings (67) believed that linoleic acid was a dietary essential for normal development and reproduction. Sterile females did not contain fatty acids having unsaturation greater than one double bond.

Fraenkel and Blewett (23) stated that the moth, *Ephestia elutella*, requires a fat-soluble factor, contained in wheat germ oil, identical with linoleic acid.

The sterol requirements of insects have been the subject of a number of investigations. Tatum (84) noted that *Drosophila* required three yeast factors in addition to its needs for carbohydrates, amino acids, vitamins, and cholesterol.

Van't Hoog (93) cultured *Drosophila melanogaster* aseptically on agar slants. Fat as such was not required, but a factor present in the unsaponifiable portion of various oils was needed. There were no requirements for vitamins A, D, E, and F. In a later work (94) he identified the factor present in the unsaponified fraction of fat as a sterol. Cholesterol, ergosterol, sitosterol, stigmasterol, phytosterol, dihydrocholesterol, and cholestenone were active at dosages of approximately 100–200 gamma per 5 ml. of medium. Calciferol, bile acids, theelin, certain carcinogenic compounds, cholesteryl-anilins, phenyl-cholesterol, chlor-cholestane, and epi-dihydrocholesterol appeared to be inactive even at higher dosages.

Hobson (40, 41) reported that larvae of the blowfly, *Lucilia sericata*, require a growth factor found in muscle oil, wool wax, wheat germ oil, egg yolk, cod-liver oil, and butter. Because the growth-promoting effect of these substances could be correlated with their cholesterol or sitosterol content, he concluded that the fat-soluble factor was a sterol. Ergosterol, lanosterol, and sitosterol were found to be less active than cholesterol. The larvae did not require fatty acids or fat-soluble vitamins.

Gay (32) reared *Dermestes vulpinus (maculatus)* larvae on a diet of vitamin-free casein, debittered dried yeast, cholesterol, cystine, and MacCollum's salt mixture. When cholesterol was omitted, the larvae did not develop beyond the third instar. Fraenkel *et al.* (24) found that cholesterol, dehydrocholesterol, cholesteryl acetate, and 7-dehydrocholesteryl monobenzoate, at dosages of 1 mg. or less per 3 g. of food, satisfied sterol requirements of *D. vulpinus*. Sitosterol, ergosterol, zymosterol, cholestanol, cholestene, 7-keto-cholesteryl acetate, 7-hydroxycholesterol 7-hydro-cholesteryl dibenzoate, and calciferol were inactive. Fuentes (28) noted that 0.1 per cent cholesterol partially restored for *D. vulpinus* the growth factor removed from sardine fish meal by ether and chloroform extractions.

Nutritional tests with the confused flour beetle and the bean weevil were conducted by Chiu and MacCay (13). The requirements of the former, *Tribolium confusum*, were satisfied by a diet of casein, corn starch, yeast, cottonseed oil, and Osborn-Mendel salt mixture. Fat-soluble vitamins A and D and the ether-soluble fraction of yeast did not appear to be diet essential. Results from the addition of cholesterol to a medium containing ether-extracted yeast indicated that this sterol did not seem to be an essential growth factor. To the contrary, the bean weevil, *Acanthoscelides obtectus*, required a growth factor present in the ether extract of the kidney bean. This factor could be replaced by the addition of cholesterol.

Fröbrich (26) found that *Tribolium confusum* required two factors present in the water-insoluble fraction of yeast. One was identified as a sterol; the other was termed "Factor U." Maximum growth was obtained on a diet including 100 gamma of ergosterol per 1.5 g. of medium. The same ergosterol requirement existed for the saw-toothed grain beetle, *Oryzaephilus surinamensis*. Offhaus (64) termed the two factors "a vital necessity U_1 and a growth accelerator U_2 ." Factor U_1 was identified as ergosterol, and factor U_2 was fully replaced by histidine.

Fraenkel and Blewett (22) reported that some common stored grain pests, including *Sitotrepa*, *Ptinus*, *Ephestia*, *Tribolium*, *Lasioderma*, and *Silvanus*, required a sterol in the diet. The first three of these species had greater quantitative requirements.

According to Souza and Sreenivasaya (79), a fat-soluble factor was required for growth and pupation of *Corcyra cephalonica*. Cholesterol, sitosterol, phytosterol, and ergosterol satisfied the demands. Calciferol did not support growth, and even appeared to exert a toxic effect.

SYNTHESIS OF FAT FROM CARBOHYDRATES

Conversion of carbohydrates to fat in insects has been reported by several investigators. Johansson (46) determined a respiratory quotient greater than 1.0 for *Tenebrio molitor* larvae on a carbohydrate-rich diet. This was interpreted as indicating synthesis of fat.

Timon-David (88) reasoned that large amounts of fat in xylophagous larvae originated from a synthesis at the expense of pentoses present in wood.

Fulton and Chamberlin (29) investigated changes in fat composition of the beet leafhopper, *Eutettix tenellus*, after feeding on distilled water plus 1.5 per cent glucose and 1.5 per cent fructose. Fat content of overwintered females reached a maximum at about 144 hours after feeding, spring brood females at 120 hours, and newly emerged males at 96 hours. They concluded that this leafhopper was able to synthesize glycerides from a carbohydrate diet. The ability did not continue indefinitely, and the pure sugar diet was insufficient to sustain life for a period equal to the normal span.

Fatty acids of larval fat of the beetle *Pachymerus dactris* were investigated by Collin (14). Larvae were found feeding on fat-rich endo-

sperm of nuts of *Manicaria saccifera*. Fatty acids with a lower molecular weight than oleic acid were present in larval fat in about one-half the amount found in the kernel-fat. Oleic and linoleic acids constituted about 11 per cent of kernel-fat and about 40 per cent of acids in larval fat. This suggested that *Pachymerus* built up its fat reserve partly from assimilation of vegetable fat and partly by syntheses from carbohydrate or other non-fatty components of the *Manicaria* kernel.

The metabolism of the corn-ear worm, *Heliothis armigera*, has been thoroughly studied by Ditman (17). The small amount of fat present in milk-stage corn, as compared to the more saturated fat of the ear worm, suggested a synthesis of fat from carbohydrate. Ditman and Weiland (18) noted a rapid decrease in glycogen content of *Heliothis* in the prepupal period was correlated with a simultaneous increase in fat content. This indicated a synthesis of fat from glycogen.

Schweet (74) concluded that the roach, *Periplaneta americana*, could synthesize fat from carbohydrate.

SYNTHESIS OF FAT FROM PROTEINS

Synthesis of fat by insects reared on a protein-rich diet has been demonstrated in several instances. In each of three experiments, Hofmann (42) determined that fat content of mature *Muscida vomitoria* larvae reared on defibrinated blood exceeded that of the medium plus the seeded eggs. He concluded that these flies could synthesize fat from protein. Weinland (96) reported that larvae of the fly, *Calliphora*, could form body fat from diet proteins.

Bogdanow (9) was unable to confirm the results of Hofmann and Weinland. In each of two experiments, the higher fatty acid content of flesh-fly larvae plus the food residue was considerably less than that of the original medium.

Nishikata (63) concluded that the flesh-fly, *Sarcophaga carnaria*, was able to synthesize fat from protein since the fat content of larvae plus the food residue was slightly greater than that of the original medium of horse meat powder or blood fibrin powder. The investigation did not indicate if the fat was formed directly from amino acids or through the intermediate of carbohydrates.

Abderhalden (1) reared the dermestid, *Anthrenus museorum*, on a diet of silk thread (silk fibroin plus silk glue). He concluded that this insect must be able to form fat and carbohydrate from protein.

According to Sinoda and Kurata (75), the very low iodine number of the ether extract of *Dermestes*, as compared to that of the food, seemed to support the hypothesis that the body fat is partially synthesized from protein.

Melampy and Maynard (57) stated that the German roach *Blattella germanica*, was able to convert diet protein into body lipid. Schweet (74) concluded that the American cockroach, *Periplaneta americana*, was able to synthesize fat from protein, although to a lesser degree than synthesis from carbohydrates.

SYNTHESIS OF FAT FROM NON-FATTY SUBSTANCES

In a few cases, the diet source from which insect lipids were derived has not been specified. Loeb (52) reared *Drosophila* in a medium of cane or grape sugar solution, inorganic salts, a small quantity of macerated filter paper to keep the flies from drowning, and a nitrogen source. The complicated nitrogen compounds of the body were evidently formed from the alanine, glutamic acid, ammonium tartrate, or ammonium succinate added to the solution. Body lipids were presumably synthesized from the sugars or the nitrogenous compounds.

Collin (14) concluded that larvae of the beetle *Pachymerus dactris* could synthesize fat from carbohydrates or other non-fatty substances contained in the kernel of *Manicaria*.

Parkin (65) reared *Lyctus* powder-post beetle larvae on a diet of ether-extracted oak sapwood. The larvae evidently formed body fat from carbohydrates or proteins present in the wood.

MacCay (53) reared *Blattella germanica* on a diet of dried skim milk and ground whole wheat containing 0.86 per cent ether extractives (dry basis). This insect was able to synthesize fat inasmuch as the adults, reared on a weighed amount of food, contained about three times as much lipid as the ingested foodstuff.

LIPID CONTENT OF INSECTS

Entomological literature contains many references pertaining to the lipid content of insects. In many instances the method of preparation of the insect sample and the method of analysis are not clearly set forth. It is often impossible to determine if an effort was made to decrease gut contents of the insect before analysis. By far the most common method of analysis is extraction of a large number of insects with ether, and determination of the weight of the residue after evaporation of the solvent. The results are most often expressed as "per cent fat" or "per cent ether extract" and do not always specify if the analyses are on a dry weight basis or a wet weight basis.³

Factors which influence the character of stored fat in insects have been discussed by Timon-David (90), Ditman (17), and Schweet (74). An enumeration of such factors includes the following: development, nutrition, environmental temperature, sex, systematic position, starvation, hibernation, and cold hardiness. In general, total lipid content of insects increases during development of the immature form. This is followed by a decrease during pupation of holometabolic insects. Timon-David (90) reported an exception to this for *Leptinotarsa decemlineata*. The fat content in this species increased from three per cent of the live weight in larvae to 13.4 per cent in adults.

The body fats of an insect are affected both quantitatively and qualitatively by the diet fat. A more complete discussion of this factor is included later under a separate heading.

³For purposes of interpretation of data, water contents, where available in the citation, are included in the following summaries.

Insects of tropical regions appear to form body fats with higher iodine values than fats deposited by species of temperate regions. Timon-David (90) cited the example of a curculionid, *Rhynchophorus palmarum*.

Females usually contain a higher percentage of ether extractives than males of the same species. This is correlated with a storage of food reserves for egg production. In some cases, there is only a slight difference between the two sexes, and in the silkworm, *Bombyx mori*, the male contains a higher percentage of fat than the female [Timon-David (90)].

Insects of the same genus and family often have similar food habits; consequently, species with close systematic relationships have stored fats of a similar nature. As an example, aphids possess a body fat characterized by a low iodine value [Timon-David (90)].

Starvation affects the lipid content of insects because fat reserves are among the first class of reserve foodstuffs to be consumed during periods of want. This experience is closely related to that of hibernation in that the end result is the same. If the insect survives either starvation or hibernation, it emerges with depleted fat reserves.

Cold hardiness, as a factor influencing the character of stored fats, is mentioned in a citation of the work of Sacharov (72) and Kozhantshikov (51). Fat content and characters may possibly influence the cold hardiness of insects.

The factor of migration should probably be added to the above list. In species possessing both solitary and gregarious phases, the gregarious form seems to contain greater fat reserves [Matthée (56)]. In migrating Lepidoptera the stored fat is consumed but may be replenished after normal food habits are resumed [Beall (5)].

It is possible to make a few general statements concerning insect fats. Major components of the fatty acid fraction appear to be oleic, linoleic, palmitic, and stearic acids. Stearic acid predominates over palmitic in most instances. Linolenic, arachidic, and other higher fatty acids have been isolated from insect lipids. Acids of lower molecular weight have been identified in insect waxes by Gadamer (31) and Schulz (73), and in the extract of *Pemphigus* (Aphididae) by Timon-David (89). A review of available literature does not give sufficient information to warrant generalizations as to the phospholipid and sterol fractions of the total lipid.

Specific information regarding lipid content has been arranged in the following sections devoted to various orders of insects.

ORTHOPTERA

Nutritional studies with the German roach, *Blattella germanica* (Blattidae), were conducted by Melampy and Maynard (57). Lipid content of nymphs was 5.72 per cent; females with egg capsules, 4.78 per cent; and males, 1.70 per cent. The iodine number was 69 for nymphs and 74 for males and females. MacCay (53) also investigated nutritional

requirements of the German cockroach. When fed a diet of dried skim milk and whole ground wheat, adults contained 15.6 to 17.1 per cent ether solubles (dry basis) with an iodine number of 55 to 57. The water content was 64.3 to 66.3 per cent. Insects were fasted for 24 hours prior to analysis to decrease gut contents.

Timon-David (90) reported that adults of the cockroach, *Periplaneta orientalis* (Blattidae), contained 4.3 per cent ether extractives (wet basis). Schweet (74) reared the roach *P. americana* on a stock diet of banana, whole wheat bread, and white bread moistened with distilled water. Adult females contained 28.63 per cent lipid; adult males, 25.55 per cent (dry weight basis). Average water content was 63.33 per cent for females, and 67.81 per cent for males.

An examination of cold resistance of certain insects was conducted by Sacharov (72). Fat content (wet basis) of eggs of the grasshopper *Locusta migratoria* (Acridiidae) was 2.43 per cent, and of three- to five-day nymphs, 2.75 per cent. Water content of the two stages was 66.46 per cent and 86.20 per cent, respectively. Fat was determined by extraction with trichloroethylene and evaporation to constant weight at 100°C. Matthée (56) investigated some of the biochemical differences between the solitary and gregarious phases of two species of locusts. The fat content of *Locusta migratoria solitaria* (fifth instar) was 2.83 per cent on a wet basis, or 11.11 per cent on a dry basis. This content increased to 3.56 per cent (wet basis) or 14.02 per cent (dry basis) in *L. migratoria gregaria*. The fat content of *L. pardalina solitaria* (fifth instar) increased from 2.87 per cent (wet basis) or 12.79 per cent (dry basis) to 3.66 per cent (wet basis) or 14.63 per cent (dry basis) in the migratory phase. Fat was determined by extraction with ethyl ether and evaporation to a constant weight.

The nature of the fat in the grasshopper, *Melanoplus atlantis* (Acridiidae), was reported by Giral *et al.* (35). Extraction of 2.2 kg. of dry material gave 18.0 g. (about 0.8 per cent) neutral fat and 53.0 g. (about 2.4 per cent) free fatty acids. Free acids consisted of stearic acid, 9.1 per cent; palmitic, 6.7 per cent; arachidic, 2.1 per cent; unsaturated C₁₈ acid, 4.4 per cent; unsaturated C₁₈, 31.5 per cent; unsaturated C₂₀, 40.5 per cent; and unsaturated C₂₂, 5.7 per cent. Linolenic acid was not present but triethenoid acids of the C₂₀₋₂₂ series appeared to be present.

Slifer (76) extracted fatty acids from eggs of another grasshopper, *M. differentialis* (Acridiidae). Newly deposited eggs contained higher fatty acids in the amount of 9 to 12 per cent of the fresh weight. At hatching, approximately 46 per cent of the fatty acids remained. The iodine value remained fairly constant during the developmental period (131.5 for eggs one day old). Pfeiffer (68) investigated the effects of removal of the *corpora allata* on the fat and water content of *M. differentialis*. Females allatectomized shortly after emergence contained 24 per cent fat (wet basis) and 51 per cent water on the eighty-seventh

day of adult life, as compared to 3.5 per cent fat (wet basis) and 68 per cent water in normal females of the same age.

Timon-David (90) reported that *Orthacanthacris aegyptia* (Acridiidae) contained 2.5 per cent fat (wet basis).

Tsujimoto (92) conducted a fat analysis of *Oxya japonica* (Acridiidae). This species contained 3 per cent fat (dry basis) characterized by a saponification number of 171.5, an iodine value of 122.6, and 15.75 per cent unsaponifiable matter. Sterols constituted 44.1 per cent of the latter according to the digitonin method. Palmitic, stearic, oleic, linoleic, and linolenic acids were identified.

Components of body fat of *Taeniopoda auricornis* (Acridiidae) were reported by Giral *et al.* (34). Fatty acids of females were segregated as 35.0 per cent saturated acids, 6.5 per cent oleic acid, and 58.5 per cent linoleic acid. Fatty acids of males consisted of 15.5 per cent saturated acids, 24.0 per cent oleic acid, and 60.5 per cent linoleic acid. The lipid of the female contained 5.1 per cent unsaponifiable matter; that of the male, 6.5 per cent.

According to Giral (33), 2.52 per cent of fresh weight of adult *Sphenarium purpurascens* (Acridiidae) was extracted by petroleum ether. The extract was characterized by a saponification value of 170; an iodine value of 93.8; and 10.9 per cent unsaponifiable matter. A triethenoid acid was present but was probably not linolenic.

Stoneburg (80) analyzed lipids present in fresh muscle from the grasshopper *Brachystola magna* (Acridiidae). Thoracic muscle contained 1.025 per cent phospholipid; thigh muscle, 1.24 per cent. Cholesterol constituted 0.045 per cent of the fresh weight.

Ether extract of *Acheta mitrata* (Gryllidae) was characterized by Tsujimoto (92). Body lipid, constituting 2.4 per cent of fresh weight, exhibited a saponification number of 181.5, and an iodine value of 116.0. Unsaponifiable matter made up 11.32 per cent of the extract, and contained 45.45 per cent sterols.

Timon-David (90) gave the fat content of adult *Gryllotalpa vulgaris* (Gryllidae) as 7.0 per cent (wet basis).

ODONATA

The fat of a dragon-fly, *Aeschna* sp. (Aeschnidae), constituted 2.4 per cent of the live weight, and had an iodine value of 103 [Timon-David (90)].

HEMIPTERA

The ether-soluble extract of the chinchbug, *Blissus leucopterus* (Lygaeidae), was determined by Schweet (74). The lipid content was 36.27 per cent (dry basis) in July. By February of the following year, after four months of hibernation, the figure was 27.19 per cent; in April, when the chinchbugs were becoming active, the content had decreased to 10.25 per cent.

Maciuca (54) analyzed specimens of *Pyrrhocoris apterus* (Pyrrhocoridae) throughout the year. The fat content reached a maximum of 32.7 per cent (dry basis) in November, declined during the winter months, and decreased to a minimum of 18.11 per cent in April.

HOMOPTERA

Fulton and Chamberlin (29) determined fat content of the leafhopper, *Eutettix tenellus* (Cicadellidae), at intervals after adults had been exposed continuously to 1.5 per cent glucose or 1.5 per cent fructose solution. Fat content of overwintered females increased from 34.2 per cent (dry basis) to a maximum of 42.2 per cent at 144 hours after feeding, and then declined to approximately 35 per cent at 336 hours. The fat content of young males ranged from 11.5 per cent (dry basis), at emergence; to 13.2 per cent at 96 hours after feeding; and to approximately 12 per cent after 240 hours. Evidently neither of the pure sugar diets was sufficient and the leafhoppers were unable to maintain themselves. Fulton and Romney (30) found a correlation between the chloroform-soluble fraction of beet leafhoppers and the distance they had dispersed in the spring. Along the first route of dispersal the percentage of total chloroform extractives decreased from 38.4 per cent (dry basis) in *Eutettix*, taken nearest to the breeding source, to 8.9 per cent in specimens collected 205 miles away. Along the second route, the chloroform extract decreased from 39.5 per cent to 6.6 per cent over a distance of 398 miles. The ether extractive content of female beet leafhoppers, after feeding on sugar beets or desert sage during the fall and winter seasons, was determined by Cook (16). The average female *Eutettix* weighed 1.00 to 1.40 mg. and contained 0.40 to 0.75 mg. dry matter. The average total ether extractives of females placed on sugar beets decreased from 0.290 mg. to 0.073 mg. at the end of 14 weeks. The ether extractives of females placed on desert sage decreased from an average of 0.284 mg. to 0.041 mg. at the end of 10 weeks. Overwintering females normally live for a month or longer during the winter on perennial shrubs such as desert sage before moving to a new host plant.

The fat content of several aphids (Aphididae) has been reported by Timon-David (89, 90). *Pemphigus utricularius* and *P. cornicularius* contained 19.5 per cent ether extractives (wet basis) characterized by a saponification number of 255 and iodine values of 1.2 to 7.5. The extract of *P. utricularius* contained 1.7 per cent unsaponifiable matter. Fat content of other aphids was as follows: *Aphis rumicis*, 7.5 per cent; *Hyalopterus pruni*, 6.2 per cent; and *Aphis rosae*, 6.0 per cent. The iodine values ranged from 16.2 for *A. rosae* to 22.0 for *H. pruni*.

LEPIDOPTERA

Different stages of the silkworm, *Bombyx mori* (Bombycidae), have been analyzed for fat by several workers. According to Tichomirowff (86), overwintering eggs of the silkworm contained 8.08 per cent

fat, 1.04 per cent lecithin, and 0.40 per cent cholesterin. Developing eggs contained 4.42 per cent fat, 1.76 per cent lecithin, and 0.35 per cent cholesterin. The above determinations are presumed to be on a fresh weight basis.

Fat content of spinning larvae and pupae of *B. mori* was determined by Kotake and Sera (49). The fat content of spinning larvae varied from 2.82 per cent to 3.80 per cent. Fat content decreased about 43 per cent after 13 days of pupation in one case, and about 33 per cent after 14 days of pupation in another case. The unsaturated fatty acids of *Bombyx chrysalis* oil were investigated by Kimura (47). The oil contained 71.3 per cent liquid fatty acids with an iodine value of 173. The acids consisted of 29.8 per cent oleic acid, 48.9 per cent linoleic acid, and 21.3 per cent linolenic acid. The above percentages were based on the bromide method. Calculated by the thiocyanogen method, Kimura (48) determined that the unsaturated acids were oleic acid, 29.2 per cent; linoleic acid, 35.9 per cent; and linolenic acid, 34.9 per cent. Suzuki and Yokoyama (82) reported that the pupal oil of *B. mori* consisted of glycerides of palmitic, oleic, isolinoleic, and linolenic acids. Crude glycerides comprised 83 per cent of the oil and triolein made up more than one-half of this amount. According to Bergmann (7), chrysalis oil fatty acids consisted of 20 per cent palmitic, 4 per cent stearic, 2 per cent palmitoleic, 35 per cent oleic, 12 per cent linoleic, 28 per cent linolenic, in addition to about 1 per cent saturated and 1 to 2 per cent of unsaturated acids containing more than eighteen carbon atoms. Un-saponifiable matter of the chrysalis oil amounted to about 1.5 to 1.6 per cent of the total, and contained 33 per cent sterols.

Various stages of *B. mori* and *Deilephila* (Sphingidae) were analyzed for fat by Heller (39). Larvae of *Bombyx* contained 3.20 per cent fat (wet basis); pupae, 5.95 per cent; and adults, 9.06 per cent. This increase in fat content was accompanied by a decrease in water content from 80.34 per cent in larvae to 71.77 per cent in adults. Mature larvae of *Deilephila* contained 3.5 per cent fat (wet basis); pupae, 3.83 per cent; and newly emerged adults, 6.1 per cent.

Thoms (85) stated that the moth *Myelobia smerintha* (Galleriidae) contained 22 per cent fat, with the fatty acids consisting of about one-third saturated acids and two-thirds unsaturated acids.

Moisture and fat contents of the tent caterpillar, *Malacosoma americana* (Lasiocampidae), were studied by Rudolfs (70, 71). Fat content of eggs decreased from 4.45 per cent (dry basis), at the time of deposition, to 0.56 per cent at the time of hatching. A trace of cholesterol was present in freshly laid eggs but was not identifiable after development began. Fat deposits increased throughout larval development and reached a maximum of 28.82 per cent shortly after pupation. Fat constituted 24.72 per cent of the adult dry weight. Moisture content increased rapidly during the first two larval instars; remained constant until larval maturity; and decreased during pupation. The maximum water content of 83 to 85 per cent was reached during the third to the fifth instar.

Sacharov (72) made fat determinations of several lepidopterous insects in a study of cold resistance. Hibernating caterpillars of the brown tail moth, *Euproctis chrysorrhoea* (Lymantriidae), contained 71.83 per cent water and 4.93 per cent fat (wet basis). After feeding for a few days, water content increased to 82.94 per cent and fat content decreased to 2.52 per cent. Larvae of *Euxoa segetum* (Noctuidae) contained 6.42 per cent fat (wet basis) in autumn; 5.24 per cent in spring; and 1.83 per cent in summer. Water content increased from 71.38 per cent in autumn to 84.69 per cent in summer. Hibernating adults of *Scoliopteryx libatrix* (Noctuidae) contained 48.65 per cent water and 18.18 per cent fat (wet basis). Cold hardiness was correlated with a high fat content.

Fat and carbohydrate metabolisms of adult lepidoptera were studied by Kozhantshikov (50). Newly emerged females of *Agrotis segetum* (Noctuidae), fed 49 per cent glucose solution, were able to increase their average fat content from 12.3 per cent (wet basis) to 13.5 per cent. Female moths of the European corn borer, *Pyrausta nubilalis* (Pyraustidae) were not able to maintain their average fat content of 14.5 per cent (wet basis) when fed 40 per cent glucose solution. Fat reserves were depleted through oviposition unless more concentrated sugar solutions were fed.

Kozhantshikov (51) analyzed several lepidopterous insects in an investigation of cold hardiness. Data concerning fat and water content are summarized in Table 1. Fat content exhibited no evident correlation with the cold hardiness in the species studied. The author postulated that an important role in cold hardiness in insects may be taken by unsaturated fatty acids.

Bachstetz and Aragon (3) chemically characterized the oil of *Acentrocneme hesperaris* (Hesperidae). The oil, which made up 10 per cent of the fresh weight of the larva, had a saponification number of 179.85 and an iodine value of 59.25. Unsaponifiable matter accounted

TABLE 1
WATER AND FAT CONTENT OF SEVERAL LEPIDOPTEROUS INSECTS
[FROM KOZHANTSHIKOV (51)]

Species	Family	Stage	Percentage Water	Percentage Fat*
<i>Acronycta rumicis</i>	Noctuidae	pupa	63	25.5
<i>Agrotis segetum</i>	Noctuidae	4 and 5 instar larvae	88	23.1
		prepupa	73	30.1
<i>Calocasia coryli</i> †	Noctuidae	pupa	63	29.5
<i>Daseochaeta alpium</i>	Noctuidae	pupa	58	12.5
<i>Loxostege sticticalis</i>	Pyralididae	3 and 4 instar larvae	85	29.7
		pupa	60	30.2
<i>Lymantria dispar</i>	Lymantriidae	eggs	62	6.0

* Dry basis.

† Probably *Calophasia*. *Calocasia* is not listed by Neave (62).

for 2 per cent of the total lipid. Fatty acid composition was: palmitic acid, 30.0 per cent; stearic acid, 3.6 per cent; oleic acid, 60.1 per cent; and linoleic acid, 4.3 per cent. Linolenic acid was not present.

Pepper and Hastings (67) characterized the fat of different stages of the sugar beet webworm, *Loxostege sticticalis* (Pyralididae). Data are summarized in Table 2.

Fat of diapausing larvae of the codling moth, *Carpocapsa pomonella* (Eucosmidae), was studied by Hastings and Pepper (36). The ether extract, amounting to 44.2 per cent of dry weight, had a saponification

TABLE 2
LIPID ANALYSIS OF VARIOUS STAGES OF *Loxostege sticticalis*
[FROM PEPPER AND HASTINGS (67)]

Stage	Percent- age Fat	Iodine Number of Fat	Percent- age Unsaponi- fiable Matter	Percent- age Satur- ated Acids	Percent- age Oleic Acid	Percent- age Linoleic Acid	Percent- age Linolenic Acid
1 instar.....		134.9					
2 instar.....		131.3					
3 instar.....		126.1					
4 instar.....		124.4					
5 instar.....	5.9	122.2	3.8	23.2	31.5	26.1	18.5
prepupa.....	7.5	119.4	3.5	24.0	38.3	13.3	23.4
pupa.....		112.8	2.8	24.1	41.4	13.2	20.1
female (fertile).....	9.5	69.8	3.1	34.1	54.5	0.8	10.3
female (partially fertile*).....			3.2	24.1	63.6	<1.0	9.9
female (sterile).....			2.3	24.5	70.8	0	0
male.....	3.2						

* Some of the females included in this sample were sterile.

number of 202 and an iodine value of 100. The total lipid contained 1.34 per cent unsaponifiable matter. Analysis of the glyceride composition resulted in the following values: 3.6 per cent saturated acid glycerides; 74.3 per cent oleic acid glycerides; and 20.8 per cent linoleic acid glycerides. Total fatty acids included 12.0 per cent saturated acids, and 88.0 per cent unsaturated acids.

Differences in fat content of solitary and gregarious phases of two species of noctuid moths were investigated by Matthée (56). *Laphygma exempta solitaria* larvae contained 1.51 per cent fat (wet basis), whereas larvae of *L. exempta gregaria* contained 2.73 per cent. In the case of *Spodoptera abyssinia*, the fat content of *solitaria* larvae amounted to 3.12 per cent of the fresh weight; that of pupae, 7.11 per cent. Larvae of *gregarisa* contained 4.95 per cent fat; pupae contained 9.35 per cent. The differences in the fat content of the two phases were statistically significant.

Fat content of two migrant moths has been reported by Williams (97). Analysis of the total body minus the wings was made by determining the difference in dry weight before and after extraction. The average fat content of *Phlogophora meticulosa* (Phalaenidae) females was 18.8 per cent; that of males, 15.6 per cent. Females of *Plusia gamma* (Noctuidae) contained an average of 33.8 per cent fat, and males contained 31.4 to 34.8 per cent. A large variation existed between replicate determinations.

Beall (5) checked on the effect of migration on fat content of *Danaus plexippus* (Nymphalidae). The trunk of the body was extracted in a Bailey-Walker extraction apparatus for twenty-three hours with ether. Results were expressed as "per cent of lean weight," lean weight being the dry weight minus the weight due to fat. Fat content of the trunk of a female *Danaus* in Ontario during summer was 21 per cent (lean weight basis) and that of a male was 16 per cent. In autumn these amounts increased to 74 per cent and 72 per cent, respectively. That the fat reserves were depleted during migration was evidenced by the analyses of adults collected in Louisiana in late October. Values from post-migration specimens were 3 per cent for females and 2 per cent for males. Still later, stored fat increased again in migrated adults to 23 per cent for females and 12 per cent for males.

Timon-David (87, 89, 90) reported on the fat content of several lepidopterans. The data are summarized in Table 3.

COLEOPTERA

The larva-fat of *Pachymerus dactris* (Bruchidae) was studied by Collin (14). Semi-solid fat, making up approximately 47 per cent of the dry weight, had a saponification equivalent of 260.7 and an iodine value of 37.4. Analysis of the fatty acids gave the following results: lauric acid, 24 per cent; myristic, 21 per cent; palmitic, 8 per cent; oleic, 32 per cent; linoleic, 3 per cent; and stearic, oleic, or linolenic, 12 per cent.

Changes in lipid composition of the potato beetle, *Leptinotarsa decemlineata* (Chrysomelidae), during hibernation, were investigated by Busnel and Drilhon (10). Fatty acid content increased from 2.65 per cent (wet basis) in September to a maximum of 13.4 per cent in January. In April females contained 3.47 per cent; males, 3.27 per cent. Unsaponifiable matter increased from 0.31 per cent (wet basis) in September to 1.03 per cent in November; in April, the values were 0.71 per cent for females, and 0.61 per cent for males.

Sinoda and Kurata (75) found that ether extract of larvae of *Dermestes* (Dermestidae) amounted at times to as much as 47 per cent of the dry weight. Saturated fatty acids, comprising 33 per cent of the total acids, consisted of 38 per cent stearic and 62 per cent palmitic. The presence of oleic, linoleic, and linolenic acids was confirmed.

Ether extract of adult fireflies, *Luciola vitticollis* and *L. parva* (Lampyridae), was reported by Tsujimoto (92) to comprise 4.8 per

cent of the live weight (minus wings). Iodine value of the total extract was 116. Fatty acid and unsaponifiable fractions, amounting to 85 per cent of the total, consisted of 87 per cent fatty acids and 13 per cent unsaponifiable matter.

According to Janot and Faudemay (45), fatty acids of the blister beetle, *Lytta vesicatoris* (Meloidae), consisted mainly of palmitic and oleic acids with smaller amounts of stearic, linoleic, and linolenic acids. Iyer and Ayyar (43) stated that body fat of *Mylabris pustulata* (Meloidae) constituted 12.5 per cent of dry weight. Component acids were: palmitic, 13 per cent; stearic, 32 per cent; arachidic, 1 per cent; and oleic, 54 per cent.

TABLE 3
FAT ANALYSIS OF SEVERAL LEPIDOPTEROUS INSECTS
[FROM TIMON-DAVID (87, 89, 90)]

Species	Family	Stage	Percentage Fat (Wet Basis)	Iodine Number	Percentage Unsaponifiable Matter
<i>Arctia caja</i>	Arctiidae	larva	4.1	133.3	.....
<i>Cossus ligniperda</i>	Cossidae	larva	27.5	76.2	.....
		adult	14.2	.....	.....
<i>Myelobia smerintha</i>	Galleriidae	adult	22.0	.....	.....
<i>Malacosoma franconica</i> ...	Lasiocampidae	larva	1.9	138.0	.....
<i>Asura conferta</i>	Lithosiidae	larva	1.03	102.9	.....
<i>Lymantria dispar</i>	Lymantriidae	larva	1.5	106.9	.....
<i>Lycophotia margaritosa</i> ...	Noctuidae	larva	0.94	.....	.....
<i>Vanessa urticae</i>	Nymphalidae	larva	3.7	159.9	.....
<i>Pieris brassicae</i>	Pieridae	pupa	.....	100.5	ca. 10
<i>Ephestia figulella</i>	Pyralidae	larva	21.4	65.4	.....
<i>Pyrausta nubilalis</i>	Pyralidae	larva	26.5	80.8	1.68
		adult	12.7	.....	.....
<i>Saturnia pernyi</i>	Saturniidae	larva	1.0	140.4	.....
<i>Saturnia pyri</i>	Saturniidae	larva	4.03	164.5	.....
<i>Cnethocampa pilyocampa</i> (<i>Thaumetopoea</i>).....	Thaumetopoeidae	larva	3.5	112.0	8.5

Slowtsoff (77) found that fat content of *Geotrupes stercoralis* (Scarabaeidae) decreased from 3.96 per cent to 1.88 per cent after starvation. The water content decreased from 63.88 per cent to 56.19 per cent.

Sacharov (72) determined a fat content of 6.07 per cent (live weight basis) for hibernating larvae of *Melolontha hippocastani* (Scarabaeidae). Water content was 79.16 per cent. Larvae of *Plagionotus arcuatus* (Cerambycidae) contained 14.36 per cent fat and 54.12 per cent water.

Schweert (74) reported that females of the June beetle, *Phyllophaga rugosa* (Scarabaeidae), contained 7.70 per cent fat (dry basis) and males 8.98 per cent. Water content was 66.56 per cent for females and 67.98 per cent for males.

Finkel (21) determined the lipid composition of the meal worm,

Tenebrio molitor (Tenebrionidae), at intervals of 25 days during larval development. Total lipid and its major component, neutral fat, became an increasing proportion of wet weight as development proceeded. Larvae reared at 30°C. contained 9.05 per cent total lipid at 50 days, and 13.13 per cent at 200 days. With the exception of that at 175 days, total cholesterol content ranged between 0.11 and 0.32 per cent of live weight. Phospholipid content decreased from 1.54 per cent at 50 days to 0.66 per cent at 200 days. With regard to total lipid, neutral fat and total fatty acids contents increased; phospholipid decreased; and total cholesterol exhibited very little change, as development progressed.

Chemical changes associated with metamorphosis of *T. molitor* were investigated by Evans (20). During the prepupal period, 8.04 per cent of the live weight was fatty acids, and, at the end of pupation, 7.90 per cent. Mean molecular weight of the acids was 267 to 274.

According to Becker (6), fat content of *T. molitor* decreased during metamorphosis; larvae contained 12 to 14 per cent of live weight; pupae, 8.9 per cent; young beetles, 8.1 per cent; and old beetles, 4.6 per cent. Saponification values and iodine numbers varied only slightly, and ranged between 181.7 to 185.8 and between 92.2 to 95.8, respectively. The unsaponifiable fraction decreased from 1.56 per cent in larvae to 0.93 per cent in pupae, and then increased to 6.3 per cent in old beetles.

The fat content of several coleopterous insects has been determined by Timon-David (87, 89, 90). The data are summarized in Table 4.

HYMENOPTERA

Chemical changes occurring in worker and drone castes of *Apis mellifica* (Apidae) were investigated by Straus (81). Fat content of workers increased from 1.53 per cent (wet basis) in larvae two days old, to a maximum of 4.11 per cent in the first day of pupation. There was a gradual decrease in body fat during the twelve days of pupation, and newly emerged adults contained 0.93 per cent fat. This percentage rose to 1.95 per cent in flying workers. Drones increased their fat content from 3.10 per cent as three-day old larvae to approximately 6.12 per cent on the third day of pupal life. The value decreased during pupation, and adults contained 1.52 to 1.58 per cent fat. Sacharov (72) stated that adults of *A. mellifica* analyzed 74.05 per cent water and 2.66 per cent fat. According to Melampy *et al.* (58), the queen honeybee attained a maximal weight of more than 260 mg. during development, with a maximal lipid content of 12.84 mg. Compared to these values, the worker bee had a maximal weight of 144 mg. and fat content of 5.37 mg. A queen pupa analyzed approximately 5.3 per cent lipid at pupation, whereas a worker pupa analyzed only 3.7 per cent.

Timon-David (87, 90) reported the lipid content of two species of Formicidae, Larvae of *Camponotus vagus* contained 2.45 per cent ether extract (wet basis) with an iodine value of 68.5. Adults of *Crema-togaster scutellaris* contained 10.9 per cent extract with an iodine value of 62.4.

Kozhantshikov (51) determined that diapausing prepupae of *Croesus septentrionalis* (Tenthredinoidea) contained 61 per cent water and 26.0 per cent fat.

DIPTERA

Changes in fat composition of adult *Culex pipiens* (Culicidae) during hibernation were studied by Buxton (11). The maximal content of 27.9 per cent (wet basis) in October decreased to 23.6 per cent in

TABLE 4
FAT ANALYSIS OF SEVERAL COLEOPTEROUS INSECTS
[FROM TIMON-DAVID (87, 89, 90)]

Species	Family	Stage	Percent- age Fat (Wet Basis)	Iodine Number	Percent- age Unsaponi- fiable Matter
<i>Eurythrea micans</i>	Buprestidae	larva	13.2	.....	.....
<i>Cebrio gigas</i>	Cebrionidae	larva	14.4	80.8	.....
<i>Cerambyx scopoli</i>	Cerambycidae	adult	8.5	90.7	.....
<i>Ergates faber</i>	Cerambycidae	larva	13.0	68.5	0.75
<i>Rhagium inquisitor</i>	Cerambycidae	larva	7.0	80.5	.....
<i>Colaspidema atra</i>	Chrysomelidae	larva	3.9	113.4	3.5
<i>Galerucella luteola</i>	Chrysomelidae	adult	7.03	118.2	.....
<i>Leptinotarsa decemlineata</i> ..	Chrysomelidae	larva	3.0	121.9	5.9
		adult	13.4	108.6	.....
<i>Heliotaurus menticornis</i>	Cistelidae	adult	6.0	104.4	12.5
<i>Silvanus surianamensis</i>	Cucujidae	larva	24.0	74.0	.....
<i>Balaninus elephas</i>	Curculionidae	larva	28.0	.....	.....
<i>Laria irrescens</i>	Lariidae	larva	23.6	.....	.....
<i>Oryctes nasicornis</i>	Scarabaeidae	larva	.....	41.0	.....
<i>Tenebrio molitor</i>	Tenebrionidae	larva	14.5	86-92.8	1.19

December, and 6.3 per cent in March. The proportion of water increased during this period.

In checking on the metabolism of *Cyclorrhapha*, Frew (25) found that the alcohol-ether soluble fraction of the body did not decrease during the first part of pupation but did so gradually during the latter part.

According to Weinland (95), fat of *Calliphora vomitoria* (Calliphoridae) reached a maximum of about 7.8 per cent of body weight just prior to pupation. This content was reduced approximately one-half at the end of metamorphosis. Adults of *C. erythrocephala* contained 3.4 per cent fat (dry basis) with an iodine value of 80.7 [Timon-David (90)]. Kozhantshikov (51) reported that full-grown larvae of this species contained 73 per cent water and 30.0 per cent fat (dry basis).

Changes in fat composition of *Lucilia sericata* (Calliphoridae) during pupation were investigated by Evans (19). The fatty acid content decreased from the time feeding ceased until about the tenth day of pupation. Then followed a synthesis of both saturated and unsaturated

fatty acids until a second maximum was reached on about the fourteenth day. A second decrease continued until emergence. The mean molecular weights of fatty acids ranged from 270 to 287 and iodine values ranged from 79 to 96. Yuill and Craig (98) reported that fat of *L. sericata* increased from 6 per cent of dry weight in young larvae to 30 per cent in full-grown larvae; fat content decreased to 20 per cent in pupae. The decrease in water content during development was correlated with the increase in ether extract.

Fat content of *Phormia regina* (Calliphoridae) during metamorphosis was studied by Patton *et al.* (66). A content of 7.10 per cent (wet basis) in larvae diminished to 3.73 per cent on the fourth day of pupation, and to 1.57 per cent in adults. Haub and Hitchcock (37) found that ether extract of *P. regina* decreased from 8.9 per cent of live weight in larvae to 6.8 per cent on the fourth day of pupation, and to 5.2 per cent in adults. Empty pupal cases contained 1.7 per cent extract. There was little change in water content during metamorphosis.

Mellanby (59) reported that fat reserves in adult *Glossina palpalis* (Muscidae) constituted 21.9 per cent of the dry weight in males and 22.7 per cent in females. These reserves were consumed at the same rate by flies starved in different humidity environments. Water and fat contents of *Glossina morsitans* were studied by Jackson (44). Fat content was 15.93 per cent of the dry weight in young males, and 15.25 per cent in young females. This latter value increased to 16.84 per cent in mature females. The fat of males ranged from 14.56 per cent of dry weight in hungry males to 35.28 per cent in replete males.

Timon-David (87, 90) determined fat content of two species of dipterous insects. Larvae of *Gastrophilus intestinalis* (Oestridae) contained 5 per cent fat (wet basis) with an iodine value of 37.3. Larvae of *Eristalis tenax* (Syrphidae) analyzed 1.7 per cent fat.

LIPID CONTENT OF INSECT PRODUCTS

A few substances that may be termed "insect products" have been analyzed for lipid content. Among the more common of these are the waxes secreted by certain insects. Wax of the wild bee *Trigona* (Meliponidae) was fractionated by Gadamer (31). Isolated alcohols consisted of the following: melissyl alcohol, 28 per cent; a compound with the formula $C_nH_{2n-2}O$ where n was 26 to 30, 13 per cent; a glycol where $C = 30$, 10 per cent; and ceryl alcohol, 7 per cent. The acids included a hydroxy ricinoleic acid; a resinic acid; volatile acids consisting of acetic and iso-butyric; and higher fatty acids. A saturated hydrocarbon was also identified. Iodine values of the original acids ranged from 60.2 to 61.4.

Schulz (73) reported on fatty acids isolated from wax of *Schizoneura lanigera* (Aphididae). Acids constituted 68.3 to 76 per cent of the total lipid, and had a molecular weight of 230 to 240. Chemical characterization indicated the presence of a branched chain acid not identifiable with the normal fatty acid series.

Literature on the composition of insect waxes has been summarized by Chibnall *et al.* (12). In general, the waxes consist of even-numbered primary alcohols in which $C = 24$ to 34 ; even-numbered n-fatty acids where $C = 24$ to 34 ; and odd-numbered paraffins where $C = 25$ to 37 .

According to Aeppler (2), royal jelly (a product of the lateral pharyngeal glands of the worker honeybee) contained 15.22 per cent total ether extractives (air dried basis) with an iodine value of 12.51. Fat-soluble vitamin A was not present in high enough concentration to support normal growth in the rat. Townsend and Lucas (91) obtained 10 to 15 per cent of the dry weight of royal jelly by Soxhlet extraction with ether. The extract possessed a gonadotropic factor for *Drosophila melanogaster*.

Bergmann (8) isolated a mixture of paraffins of the order $C = 27$ to 31 ; and esters, in which C of the alcohol and acid was 26 to 30, from exuviae of the silkworm, *Bombyx mori*.

EFFECT OF DIET FAT UPON BODY FAT

Melampy and Maynard (57) experimented with the effect of diet fat on stored fat of *Blattella germanica*. Data are summarized in Table 5. The degree of unsaturation of diet fat was evidently reflected in body

TABLE 5
EFFECT OF DIET FAT ON BODY FAT OF *Blattella germanica*
[FROM MELAMPY AND MAYNARD (57)]

Diet	Iodine Number of Diet Fat	Iodine Number of Tissue Lipid	Percentage Fat in Diet	Percentage Lipid in Tissue (Wet Basis)
(1) Casein, yeast, sucrose, lactalbumin.....			0.39	
(2) Diet No. 1, plus coconut oil..	7	51	28.0	7.8
(3) Diet No. 1, minus sucrose, plus butter oil.....	27	59	56.0	21.0
(4) Diet No. 1, minus sucrose, plus lard.....	49	64	56.0	13.2

fat. It may also be concluded that degree of utilization varied to some extent with the type of fat.

Effects of different diets on lipid composition of *Periplaneta americana* were investigated by Schweet (74). There was no significant difference in lipid content of roaches reared on media in which the fat content ranged from 1 per cent to 30 per cent. An exception was noted in that roaches reared on steak containing 3 per cent fat analyzed only 8 per cent fat. The iodine value of the fat of roaches reared on low fat diets was not correlated with the iodine value of the diet fat.

Ditman (17) reported that fat content of mature larvae and pupae of the corn ear-worm, *Heliothis armigera*, was affected by variation of the larval diet. Prepupae and pupae of individuals reared on dough-

stage corn contained a higher percentage of fat, and this fat had less saturation and lower saponification number than fat in those reared on milk-stage corn. Fat content of maturing corn increased from 3 per cent to 6 per cent of the dry weight. The iodine and saponification values of the corn lipid remained almost constant.

Yuill and Craig (98) reared larvae of *Lucilia sericata* on fish heads, or on a sterile synthetic diet with butter as the fat source. Fat of larvae reared on fish heads had a saponification value of 190 to 215 and an iodine value of 120 to 140, compared to values of 195 and 113, respectively, for the fish head fat. On the synthetic diet, the insect fat had a saponification value of 220 and an iodine value of 60 compared to values of 210 and 30, respectively, for the diet fat. The authors concluded that the type of larval fat and changes in the fat composition during growth were related to the diet fat.

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CHEMISTRY OF GLYCEROL DICHLOROHYDRIN AS A REAGENT FOR THE DETERMINATION OF VITAMIN A¹

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The analysis of vitamin A by colorimetric methods has been the topic of many investigations in the past 25 years. Numerous methods have been proposed, tested, and finally discarded with the conclusion that they lacked specificity and/or the required sensitivity to measure small amounts of vitamin A in biological materials. In 1945 a new colorimetric reagent, which has many desirable features for the measurement of vitamin A, was introduced. The reagent is glycerol dichlorohydrin (GDH) which is activated by vacuum distillation with a small amount of antimony trichloride.

Pure glycerol dichlorohydrin gave no color test with vitamin A, but was activated by the addition of small amounts of certain inorganic acids, metallic and non-metallic halides, acyl halides and several other compounds. Compounds or solutions which were good activating agents included concentrated hydrochloric acid, concentrated sulfuric acid, chlorosulfonic acid, 60 per cent perchloric acid, phosphorus trichloride, phosphorus oxychloride, aluminum chloride, arsenic trichloride, and methyl sulfate. The hydrogen ion *per se* is not the sole activating agent since addition of nitric acid, acetic acid, monochloroacetic acid, or trichloroacetic acid did not result in an activated reagent.

Good activation of GDH was produced by concentrations of anhydrous hydrogen chloride ranging from 0.002 to 0.08 N, with optimum activity at 0.01 N hydrogen chloride.

Good activation was produced by concentrations of chlorosulfonic acid ranging from 0.02 to 0.5 per cent acid, with optimum activity at 0.1 per cent chlorosulfonic acid.

The activity of GDH activated with either anhydrous HCl or chlorosulfonic acid changed on standing in the laboratory. Reagents originally showing optimum activity became less active, while those having excess or mere traces of acid became somewhat more active on standing at room temperature and on exposure to laboratory light.

GDH activated by the addition of 1 per cent concentrated sulfuric acid produced a blue color when first mixed with a chloroform solution of vitamin A. Within 5 or 6 minutes the blue changed to a fairly stable but not very intense red-violet color with maximum absorption at 545 m μ and a smaller absorption band at 452 m μ .

¹ Doctoral thesis number 1003, submitted October 5, 1949.

GDH was activated by heating up to 4 hours at 85°C. with concentrations of antimony trichloride ranging from 0.3 to 1 per cent. Activity was greatest with the higher levels and longer heating periods. The ultraviolet absorption spectrum of GDH activated by heating with 0.3 per cent antimony trichloride indicated a change in the reagent due to a reaction of antimony trichloride with GDH to produce a derivative containing antimony or a chemical bonding between the reactants.

Good activity was produced by vacuum distilling several brands of GDH with 1 per cent antimony trichloride. No significant difference between brands was observed when solvent reagent ratios of 1:5 and 5:1 were employed. The activity of these reagents was equal to or better than GDH activated with either HCl or ClSO_3H . Apparently antimony trichloride reacted with GDH during the heating and distillation to produce HCl along with a distillate which contained antimony.

Glycerol dichlorohydrin activated by the addition of concentrated hydrochloric acid, chlorosulfonic acid, or by vacuum distillation with antimony trichloride, when present in excess, reacted with vitamin A acetate to produce a violet color which had a principal absorption maximum at 555 $\text{m}\mu$ and a small absorption band at 358 $\text{m}\mu$. The stability of the color was determined by measuring the absorption spectrum at various time intervals after initiation of the color reaction. In each case the extinction coefficient at the 555 $\text{m}\mu$ maximum decreased on standing.

Antimony trichloride-activated GDH was deactivated by heating with activated charcoal, filtering, addition of a small quantity of aqueous KOH and finally vacuum distilling to give a clear, colorless reagent. On standing in a clear, glass-stoppered bottle for several weeks, this product became active due to decomposition, a process which was hastened by heating. Free chloride ion was found in this active reagent. It was postulated that hydrogen chloride was one of the decomposition products responsible for the activation of the GDH.

Glycerol α -monochlorohydrin gave weak color tests when activated by the same agents which activated GDH. The absorption spectrum of the color produced when vitamin A reacted with antimony trichloride-activated glycerol monochlorohydrin was not unlike that of the GDH-vitamin A color except in magnitude. The monochlorohydrin color was only about half as intense as that produced by the GDH-vitamin A reaction when a 1:5 solvent-reagent ratio was used. At the 5:1 ratio the absorption at 373 $\text{m}\mu$ was nearly the same with both reagents. Vacuum distillation of 1,2,3-trichloropropane with 1 per cent antimony trichloride failed to produce an active reagent. It is concluded that no glycerol derivative thus far tested is as effective as a vitamin A colorimetric reagent as glycerol dichlorohydrin. This evidence supports the view that a hydroxyl group and two chlorine atoms, each on separate carbon atoms of a propane skeleton are required for maximum color formation with vitamin A.

Solvent-reagent ratios of 1:9, 1:7, 1:5, 1:3, 1:1, 3:1, 5:1, 7:1, and 9:1 were tested. The extinction coefficients at 555 $\text{m}\mu$ were essentially

the same when the 1:9, 1:7, 1:5, and 1:3 ratios were employed. As the ratios were increased above 1:3, the absorption at 555 $m\mu$ decreased while the absorption at 338, 353, 373, 397, and 422 $m\mu$ increased. These maxima in and near the ultraviolet possibly indicate the formation of anhydrovitamin A.

Pyridine, aniline, *n*-butylamine, aqueous ammonia and epichlorohydrin inhibit the GDH-vitamin A color reaction. Aqueous KOH, ethanol, water and dioxane had some inhibitory action. Apparently compounds that react readily with HCl prevent the GDH-vitamin A color reaction.

Activated GDH reacted with β -carotene to form a product which absorbed strongly at and apparently above 1000 $m\mu$. Above 880 $m\mu$ the stability of the extinction coefficients decreased with increasing wavelength at which measurements were made.

The GDH-vitamin A color reaction was readily quenched by adding ethanol. The ultraviolet absorption spectrum of the clear solution resulting when the reaction was quenched within 1 minute indicated the presence of a substance which absorbed at 335, 349, and 369 $m\mu$. This absorption spectrum closely resembled that of isoanhydrovitamin A.

QUANTITATIVE SPECTROGRAPHIC ANALYSIS OF HAFNIUM-ZIRCONIUM MIXTURES¹

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In general, the analysis of mixtures of chemically similar elements by traditional analytical procedures is a difficult, if not impossible, task. The techniques of quantitative emission spectroscopy offer a particularly good solution to this problem, except that their use is usually restricted to the determination of small concentrations of elements. This thesis describes a spectrographic method of analyzing mixtures of two chemically similar elements, zirconium and hafnium, in concentrations from 0.1 to 99 per cent hafnium with an error of $\pm 1-2$ per cent. The successful analysis of higher concentrations of hafnium was shown to depend upon the use of (a) a nearly ideal internal standard, (b) line pairs which possessed similar excitation potentials, (c) lines which were susceptible to a minimum of self-absorption, (d) a controlled excitation source, and (e) certain refinements in the photographic photometry.

A Jarrell-Ash Wadsworth mounting 21-foot grating spectrograph was employed in this work. The external optical system was designed to focus the source on the collimating mirror. A rotating stepped sector was placed in front of the slit in order to achieve intensity gradations. An ARL-Dietert Multisource Unit was used as the exciting source with 14 microfarads, 480 microhenries, and 65 ohms in the power circuit. The spectra were photographed in the first order on Eastman Spectrum Analysis No. 1 emulsion and the emulsion response was determined by the two-step, preliminary curve method.

Preliminary studies showed that when an over-damped condenser discharge was used to excite $\frac{1}{4}$ -inch diameter pellets of zirconium-hafnium oxide and graphite, reproducible intensity ratios of hafnium lines to zirconium lines were observed. Moving plate studies showed that the ratio of intensities was constant with time. Since there was no selective volatilization of either element, it was possible to use one pellet for several determinations.

Standard samples were prepared from ZrO_2 containing some hafnium as an impurity and HfO_2 containing some zirconium as an impurity. The amount of impurity in each was determined by the method of zero intercepts. Pellets weighing 500 mg. were made of this material and graphite powder in the ratio of 1:4. At low hafnium concentrations an oxide-graphite ratio of 1:1 was used.

¹ Doctoral thesis number 1068, submitted June 5, 1950.

Seven line pairs were used for the concentration range. Except at very low and at extremely high hafnium concentrations, each was useful over a short concentration range, i.e., their intensity ratio was between 0.6 and 1.7 over this range. Such a procedure minimized the errors in photometry. Line pairs which were selected for quantitative calibrations possessed similar excitation potentials; were relatively free from interferences; and, with one exception, were within 25 Å from one another. Straight lines which had slopes near the theoretical slope of one resulted when log intensity ratio was plotted against log concentration ($\text{Hf/Zr} \times 100$).

Studies were made on the effect of changing the experimental variables. It was found that the graphite-oxide ratio, the crystal structure of the oxide, and the base material itself had little or no effect on the intensity ratios. The effect of additions of extraneous materials in the form of sodium chloride and calcium up to the amount of 5 per cent was investigated and was found to be negligible. It was found that line pairs which possessed unfavorable excitation characteristics likewise were unaffected by these latter additions.

A study was made of the effect of changes in excitation on line pairs possessing similar and dissimilar excitation potentials. Those line pairs which had nearly the same excitation potentials were relatively constant throughout wide changes in excitation, but those line pairs whose excitation potentials varied by a two-fold difference exhibited wide, erratic variations throughout the same range of excitation conditions.

The precision of the line pairs used in the quantitative calibrations was found to average 1.5 per cent standard deviation. A line pair possessing unfavorable excitation characteristics showed a per cent standard deviation of 5.05.

The accuracy of this method was determined by comparisons with independent spectrographic methods, with synthetic standards made up by an independent laboratory and with samples which had been analyzed by a chemical (atomic weight) method. The former two agreed within 1-2 per cent of the amount present. The latter determinations, made at an independent laboratory, averaged, with one exception, about 5 per cent higher than the spectrographic results. This discrepancy may be due to impurities in the selenium dioxide which was used in the chemical analysis.

FACTORS IN THE BIOSYNTHESIS OF TRYPTOPHAN AND TYROSINE BY *LACTOBACILLUS ARABINOSUS*¹

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PART I. STUDIES ON THE CONVERSION OF ANTHRANILIC ACID TO TRYPTOPHAN BY *LACTOBACILLUS ARABINOSUS*

Lactobacillus arabinosus is capable of converting anthranilic acid to tryptophan, but unable to synthesize the latter compound. It is therefore a promising organism for study of the later steps in tryptophan synthesis without interference from earlier reactions.

In synthetic medium lacking tryptophan, anthranilic acid is converted to tryptophan in good yield when added at low levels in the presence of pyridoxine or pyridoxamine. Higher levels of the acid inhibit growth. The anthranilic acid response curve is characterized by regular increase in growth to about 100 micrograms per 10 milliliter culture, steady decrease to about 500 micrograms, nearly complete inhibition from 1000 to 5000 micrograms, and fair growth above 10,000 micrograms. The inhibition is prevented by low concentrations of indole or tryptophan or by allowing initiation of growth at lower levels of anthranilic acid. Although added at normally inhibitory levels, anthranilic acid is then converted to tryptophan and heavy growth ensues.

The inhibition is believed to involve interference with some essential cellular process, possibly a step in the conversion of anthranilic acid to tryptophan. Neither *p*-aminobenzoic acid nor nicotinic acid prevents inhibition by anthranilic acid.

A mutant strain overgrows inhibited cultures in 2 to 3 days. This mutant apparently differs from the parental strain only in its insensitivity to anthranilic acid at levels inhibitory to the latter strain.

Several compounds which are related structurally to anthranilic acid, indole, or tryptophan were tested for tryptophan activity and for ability to inhibit the conversion of anthranilic acid to tryptophan. A group of *N*-substituted anthranilic acid derivatives—ethyl, methyl, acetyl, formyl, and carboxymethyl—replaced tryptophan to varying degrees, apparently by conversion to anthranilic acid. On prolonged incubation, *N*-carboxymethylanthranilic acid appears as active as the parent acid itself. The activity of the formyl derivative (about 6 per cent) is enhanced by autoclaving. The other derivatives possess only slight activity. 5-Chloro- and 5-methylanthranilic acids showed no significant activity either in replacement of tryptophan or inhibition

¹ Doctoral thesis number 999, submitted August 22, 1949.

of its synthesis. Similar results were obtained with *o*-chloro-, *o*-bromo-, and *o*-methylbenzoic acids, skatole, indoleacetic acid, and cinnamic acid.

Attempts to obtain conversion of indole to tryptophan by nondividing cell suspensions were successful.

PART II. TWO MUTATIONS AND A STRUCTURAL ANALOG WHICH
AFFECT SYNTHESIS AND METABOLISM OF ARYLALANINES
IN *LACTOBACILLUS ARABINOSUS*

Two *L. arabinosus* mutants, one able to synthesize tyrosine and the other synthesizing both tyrosine and phenylalanine, were isolated. (Both mutations had been observed previously.) The relation of such mutations to the hypothesis that unused biochemical abilities are normally lost was discussed.

Quantitative comparison of the requirements of parental and mutant strains for phenylalanine and tryptophan indicated that neither step of the sequence tryptophan \rightarrow phenylalanine \rightarrow tyrosine, which has been reported for *Escherichia coli*, is utilized by the *L. arabinosus* mutants.

Inhibition of growth of *L. arabinosus* by *p*-fluorophenylalanine is reversed competitively by phenylalanine with a 50 per cent inhibition ratio (20 hours) of about 0.7. Tyrosine is without effect on the inhibition of parental or either mutant strain. This amino acid is therefore not a precursor in synthesis of phenylalanine by the mutant which performs this synthesis. The time course of the inhibition was followed, and the dependence of such values as inhibition ratios and antibacterial indices on time of incubation was discussed. In the presence of low levels of phenylalanine, small amounts of the fluoro derivative enhanced growth. Neither phenylalanine nor tyrosine is antagonized by *p*-chlorophenylalanine.

Increasing the molar ratio of fluorophenylalanine to phenylalanine causes a decrease in rate and extent of growth until a critical ratio (about 2) is reached. At levels of analog above this ratio, visible growth occurs only after a marked time lag, and appears to consist of a mutant strain resistant to the inhibitor. The lag period tends to vary with the level of inhibitor.

Increased specificity for phenylalanine of the enzyme mediating the block reaction is proposed as the most likely mechanism of the mutation. The implications of such a mechanism for the development of drug resistance and of enzyme specificity in general are discussed.

The three mutants studied, as well as one reported in Part I, are suppressed in some manner by the parental strain under conditions allowing only moderate growth of the latter strain. This suppression is denoted by the occurrence of a depression in total growth under conditions intermediate between those allowing normal growth of the parental strain and those causing clean selection of the mutant. The mechanism of this suppression is not known.

SOME FACTORS AFFECTING QUANTITY AND QUALITY OF EGGS MARKETED BY CERTAIN PRODUCERS ¹

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The objectives of this study were: (1) to determine how the egg marketing operations of selected egg producers and handlers in Iowa compare to certain portions of what may be considered a perfect market; (2) to determine the effect of cost-price relationships on the quantity of eggs produced in the United States; (3) to determine the relationships of the egg production and marketing on record-keeping farms in Iowa to the farm as a production unit and to the household; and (4) to determine what record-keeping farmers in Iowa consider to be the most important factors affecting quantity adjustments in egg production.

The results of this study indicated that egg producers in Iowa were generally confronted with a marketing system which did not reflect market demands from a form (grade) standpoint. There was an indication that place price differentials existed. Sales during the fourth quarter of the year were an important price-factor among record cooperators. There was also slight indication of price differentials for what might be called quantity utility.

The form (grade) imperfection in the market for Iowa egg producers was quite apparent. There was a general tendency for handlers to buy eggs on a smaller number of grades than the number on which they sold the eggs.

The major effect on Iowa producers of grade buying was the lowering of the percentage of dirty eggs sold by producers. The interior quality of eggs was considerably higher during the summer months and somewhat higher during the spring months for eggs sold on a graded basis than those sold on an ungraded basis. The use of farm routes did not result in higher quality of eggs as compared to door deliveries. In some instances, door-delivered eggs were of higher quality than farm-route eggs. No comparisons were made between dealer-route eggs and farm-route eggs. There was no apparent relationship between the quantity and quality of eggs sold by producers.

There was little apparent quality deterioration from the time the eggs were graded at the first-buyer's plant until they were graded at the carlot shipper's plant. This low deterioration may have been due to the relatively short time interval between gradings.

¹ Doctoral thesis number 998, presented August 22, 1949.

A sample of 1100 Iowa producers indicated that those who sold eggs on a graded basis received a significantly higher price per dozen eggs in August 1948 than producers who sold on a current receipts basis. Farm record cooperators in Iowa who sold eggs on a graded basis in 1947 also received higher prices than those who sold eggs on a current receipts basis. In the latter group, method of sale appeared to be of greater importance in price determination than the quality maintenance practices followed.

Egg producers in the United States responded to changes in cost-price relationships by raising more or fewer flock replacements. The indicator of cost-price relationships was the ratio of the value of the eggs produced by the average hen to the cost of 1 pound of poultry ration. More than 93 per cent of the variance in the number of potential layers on U. S. farms on October 1, 1930 to 1947 was associated with changes in the number of potential layers on farms the preceding October 1 and changes in a weighted value of eggs produced per hen-feed price ratio. Nearly 86 per cent of the variation in the number of pullets on U. S. farms on October 1, 1930 to 1947 was associated with changes in the above ratio. Although the value of eggs produced per hen-feed price ratio was a good indicator of the initial size of laying flock, only about 25 per cent of the rate of decline in the number of hens on U. S. farms was associated with this cost-price measure. Nearly 99 per cent of the variance in October 1 to September 30 egg production for the period 1930-31 to 1946-47 was associated with changes in the number of potential layers on farms and egg production per hen in October.

Increased egg production per hen was an important factor in increased total egg production. The price of eggs relative to hog prices decreased from 1925 to 1948 but the ratio of the number of eggs to the number of pigs saved increased. There was no indication, from an aggregate standpoint, of competition between hog production and egg production in either Iowa or the United States.

Among a sample group of farm record cooperators in Iowa, egg production was higher on the average size farms than on either the smallest or largest farms. Owner-operators kept more hens than did tenant-operators. This was a partial reflection of the better housing facilities provided on owner-farms. Operators in the 41-50 age group kept more hens than either younger or older operators. Hog and egg production were considered competitive by a few operators. There was apparent competition between specialized dairy or beef production and egg production.

The exact contribution made toward maximization of managerial return by family care of the poultry flock was not apparent. The number of children of ages 13 to 18 was closely associated with the number of hens kept on these farms, however. There was a greater percentage of flocks in the 200 to 299 hen group among farms on which family labor had major responsibility for the care of both hens and chicks.

Among the farm record cooperators in Iowa, producers selling eggs on a graded basis had larger flocks and received a greater percentage of their cash income from the sale of eggs than those selling on an ungraded basis. There was little relationship between other portions of the farm enterprise and marketing practices followed.

The record-keeping farmers in Iowa considered housing facilities to be the most important factor affecting the number of chickens to raise. This is a short-run consideration since housing facilities could be provided on owner farms if the long-run outlook for egg prices appeared to be particularly favorable. Cost-price factors were ranked as second in importance and competitive factors were seldom included.

Many of these producers changed breeds of hens during the last five years in an attempt to get greater egg production. Many of them also bought sexed pullets because of the relatively greater returns from eggs than from chickens. There was little indication that cost-price relationships, as such, were of any importance in determining when to sell hens.

Among a group of ninety-eight farm record cooperators in Iowa with 10-year records, producers who decreased the hen flock size by 100 to 199 birds from 1937 and 1938 to 1946 and 1947 increased their management return significantly more than producers who increased their laying flock size by 100 or more birds. However, the size of the laying flock, per se, was not an important factor in determining management return.

OXIDATION OF FATTY ACIDS BY *CANDIDA LIPOLYTICA* AND *PSEUDOMONAS FRAGI*¹

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The ability of microorganisms to break down fats and utilize the resulting products in their metabolism has been recognized for some time; however, microbial lipases have been studied in greater detail than have the microbial oxidases. The present investigation was undertaken to study the ability of *Candida lipolytica* and *Pseudomonas fragi* to oxidize sodium salts of fatty acids, and various nutritional and environmental factors which may affect this oxidation.

Highly oxidative strains of *C. lipolytica* and *Ps. fragi* were selected by using butterfat-emulsion agar plates and flooding the plates with an aqueous solution of tetramethylparaphenylenediamine hydrochloride, after 4 days growth at 21°C. The lipolytic ability of these strains was determined by growth for 4 days at 21°C. on butterfat-emulsion agar plates to which Nile blue sulphate had been added. The *Ps. fragi* strain selected was atypical since it exhibited no lipolytic activity.

The cells were propagated on tryptone-glucose-extract agar slants, harvested by washing from the agar with chilled saline and the centrifugation and washing repeated three times. The cell suspensions were adjusted to a constant reading of 250 with chilled saline, using a Klett-Summerson photoelectric colorimeter.

The ability of resting cell suspensions of these microorganisms to oxidize the sodium salts of acetic, propionic, butyric, caproic, caprylic, capric, lauric, myristic, palmitic, stearic, oleic, and linoleic acids at various pH levels was determined using conventional Warburg respirometer technics. Pure fatty acids were preferred to natural fats or monoglycerides as substrata since they had no glycerol component which could be oxidized to yield misleading results. Furthermore if fats or monoglycerides were used, the lipolytic ability of the organisms tested would be the limiting factor, in some instances, in making the fatty acids available for oxidation. Selected fatty acids were used as test substrata in other phases of this study.

The buffers selected for use in the reaction flasks of the Warburg apparatus were chosen on the basis that they would cover a wide pH range, that they were not highly toxic to the microorganisms used and that they would maintain the pH relatively constant at each pH level tested for a 2.5-hour run. A 0.05M McIlvaine citrate-phosphate

¹ Doctoral thesis number 1031, submitted March 8, 1950.

buffer was selected for *C. lipolytica* and a 0.07M Palitzsch borate buffer for *Ps. fragi* cells.

Incubation of *C. lipolytica* and *Ps. fragi* cells for 24 hours at 30°C. and 21°C., respectively, gave the highest oxygen uptake values, and were used in this investigation. A run covering the period from 0.5 to 2.5 hours gave higher uptake values than a run of 0 to 2.0 hours; accordingly the 0.5- to 2.5-hour interval was used in this investigation.

The action of *C. lipolytica* cells upon the twelve test substrata previously listed indicated the optimum range of reaction to be pH 3.4 to pH 7.8, with the optima for the majority of the substrata falling within the range of pH 5.8 to 6.6. This pH range agrees closely with the pH range found to be optimum for the lipase enzyme of *C. lipolytica*.

The action of *Ps. fragi* cells upon the twelve test substrata indicated the range of greatest activity to be pH 8.0 to pH 8.45, with the majority of the substrata being oxidized most readily within the range of pH 8.25 to 8.45. This pH range is in close agreement with the optimum pH values found for various bacterial lipases.

Cells of *C. lipolytica* grown on tryptone-glucose-extract agar adjusted to pH 3.8 to 4.4 showed higher oxygen uptake values than cells grown on agar adjusted to higher pH levels. The cells of *Ps. fragi* grown on tryptone-glucose-extract agar adjusted to pH 5.0 to 7.8 showed higher uptake values than cells grown on agar adjusted to lower pH levels.

In the present study there is some evidence of an enhancement of oxidase production by *C. lipolytica* and *Ps. fragi* when grown in the presence of certain added nutrients. This is not a true adaptive enzyme production in the usual sense, because the cells grown in the absence of the fatty acids possessed oxidizing ability to a considerable degree.

Suitable synthetic media were chosen for the cultures used, when studying the effect of added nutrients upon oxidase production. The presence of such added complex nutrients as skimmilk, peptone, casein hydrolysate, yeast extract or beef extract caused no appreciable enhancement of oxidase production by either *C. lipolytica* or *Ps. fragi*. Cells of *C. lipolytica* grown in the presence of 20 per cent cream gave higher uptake values than the cells grown in the presence of skimmilk, indicating an enhancement of oxidase production in the presence of butterfat. The failure of cream to enhance the production of oxidase enzymes by *Ps. fragi* undoubtedly is due to the inability of the test culture to hydrolyze butterfat to a detectable degree. In the absence of free fatty acids the stimulus for increased production of enzymes oxidizing these acids would be lacking.

The addition to the growth media of fatty acids such as acetic, propionic, butyric, or caproic resulted in definite enhancement in the ability of both *C. lipolytica* and *Ps. fragi* to produce oxidase enzymes. Some tendency toward specificity of the enzymes responsible for oxygen uptake seems apparent since the stimulation for utilization of one acid sometimes was not apparent to the same degree for all other acids in

the homologous series. Acetic acid appeared to behave quite differently from butyric acid in that the latter stimulated to a much greater degree the production of oxidases active against the fatty acids which usually are found as components of natural fats; propionic acid also had some tendency to be less active than butyric acid in stimulating production of fatty acid oxidases.

The addition of monoacetin and monobutyrim to the growth media appeared to have little effect in enhancing the oxidizing ability of either *C. lipolytica* or *Ps. fragi* when tested against the sodium salt of the fatty acid present in the monoglyceride. Cells grown in the presence of monobutyrim showed uptake values appreciably higher than the control values when myristate was the test substrate. When caproate was used as the test substrate for cells grown in the presence of either of these addenda, no detectable increase over the control values was noted.

An enhancement of the oxidizing ability of cells of both *C. lipolytica* and *Ps. fragi* when grown in the presence of fatty acids and natural fat gives proof that these cells react to the stimulus of the presence of a fatty acid by increasing the amount of enzyme available for the utilization of the substrate. Natural fat added to the growth medium gave no increase with *Ps. fragi* cells, probably because the strain of *Ps. fragi* chosen for this study was non-lipolytic.

In dairy products containing butterfat both *C. lipolytica* and the normally-lipolytic forms of *Ps. fragi* would be stimulated to produce considerable quantities of oxidases active on fatty acids, whether these fatty acids resulted from the lipolytic activity of the organisms, synthesis by other microorganisms or by the action of milk lipases.

GROWTH OF THE MAIZE ROOT TIP¹

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Growth of the primary maize root has been found to be limited to the first 4 millimeters behind the root cap. The division zone, defined as that fraction in which anticlinal divisions are taking place, has been further separated into two rather distinct portions. One of these is formed by the group of cells located in the first millimeter above the root cap base, and is characterized by slow growth, small-sized and non-vacuolated cells. This section is rounded and somewhat tapered, so that it was in our tests, 40 per cent smaller than the second millimeter section. The cells of the first section were found to be isodiametric, 11 μ long, high in protein (61 per cent of the dry weight) and dry matter (about 20 per cent). Generation time for one complete cell division was 29 hours at 15° and 18 hours at 25°C.

In the second millimeter a rapid change from cell division to cell enlargement occurred. The first quarter of this section was similar to the preceding region except that cell division was probably accelerated by higher temperature. The maximum rate of cell division, with a generation time of less than 10 hours and possibly as low as 6 hours was estimated for the second quarter of this region. At the same time, the average cell length nearly doubled to give a sharp peak of total growth. Enlargement continued and cell division slowed in the third and ceased in the fourth quarter of the second millimeter. Average protein nitrogen per cell in the second millimeter was double that in the first and average cell length was not quite double. Rapid protoplasm synthesis was indicated.

The third millimeter grew by enlargement only, at a rate one-third less than the combined effects of cell division and enlargement in the second section. Total nitrogen per cell unit doubled again over the second section but cell length increased merely three times. Protein synthesis began to lag. The hydration index (water/dry matter) increased from 4.2 in the first millimeter to 5.2 in the second and 6.8 in the third. This increased hydration was accompanied by an accumulation of soluble nitrogen and sugars which would tend to induce hydration by vacuolation. The change in the hydration ratio reached a maximum between the third and fourth millimeters where it jumped from 6.8 to 11.8. At the same time, dry matter, protein, ash, and most cell

¹ Doctoral thesis number 1042, submitted March 14, 1950.

constituents except sugar and cellulosic materials decreased on a cell unit basis, indicating rapid vacuolation.

Because of the inevitable time lag in growth measurements, the enlargement rates assigned to the third millimeter occurred for the most part in the fourth millimeter. For the same reason the low growth totals shown for the fourth millimeter mean a short period before the fourth millimeter became the fifth, rather than a slow rate. Cell length increase between the fourth and fifth millimeter was the second largest observed. Since no measurable growth was recorded in the fifth millimeter, the changes in this and succeeding sections were considered to be confined to differentiation reactions, among which the increase of cellulosic materials was notable.

It has already been indicated (1) that the rates of cell division in the first and second millimeters were increased by temperature changes from 15 to 25°C. Specific division rates for the two temperatures were 0.035 and 0.055 in the first millimeter, and 0.036 and 0.092 in the second, over a 3-hour interval. A possible rate of 0.126 was estimated for the distal part of the second millimeter.

The rate of cell enlargement also showed high temperature coefficients; on the order of 3-4 for a rise of 10°C. in the third millimeter where no cell division occurred. This coefficient indicated that chemical rather than physical reactions were limiting for cell elongation processes (2). Root tip sections held in aerated water showed small water absorption. The same sections held in 2 per cent sucrose solution absorbed a little more water than the checks, but sections in indoleacetic acid, and particularly in indoleacetic acid plus sucrose increased 50 per cent in fresh weight in one hour and their hydration ratio doubled. Cell enlargement would seem to be limited by enzymatic reactions affected by the presence of auxins. These reactions possibly involved the lengthening of the cellulose micelles of the cell wall in such a way as to allow further expansion of the entire cell.

Division of rapidly vacuolating cells was not detected in the meristematic tissues of primary maize roots. This observation suggests the occurrence, at specific radicle levels, of irreversible changes in the nature of the meristematic development. The protein material in the apical two millimeter section was relatively dense, as shown by the small cells with their high protein content and viscosity. With hydration, the structure of the proteins may be irreversibly altered, somewhat in the manner shown *in vitro* (4) for films of a number of proteins. The general level of metabolic and particularly of structural activity might be reduced by the tendency of protein molecules to unfold when hydrated. Such changes in protein structure may account for the failure of hydrated protoplasm to continue division.

AVAILABLE COMPOUNDS

Total reducing substances after hydrolysis with invertase showed the expected gradient, being highest nearer the endosperm source and

lowest in the apical section. Soluble nitrogen, which may be considered to be a translocation form, did not show the same pattern but was highest in the third millimeter section and lower both apically and basally from this region. Concentrations here suggested synthesis of proteins in the zones of division and digestion in the third and later zones. There is evidence (3) that storage proteins are retranslocated only after digestion to simpler water soluble forms and that the various soluble organic materials are more or less interchangeable in their effects on growth. A sharp decline in soluble nitrogen with the corresponding increase in colloidal nitrogen may be indicative of optimal environmental conditions required for the condensation of simple nitrogenous compounds into proteins and new protoplasts.

RESPIRATION

Respiration measurements on the isolated meristematic regions of primary maize roots led to the differentiation of each growing region in terms of their distinct respiratory activities. Endogenous respiration tended to be highest in the zone of cell enlargement, but differences were surprisingly small and the rate in the zone of differentiation was almost as high as either of the others. Exogenous respiration rates showed that the relatively high rate of the differentiation zone was due to its high sugar content. The endogenous respiration decreased consistently with time after cutting. This trend suggested that the endogenous rate of respiration depended largely on a steady supply of substrate from the seed. The greater susceptibility to cyanide and iodoacetate inhibition in the enlargement zone indicated basic differences in the nature and activity of the respiratory systems operating in these zones.

SUMMARY

The temperature coefficients for cell enlargement, the relatively large accumulation of soluble nitrogen, the high respiration rate and the sensitivity to inhibitors, provided several indications that the meristematic regions of primary maize roots undergoing cell enlargement included the most active centers of the root in many metabolic functions.

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NEW TITRIMETRIC METHODS FOR THORIUM¹

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Of the large number of methods which have appeared in the literature for the determination of thorium, practically all are based on precipitating the thorium in some form from an acid or neutral solution and completing the determination by a gravimetric method. The precipitate is either ignited to the dioxide directly or dissolved and the thorium precipitated as the oxalate after which it is converted to the dioxide by ignition. The work being reported, in which successful titrimetric methods for thorium are described, was prompted by the need for a rapid and accurate method for determining thorium in various alloys and mixtures.

ADSORPTION INDICATOR METHODS

Thorium nitrate solutions were titrated with various precipitating agents such as ammonium paramolybdate, phenylarsonic acid, ammonium phosphate, and potassium pyrophosphate using such indicators as methyl violet, phenosafranin, rhodamine 6G, and tartrazine. None of the above combinations gave a satisfactory end-point.

OXIDIMETRIC MOLYBDATE METHOD

A new titrimetric method for thorium has been developed which is based on the quantitative precipitation of thorium as the normal molybdate and the subsequent reduction and titration of the molybdenum that is combined with the thorium.

The general procedure for the determination of thorium is given below. Samples containing 0.15 to 0.2 g. thorium dioxide are weighed out and placed in 250 ml. beakers. After the samples have been dissolved any large excess of mineral acid is destroyed by evaporating the solutions nearly to dryness. The samples are then diluted to 150 ml. with water and made about 7 per cent in acetic acid by adding 11 ml. of glacial acetic acid. Fifteen ml. of thick filter pulp and 1 ml. of a diphenylcarbazide solution (0.5 g. per 200 ml. 95 per cent ethanol) are added. The ammonium paramolybdate solution (7.6 g. per liter) is added from a buret with stirring until the indicator imparts a deep pink color to the solution. After the precipitates have settled the supernatant liquid may be tested for complete precipitation. The contents of the beakers are heated to boiling and filtered while hot through

¹ Doctoral thesis number 811, submitted August 21, 1946.

11 cm. Whatman No. 42 filters into 400 ml. beakers. The precipitates are washed 5-6 times with hot 1:100 acetic acid. The 250 ml. beakers need not be scrubbed out with a policeman but only carefully rinsed out 2-3 times with wash solution. The washed precipitates and filters are transferred to the 250 ml. beakers in which the precipitations were carried out and 25 ml. of concentrated hydrochloric acid added to each beaker. The contents are stirred until the filters disintegrate. Seventy-five ml. of water is added, the mixtures heated to boiling (long boiling results in reduction of molybdenum and decomposition of the filter pulp) and filtered, while hot, through 11 cm. Whatman No. 42 filters into 400 ml. beakers. The filter pulp and filters are washed 5-6 times with hot 1:100 hydrochloric acid. The filtrates after being cooled to room temperature, are passed through an amalgamated zinc Jones reductor into an excess (five times the theoretical of 10 per cent) of ferric alum to which 2-3 ml. of concentrated phosphoric acid has been added and titrated with 0.1 N ceric sulfate using two drops of ferroin as indicator. The end-point is taken as that point when the pink color of the solution changes to colorless or blue.

This method has been found to be very useful in the separation of thorium from calcium and uranium. One hundred seventy mg. of thorium dioxide can be separated from as much as 400 mg. of calcium and determined to within less than two parts per thousand. The addition of ammonium acetate is necessary in the case of uranium to prevent the precipitation of uranyl molybdate. The same amount of thorium dioxide can be separated from 200 mg. of uranium oxide, U_3O_8 , and determined to within four parts per thousand.

The separation of thorium from rare earths such as lanthanum, cerium, samarium, neodymium, and also yttrium was tried with various acetic acid concentrations and at various temperatures but quantitative separation was not obtained.

Molybdenum can be determined by reversal of the above method. Thus 140 mg. of molybdenum trioxide, MoO_3 , can be conveniently separated from 240 mg. of uranium oxide, U_3O_8 , by precipitating it as thorium molybdate from a 7 per cent acetic acid solution containing ammonium acetate. The molybdenum can be determined to within three parts per thousand.

ELECTROMETRIC METHODS

The possibility of detecting the end-point electrometrically when thorium is titrated with ammonium paramolybdate was investigated and found to be very promising. Of the various conditions tried for this titration the best was a 7 per cent acetic acid solution at 50°-55° with a 0.1 N calomel reference electrode and a molybdenum wire indicator electrode.

This electrometric method was found to be very useful for determining thorium in the presence of calcium. One hundred fifty mg. of thorium dioxide can be determined in the presence of as much as 400 mg. of calcium with an error of about three parts per thousand.

OXIDATION OF L-TYROSINE BY LIVER TISSUE¹

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Previous work on the metabolism of L-tyrosine has failed to disclose many of the important features involved. In the present work the fate of the nitrogen of tyrosine when the amino acid is oxidized by normal guinea pig liver tissue is the primary issue. As a tool for studying this problem, tyrosine containing isotopic nitrogen (N^{15}) has been synthesized.

The method of synthesis was an adaptation of the "azlactone synthesis" of Herbst and Shemin, by which they synthesized phenylpyruvic acid. Since the intermediate required for the introduction of isotopic nitrogen for our work was *p*-hydroxyphenylpyruvic acid, the following modifications were made: 0.37 moles of *p*-hydroxybenzaldehyde, 0.4 moles of acetylglycine, 0.3 moles of anhydrous sodium acetate and 1.33 moles of acetic anhydride were refluxed for five hours to produce the corresponding azlactone, 2-methyl-4-(4'-acetoxybenzal)-5-oxazolone. This compound was converted to *p*-acetoxy- α -acetamino-cinnamic acid by refluxing with acetone and water. Hydrolysis of this with 1 *N* hydrochloric acid afforded the desired *p*-hydroxyphenylpyruvic acid. The yields of these three steps were 66, 94, and 53 per cent, respectively.

The isotopic nitrogen was introduced into the molecule by catalytic reduction of the *p*-hydroxyphenylpyruvic acid at low pressure in the presence of ammonia containing N^{15} . This produced N^{15} -DL-tyrosine in 73-90 per cent yields.

Since the natural L-isomer was desired for our work, an attempt was made to resolve the isotopic DL-tyrosine by converting it to acetyl-DL-tyrosine and fractionally crystallizing the brucine salt. This method was not satisfactory under the conditions employed, and a new resolution method was developed. This new method involved fractional crystallization of the salt N^{15} -acetyl-L-tyrosine-*d*- α -phenylethylamine from absolute ethanol. This salt was obtained in 43-60 per cent yields in optically-pure form after only two or three crystallizations. From this salt the N^{15} -L-tyrosine was obtained in 76 per cent yield.

The N^{15} -L-tyrosine was incubated with normal guinea pig liver homogenate in the Warburg respirometer. The deproteinized incubation mixture was then fractionated and the different fractions investigated for isotopic nitrogen content. In an effort to prove or disprove a previous theory that the amino acid, alanine, is formed on an equimolar basis when tyrosine is oxidized by liver tissue, normal alanine was added to

¹ Doctoral thesis number 1006, submitted November 23, 1949.

the incubation mixture as a carrier and alanine then isolated as the salt of azobenzene-*p*-sulfonic acid. This derivative was purified and the N^{15} content determined on the mass spectrometer. Other fractions analyzed included a room-temperature precipitate with the azobenzene-*p*-sulfonic acid, a fraction adsorbed to barium acetate and barium sulfate, and butanol-soluble and butanol-insoluble fractions.

The atoms per cent excess N^{15} of each fraction was converted to milligrams of excess N^{15} in order to calculate the yield of isotope found in each fraction. All fractions had negligible isotope content except the butanol-insoluble fraction, which had 20.99 per cent of the isotope present in the reaction, and the alanine-azo-benzene-*p*-sulfonate salt, which had 99.84 per cent of the isotope present. The butanol-insoluble fraction probably included some unreacted N^{15} -L-tyrosine.

Previous experiments with tyrosine labeled with radioactive carbon in the α -position of the side chain had proved conclusively that the side chain of tyrosine and part of the benzene ring contribute to acetoacetic acid formation in the oxidation of this amino acid. Therefore there are only two possibilities for formation of alanine from tyrosine under normal oxidative conditions. One, oxidative deamination to form *p*-hydroxyphenylpyruvic acid and ammonia; and two, transamination, in which the amino group is passed from the tyrosine to α -ketoglutaric acid to form glutamic acid, and from the glutamic acid to pyruvic acid to form alanine. In the first case, the ammonia so formed presumably would react with pyruvic acid to form the alanine. The presence of glycogen in liver homogenates has been noted in our experiments. The large uptake of oxygen upon incubation of liver homogenates without added amino acid as substrate indicates a very active glycolysis, which would provide more than adequate concentrations of α -ketoglutaric acid and pyruvic acid for either mechanism suggested.

Feeding experiments also were conducted with the N^{15} -L-tyrosine. A guinea pig was fed a scorbutigenic diet supplemented with the isotopic tyrosine, a scorbutigenic diet supplemented with isotopic tyrosine and ascorbic acid, and the same diet supplemented with isotopic tyrosine and pteroylglutamic acid. The urine was fractionated into ammonia, urea, and residual nitrogen for isotope analysis.

In all three cases insufficient ammonia was excreted to analyze the N^{15} content. In the control and the vitamin C-supplemented experiments, the isotopic contents of the urine were essentially the same, as were the two urea fractions. The urine from the pteroylglutamic acid-supplemented guinea pig contained about 12 per cent more isotope than did the control; most of this increase was in the urea fraction. It was evident from these preliminary experiments that although vitamin C exerts an influence on the complete oxidation of tyrosine, it apparently does not operate in the step which detaches the nitrogen from the amino acid. Then it is apparent that the mechanism of action of the two vitamins in the tyrosine oxidation scheme is different.

SUMMARY

1. The synthesis of DL-tyrosine containing isotopic nitrogen has been effected in good yields by a four-step process: the azlactone synthesis (52-66 per cent yield); breaking the ring by mild hydrolysis with acetone and water (71-94 per cent yield); acid hydrolysis to obtain *p*-hydroxyphenylpyruvic acid (48-53 per cent yield); and catalytic hydrogenation of the substituted pyruvic acid in the presence of isotopic ammonia (73-90 per cent yield).

2. N¹⁵-Acetyl-DL-tyrosine has been resolved by the use of *d*- α -phenylethylamine to give yields of 43-60 per cent of the salt of the L-isomer, from which N¹⁵-L-tyrosine was isolated in 77 per cent yield.

3. The isotopic tyrosine was oxidized *in vitro* by guinea pig liver homogenate, and alanine subsequently isolated from the reaction mixture as the azobenzene-*p*-sulfonate salt.

4. Isotopic analysis of the isolated compound showed that almost all of the N¹⁵ from the tyrosine was contained in the alanine derivative.

5. Isotopic tyrosine was fed to guinea pigs on scorbutigenic diets with and without supplements of ascorbic acid and pteroylglutamic acid, and the urine and feces examined for isotopic nitrogen content. These experiments indicated that the vitamins apparently have little effect on the disposal or fate of the amino-nitrogen of tyrosine.

EFFECT OF BENZENE AND SIX SELECTED SALICYLATES
ON THE DEVELOPMENT OF IMMUNITY IN
TRYPANOSOMA LEWISI INFECTIONS¹

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A study was made of the effect of benzene, ethyl alcohol², and six salicylates on the development of immunity to *Trypanosoma lewisi* infection in albino rats. Certain aspects of the blood picture were followed.

Bartonella-free, Wistar A rats were infected with Becker's strain of *Trypanosoma lewisi* by the intraperitoneal injection of diluted blood containing over 100,000 parasites. Methyl salicylate (0.1 to 0.2 ml.), acetylsalicylic acid (45 to 98 mg.), para-aminosalicylic acid (50 to 100 mg.), phenyl salicylate (45 mg. per 100 g.), sodium salicylate (45 mg. per 100 g.), salicylic acid (45 mg. per 100 g.), benzene (approximately 0.2 ml. per 100 g.), benzene (0.1 to 0.2 ml. per 100 g.) plus sodium salicylate (45 mg. per 100 g.), or 35 per cent ethyl alcohol (2.0 ml.) was administered daily throughout the course of the infection to test rats by stomach tube. Test substances were suspended in a 12 per cent aqueous solution of gum arabic or were dissolved in distilled water or 35 per cent ethyl alcohol. Comparable amounts of the carrier substance were administered daily to *Trypanosoma lewisi*-infected control rats by stomach tube.

Tail blood was examined on the day of inoculation of trypanosomes, on the third day of the infection, and on alternate days thereafter. Total trypanosome counts were made by the standard hemacytometer method for counting leucocytes. Hemoglobin concentration of the blood was determined with the use of a Spencer Hb-meter. Blood smears were stained with Wright's blood stain and were used in making differential leucocyte counts, determinations of the percentage of dividing trypanosomes (blepharoplast dividing or divided), and, occasionally, calculations of standard deviation for total length of trypanosomes. Standard deviation was calculated by the method of Taliaferro and Taliaferro (1922) (1). Total trypanosome counts served as an index of the effectiveness of the trypanocidal antibody. The percentage of dividing parasites (division forms) and the standard deviation for total length

¹ Doctoral thesis number 1035, submitted March 11, 1950.

² Ethyl alcohol was administered to a few test rats, since it was used as the solvent for acetylsalicylic acid in two experiments, and there was some question as to the effect it might have on the development of immunity.

of trypanosomes served as indices of the anti-reproduction (parasite) resistance factor, ablastin.

Control rats responded to the protozoon by developing three types of immune bodies: (1) Taliaferro's ablastin, which appeared early in the infection and prevented further multiplication of the trypanosome; (2) Taliaferro's trypanocidal substance, which appeared within a short time after ablastin had produced its effect, and killed many of the adult trypanosomes by lytic action; and (3) a trypanosome-agglutinating substance, which became effective about the same time as the trypanocidal factor and also seemed to be instrumental in removing the adult trypanosomes from the blood stream.

Infections in para-aminosalicylic acid-treated rats and in ethyl alcohol-treated rats were essentially like control infections. All other test substances altered the typical course of the trypanosome infection by affecting the development of host-resistance to the parasite.

Methyl salicylate, acetylsalicylic acid, phenyl salicylate, sodium salicylate, salicylic acid, and benzene plus sodium salicylate partially or completely inhibited both ablastic action and the agglutination of the trypanosomes in the blood. The above test substances seemed to have no effect on the trypanocidal factor. Infections in rats treated with the test substances listed above were characterized by continued reproduction of the parasites throughout the course of the infection and by extremely dense trypanosome populations, with the time of the peak of the infection delayed. The infection in many of the treated rats took a pathogenic course, either of the continuous or of the relapsing type. The infection was prolonged in test rats which recovered.

Benzene, alone, partially inhibited the production of the trypanocidal resistance factor but had no effect on the elaboration or action of ablastin or of the trypanosome-agglutinating substance. Benzene-treated infections were characterized by cessation of parasite reproduction at the expected time and by larger-than-control trypanosome populations. Benzene-treated infections were also definitely prolonged.

Certain deviations from the normal blood picture were noted regularly for the majority of *Trypanosoma lewisi*-infected rats, control as well as test, except for those treated with benzene or with benzene plus sodium salicylate. The deviations seemed to be attributable directly to the trypanosome infection rather than to the treatment except as the latter influenced the size of the trypanosome population. They included: (1) an occasional slight increase in hemoglobin; (2) a reduction in the hemoglobin concentration of the blood which seemed to be directly proportional to the density of the trypanosome population (also observed for rats treated with benzene plus sodium salicylate); (3) an initial leucopenia; (4) a leucocytosis which was evident by the peak of the infection and which persisted until the parasites disappeared from the blood; (5) a slight increase in the incidence of mononuclear leucocytes as the infection progressed; (6) a comparable slight relative decrease in neutrophils; and (7) a slight increase in the incidence of

basophils (also observed for rats treated with benzene or with benzene plus sodium salicylate). The incidence of eosinophils was unaffected by the trypanosome infection.

Benzene, alone, markedly affected the hemoglobin concentration of the blood and the total and differential leucocyte counts. Benzene treatment was accompanied by fluctuating increases and decreases in hemoglobin and by sharp reductions in the total leucocyte count and in the percentages of mononuclear leucocytes and eosinophils. The relative number of neutrophils increased as the percentage of mononuclears decreased. The incidence of basophils was unaffected by benzene treatment, but was affected by the trypanosome infection.

Benzene plus sodium salicylate indirectly affected the hemoglobin concentration of the blood by virtue of the sodium salicylate effect on immunity, which favored a large trypanosome population. The effect of benzene on hemoglobin was not evident. However, the typical benzene effects on total and differential leucocytes, described above, were noted, the incidence of basophils again being affected by the infection rather than by treatment with benzene plus sodium salicylate.

The literature review includes: (1) a discussion of the typical *Trypanosoma lewisi* infection in non-treated rats following intraperitoneal injection of the parasites; (2) the most important theories regarding the nature of the rat's immunity to the trypanosome; (3) general effects of salicylates and of benzene on mammals; and (4) the effect of salicylates, benzene, and alcohol on the development of immunity.

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APPLICATION OF SPRAY DRYING PRINCIPLES TO THE DESOLVENTIZATION OF MISCELLA ¹

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The desolventization of miscella (mixtures of soybean oil and trichloroethylene) by application of the principles of spray drying was investigated to ascertain if this method could insure stripped oil of higher quality at an operating cost less than that of conventional methods. High quality oil depends, among other things, on a low fraction of red color which in turn demands that even rather short exposure to high temperatures be avoided. Vaporization from a particulate system occurs at the boiling point of the solvent under the conditions of atomization, and for the miscella studied the trichloroethylene solvent will evaporate at 52.5°C. under 20 inches Hg vacuum. If a correct particle path has been selected the remaining oil after vaporization of the solvent need not be heated appreciably above 55°C.

While spray drying has been applied to almost every conceivable case involving desiccating, concentrating, or desolventizing a solution or suspension, until the time of this investigation no known application had been made to the separation of vegetable oil from the solvent which had been used to extract it from the seed. The feasibility of such application was shown and the investigation should pioneer further work in this field. Consequently, an exhaustive literature survey was made to gather related material on the theory and practice of spray drying as an aid to future workers. Very few references on the transfer of heat to particulate systems were found which possessed sufficient merit to be included in the survey.

Of the several types of spray nozzles studied only one was found suitable for semi-pilot plant research. The essential feature of the hydraulic nozzle selected was its nonclogging performance at relatively low feed rates. It was concluded that a centrifugal disc atomizer would yield more satisfactory and uniform operation than any of the various other atomization devices.

The minimum dimensions of an operable spray chamber were found to be those of a cylinder 2 feet in diameter and 4 feet high, containing a cone bottom whose vertical axis measured 1 foot. For the small scale of operations employed it was found desirable to add an internal heating coil of copper tubing pressed against the inner surface of the upper portion of the chamber.

¹ Doctoral thesis number 1011, submitted December 10, 1949.

Direct superheated steam at temperatures to 357°C. was employed as the dessicant with no noticeable effect on the oil quality. Even though the optimum degree of contact between the steam and particle cloud was not attained, nevertheless the steam requirements were found to be about one-half those in conventional desolventization methods. Further investigations of the method by which the dessicant may be introduced to the particles should be made.

The relation between vapor pressure and temperature was studied for several concentrations of miscella between 30° and 90°C. Between concentrations of 0 and 20 weight per cent oil the vapor pressure above the miscella was found to be consistently higher than that for pure trichloroethylene alone. Above 20 per cent oil the vapor pressure decreased but still remained above that for pure trichloroethylene over a concentration range dependent on the temperature. Similar variation was noted in the relation of the refractive index to the concentration.

A section is included which brings together many properties and relations of pure trichloroethylene, pure soybean oil, and the system: trichloroethylene-soybean oil. Such grouping has not been done heretofore and will facilitate future work in the field.

PASTURAGE AND ENVIRONMENTAL TEMPERATURE EFFECTS ON THE DEGREE OF UNSATURATION OF COW MILK FAT¹

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In a previous trial at this station, Frye (1) found that the environmental temperature to which cows were subjected was highly correlated with the iodine numbers of the milk fat they produced. In the light of these results a study was initiated to determine whether or not the great increase in milk fat unsaturation attending pasturing of cows results wholly from ingestion of pasture or is in part the result of higher temperatures characteristic of the grazing season.

Three lots of four cows were used. The four cows in each lot freshened at approximately the same time of the year, but each lot freshened at a different time of the year. This type of cow selection was employed with the hope that it might be possible to separate the effects produced by lactation from those that might result from temperature. Of each quartet, two cows were fed prairie hay and grain mixture (stall-fed) throughout the experiment; the other two were pastured and fed a grain mixture during the grazing season. The pasture group grazed at night only; the stall-fed group was placed in a drylot during the time the other group was on pasture in order to keep temperature effects as nearly alike as possible between the two groups. Both groups were kept in the barn during the day. Daily records of the environmental temperature were kept. Iodine and thiocyanogen values were determined on the milk fat resulting from a daily composite sample collected from each animal at approximately six-day intervals.

The data reveal that pasture and stage of lactation have primary influences on the degree of unsaturation of milk fat while changes in temperature appear to be of little importance.

Production of fats with a high iodine value at the peak of milk production followed by a decline in the iodine value (ca. 8 iodine units av.) to the fourth or fifth month of lactation and then a slight increase (ca. 3 iodine units av.) to the end of lactation appear to be definite lactation trends in the majority of the animals. These trends appear regardless of seasonal changes in temperature. The changes in iodine value were largely dependent on the changes in the oleic acid content of the milk fat. The percentage of linoleic acid decreased slightly in a linear manner during the lactation period.

Pasture feeding (measured in periods in which the effect of lacta-

¹ Doctoral thesis number 980, submitted July 13, 1949.

tion was at a minimum) increased the iodine value an average of 5 units. This increase was sustained throughout the period (in some instances 3 months) during which the cows were on pasture. When pasture was removed from the diet, the iodine value dropped rapidly to values that might be considered normal. Pasture feeding had little effect on the linoleic acid content of the milk fat. Changes in iodine value were largely dependent on the changes in the oleic acid content of the fat.

The high correlations between temperature and iodine value found by Frye can now possibly be explained as resulting from coincidence of lactation and temperature trends. A study of the freshening dates of the animals used by Frye indicate that this is likely.

A composite sample of milk fat was obtained from the cows in the college herd (approximately 120 cows) on the same dates that samples were collected from the experimental animals. The iodine value of the milk fat increased when the herd was pastured. This increase was not maintained. The iodine value gradually declined as the pasture season progressed. The herd cows were fed corn silage during the grazing period in addition to pasture. Since the six experimental cows which received pasturage but no silage during the grazing season maintained high iodine values throughout this period it was suspected that the decline in the iodine value of the herd sample during pasturage resulted from feeding corn silage. The possibility of decreasing summer milk fat unsaturation by feeding silage during the grazing season should be investigated.

In an attempt to obtain some information as to the cause of the high degree of unsaturation of milk fat resulting during pasturage and in early lactation, the following brief experiment was conducted. Thyroprotein was fed alternately to two cows to learn what effect an increased metabolic rate (resulting from thyroprotein feeding) would have on the iodine value of milk fat, since the metabolic rate of lactating cows is believed to be high during early lactation and during the pasture season. Thyroprotein caused the iodine value of the milk fat of one animal to be increased 6 units during the first 11 days of thyroprotein feeding. Thereafter the iodine value decreased and returned to the pre-thyroprotein level about 20 days later although thyroprotein continued to be fed. The increase in iodine value occurred during the period when the animal was losing body weight. The second cow was fed extra feed during thyroprotein administration. The iodine value of her milk fat increased 7 units after thyroprotein feeding. This increase was sustained for a period of 24 days (to the end of the experiment). This animal decreased in body weight during the first 14 days during thyroprotein feeding. However, the highest iodine values were found when the weight of the animal had stabilized. The extra feed supplied to this animal was thought to cause the iodine values to remain high. Since extra feed will increase the metabolic rate of cows fed thyroprotein (2) it was

thought that an increased metabolic rate of this animal was a factor responsible for increasing the iodine value of her milk fat.

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CERAMIC APPLICATIONS OF ZEOLITES ¹

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Synthetic zeolites have been used in the making of ceramic glazes but no actual comparison had ever been made or reported between glazes containing zeolite and glazes of the same identical chemical composition but made without zeolite. To make such a comparison, colored glazes were compounded using zeolites which had been treated with ion-bearing solutions, such ions being capable of producing ceramic colors. Other glazes were compounded whose ultimate melted compositions were identical with the zeolite bearing glazes, but in which were used feldspar and color-producing metallic oxides. All of these glazes received the same treatment and were fired to the same temperature for comparison. A cone 4 base glaze was used throughout.

0.60 PbO		
0.20 Na ₂ O	0.4 Al ₂ O ₃	2.4 SiO ₂
0.20 CaO		

The use of zeolite as a medium for carrying coloring ions in glazes which were never ground in a ball mill was also investigated. Zeolite and oxide-bearing feldspar glazes of the same composition were compared for advantages and disadvantages, both glazes being merely mixed in a high speed mixer, but neither was ground in a ball mill.

In an attempt to minimize or completely overcome some slight difficulties arising from the incorporation of zeolite into the glazes, mainly excessive shrinkage sometimes resulting in tearing and crawling, studies were made on the stabilization of zeolite. This was attempted both by use of heat treatment and by acid leaching. The temperature necessary to render the zeolite to such a state as to be unable to exchange ions was also determined.

A study was made of the effects of zeolite used as a deflocculant upon clay casting slips. These slips were compared insofar as pH and viscosity were concerned with slips of the same base composition and water content, but with sodium carbonate used as the electrolyte to

¹ Doctoral thesis number 1020, submitted December 14, 1949.

produce deflocculation. The composition used was that of a ceramic body previously found to be castable.

English China Clay	38
English Ball Clay	10
Feldspar	30
Whiting	2
Flint	20

A zeolite was prepared by leaching of sodium zeolite with hydrochloric acid until evidence of the aluminum in the leach water was found. After rinsing until chloride free, this material was found able to absorb sodium ions from dilute solutions. This material was added to over-deflocculated casting slips in an attempt to remove the excess sodium ions which produced the over-deflocculation. The sodium ions were present as a result of additions of sodium carbonate to the slip in order to produce over-deflocculation.

As a result of the work done to investigate the use of zeolite in ceramic glazes the following facts have been established:

1. The zeolite-bearing glazes were of excellent color, varying from pastels to darker shades. It was difficult, however, to establish with the means available that these glazes were superior in color intensity or color distribution to the glazes made in the conventional method.

2. The zeolite did materially aid in the melting of the glazes. At lower temperatures the zeolite glazes were less viscous than the feldspar glazes. At higher temperatures, since the compositions were identical, the melted glasses formed had equal properties for both types of glazes.

3. The zeolite glazes exhibited less pinholding and the presence of fewer bubbles than did the feldspar glazes fired to the same temperatures. This is a result of the higher rate of fusion afforded by the use of zeolite instead of feldspar.

4. Some of the feldspar glazes fired to lower temperatures had matte appearances indicating undissolved material, whereas the corresponding zeolite glazes fired to same temperatures had no or only slight matte appearances. This is also related to the ease of fusions.

5. The zeolite glazes had a greater range of firing temperatures than the feldspar glazes. This was exhibited by the fact that the feldspar glazes fired to lower temperatures were not completely in solution. This resulted in their becoming crazed after short periods of time. The zeolite glazes indicated no tendencies toward crazing.

6. The ease of crushing and grinding of the zeolite when the glaze was milled was beneficial in aiding the melting process. The extremely fine particle size of the zeolite did result in a tendency of some of the glazes to tear on drying and crawl on subsequent firing. This was minimized by correct application procedure and eliminated by sufficient heating of the zeolite prior to incorporation in the glazes.

7. Glazes of excellent color distribution and intensity can be pro-

duced, by use of zeolites, in glazes which have never been milled. Glazes made of feldspar and coloring oxides had speckled appearances, indicating poor color distribution. The advantage of the zeolite in this type of glaze is very apparent and could well lead to a new method of glaze formation.

Studies were made on the stabilization of zeolites from which the following conclusions were drawn:

1. Unwashed stock zeolite contains sodium carbonate which can interfere with the expected behavior of the zeolite. It is best removed by means of acid leaching with dilute acid.

2. All of the water of hydration of zeolite is completely removed by heating to a temperature of about 400°C., most of it being lost prior to this temperature.

3. It is necessary that zeolite be heated to 950°C. for at least 5 hours or to 1000°C. for at least 3 hours to prevent the release of sodium upon subsequent grinding.

4. The use of dialysis as a means of removing the excess sodium ions present in freshly crushed zeolite is impractical.

Experiments were conducted on the use of zeolites in casting bodies. The following results are known:

1. Zeolite can be used satisfactorily and to an advantage as a deflocculant of clay casting slips. The zeolite is able to furnish the needed sodium ions and at the same time adsorb the undesirable calcium, magnesium, or other ions.

2. Casting slips deflocculated by zeolite have lower pH values for the same water content and viscosity than do the slips deflocculated by sodium carbonate.

3. The zeolite had a greater range of additions than did the sodium carbonate used for comparison. Five times as much zeolite as the theoretical minimum for deflocculation could be added. Increasing the minimum amount of sodium carbonate by one-third resulted in an over-deflocculated slip.

4. The treatment of zeolite with hydrochloric acid resulted in a zeolite capable of adsorbing sodium ions and lowering the viscosities of over-deflocculated slip.

5. The use of such a zeolite as mentioned (4) is governed by the particle size, the time allowed for reaction, and the amount of agitation or intimate mixing to insure complete ion exchange.

6. The use of a zeolite which can adsorb sodium ions should prove valuable in other fields as very few methods are available for the removal of sodium ions from solutions.

REACTIONS OF ORGANOMETALLIC COMPOUNDS WITH SOME BENZOTHIAZOLE AND QUINOLINE TYPES¹

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The reactions of benzothiazole with organometallic compounds and the preparation of organometallic derivatives of benzothiazole have not been seriously investigated up to the present time, though Courtot and Tchelitcheff (1) have reported the metalation of benzothiazole by ethylmagnesium bromide. It was the purpose of this investigation to see if benzothiazole would form synthetically-useful organometallic derivatives and, also, if addition of organometallic compounds to the azomethine linkage of benzothiazole could be employed in the synthesis of 2-substituted benzothiazoles. In an attempt to explain some of the results obtained, certain 2-substituted quinolines were subjected to reactions with organometallic compounds. The literature review, therefore, was concerned with the activity of substituents, in the 2- and 4-positions of quinoline and pyridine, the 2- position of benzothiazole, and the 1- position of isoquinoline.

Benzothiazole was metalated in 90 per cent yield by *n*-butyllithium at -75° , and the resulting 2-benzothiazolyllithium was not stable above -35° (bath temperature). 2,2'-Bibenzothiazole was obtained in 44 per cent yield as one of the decomposition products. 2-Benzothiazolyllithium reacted with aldehydes, ketones, nitriles, and carbon dioxide to yield the expected products, but only a trace of 2-benzothiazolyl phenyl ketone was obtained from benzoyl chloride; no 2-benzylbenzothiazole was obtained from benzyl chloride; and no reaction was obtained with quinoline. Reactions which did not take place below -35° were complicated by decomposition of the 2-benzothiazolyllithium above this temperature. Under the same conditions that resulted in 90 per cent metalation of benzothiazole, quinoline gave an 84 per cent yield of 2-*n*-butylquinoline. Benzoxazole may have metalated under similar conditions, but attempts to detect the 2-benzoxazolyllithium by carbon dioxide and benzophenone, respectively, were unsuccessful.

Phenyllithium reacted with benzothiazole at 0° or above to yield some 2-phenylbenzothiazole. The yield was lower if 1 mole of phenyllithium was used than if 2 moles were used. The highest yield of purified 2-phenylbenzothiazole was 31.7 per cent. This was obtained from 2 moles of phenyllithium to 1 mole of benzothiazole at 0° for 1 hour. The reaction may have proceeded either by addition to the azomethine

¹ Doctoral thesis number 978, submitted July 8, 1949

linkage, if the phenyllithium added to the benzothiazole before metalation, or possibly by cleavage of the sulfur-carbon bond, if the reaction was between phenyllithium and 2-benzothiazolylithium.

Phenyllithium reacted with 2-phenylbenzothiazole to yield bis-(*o*-aminophenyl) disulfide (7.70 per cent) and triphenylmethanol (8.36 per cent). This reaction probably involved both addition to the azomethine linkage and cleavage of the sulfur-carbon bond.

It was found that *p*-tolyl 2-quinolyl sulfide was cleaved at room temperature by phenyllithium to *p*-thiocresol and 2-phenylquinoline in good yield. This led to reactions of phenyllithium and other organometallic compounds (*n*-butyllithium, phenylmagnesium bromide, and phenylcadmium chloride) with other 2-electronegatively substituted quinolines (2-phenoxyquinoline, 2-ethoxyquinoline, 2-allyloxyquinoline, 2-benzyl-oxyquinoline, 2-(*N*-piperidyl)quinoline, 2-chloroquinoline, and 2-benzylquinoline). In most cases, except with phenylcadmium chloride, some 2-phenylquinoline was obtained though the yields with phenylmagnesium bromide were low. Phenylmagnesium bromide did, however, react with 2-chloroquinoline to give a fairly good yield (31.2 per cent) of 2-phenylquinoline (2). Though *n*-butyllithium was the most reactive of the organometallic compounds, the yield of 2-*n*-butylquinoline was not so high as the yield of 2-phenylquinoline from phenyllithium because of more extensive side reactions. One of these side reactions resulted in 2-ethoxyquinoline-3-carboxylic acid, which was isolated from the reaction between 2-ethoxyquinoline and *n*-butyllithium followed by carbonation. The acid was identified by melting point, analysis, and conversion to 2-ethoxyquinoline-3-carboxamide (5), which was identified by a mixed melting point determination. Of the substituted quinolines, the 2-allyloxy- and 2-benzyl-oxyquinolines showed the most side reactions. The 2-(*N*-piperidyl)quinoline was least reactive, and the 2-benzylquinoline, which was prepared from benzylsodium and quinoline, did not react. The reaction which results in cleavage may proceed by addition to the azomethine linkage or by a nucleophilic displacement.

Phenylcadmium chloride apparently gave a complex with quinoline, but, under the conditions of the experiment, did not form any 2-phenylquinoline. Phenylcadmium chloride did react with quinoline methiodide as does phenylmagnesium bromide to yield 58 per cent of *N*-methyl-2-phenyl-1,2-dihydroquinoline (4).

p-Tolyl 2-quinolyl sulfide (3) was prepared from 2-chloroquinoline and lithium thiocresoxide (80 per cent yield) and lead thiocresoxide (75 per cent yield), respectively. After crystallization from petroleum ether (b.p. 60–70°) the product melted at 68°.

2-(*N*-Piperidyl)quinoline was prepared from 2-chloroquinoline and lithium piperidide in 36.2 per cent yield and from 2-chloroquinoline and piperidine in 81.6 per cent yield. The melting point after crystallization from petroleum ether (b.p. 60–70°) was 51°.

The compounds prepared from 2-benzothiazolylithium and aldehydes, ketones, and benzonitrile are listed below:

α -(*p*-dimethylaminophenyl)-2-benzothiazolemethanol (59.6 per cent yield) was recrystallized from benzene and melted at 157°; α -(*n*-propyl)-2-benzothiazolemethanol (55.7 per cent yield) melted at 82° after recrystallizing from petroleum ether (b.p. 77–115°); α,α -di-(*p*-dimethylaminophenyl)-2-benzothiazolemethanol (64.3 per cent yield) melted at 195° after recrystallization from benzene; α -methyl- α -(*p*-tolyl)-2-benzothiazolemethanol (62.9 per cent yield) was recrystallized from petroleum ether (b.p. 77–115°) and melted at 100.5°; α -phenyl-2-benzothiazolemethanol (66.2 per cent yield) melted at 123.5° after recrystallization from 95 per cent ethanol; α -methyl- α -phenyl-2-benzothiazolemethanol (56.0 per cent yield) was recrystallized from petroleum ether (b.p. 77–115°) and melted at 89°; α -(*p*-chlorophenyl)- α -methyl-2-benzothiazolemethanol (53.7 per cent yield) was recrystallized from 95 per cent ethanol and melted at 134–136°; α,α -diphenyl-2-benzothiazolemethanol (80.0 per cent yield) melted at 150° after recrystallization from absolute ethanol; di-(2-benzothiazolyl)phenylmethanol (61.5 per cent yield) melted at 150° after recrystallization from absolute ethanol; 2-benzothiazolyl phenyl ketone (71.1 per cent yield) was recrystallized from 95 per cent ethanol and melted at 102.5°. The phenylhydrazone of 2-benzothiazolyl phenyl ketone melted at 149°.

Some generalizations, based on the experimental work, were presented. One was concerned with the relative reactivities of organometallic compounds. The other generalization was concerned with the relative ease of replacement of the electronegative groups in the 2- position of quinoline.

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EFFECT OF HIGH SCHOOL SUBJECT PATTERNS UPON INITIAL
ACHIEVEMENT IN THE CURRICULA OF THE DIVISION
OF AGRICULTURE AT THE IOWA STATE COLLEGE¹

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The greatly increased enrollment during the past few years has brought students with a great variety of high school backgrounds into college. It was the purpose of this study to evaluate the various types of high school background submitted by the students for entrance into the Iowa State College Division of Agriculture. The evaluation was made in terms of the college achievement of the students with the various high school backgrounds. The criteria of achievement were (1) honor point ratio earned in first-quarter agriculture courses; (2) mark received in the initial course in chemistry; and (3) attrition-survival beyond the freshman year. No attempt has been made to define college achievement in terms of intangible benefits to the students such as personal satisfaction. Neither was there any attempt made to evaluate the various types of high school programs in terms of objectives of secondary education.

There were 997 male freshman students who entered the Iowa State College Division of Agriculture during the fall quarters of 1946, 1947, and 1948.

Transfer students, female students, and students for whom records were incomplete were eliminated from the study. The 997 students were classified into four high school pattern groups. All students who had taken three or more units of high school agriculture were designated as vocational agriculture high school students. All students who had taken six or more units of any combination of high school mathematics and science were designated as mathematics-science students. All students who had taken six or more units of high school vocational subjects other than agriculture were designated as other vocational students. All students with other combinations of high school background were designated as general pattern students. Because achievement in agriculture might be related to farm experience each of the foregoing groups was stratified into farm and nonfarm subgroups. The basis of the latter stratification was the father's occupation which the student reported.

For the purpose of making allowances for individual differences in

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student ability, scores made on the American Council on Education Psychological Examination and first marks earned in the initial English course were used.

AGRICULTURE ACHIEVEMENT

Analysis of variance single classification, analysis of variance multiple classification with correction for disproportion among subgroups, and analysis of covariance single classification with American Council on Education Psychological Examination scores and English marks controlled were used to compare the agriculture achievement of the various groups and subgroups. No significant differences could be found in the achievement of the students in the various years. Students with farm backgrounds made significantly greater agriculture achievement than did students with nonfarm backgrounds. Significant differences in agriculture achievement were found among the high school pattern groups. When each high school pattern was compared with all others, the vocational agriculture group was found to have made greater agriculture achievement and the general pattern group was found to have made smaller agriculture achievement than had all other groups combined. The agriculture achievement of the mathematics-science group and the other vocational pattern group did not significantly differ from that of all other groups combined.

Within each high school pattern group the students with farm backgrounds were found to have made significantly better agriculture achievement than had the nonfarm students with the exception of the vocational agriculture pattern group. Within the vocational agriculture pattern group no significant difference in agriculture achievement could be found, between the farm and nonfarm background subgroups. To the degree that the various high school patterns can be evaluated in terms of first-quarter agriculture course achievement, the vocational agriculture pattern gave the best preparation and the general pattern the poorest preparation for college.

CHEMISTRY ACHIEVEMENT

Because the first course in chemistry could be taken at any time during the freshman or sophomore years the students who had entered college in the fall of 1948 had not all taken the first course in chemistry. Therefore, the 1948 group were excluded from the study of chemistry achievement. There was a total of 286 students who entered the Iowa State College Division of Agriculture during the fall quarters of 1946 and 1947 and had taken an initial chemistry course by the fall of 1949.

The first quarter of chemistry was reported as either 100A or 101. Chemistry 100A was the first course of a two-course sequence which dealt with the same subject matter as was presented in Chemistry 101. The marks reported were weighted for evaluation of achievement in an arbitrary 3 to 2 ratio as a compromise between considering quality

of achievement and quantity of material covered by the students in the two courses.

The weighted chemistry marks of the previously described groups and subgroups were compared by techniques similar to those employed in the evaluation of agriculture achievement. It was found that no significant differences in chemistry achievement could be demonstrated between the farm and nonfarm background groups. The farm and nonfarm groups were combined for subsequent analyses. When the chemistry achievement of the various high school groups was compared, significant differences were found. The chemistry achievement of the vocational agriculture, the other vocational and the general high school pattern groups was compared. No significant differences could be found. The previously noted differences in chemistry achievement were concluded to be associated with the mathematics-science group. A comparison of the mean weighted achievement of the various high school pattern groups corrected for differences in American Council on Education Psychological Examination scores and English marks revealed that the mathematics-science group made significantly greater chemistry achievement than did the other pattern groups.

To the extent that the various high school patterns can be evaluated in terms of weighted chemistry achievement, the mathematics-science pattern gave the best preparation for success. The other patterns did not differ from each other in the quality of preparation for achievement in initial college chemistry which they provided.

ATTRITION AND HIGH SCHOOL PATTERN

Of the 997 students included in this study, 606 were enrolled in the Iowa State College for the fall term following that in which they had entered as freshmen. The 391 students who failed to return were designated as the attrition group.

The differences among the various high school pattern groups in the proportions of students dropping out were made without control by chi square analysis in which expected numbers were derived from row and column totals. Using American Council on Education Psychological Examination scores and English marks as control factors, a modified discriminant function technique was used to derive expected numbers for a further chi square analysis. There were significant differences found among the high school pattern groups both with and without control. When an analysis was made on the attrition ratio among the vocational agriculture, other vocational and general pattern groups with the exclusion of the mathematics-science pattern group, no significant differences could be found.

In so far as the various high school pattern groups can be evaluated in terms of their attrition ratios, the mathematics-science group is apparently the most effective. The other three pattern groups appear to be equally effective.

AN ECONOMIC ANALYSIS OF PUBLIC LABOR POLICY¹

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The broad field of labor economics has been experiencing the pattern of expansion undergone by most other specialisms in the past. Numerous studies have been made dealing with labor legislation, trade-union behavior, unemployment insurance, wage theory, and labor problems during prosperity and depression. Although labor economists divide the field into rather arbitrary categories few include perhaps the most significant area: labor policy. This may at first seem odd, since the term labor policy appears frequently in the literature. This study, however, attempts to show that the term, as it is currently being used in the field, is misleading. A distinction should be made between industrial relations policy and labor policy. Industrial relations policy deals with the rights and duties of the parties in their contractual relations with each other and the extent to which government ought to intervene in the settlement of lawful industrial disputes. Labor policy concerns itself with the regulation and control of labor markets for the purpose of modifying the play of economic forces affecting the allocation of resources and the level of employment in the economy. It is the latter rather than the former area which this study intends to investigate.

Since society recognizes the need for policies dealing with periodic fluctuations in income and employment the major portion of this work addresses itself to the problem of integrating labor policy with the twin goals of full employment and continued economic growth.

The present study, therefore, attempts (1) to pull together the many investigations which have contributed to the area of labor policy as a bona fide subdivision of labor economics; (2) to explore the existing gaps in economic theory as they apply to questions of labor policy; and (3) to anticipate the major avenues of approach to be followed in the future.

Summarizing the findings of this work, we can make the following observations:

1. With relative equality of bargaining power between labor and management established, public policy must now concern itself with the economic consequences of wage-price determination on the part of trade unions and business firms.
2. Industrial relations policies are appropriate as a means of settling

¹ Doctoral thesis number 1002, submitted September 17, 1949.

industrial conflict. More important, however, are the independent actions of trade unions and business firms which do not give rise to conflict but manifest their effects on the level of employment and the allocation of resources.

3. The absence of public policy in this regard has compelled trade unions and business firms to deal with their own special problems through the process of adaptation.
4. The process of adaptation takes a number of forms designed to meet the following variety of circumstances:
 - a. Insecurity and uncertainty growing out of technological change.
 - b. Desire to maintain a particular job for the purpose of avoiding the problem of relocating in a new community, firm, or industry.
 - c. Desire to increase income, status, and prestige by means of restriction or the use of noneconomic codes of conduct.
 - d. Fear of suffering a reduction in income due to cyclical fluctuations in business activity and employment.
5. The cumulative effects of the process of adaptation as well as the rapid rate of economic progress are responsible for secular misallocations of labor.
6. Labor markets exhibit secular maladjustments with respect to supply in terms of regional variations in population growth and the disparity between actual increases in population and the rates of increase required for the maintenance of economic progress.
7. Secular maladjustments also appear on the side of demand and are largely a function of technological change and alterations in consumer's preferences.
8. With the development of new techniques, labor orientation becomes less of a factor in the determination of industrial location. Because of increased locational flexibility, secular labor policy must direct its attention toward narrowing the discrepancies between the regional demand and supply of labor resources by increasing the mobility of all factors of production.
9. The process of adaptation as well as secular labor market maladjustments can be overcome by remedying the periodic fluctuations in income and employment.
10. Recognition of full employment as a continuing policy of the national government has already been established. Unless an integrated public labor policy is also undertaken, no real solution for the problems already enumerated will be achieved. Moreover, serious difficulties, involving continuing inflation, will arise should labor policy be divorced from the goal of full employment.
11. Public labor policy must concern itself with two separate problems: (a) the income problem and (b) the resource problem. The political climate, however, will determine the means appropriate for each of these.
12. Integrating public labor policy with the goal of full employment, such that the optimum allocation of labor resources and stable

prices are achieved, can only be accomplished under economic totalitarianism.

13. Under relatively free collective bargaining a full-employment program will not mitigate the resource problem and continuing inflation will prevail.
14. With limited government intervention, arbitrary limits must be established with respect to permissible unemployment and price fluctuations. Such flexibility, however, reflects the price society must pay for maintaining some degree of freedom in the disposition of resources.
15. Although it may be useful, analytically, to assume the existence of separate political categories, in reality combinations of the political frameworks, mentioned above, may prevail. The acceptability of specific proposals in each category may be modified by the use of framework incentive planning and the principle of compensation.

ANALYTICAL STUDY OF DYNAMIC LOADS ON ELASTICALLY SUPPORTED SLABS¹

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Considerable work has been done during the past century on the general subject of analysis of plates. Expressions have been found for the deflection in plates of various shapes, these deflections having been caused by several different kinds of loading. The plates have been supported in diverse ways.

The present work was undertaken to study the effect of a dynamic load moving along a rectangular plate supported by an elastic foundation. The edges of the plate were pinned, that is, boundary conditions were imposed so that there was no deflection along the edges of the plate and the moments at the edges were zero. The initial conditions imposed were that at time $t = 0$ the deflection of the plate was zero and the plate was at rest.

The differential equation to be satisfied was

$$D \left[\frac{\partial^4 w}{\partial x^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} \right] + \rho w_{tt} + kw = f(x, y, t),$$

where w is the deflection, D the flexural rigidity, and ρ the mass density of the plate. The modulus of the foundation is designated by k . The function $f(x, y, t)$ represents the applied load.

Formal expressions for the deflection of an elastically supported rectangular plate of finite dimensions were found. First an expression for the deflection caused by a block load moving with a constant velocity was derived. This expression was changed, through a limiting process, to an expression that would give the deflection caused by a moving line load, and, from this, an expression for a moving point load was developed. No attempt was made to determine explicit values of the deflection in these three expressions.

An expression for the deflection caused by a point load moving with a constant velocity along a semi-infinite strip was next developed. This was done by letting the dimension a , the length of the plate in the x -direction, increase without limit. The expression for the deflection caused by this point load was expressed as a double integral.

The first of these integrations was performed using Cauchy's theorem of residues. The expression was then broken down into three terms. The location of the poles of the integrands, in the second integra-

¹ Doctoral thesis number 1013, submitted December 12, 1949.

tion, depended upon the velocity at which the point load was moving. Five distinct cases were considered. Only the steady state deflections in the neighborhood of the load were wanted, that is, the deflections near the load when $t \rightarrow \infty$. The saddlepoint method was used to evaluate these integrals as this method was applicable for large positive values of time. Cauchy's theorem of residues was again used. The location of the saddlepoint was found to be a function of x . As the contour of integration always passed through the saddlepoint, several different variations as to the number of poles falling within the contour were found. This caused each of the three terms to have several different values. These values depended upon the velocity at which the load was moving and also upon the location of the point, with respect to the load, at which the deflection was to be calculated. Different combinations of these three terms gave the proper deflection expressions.

The final results express the deflection functions as infinite series. These functions approach validity as time increases indefinitely, that is, only after the load has been in contact with the plate for a long period of time.

BONE DARKENING IN FROZEN POULTRY¹

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This was a study of the factors involved in bone darkening of frozen poultry. The methods of processing, freezing, storing, thawing, and cooking were investigated to determine their effect on the discoloration of the bones. Attempts were made to elucidate the causes of bone darkening and to find means of preventing its occurrence.

Twelve-week-old New Hampshires of both sexes were used for most of the experiments. A few mature birds were also observed. After freezing, storing, and thawing, the birds were cooked and the meat was removed from the bones. The extent of bone darkening was measured subjectively by a panel of four judges using for comparison standard bones that were selected to represent scores of 0 to 10. A bone without appreciable color was scored 0.

It was demonstrated that freezing and thawing hemolyze the red blood cells of the bone marrow. The hemoglobin thus liberated penetrates the walls of the bones, causing discoloration. However, when the bone marrow erythrocytes were hemolyzed without freezing (by injecting a 2 per cent saponin solution into the bones) no darkening resulted. It was indicated, therefore, that freezing and thawing not only liberate the hemoglobin in the bone marrow but also make it possible for the hemoglobin to penetrate to the outer surface of the bone.

Examination of unfrozen and frozen, defrosted fryers revealed that all bones were somewhat darkened by freezing and thawing but the leg, thigh, and coracoid bones were the most seriously affected. In the raw state, frozen, defrosted bones were shown to be red in color but when cooked the color changed to a reddish brown. Freezing and thawing did not darken the bones of yearling New Hampshire hens.

It was found that the conditions of freezing and storing did not influence bone darkening sufficiently to be of practical importance. The factors studied included freezing rate, temperature of storage, length of the storage period, and temperature fluctuations during storage.

The effects of various processing methods on bone darkening were observed. The extent of bleeding, the degree of carcass separation, and the chilling method did not affect the color of the bones of frozen birds. Refreezing defrosted stock was not found to produce increased bone darkening. Covering the disjointed carcasses with water or solutions

¹ Doctoral thesis number 995, submitted August 20, 1949.

of NaCl, ascorbic acid, or KNO_3 prior to freezing did not reduce the extent of bone discoloration.

New Hampshires between the ages of 7 and 14 weeks did not differ significantly with respect to bone darkening when frozen. At the age of 16-17 weeks, however, bone color scores were reduced. On the basis of the bone darkening observed in various breeds and crossbreeds, it was concluded that the genetic background of the birds is not an important factor.

Removing the bone marrow from the leg and thigh bones prior to freezing prevented bone darkening. A practical method for removing bone marrow was proposed. The failure of the bones to darken after removal of the bone marrow, coupled with the fact that poor bleeding did not increase bone darkening, indicated that the bone marrow is the only source of the pigment discoloring frozen bones.

Different methods of cooking (i.e. frying, boiling, and roasting) were not found to differ greatly with respect to the development of bone discoloration in frozen birds. However, roasting the pieces of chicken 30 minutes or more prior to freezing reduced the bone color scores considerably.

Rapid thawing was accomplished by placing the frozen birds in the oven to cook without prior defrosting and by immersing the packages in water at 140°F . Either of these procedures prevented the development of dark bones provided that the birds had been frozen and stored at -30°F . and were cooked immediately after thawing. Rapid thawing did not prevent bone darkening when the birds had been frozen and stored at -10°F . nor when cooking was delayed for 72 hours after thawing.

TECHNIQUE FOR EVALUATING THE ABILITY OF TEACHERS TO APPLY PRINCIPLES CONCERNED WITH THE DEVELOPMENTAL NEEDS OF ADOLESCENT GIRLS¹

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The purpose of this study was to develop a technique for evaluating the ability of secondary school teachers to apply the principles concerned with the developmental needs of adolescent girls. The first hypothesis was that pencil-and-paper tests could be developed which would measure the ability of teachers to recognize and apply principles concerned with human growth and development of adolescents. Two tests were developed to measure this ability: Test A, Recognition of Principles, and Test B, The Case of Jacqueline Croner, essay and short-answer forms. The second hypothesis was that one case study would be sufficient to measure this ability.

The assumption was that it is important for all teachers to be able to apply principles concerned with the developmental needs of children. The experimental group in the study was composed of home economics teachers at the secondary level, on the further assumption that instruments which were valid and reliable for that group would be equally useful for all secondary school teachers.

Test A, Recognition of Principles, was made up of principles which related to the needs of adolescents in three major aspects of development: physiological, social, and integrative.

Test B, The Case of Jacqueline Croner, was designed to measure the ability which teachers have to apply principles in interpreting data concerned with the developmental needs of adolescents, and to select educational means for helping pupils with their problems. The test was a description of an adolescent based on data from a cumulative record of a high school girl.

Tests A and B were revised after having been administered to a preliminary group of thirty-five home economics teachers to discover any lack of clarity in vocabulary and statements, to discover difficulties in administration, and to determine the length of time required to give the test. The revised tests were administered to juries of four to six judges, and from their responses the keys for scoring were determined.

The group to whom the tests were then administered was made up of eighty-eight home economics teachers in West Virginia who had signified a willingness to participate. Several factors were considered in

¹ Doctoral thesis 1005, submitted November 2, 1949.

selecting these teachers: marital status, recency of graduate study, length of teaching experience, and the feasibility of visits by the writer.

Test B, *The Case of Jacqueline Croner*, essay form, was sent to each of the participants. This was followed by Test B, short-answer form, and Test A, *Recognition of Principles*.

The reliabilities of Tests A and B were determined by obtaining the correlation coefficient between scores on split halves. A Pearsonian coefficient of correlation was obtained, .73 and .840 respectively, and when corrected for double length by the Spearman-Brown modified formula became $.848 \pm .030$ and $.913 \pm .018$.

Two methods for establishing validity of the instrument were employed. One was the correlating of scores on Test A and on Test B, essay form, as well as the scores on Test A and Test B, short-answer form. The coefficients obtained were:

Test A and Test B, essay	.955 \pm .009
Test A and Test B, short-answer	.976 \pm .005
Test B, short-answer, and Test B, essay	.936 \pm .013

In order to have greater confidence in the results, an additional group of ninety home economics teachers in West Virginia took tests A and B. The procedure except for visits and interviews was duplicated and the coefficients of correlation were again obtained.

The coefficients for the second group were:

Test A and Test B, essay	.951 \pm .010
Test A and Test B, short-answer	.956 \pm .009
Test B, short-answer, and Test B, essay	.925 \pm .015

These results would seem to indicate that the high correlations of the first group were not due to sampling, since the differences in the correlations are slight.

A second method of validation used was that of computing coefficients of correlation between the performance on the tests and a criterion assumed to be valid. In this study that criterion was the scores obtained on interviews which the writer had with the teacher, the principal and/or the superintendent and the score on a 1-day observation of the teacher, designated as an interview-observation score. This score was obtained from information relative to how the teacher applied principles concerned with the developmental needs of adolescent girls in a real-life situation. It was determined by the use of a scale which had a range of 1 to 15. When coefficients of correlation were computed between the scores on the tests and the interview-observation scores, the correlations were:

Test A and interview-observation scores	.875
Test B, essay, and interview-observation scores	.901
Test B, short-answer, and interview-observation scores	.911

Since Test B was designed to measure the ability of the teacher to

diagnose problems and select remedial measures, coefficients of correlation to determine whether one section of the test was more valid than the other were computed. The correlation between the diagnostic sections on the two forms of Test B was $.788 \pm .040$ whereas the correlation between the scores on the two remedial sections was $.433 \pm .087$. Also computed were coefficients of correlation between the scores on the remedial section of the short-answer form of Test B and the interview-observation scores; the result was a coefficient correlation of $.787 \pm .041$.

The items on both Test A and Test B were analyzed to determine internal consistency and to discover items which should be discarded or revised because they were not discriminating. All except 13 of the 62 items in Test A and 30 items of the 110 in Test B were satisfactorily discriminating.

In a teacher-education program it would be valuable if devices which could be administered easily were available, so that a prediction of what a teacher would do relative to the application of principles when she is faced with a real-life situation could be made. In the present study paper-and-pencil tests have been developed which appear to be valid and reliable, hence can be used as the independent variables in computing regression equations. For the criterion, the interview-observation score, which was used as the dependent variable in determining regression, the validity was assumed.

There were three main problems to be considered in analyzing the regression data. Can a regression equation which will predict teacher behavior in a real-life situation with reasonable accuracy be determined? How accurate would the prediction be if only the short-answer tests, X_1 and X_2 , were used? How much better is the interview-observation technique than the combination of written tests?

In the following discussion of regression, the scores on the two tests and the interviews and observations will be designated by these symbols:

X_1 = Test A: Recognition of Principles Test

X_2 = Test B: The Case of Jacqueline Croner (short-answer form)

X_3 = Test B: The Case of Jacqueline Croner (essay form)

Y = Interview-observation.

The first problem was to set up regression equations. The equation using all three variables is:

$$Y = -6.0096 - .2235X_1 + .2556X_3 + .2517X_2$$

The equation using two variables is:

$$Y = -.0741X_1 + .2644X_2 - 5.9562$$

The equation using one variable is:

$$Y = 2140X_1 + 1.9382$$

To ascertain the usefulness of these equations it was necessary to determine the multiple coefficients obtained when all variables were used or progressively dropped; to determine the standard partial regression correlations holding various ones of the variables constant; and

to make tests which indicate the significance of regression coefficients.

The multiple correlation coefficient obtained between all the estimated Y values and the actual values was .9366.

The multiple R^2 is .8773 which means that 87.73 per cent of the variability among teachers in their ability to apply principles in this area can be measured by the three pencil-and-paper tests. If Test B, X_3 , is omitted from the multiple correlations, R^2 becomes .8394. If this independent variable is dropped from the equation, an additional 4.24 per cent of the variability remains unaccounted for by regression.

The standard partial regression coefficient specifies changes in Y , independent of the changes in the other independent variables. The b' for each of the three tests is:

$$\begin{aligned} X_1 &= .9139 \\ X_2 &= 1.1492 \\ X_3 &= .6984 \end{aligned}$$

It is obvious that X_2 is the most important test in predicting Y .

Standard partial regression coefficients may also be used to judge which of the independent variables are most important in estimating Y . If X_2 is held constant and X_1 is compared with Y , the correlation is low, .0160. If X_3 is held constant and X_1 is compared with Y the correlation is low, .1071.

If X_1 is held constant the correlations between X_2 and Y and between X_3 and Y are:

$$\begin{aligned} r_{Y 2.1} &= .5449 \\ r_{Y 3.1} &= .4577 \end{aligned}$$

When X_3 is held constant the correlations between X_1 and Y , between X_2 and Y , and between X_1 and X_2 are:

$$\begin{aligned} r_{Y 1.3} &= .1071 \\ r_{Y 2.3} &= .4431 \\ r_{12.3} &= .7840 \end{aligned}$$

When X_1 is held constant, the correlation between X_3 and X_2 is:

$$r_{32.1} = .0619$$

When each independent variable is compared with Y , the other two variables being held constant, the following correlations are obtained:

$$\begin{aligned} r_{Y 1.23} &= .4318 \\ r_{Y 2.13} &= .5818 \\ r_{Y 3.12} &= .5495 \end{aligned}$$

Since all t tests coefficients 5.385, 6.559, and 4.385 are highly significant, each of the independent variables may be assumed to be related to the dependent variables in a linear manner.

Throughout the statistical analysis X_3 , the essay form of Test B, The Case of Jacqueline Croner, proved to be the least valuable of the variables to use for prediction purposes. It had the smallest standard partial regression coefficient, the smallest partial correlation with the Y variable, and the smallest t value. It seems, therefore, that it is justifiable to drop

it from the regression equation and lose a very small part of the total predictable information in favor of more easily administered and time-saving tests.

The recommended regression equation obtained is:

$$Y = -.0741X_1 + .2644X_2 - 5.9562$$

It can be reasonably assumed that the ability of individuals to apply principles can be measured by the use of X_1 and X_2 . These tests should make it unnecessary for teacher-educators to expend time, energy, and money in visiting widely distributed schools for the purpose of observing teachers in their classrooms and during extra-curricular activities, of interviewing them and consulting their administrators in order to determine their ability to apply principles in this area.

CONTROL OF ASPHALTIC CONCRETE MIXTURES AT HOT-MIX PLANTS¹

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Asphaltic concrete pavements have been extensively used for primary roads during recent years. Most of them belong to the hot-mix, hot-laid type. Since the knowledge about asphaltic concrete mixtures is not so complete as that regarding other common engineering materials, there are still many uncertainties involved in the design, manufacturing, and laying of such mixtures. Consequently, every step in asphaltic paving deserves critical attention. This study covers the control of the mixture at hot-mix plants.

By reviewing the process in manufacturing asphaltic concrete mixtures, it is seen that there are many hard to control factors which affect the quality of output. If there is no rapid plant test to indicate quality of mixture, the plant inspector cannot assure that the output is always satisfactory.

A survey of prevailing inspection practices reveals that the desired rapid quality-indicating test is not available now. Many states depend too much upon personal experience of engineers and inspectors; others specify certain laboratory stability tests as a control for plant operation. Although personal experience is helpful in all constructional works, some definite control test seems to be more desirable. On the other hand, stability tests performed at the central laboratory are usually not so effective for plant control because there is too much delay for the delivery of sample and report. Laboratory tests are good only for preliminary design and occasional check. In order to facilitate immediate control at asphaltic concrete plants, it is necessary to have a rapid quality-indicating test which can be conveniently applied at the plant.

The main objective of this research project is to develop the desired rapid quality-indicating test. The term Plant Stability Test will be used for this test device. Plant Stability Test is empirical in nature, but every effort has been made to simulate the actual loading under service conditions. Although this test involves plastic properties of asphaltic concrete mixtures, only the compressive strength of the specimen is recorded. Compressive strength of the specimen is considered as a measure of resistance to deformation. Previous studies in the field of asphaltic concrete paving have shown that resistance to

¹ Doctoral thesis number 1000, submitted August 24, 1949.

deformation of any asphaltic mixture is affected by type and gradation of aggregate (including filler), type and content of asphalt binder, density of mixture, etc. Therefore, the first step for investigating the effectiveness of this test was to verify its sensitivity to all these factors. Experiments indicated that the suggested test had a high degree of sensitivity.

In order to have some idea about the relationship between this test and the more common mechanical tests, a comparative study has been made. Specimens prepared with similar compactive effort were tested by Hveem Stabilometer, Hubbard-Field, Marshall, Unconfined Compression and the suggested method. Results disclose that the Plant Stability Test is as effective as an indicator of quality as any of the other tests.

The most unique feature for the Plant Stability Test is the elimination of a constant temperature oven or water bath used for heating the specimen before testing. Since it is absolutely necessary to test specimens at a definite temperature, a technique has been developed in which an armored thermometer is inserted in the specimen to indicate temperature at the time of test. Various experiments have been performed in order to verify the dependability of this procedure. By controlling the temperature for both the mold and mixture just before molding, it is possible to get a positive temperature control for the specimen during testing.

Another feature of the suggested test is the use of the same cylindrical mold for both molding and testing. By such a device, time and labor for extrusion of the specimen from the mold after molding can be saved.

Compactive effort for the preparation of the specimen has been studied by laboratory experiments correlated with actual field conditions. It is recognized that density alone cannot represent the efficiency of consolidation. Orientation of aggregate particles plays an important role in establishing the stability of any compacted mixture. Since there is a definite tamping action in modern asphaltic concrete paving machines, a dynamic load furnished by a 10-pound hammer is applied to the specimen before the compaction by static load. It is intended to simulate the actual efficiency of consolidation by such a combined compactive effort.

Other laboratory investigations in regard to the test specimen include temperature of mold, height of specimen, etc. All laboratory experiments act as experimental backgrounds for the development of Plant Stability Test.

As Plant Stability Test was designed for the use at hot-mix plants, it must be actually applied at the plant in order to verify its practical value. A portable testing machine and other equipment were built for this purpose. Results indicate that this test can be very conveniently applied for plant control. The principal testing procedure is outlined as follows:

Weighing—Proper amount of hot mixture is weighed out in an insulated pan. A thermometer inserted in the pan indicates the temperature of mixture.

Molding—Molding of specimen must be started when temperature of mixture drops to 260°F. The specimen receives fifty blows by a 10-pound hammer dropping from a height of 18 inches. Then, a static load of 1,000 pounds per square inch is applied for 1 minute.

Testing—An armored thermometer is attached to the compression ram which has been placed over the specimen during molding. This thermometer measures the temperature at the center of the specimen. When the thermometer reading drops to 160°F., the specimen is tested right in the mold with removable walls taken away. The compressive strength of the specimen is termed the stability value of the mixture.

Time from the beginning of molding to the end of testing is approximately 10 minutes. With such a rapid control test, a plant inspector knows the quality of mix. He can make any necessary adjustment of the mix if the stability value found from this test is below the minimum requirement. By applying the suggested test at hot-mix plants, effective control of asphaltic concrete mixture will not be difficult.

FACTORS ASSOCIATED WITH PERFORMANCE
OF 4-H CLUB VOLUNTEER LEADERS IN
NEW YORK STATE, 1946-48¹

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This abstract summarizes a study of Factors Associated with Performance of 4-H Club Volunteer Leaders in New York State, 1946-48. The study was designed to analyze some of the social, group, and cultural factors influencing adult volunteer leaders as they function in a group situation in rural communities.

Many studies have been conducted covering various phases of 4-H Club volunteer leadership. The highly significant area of factors which explain satisfaction and its relationship to performance and tenure needs intensive study if problems of selection, training, and recognition of volunteer leaders are to be better understood.

The purposes of this study are: (1) to explain varying degrees of satisfaction among adult volunteer leaders associated with the 4-H Club program; (2) to determine the relationship of satisfaction to such criteria as success, performance, and tenure; (3) to suggest areas for further research; and (4) to set forth certain suggestions and recommendations, based on the findings and conclusions of this investigation, that would aid professional workers in developing a more effective program.

Information was obtained from 760 club leaders located in twelve counties of New York State. A pretested schedule was used by trained interviewers in obtaining the basic data.

Leaders were divided into two groups—those currently active (present leaders) numbering 510, and those who had discontinued their leadership duties (past leaders) of which there were 250. Leaders were classified by the use of attitude scale analysis into five scale types of satisfaction, representing the range from the most satisfied to the least satisfied on a continuum. Four scale types of success were established based on opinion ratings of 4-H Club Agents and the interviewers. Three levels of performance—high, medium, and low—were developed on the basis of numerical performance of the clubs with which the leaders were associated. Each of the three criteria of satisfaction, success, and performance was related to the other by the use

¹ Doctoral thesis number 1045, submitted May 19, 1950.

of chi-square. The three criteria were combined into a composite rating termed *desirability*.

Within the limitations of the criteria for measuring satisfaction, success, and performance and the statistical methods used in this study, the following tentative conclusions may be offered:

1. Scale analysis provides a statistical model and an objective procedure for approaching the problem of measuring attitudes of satisfaction and success. Scale analysis does not, however, define the attitude or what constitutes success.

2. One can conclude that the association between satisfaction, success, and performance of the 760 leaders studied is so marked that we cannot believe the three criteria are not associated in the universe of 4-H Club leaders from which our sample was drawn.

3. In general the association between satisfaction, success, and performance was more pronounced for present than for past leaders.

4. There was a marked association between satisfaction, success, and performance as expressed by 4-H Club leaders and such measurable personal factors as age, education, income of the household, social participation, and occupation. The number of years of operation of the 4-H Club with which the leader was associated, the number of years the person had been a 4-H Club leader, the kind of recognition received, the number of training meetings the leader had attended, and the degree of importance the leader placed on prizes and awards received by his club members were also significantly associated with scale types of satisfaction and success and levels of performance.

5. Factors which did not appear to be significantly associated with these three criteria were: marital status, place of residence, type of 4-H Club, the number of persons in the leader's household, whether or not there were 4-H Club members in the leader's household, and the amount of recognition which the leaders had received.

6. When the interdependence of such factors as tenure, occupation, education, and participation were determined in relation to desirability, it was found that: (a) participation and tenure appeared to be associated with the desirability of persons as 4-H Club leaders; (b) the farmer and homemaker occupational grouping also appeared to be indices of desirability; (c) the professional, white collar, teacher, and student occupational grouping did not appear to make for desirability as 4-H Club leaders; (d) persons with twelve grades of schooling or less appeared to be more desirable as 4-H Club leaders than did individuals with college and technical training.

7. Recognition to the leaders in the form of interest and appreciation shown by 4-H Club members, their parents and people of the community was a more effective means of motivation than that provided by awards, banquets, publicity, and trips.

8. Four-H Club leaders who discontinued their leadership duties after 1 to 3 years were, in general, younger, males rather than females,

had less formal schooling, single rather than married, had lower incomes, and were less active in community organizations and agencies than were leaders who continued to assume their responsibilities for more than 3 years.

Additional areas for research suggested by this particular study are the interrelationship of such factors as tenure, education, occupation, and participation, as criteria for predicting success and performance of 4-H Club leaders; the "halo" effect of self evaluation and rating of others; the leadership role of an adult in relation to the social, group, and cultural patterns of the community in which the club is located; factors which serve to effectively motivate leaders; and the role of the professional leader (4-H Club Agent) in relation to volunteer leaders.

Some of the implications that can be drawn from this study are as follows: (1) The selection of 4-H Club Leaders should be largely the responsibility of the community concerned rather than the 4-H Club Agent. The former procedure helps to identify the leader and his responsibilities with the needs and support of the community. (2) Assuming the goal is to choose leaders who will achieve the maximum satisfaction and performance, one should emphasize those personal and group factors which this study showed are significantly related to these important criteria. (3) The 4-H Club Agent will find it advantageous to have more direct, face-to-face contact with club leaders. Leaders desire personal counsel and encouragement on many problems arising in the early stages of their leadership duties. (4) Every effort needs to be directed toward sensitizing the parents of club members, the members themselves, and people of the community to the need for, and importance of, expressing verbal and written approval to the 4-H Club leader for what he is doing.

RELATIONSHIP OF THE NUTRITION OF *STREPTOCOCCUS LACTIS* TO BACTERIOPHAGE PROLIFERATION¹

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Evidence now exists that bacteriophage reproduction, although related very closely to bacterial reproduction, may be influenced separately under certain nutritional conditions. This investigation offers information concerning the relation of the multiplication of *Streptococcus lactis* to bacteriophage multiplication in various chemically defined media.

The chemically defined medium reported by Niven (1) was used as a basis for the study. Turbidity measurements were used as an indication of organism growth, and the numbers of bacteriophage particles were determined by the limiting dilution method in litmus milk. Three samples of each dilution were made, and the most probable number of bacteriophage particles per milliliter was computed using probability tables. An incubation temperature of 32°C. was used for all experiments.

The synthetic medium of Niven was found to support the growth of twenty-two of thirty-one strains of the *Streptococcus lactis* type, but it did not support the growth of any of twenty-two strains of the *Streptococcus cremoris* type. Since homologous bacteriophages were not available for nineteen of the twenty-two strains of *S. lactis* which grew on the synthetic medium, work was conducted using only three *S. lactis*-bacteriophage combinations. Bacteriophages active against two of these three strains of *S. lactis* were found to multiply readily on their respective host cells in the synthetic medium. The most probable number of bacteriophage particles usually increased from about one thousand to about one million per milliliter during a 7-hour incubation period. While the third strain of *S. lactis* grew readily on the synthetic medium, the homologous bacteriophage did not multiply.

In a study to determine the effect of the omission of individual components from the medium upon the multiplication of the two *S. lactis*-bacteriophage combinations, each amino acid, vitamin, and purine or pyrimidine base was omitted individually from the complete medium. When the omission of an individual component from the medium caused a decrease in bacteriophage multiplication, a parallel decrease in bacterial growth also was encountered. Bacteriophage multiplication seemed to be very closely related to bacterial multiplication for these two combinations.

¹ Doctoral thesis number 981, submitted July 13, 1949.

A study was made to determine the nutrients necessary for the growth of other strains of the lactic group in the synthetic medium. When small amounts of sodium acetate and Tween 80 were included in the synthetic medium, turbidity was developed by the twenty-two strains of the *S. cremoris* type and the nine strains of the *S. lactis* type which did not grow in the medium of Niven. Those strains of the lactic group which did not require sodium acetate and Tween 80, a source of oleic acid, were stimulated when these nutrients were present. Neither sodium acetate nor Tween 80 alone would suffice for serial transfer of many cultures; however, sodium acetate alone was effective for more cultures than was Tween 80 alone. The requirement of strains of the lactic group for sodium acetate and Tween 80 could not be modified by a mixture of several growth factors which have been reported important in the nutrition of various lactic acid bacteria. The liver extract, reticulogen, however, could substitute, in comparatively much smaller amounts, for sodium acetate and Tween 80. In addition, reticulogen stimulated the growth of one strain of the *S. cremoris* type which did not become turbid until after 24 hours when the supplement was sodium acetate and Tween 80.

While the synthetic medium supplemented with sodium acetate and Tween 80 supported the growth of all organisms used, it was inadequate for the multiplication of bacteriophages on the nine *S. cremoris* strains which were used in this portion of the study. Even when supplemented with a mixture containing all of the known vitamins of the B complex, including B₁₂, and several other known growth factors, the bacteriophages did not multiply. Such complex mixtures as yeast extract, tomato juice, proteose peptone, reticulogen, peptonized milk, and hydrolyzed casein were used to no avail. Even the addition of 5 per cent dried skimmilk did not make the medium adequate for the multiplication of bacteriophages until potassium phosphate was left out of the medium. It then was discovered that when calcium was available, the completely synthetic medium was adequate for the multiplication of all of the bacteriophages which would not multiply on the medium as used previously. In the synthetic medium supplemented with 0.1 per cent calcium chloride, the precipitation of tricalcium phosphate was avoided by decreasing the potassium phosphate content to 0.1 per cent and by either sterilizing the complete medium by filtration or autoclaving the potassium phosphate separately from the other components. When calcium was available in the medium, the close relationship between multiplication of bacteriophage and organism was again evident. The addition of calcium had no detectable effect on organism growth.

An adsorption study indicated that calcium possibly was not necessary for the adsorption of bacteriophages to bacterial cells. However, the accuracy of estimation attained in enumerating the bacteriophage particles leaves considerable question as to the validity of this conclusion.

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I. IONIZATION AND HYDRATION EQUILIBRIA OF PERIODIC ACID ¹

II. SOLUBILITY AND COMPLEX ION FORMATION OF THE RARE EARTH OXALATES

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I. IONIZATION AND HYDRATION EQUILIBRIA OF PERIODIC ACID

A study of the ultraviolet absorption spectra of periodic acid as a function of the hydrogen ion activity, the activity of water, and the temperature revealed that the optical density is a function of all these quantities. Also it was found from potentiometric data that the ionization constants of periodic acid had unusually large variations with temperature changes, becoming a stronger acid at higher temperatures. In addition, it was found that the pH of a solution of periodic acid decreased as the ratio of methanol to water in the solvent was increased. Thus, periodic acid appeared to be a stronger acid in methanol-water mixtures than in pure water. All of the above observations have been quantitatively explained by postulating that periodic acid exists in solution mainly as a mixture of two acids, the relatively weak paraperiodic acid, H_5IO_6 , and the very strong metaperiodic acid, HIO_4 . From the ultraviolet absorption data and the potentiometric studies, the following equilibria have been evaluated in a temperature range of 0–70°C.:

$$(1) \quad \frac{(\alpha_{H^+}) (\alpha_{IO_4^-} + \alpha_{H_4IO_6^-})}{\alpha_{H_5IO_6}} = K'_1$$

$$(2) \quad \frac{(\alpha_{H^+}) (\alpha_{H_4IO_6^-})}{(\alpha_{IO_4^-} + \alpha_{H_4IO_6^-})} = K'_2$$

$$(3) \quad \frac{(\alpha_{H^+}) (\alpha_{H_4IO_6^-})}{\alpha_{H_5IO_6}} = K_1$$

¹ Doctoral thesis number 1070, submitted June 5, 1950.

$$(4) \quad \frac{(\alpha_{\text{H}^+}) (\alpha_{\text{H}_2\text{IO}_6^{2-}})}{\alpha_{\text{H}_2\text{IO}_6^-}} = K_2$$

$$(5) \quad \left(\frac{\alpha_{\text{IO}_4^-}}{\alpha_{\text{H}_2\text{IO}_6^-}} \right) \alpha_{\text{H}_2\text{O}}^2 = K_D$$

where the above constants are related by the following:

$$(6) \quad K'_1 = K_1 (K_D + 1)$$

$$(7) \quad K_2 = K'_2 (K_D + 1).$$

II. SOLUBILITY AND COMPLEX ION FORMATION OF THE RARE EARTH OXALATES

The solubility of cerium, neodymium, and ytterbium oxalates has been studied by employing radiotracer techniques in various oxalate-buffered solutions at 25°C. The solubility data gave fairly smooth functions when correlated with the $\alpha_{\text{C}_2\text{O}_4^{2-}}$, and attempts to include the $\alpha_{\text{HC}_2\text{O}_4^-}$ in the explanation of the experimental values failed to reveal any primary effect in controlling the solubility of the rare earth oxalates. Variations in the α_{H^+} were only effective in controlling the oxalate activity as calculated from the ionization equilibria and the total oxalate in solution.

$$(1) \quad \alpha_{\text{C}_2\text{O}_4^{2-}} = \frac{K_1 K_2 M}{\alpha_{\text{H}^+}^2 + \frac{\alpha_{\text{H}^+} K_1}{\gamma_1} + \frac{K_1 K_2}{\gamma_2}}$$

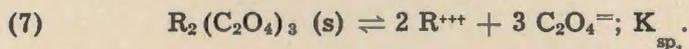
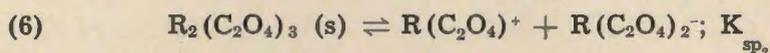
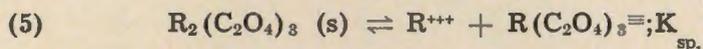
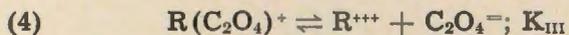
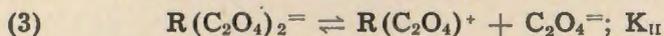
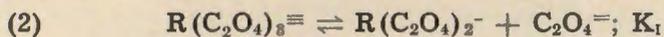
where M = total oxalate in solution

K_1 and K_2 = first and second ionization constants of oxalic acid.

Calculation of the oxalate ion activity was accomplished by means of successive approximations in which the ionic strength, and hence the activity coefficients, from each preceding computation were employed.

The possibility of ions of the type $\text{R}(\text{C}_2\text{O}_4)_n^{8-2n}$ was considered, where R is the rare earth ion. The slope of the curves representative of the data in the region of high oxalate ion activity indicated the complex species present in this region, since to a first approximation the formation of $\text{R}(\text{C}_2\text{O}_4)_3^{8-}$ would lead to a slope of + 3/2, $\text{R}(\text{C}_2\text{O}_4)_2^-$,

to a slope of $+1/2$, and $R(C_2O_4)^+$, to a slope of $-1/2$. The following equilibria explained the experimental data of the three rare earth systems studied:



The above six equilibrium constants were evaluated at 25°C. from the data.

THE EFFECT OF ROOFING MATERIALS ON TEMPERATURES IN FARM BUILDINGS¹

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This study consisted of an analysis and an experimental study of the effect of roofing materials on temperatures in farm buildings under summer and winter conditions. It was a part of the over-all study which is being carried on by the Iowa Agricultural Experiment Station to determine how various factors affect the temperature in farm buildings under both summer and winter conditions.

Five different roofing materials were included in this study. They were (1) corrugated aluminum sheet, (2) asbestos-cement shingles, (3) asphalt shingles, (4) galvanized corrugated steel sheet, and (5) wood shingles. Variations in treatment of the materials and in construction of the roofs were as follows: (1) white paint on galvanized corrugated sheet steel, (2) aluminum paint on galvanized corrugated sheet steel, (3) solid wood sheathing under aluminum, and (4) aluminum foil insulation in the roof section with wood shingles.

In the analysis, heat balances were made to determine the temperature each material would attain, and the temperature to which the interior of a building would rise, before reaching equilibrium, with respect to the energy received from the sun and the quantity of heat transmitted to the surrounding air by radiation, conduction, and convection. A study was also made of heat flow outward through the materials under winter conditions. Methods were developed to predict, (a) the quantity of solar energy absorbed and transmitted to the underside of the roof for given conditions, (b) the temperature under a given roof section, and (c) the heat flow outward through roof sections. In the development of these methods, it was assumed that the following were known: (1) the quantity of solar energy incident upon the surface, (2) the absorptivity of the material for solar radiation, (3) the emissivity of the material at ordinary temperatures, (4) the outside temperature, (5) the wind velocity, (6) the thermal capacity of stored products, and (7) the "AU factor" of the understructure.

To check the theoretical hypothesis an experimental study was made. This part of the investigation included four phases of work as follows: (1) the measurement of solar energy absorbed and transmitted to the underside of roof sections by an air duct, (2) the measurement of temperatures under roof sections in insulated compartments

¹ Doctoral thesis number 1062, submitted June 2, 1950.

with zero air change, (3) a field study of temperatures in buildings covered with various roofing materials, and (4) the measurement of heat flow outward through the various roof sections under winter conditions.

In the measurement of solar energy absorbed and transmitted to the underside of roof sections by an air duct, roof sections were placed over a duct through which air was blown. The duct was 6" x 24" x 24'-0" in cross section and was insulated on three sides with 6 inches of corkboard. The duct was mounted on an adjustable frame whereby it could be oriented or elevated so that the roof surface would be normal to the rays of the sun. By measurement of the temperature of the entering and leaving air after thermal equilibrium was established, it was possible to determine the quantity of energy which was transmitted to the underside of the roof section.

In the second phase of the study, the roof sections were placed on a 45-degree slope over well insulated compartments with north and south facings. Temperatures in the middle of the compartments, 2 inches below the inside, on the surface, against the inside and outside surface, and of the outside air were recorded. The quantity of solar energy striking the roof surfaces was measured by a pyrliometer. Wind velocity was measured by an anemometer. The results obtained in this study checked closely with the theoretical analysis which indicated that roofing material may have considerable effect on the temperature in the building.

The field study included the measurement of temperatures in several typical farm buildings. Buildings included in this portion of the study were, farrowing houses covered with aluminum and asphalt shingles, shade and range shelters covered with five different roofing materials, and a hay mow in a barn covered with aluminum. Although the results were mainly qualitative in nature, they did indicate that considerable variation in temperatures existed in buildings covered with different roofing materials.

The last phase of the study consisted of the determination of U values of roof sections under various winter conditions. The same test house with the insulated compartments which was used in the summer study was used in this study. All compartments were heated with electrical elements to the same thermostatically controlled temperature. By the determination of the energy required to maintain the inside temperature and with the outside temperature known, it was possible to calculate the U values of the roof sections. Again the agreement between the experimental and the theoretical studies was relatively close.

From the results of this study, the following conclusions were drawn:

1. The interior temperature of a building may be accurately calculated by an equation, which was developed in this study, if the characteristics of the roofing materials, the solar heat impinging on the

roof, the outside temperature, the "AU factor" of the understructure, and the quantity of air change are known.

2. The quantity of solar heat absorbed and transmitted to the interior of a building at a given temperature may be readily calculated by an equation which was developed in this study.

3. The temperature of a roofing material and the solar energy absorbed and transmitted by it to the interior of a building are dependent on the characteristics of the material.

4. The main characteristics of a roofing material affecting temperature and heat transmission to the interior are its absorptivity for solar energy, its emissivity at ordinary temperatures, and the conductivity of the material.

5. Roofing materials having approximately equal conductivity coefficients have large differences in temperatures and result in large differences in the interior temperatures if one has a higher absorptivity for solar radiation than the other.

6. Roofing materials having the same absorptivity for solar radiation, but having different emissivities at ordinary temperatures, result in different interior temperatures for a given condition with the material with the highest emissivity having the lowest interior temperatures.

7. A material with high outside emissivity and low inside emissivity is desirable if other things are constant, as this results in a low roofing temperature and the transmission of a small quantity of energy to the interior.

8. The addition of a solid sheathing is more beneficial to materials with high emissivities than to materials with low emissivities.

9. Corrugated aluminum sheet roofing is the most effective of the five roofing materials tested in this study in the prevention of the absorption and the transmission of solar energy to the interior of a building.

10. Solid sheathing is not recommended for corrugated aluminum sheet roofing for the purpose of adding insulation to prevent solar heat from being transmitted to the interior.

11. White paint is the most effective surface treatment in the prevention of the absorption and transmission of solar energy to the interior.

12. Steel painted with white paint is more effective than any other roofing material or surface treatment used in this study in preventing the absorption and transmission of solar energy to the interior.

13. Wind increases the rate of heat loss of the outside surface of the roofing material; hence the equilibrium temperature is lowered and the quantity of heat transmitted to the interior is lowered.

14. The average maximum temperature in buildings covered with the various roofing materials used in this study, ranges from 99.8°F. for insulated wood shingles to 121.9°F. for galvanized corrugated steel for the conditions of this study.

15. The most effective method to prevent the absorption and transmission of solar heat to the interior is to paint the outside surface of the roofing material with white paint and the interior surface with aluminum paint.

THE MECHANISM OF THE FISH THIAMINASE¹

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The physiological function of thiaminase is not known, and there is no evidence to establish whether its action *in vivo* is anabolic or catabolic. Before this question can be answered it is necessary to obtain more knowledge of the chemistry of thiaminase, the reaction mechanism, and the products of its *in vitro* destruction of thiamine.

Our studies were designed to furnish information on these points. Two new activators, *m*-aminobenzoic acid and *m*-nitroaniline, were discovered and were shown to exhibit a strong activating effect in concentrations as low as 5×10^{-4} M. At this concentration activations of 100 to 200 per cent have been measured for undialyzed enzyme preparations, and even higher values were obtained for dialyzed preparations. Activation of undialyzed enzyme by these compounds was not enhanced by manganous ion, but was increased for dialyzed extracts.

In the *m*-nitroaniline-activated reaction the activator concentration decreased during the course of the reaction, and with higher concentrations of activator there were proportionally greater losses. This suggested that the activator was participating in the reaction, and that the pyrimidine moiety of thiamine might be coupling with the amine. This proved to be the case, and the resulting secondary amine, N-(2-methyl-6-aminopyrimidyl-5-methyl)-*m*-nitroaniline, was isolated in a 74.5 per cent yield from the *m*-nitroaniline-activated enzyme reaction. The compound was identical to that produced on warming an alcoholic solution of the corresponding pyrimidine bromide and *m*-nitroaniline in the presence of excess sodium bicarbonate. The dihydrochloride salt of the compound melted, with decomposition, at 211°–212°C. (corrected), and the free base melted at 227.5°–228.5°C. (corrected). Its absorption spectrum exhibited a maximum at 2420–2430 Å. in 0.1 N sodium hydroxide.

Similar attempts to isolate a compound from unactivated enzyme reactions were unsuccessful.

Analysis of the optimum conditions for dialysis of the enzyme indicated that the most satisfactory conditions were those employing a low concentration of enzyme at pH 6.5–7.5 for 6 to 8 hours of dialyzing against distilled water at 5°–10°C. Losses of 50 to 60 per cent of initial activity resulted.

Activation experiments on dialyzed and undialyzed enzyme prepara-

¹ Doctoral thesis number 1007, submitted December 3, 1949.

tions indicated that the manganous ion was intimately associated with thiaminase activity. It was not, however, the sole factor. Another factor, or factors, necessary for optimum activity of the enzyme appeared to be non-dialyzable and non-heat labile and could be replaced by *m*-nitroaniline or Kochsaft, but not by cysteine.

Cysteine exhibited only a slight activating effect on dialyzed preparations. The demonstrated inhibition of thiaminase by sulfhydryl-specific inhibitors, such as iodoacetic acid, phenylmercuric chloride, and iodine, and the reversal of inhibition in the last case by excess cysteine indicate that cysteine might function more as a regulator of the oxidation-reduction state of the enzyme sulfhydryl groups than as an activator such as *m*-nitroaniline.

Cysteine at concentrations higher than 1×10^{-3} M. interfered with the Melnick-Field assay for thiamine. The interference could be avoided by destroying the excess cysteine with iodine prior to addition of the diazotized *p*-aminoacetophenone or by addition of higher concentrations of this reagent.

Attempts to purify thiaminase by fractional precipitation with cold acetone or ammonium sulfate were unsuccessful. The activity was either partly or completely destroyed in every experiment. In view of the recently discovered activators, such as *m*-nitroaniline, this work should now be reinvestigated.

A preparative method was developed for the Melnick-Field dye from thiamine or 4-methyl-5- β -hydroxyethylthiazole methiodide. Both dyes are dense, red-violet, microcrystalline compounds melting above 300°C., and their absorption spectra in 0.1 *N* sodium hydroxide have maxima at 268, 310, and 500 Å. for the thiamine derivative and 266, 306, and 490 Å. for the thiazole dye.

In a study of the nature of the Melnick-Field color reaction, the *S*-benzyl derivative of the open form of thiamine was prepared and shown to give no color in this assay procedure.

N-(2-methyl-6-aminopyrimidyl-5-methyl)-taurine was synthesized by the action of the corresponding pyrimidine bromide on taurine in an alcoholic solution containing sufficient sodium bicarbonate to make the mixture slightly alkaline. The compound melts at 211°–212°C. (uncorrected), does not form a hydrochloride, but will form a picrate which melts at 178°–179°C. (uncorrected). The absorption spectrum has two maxima at 235 and 272 Å. in alkaline media and a single maximum at 245 Å. in acid media.

SUMMARY

1. Meta-aminobenzoic acid and *m*-nitroaniline were found to be potent activators of both dialyzed and undialyzed thiaminase preparations. Activations of 100–200 per cent were measured for the undialyzed enzyme at activator concentrations of 5×10^{-4} M. Manganous ion at 1×10^{-3} M. concentration enhanced the activating effect for dialyzed enzyme, but not for undialyzed preparations.

2. The product from *m*-nitroaniline activation was isolated in a 74.5 per cent yield and shown to be identical to N-(2-methyl-6-aminopyrimidyl-5-methyl)-*m*-nitroaniline prepared from the corresponding pyrimidine bromide and *m*-nitroaniline. Attempts to isolate a similar pyrimidine derivative from unactivated preparations were unsuccessful.

3. The conditions for optimum dialysis of thiaminase were found to include low enzyme concentration at pH 6.5-7.5 for 6 to 8 hours against distilled water at 5°-10°C.

4. Manganous ion appears to have an integral part in the thiaminase system but is not the only factor. Some other factor, or factors, is necessary which is non-dialyzable and not heat labile and which can be replaced by *m*-nitroaniline or "Kochsaft," but not by cysteine.

5. Thiaminase is inhibited by sulfhydryl-specific inhibitors. Iodine inhibition could be reversed by addition of excess cysteine.

6. The interference of cysteine with the Melnick-Field assay method can be reversed by destroying excess cysteine with iodine prior to the addition of the diazo reagent, or by adding a higher concentration of the diazonium compound.

7. Purification of thiaminase by fractional precipitation with acetone or ammonium sulfate was attempted under various conditions but was unsuccessful.

8. Melnick-Field dyes were prepared from thiamine and from the methiodide of the thiazole moiety and their properties and absorption spectra compared.

9. Two new compounds, the S-benzyl derivative of the open form of thiamine and N-(2-methyl-6-aminopyrimidyl-5-methyl)-taurine, were prepared and their properties and absorption spectra listed.

PROTEOLYTIC AND COAGULATING ENZYMES OF ENTEROCOCCI¹

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Streptococcus liquefaciens, the species which was used in the present study, is a common dairy organism and belongs to the enterococcus group of the streptococci. This organism is known to be resistant to normal pasteurization procedures. In milk it is believed to produce a rennet-like enzyme which brings about rapid coagulation of milk. In addition to this, it causes considerable proteolysis, thereby producing bitterness. The exact nature of the enzyme systems involved in coagulation and proteolysis has not been determined previously.

With a view to gain a better understanding of the role of this organism, the study of its enzyme system as it affects milk proteins was undertaken. Proteolytic activity of the test enzyme was measured by the release of tyrosine and tryptophan from casein substrate at optimum pH 7.4, using intensity of color development with Folin-Ciocalteu's phenol reagent for measurement. Coagulating activity was estimated by noting the time in minutes taken by the test enzyme to coagulate 5 ml. of milk substrate at pH 5.60. The test enzyme used in both these cases was the centrifugally obtained supernatant from several test cultures grown on media of various compositions.

Study of the relationship of nutrition of the organisms to the production of proteolytic and coagulating enzyme activities showed that all nine strains (N, C, B, O, Y, E, 19, 20, and 7) examined produced these two enzyme activities when grown in litmus milk or vitamin-test casein medium. Increase in the concentration of milk solids in litmus milk used as a growth medium resulted in greater production of both types of activities. However, the amounts of the two enzyme activities produced in a buffered peptone broth were considerably less. Addition of either gelatin or casein to this broth resulted in increased production of both enzyme activities. When tryptone, tryptose, proteose-peptone, or peptonized milk was added in the concentration of 1.5 per cent to the litmus milk, decreases in the normal enzyme production occurred.

None of the nine cultures produced detectable amounts of proteolytic or coagulating enzyme activities when grown on Niven and Sherman's simplified amino acid medium, modified to increase its buffering capacity. This points out the adaptive character of the two enzymes.

¹ Doctoral thesis number 1064, submitted June 2, 1950.

Omission of individual vitamins from the vitamin-test casein medium affected both the organism growth and enzyme production. Addition of 2.0 μg vitamin B₁₂ per 5 ml. of the vitamin-test casein medium resulted in a three-fold increase in level of both types of activities in the case of culture C but had no effect on the eight other cultures. Such an addition in no case resulted in increased bacterial population. Substitution of equivalent cobalt for B₁₂ failed to duplicate the action of the vitamin. Addition of vitamin B₁₂ to the enzyme preparation did not influence either activity of the enzyme preparation.

Strains B and C required added thiamine (5 γ per 5 ml.) for growth in the amino acid medium, while the former also required this amount of the vitamin in the vitamin-test casein medium. Additions of thiamine, Tween 80, sodium acetate, ascorbic acid, *p*-aminobenzoic acid, and inositol to the vitamin-test casein medium failed to increase the enzyme production by cultures C, B, and E.

The extracellular proteolytic enzyme has its optimum pH at about 7.4 for digestion of casein and lactalbumin. No such optimum was found for the coagulating activity, the test enzyme showing greater coagulating activity as the pH of the milk substrate decreased to the point where spontaneous coagulation occurred.

Maximum stability of both types of enzyme activity was found to be in the pH range of 6.0 to 8.0. At 61.7°C., both the activities were destroyed in less than 10 minutes over the entire pH range tested (pH 5.0 to 9.0). During 8 days of storage at 2-3° and 30°C., both the proteolytic and coagulating enzymes were stable in the pH range of 5.3 to 9.0, while rapid destruction occurred at pH 4.5 and below.

Addition of sodium oxalate to milk substrate resulted in complete prevention of coagulation by the enzyme. Lowering of pH or addition of CaCl₂ restored the milk coagulating ability of the enzyme. There was a difference in the coagulating action of the test enzyme toward milk substrate heated to different temperatures for a 15-minute period. Milk heated to 70°C. showed maximum susceptibility to the coagulating action of the test enzyme, with decreased coagulating ability when the milk was heated to either higher or lower temperatures. A commercial pepsin preparation tested showed a similar behavior. However, rennet did not act in this manner, its coagulating activity decreasing with increase in heat treatment of the milk. The possibility of a chemical or a physical change in milk proteins or the presence of an enzyme-inhibiting factor in raw milk has been discussed as explanation for this phenomenon.

Different trials using adsorption and salting-out techniques did not result in separation of the proteolytic and the coagulating activities of the test enzyme. Data on heat inactivation, stability of two enzymes and failure to separate them using adsorption and salting-out methods suggest that the proteolytic and coagulating activities probably are two manifestations of a single enzyme.

A peptidase preparation obtained by cell grinding and autolysis was active against glycyl-L-leucine and DL-alanylglycine, the latter being

hydrolyzed far more readily. Two pH optima (8.0 and 5.0) for peptidase action against glycy-L-leucine were found. Similarly, two pH optima were found for DL-alanylglycine, one at pH 6.9 and the other around pH 8.2; there also was some indication of another optimum around pH 5.0. No detectable activity against either substrate was found at pH 4.0. Hydrolysis of glycy-L-leucine at pH 8.2 was activated by Mn^{++} , Co^{++} , and Mg^{++} in the declining order stated; hydrolysis of the same substrate at pH 5.0 was activated only by Co^{++} . In the case of DL-alanylglycine at pH 8.3, Mn^{++} , Co^{++} , and Mg^{++} activated the hydrolysis, while only Mg^{++} activated at pH 6.9. Cysteine, Fe^{++} , Cu^{++} , and Ca^{++} had no activating effect for peptidases active on either of the two substrates. The peptidase preparation was not inactivated by 30 minutes, heating at 61.7°C. The results indicate the possibility that several enzymes active only in particular and quite divergent pH ranges are present in the peptidase preparation. There appears to be a rather high specificity in metal activation of the enzyme preparation at different pH levels. Conceivably this could be used to distinguish several dairy organisms from each other.

Thus, both the extracellular proteinase and endocellular peptidases would be expected to be active in cheese, although at a relatively low level due both to low holding temperatures used for ripening and conditions somewhat more acid than optimum for enzyme activity. In addition to this, while the extracellular proteinase would be destroyed in the normal pasteurization of milk, the endocellular peptidases do not appear to be affected by such a treatment. The heat resistance of the latter enzymes, coupled with their activity at about pH 5.0, makes them a potential factor in the ripening process. It is obvious that the action of these enzymes would exert a considerable influence on the flavor and quality of cheese. Possibly, these enzyme preparations could be used to hasten the ripening and to improve quality of cheese.

COUPLED BENDING AND TORSIONAL FREE VIBRATION OF A SWEEP WING¹

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One of the recent trends in the aerodynamic design of high-speed airplanes is toward the use of the swept wing. The determination of the natural frequencies of the free vibrations of such wings is of great importance because the natural frequencies must be used in the determination of the critical flutter speed. The paper presents a method by which the natural frequency of the coupled bending and torsional free vibrations of a swept wing can be approximately determined.

The continuous elastic structure of the actual swept wing is approximated by a composite wing consisting of a finite number of sections. Each section contains a concentrated mass located at the outboard end of the section and an inboard weightless elastic bar of either straight or circular arc planform. The choice as to whether the straight or circular arc bar is used in any section is determined by whichever form more nearly coincides with the locus of elastic centers of the section. The introduction of the circular arc bar also makes it possible to avoid angular discontinuity between sections and at the center of the wing span.

The usual assumptions of thin bar theory are made. Deflections of the vibrating system are assumed small, so that only vertical motion in the direction normal to the plane of the elastic axis and rotation about the elastic axis are considered. Loads other than inertial loads are neglected, and the elements of the sections are assumed to be in harmonic motion.

A set of six equations is developed for a circular arc bar section. Each equation relates a shear, bending moment, slope, deflection, torque, or angle of twist at the inboard end of a section to the shear, bending moment, slope, deflection, torque, and angle of twist at the outboard end. The six relationships are then combined into a single matrix equation for each circular arc bar section.

Then a limiting process is used to derive a matrix equation for a straight bar section from the matrix equation of the circular arc bar section.

One other type of section is introduced to handle such actual concentrated masses as tip tanks, nacelles, and fuselage effects. The matrix equation for this section is obtained from the matrix equation for the

¹ Doctoral thesis number 996, submitted August 20, 1949.

straight bar by setting the length of the bar equal to zero. The swept wing is approximated by a combination of these three types of sections.

After the matrix equations for each section of the wing semi-span have been written, a trial value of the frequency is selected and its value substituted in the section matrices. Then the matrix representing the tip section is premultiplied by the matrix representing the section just inboard of the tip. The product of these two is then premultiplied by the matrix representing the next inboard station. This successive premultiplication is continued until a single matrix equation for the entire wing semi-span is obtained.

The matrix equation for the entire wing semi-span is then reduced to a set of six equations. By this procedure, the boundary conditions at the center of the wing span are related to the boundary conditions at the tip.

At the tip of the wing, the shear, bending moment, and torque are equal to zero. At the midspan, for symmetric free vibrations, the shear, slope, and torque must equal zero. At the midspan, for antisymmetric free vibrations, the bending moment, deflection, and angle of twist must equal zero. If the trial value of the frequency chosen is the frequency of one of the normal modes of symmetric or antisymmetric vibration, the boundary conditions for those modes will be satisfied. If this is not the case, additional values of the frequency must be tried. This trial process is repeated until the natural frequencies are found.

By this method the same basic matrix equations are used to locate both the fundamental and higher natural symmetric and antisymmetric frequencies.

A numerical example of a five-station swept wing is included and the computational techniques are discussed.

COMPARATIVE DEVELOPMENT OF THE EMBRYOS OF INBRED AND HYBRID MAIZE¹

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Previous investigations of heterosis have shown that on the basis of dry weight, hybrid maize embryos may be less than, equal to, or greater than the embryos of parent inbreds. The present investigation was undertaken to explore the possibility that heterosis may be expressed in histological or morphological development of different parts of the maize embryo.

Two inbred lines of dent maize, L317 and B1349, and their reciprocal hybrids were chosen for detailed study after preliminary examinations revealed that these inbreds differed strikingly in histological development. A split-ear pollination technique was employed, whereby inbred and hybrid kernels were grown on the same ears. Embryos of each inbred and each of the reciprocal hybrids were studied 5 days after pollination, and at 5-day intervals thereafter until 40 days after pollination.

Comparisons were made on the basis of visual study of longitudinal and transverse sections of the embryos at 5, 10, and 15 days, and serial transverse sections of embryos from 20 to 40 days after pollination. Four levels were chosen as the chief regions to be compared. These were: (1) the transverse section of the plumule at the level of the apical meristem; (2) the transverse section near the basal portion of the first internode, above the region of seminal root initiation; (3) the transverse section at the level of seminal root initiation; (4) the transverse section of the radicle at the most proximal region at which it is separated from the coleorhiza by a cleft. At levels 1, 2, and 4, visual observations were supported by measurements of transverse sectional areas and by statistical analysis of the data.

The two inbreds chosen for study differ markedly in plumule development with respect to: (1) time of initiation of leaves; (2) activity of marginal meristems of the leaves; (3) transverse sectional areas of plumular organs.

Embryos of the hybrid L317 x B1349, grown on the same ear with the less vigorous parent, L317, surpassed the inbred embryos of the maternal parent in plumular development throughout the entire period of embryonic growth which was studied. The expression of heterosis in this instance consists of: (1) increased leaf initiating activity of the

¹ Doctoral thesis number 1069, submitted June 5, 1950.

apical meristems; (2) increased activity of marginal leaf meristems as judged by lateral expansion of leaves; (3) increased total plumule size as indicated by transverse sectional area. This hybrid, L317 x B1349, does not equal its male parent in plumular development during early embryo growth but is approximately equal to the male parent 40 days after pollination.

Embryos of the hybrid B1349 x L317, grown on the same ear with the more vigorous inbred, B1349, were found to be inferior to the embryos of the maternal parent in plumular development until approximately 35 days after pollination. At 40 days the hybrid B1349 x L317 surpassed the inbred B1349 in transverse sectional area of the coleoptile and the first and fourth leaves, but was otherwise approximately equal to the maternal inbred. This hybrid, B1349 x L317, surpassed its male parent throughout the entire period of plumule growth on the basis of all criteria used in judging comparative development.

The difference between inbreds in rate of leaf initiation which were noted are in agreement with observations of comparative development of these lines after germination. The inbred L317 is a late maturing inbred. The hybrid L317 x B1349 and its reciprocal differ in rate of leaf initiation. Since these two hybrids are genetically identical, the difference might be explained as the result of the maternal influence. The fact that L317 x B1349 equals the more vigorous parent in leaf initiation may indicate that those genes from B1349 which influence this growth process are dominant. The fact that B1349 x L317 exceeds its more vigorous parent in total transverse sectional area might be explained as the result of additive or complementary effect of genes from both parents. An alternative explanation may be that this difference is due to the effect of hybrid endosperm.

The inbreds used in this study are strikingly different in transverse sectional area of the cortex and stele of the first internode. The hybrid embryos, L317 x B1349, grown on the same ear with the less vigorous inbred L317, surpass the inbred embryos in transverse sectional area of cortex and stele of the first internode. The hybrid embryos, B1349 x L317, grown on the same ear with the more vigorous inbred B1349, are equal to the embryos of the maternal inbred in stelar enlargement, but do not become equal in cortical enlargement until after 35 days. Maternal influence in the development of the first internode is evidenced by the fact that the hybrid embryos grown on the more vigorous inbred surpass the embryos of the reciprocal hybrid in transverse sectional area of stele and cortex at all ages.

The inbreds L317 and B1349 are not obviously different in the histological development of the radicle. Differences which do exist consist largely in the relative enlargement of stele and cortex. With respect to stelar enlargement the inbred L317 is superior to B1349 at 30 days but does not maintain this advantage. The inbred B1349 attains a slight superiority in transverse sectional area of the cortex 40 days after pollination. The embryos of the hybrid L317 x B1349 are superior to

those of the inbred L317 in transverse sectional area of the cortex at 30 and 40 days after pollination. However, this hybrid, L317 x B1349, is not superior to its maternal parent in stele at any age. The embryos of the hybrid B1349 x L317 are superior to those of the inbred B1349 in transverse sectional area of both stele and cortex at 30 days. By 35 days after pollination this hybrid, B1349 x L317, has lost its superiority in transverse sectional area of cortex, but exceeds its maternal parent in transverse sectional area of stele at all ages.

The above comparisons indicate that L317 contributes favorable genes for the growth of stele, while B1349 contributes favorable genes for growth of cortex. Therefore, heterosis in the radicle is the result of the combined effect of favorable genes that are contributed by both parents, and which influence histogenesis.

In seminal root development, the outstanding difference between the inbreds is the time of root initiation. Seminal root development in B1349 is more advanced than in L317, whereas, both hybrids approach the more advanced parent. This situation agrees with respective development in the plumule. The genes which influence early initiation of seminal roots appear to be dominant. A maternal effect is indicated by the fact that seminal root development in the hybrid embryos, grown on the same ear with the more advanced inbred embryos, exceeds seminal root development in hybrid embryos, grown on the same ear with the less advanced inbred embryos.

TOXICITY OF INGESTED
GAMMA-1,2,3,4,5,6 BENZENE HEXACHLORIDE (LINDANE)
TO ALBINO RATS¹

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The extensive use of synthetic organic insecticides has created a potential hazard to man and domestic animals. The possibility of acute or chronic toxicity reactions in mammals exposed to these insecticides warrants thorough investigation before such chemicals are released for general use.

One of the synthetic organic insecticides receiving considerable attention is gamma-1,2,3,4,5,6 benzene hexachloride (lindane). The present work was undertaken in order to determine the effect on albino rats of ingesting small amounts of this insecticide over prolonged periods. The experimental diet consisted of stock rat ration containing 500 parts per million of gamma benzene hexachloride.

It was found that weanling or older rats of the Wistar-Ames strain tolerated the experimental diet for nine months or more without evident external symptoms of toxicity at the time of sacrifice. However, if the feeding of the experimental diet to younger rats was continued until natural death, experimental female rats tended to have a shorter life span than control females. Experimental male rats of this particular strain did not exhibit this tendency toward reduced longevity.

When animals were first placed on the diet containing gamma benzene hexachloride, a decline in growth rate was evident for 2 to 4 days. This decline was more pronounced in female than in male rats. The addition of inositol to the diet did not prevent the initial drop in body weight in experimental animals. It was noted that the beginning weight loss was closely correlated with a reduced food intake.

Data are presented to show that young rats were able to differentiate treated from untreated food. When given a choice between treated and untreated food over an extended period, young rats consumed a progressively greater percentage of non-treated food. Male rats were more sensitive to the presence of the contaminant in the food than were female rats.

Although the reproductive ability of rats was not appreciably altered when gamma benzene hexachloride was included in the diet, marked changes in the ability of productive females to care for their young were evident. Three- to 6-month-old females maintained on the

¹ Doctoral thesis number 1047, submitted May 19, 1950.

experimental diet for an average of three months reared approximately 16 per cent of their young to weaning. This was in contrast to corresponding control females who reared approximately 73 per cent of their young to weaning. Generally, the longer the female rats were maintained on a diet containing 500 parts per million of gamma benzene hexachloride, the less their inclination to care for young. Experimental females apparently did not develop any tolerance for the toxicant inasmuch as the rearing performance did not improve with time. However, the detrimental effects, seemingly attributable to ingestion of the gamma isomer, disappeared when experimental females were placed on normal food at the time of subsequent mating.

The continual ingestion of the experimental diet did not produce any significant changes in either the erythrocyte or leucocyte counts in albino rats.

Experimental rats, after ingesting treated food for 2 months or more, showed an increase in the relative weight of the liver. Likewise, an increase in the relative weight of the kidneys was evident in all age groups of experimental males and in females maintained on the experimental diet for 6 months or more. Although there was a trend toward an increase in the kidney weights of females that had been on the experimental diet for 2 months, the difference at this time between the normal and experimental weights of this organ was not significant.

The relative increase in the liver-body weight ratio was similar in experimental males and females; however, the relative increase of the kidney weight of experimental males was greater than in experimental females.

No significant changes were found in weights of spleen, adrenals, and testes in rats ingesting experimental food over prolonged periods.

When examined histologically, liver damage was evident in rats maintained on the experimental diet. However, only rarely was this damage great enough to be considered irreparable. Evidence of a chronic toxicity state in the liver was indicated by albuminous and fatty degeneration. Generally, the kidneys appeared quite normal when examined microscopically although some hyaline degeneration was evident.

Using a bioassay to detect the presence of gamma benzene hexachloride in tissues, data indicated that rats were able to eliminate this toxicant from their tissues in a very short time. After 12 days on normal food, blood, muscle, liver, and even kidney and adipose tissues from females that had been on the experimental diet for a year contained only traces of the toxicant.

GLYCEROL FERMENTATION OF STARCH¹

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Most of the fermentation procedures for glycerol that have been described in the literature use sugar as the raw material, but it would be desirable from the standpoint of initial cost to use starch. There are very few references to the use of starch for this fermentation although it has been suggested in a few instances. An important difficulty in the usual sulfite process is the recovery of the glycerol from the fermented material. The high concentration of soluble salts resulting from the use of large amounts of sodium sulfite or bisulfite is the principal source of the difficulty. The purpose of the investigation on which this thesis is based was to determine the best conditions for a glycerol fermentation process using starch as the fermentation substrate. It was hoped that a process could be developed which might have practical application for commercial glycerol production. To this end most of the work was done with the use of those sulfites which would not increase the concentration of soluble salts enough to make the glycerol recovery too difficult.

Acid-hydrolyzed starch was found to provide a suitable substrate for glycerol fermentations. In all cases tried the starch medium gave practically as good yields as those reported for sugar medium. Sulfuric acid concentrations of 0.1 normal gave 96 per cent conversions to reducing sugars of 10 per cent starch mashes when heated for 2 hours at steam pressures of 25 pounds per square inch. From these mashes yields of 23 per cent glycerol, based on the glucose equivalent of the starch, were obtained. Magnesium sulfite hexahydrate was used in amounts equal to the weight of the sugar, and inoculation was made with 15 ml. of a suspension of yeast cakes for each 300 ml. of mash. The yeast suspension contained one yeast cake in each 45 ml. of a 5 per cent glucose-0.5 per cent corn steep liquor medium and was incubated at 30°C. for 6 hours before it was used for inoculation. The fermentations themselves were also carried out at 30°C. for 65 hours.

Sulfur dioxide in concentrations from 0.5 to 1.5 g. per 100 g. of water gave 67 to 80 per cent conversions of the starch to reducing sugar when heated 2 hours at 30 pounds steam pressure. The glycerol yields from magnesium sulfite fermentations of these mashes ranged from 14 per cent for the lower concentration of sulfur dioxide to 8 per cent for the higher concentration.

¹ Doctoral thesis number 989, submitted August 3, 1949.

The addition of nutrients to glycerol fermentations of acid-hydrolyzed starch was unnecessary if the large inocula described above were used. The fermentations were brought about apparently by the enzymes associated with the inocula, and there was very little proliferation of the yeast.

Magnesium, calcium, and ammonium sulfites gave yields of 23, 6, and 2 per cent glycerol, respectively. The addition of 30 g. of magnesium sulfate heptahydrate to calcium sulfite fermentations containing 30 g. of calcium sulfite dihydrate increased the glycerol yield to 10 per cent. Magnesium sulfite and yeast can be used over for successive fermentations if care is taken to maintain the activity of the yeast. The use of mixtures of magnesium, calcium, and ammonium sulfites gave poorer yields of glycerol than the use of magnesium sulfite alone. For example, a mixture of 20 g. of magnesium sulfite hexahydrate and 10 g. of calcium sulfite dihydrate gave a glycerol yield of 19 per cent, and a mixture of 30 g. of the magnesium salt, 20 g. of the calcium salt, and 10 g. of ammonium sulfite monohydrate gave only 3 per cent. Ammonium sulfite actually inhibited the fermentation so that its use in mixtures prevented the other sulfites from giving their normal yields of glycerol. Addition of 15 g. of sodium sulfite heptahydrate to a magnesium sulfite fermentation containing 15 g. of magnesium sulfite hexahydrate increased the glycerol yield to 26 per cent.

The pH of the fermentations media influenced the yields of glycerol. For magnesium sulfite the optimum value lay between 6.0 and 6.5, and for the calcium sulfite it was about 5.5. When ammonium sulfite was used, the variation of glycerol yields with pH was not great for pH values between 4.5 and 6.5. The addition of sulfur dioxide to control the pH during the fermentations did not appear to be desirable.

The percentage yields of glycerol decreased from 23 when the initial concentration of starch was 5 per cent to 17 when a 20 per cent acid-hydrolyzed starch mash was used. A similar effect was observed in series of fermentations conducted at 37°C. as well as those at 30°C. It was found that the yields of glycerol obtained at 37°C. were about 0.5 per cent higher than those at 30°C. for the same starch concentrations. Stirring was advantageous where the less soluble salts were used in the fermentations. Delaying the addition of the sulfite for 2 hours after inoculation of the fermentations decreased the glycerol yield to 20 per cent. The addition of sulfite to the yeast suspension to acclimatize it to the sulfite before inoculation did not improve the glycerol yields.

Glycerol can be produced from acid-hydrolyzed starch by *Bacillus subtilis*, Ford's strain. The maximum yield was about 22 per cent, and no aldehyde-fixing agent was required. The fermentations were inhibited increasingly by increasing additions of sulfite until the yield of glycerol had decreased to 3 per cent when 8 per cent of magnesium sulfite hexahydrate was added.

The yeast *Zygosaccharomyces acidifaciens* fermented acid-hydrolyzed starch without an aldehyde-fixing agent to give about 8 per cent

glycerol. It was found that the addition of 10 per cent magnesium sulfite hexahydrate to the fermentation increased the glycerol yield to 23 per cent. The acetaldehyde content of the fermented material increased from a negligible value in the fermentations without sulfite to a value almost equivalent to the glycerol in the fermentations where sulfite was used.

DETECTION OF NECROTIC RING SPOT VIRUS AND ITS OCCURRENCE AND SPREAD IN SOUR CHERRY NURSERIES¹

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The problems involved in the production of virus-free sour cherry trees in nurseries have been meagerly investigated in the past. Since viruses are not usually transmitted through seed, the basic assumption was that propagation of cherry trees with buds from known virus-free scion trees would solve the major problems concerned. Because virus-free budwood of several varieties was available at the outset of these investigations, it seemed that the important information needed was that which would give assurance that virus-free trees grown under isolated conditions would not become contaminated with virus. Such information should be concerned with the occurrence of virus in *Prunus* cultivated in or growing near the nurseries and with the presence or absence of virus spread in the cherry nursery. The report by Cation (6) that viruses may be transmitted through *P. Mahaleb* seed and circumstantial evidence that a portion of *P. Mahaleb* cherry rootstocks are virus infected made it imperative that the status of the *P. Mahaleb* seed trees and *P. Mahaleb* seedlings be clarified.

Investigations for acquiring quantitative data were impeded by lack of a reliable index plant which could be made available in large numbers. Very early in these investigations *P. tomentosa* gave promise of being such a plant, so that considerable information was accumulated to determine its value.

The reliability of *P. tomentosa* as an index plant for necrotic ring spot virus was tested by comparing it to Elberta peach in the field and Montmorency cherry in the greenhouse.

In the field *P. tomentosa* detected virus in more of the trees indexed than did Elberta peach. Ten of 199 *Prunus Mahaleb* L. orchard trees were found infected by indexing on *P. tomentosa*, while only seven were found with Elberta peach seedlings. All of 111 Early Richmond cherry nursery trees were found to be infected by indexing on *P. tomentosa*; only forty-one were found with peach. None of twenty Waneta plum and twenty *P. Besseyi* were found to be infected with either the *P. tomentosa* or the peach seedling index.

In the greenhouse comparison, *P. tomentosa* seedlings and Montmorency cherry trees were inoculated with nineteen strains of necrotic ring spot virus, three strains of prune dwarf virus and one strain of

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peach rosette mosaic virus. Both index plants reacted to all nineteen strains of necrotic ring spot and three strains of prune dwarf virus. *P. tomentosa* reacted to peach rosette mosaic virus while Montmorency cherry did not. Symptoms induced by the virus on *P. tomentosa* consisted of chlorotic mottling with or without necrotic rings on the leaves of new growth, accompanied in some cases with necrosis of terminal growth. Virus strains could not be differentiated by symptom expression. In these experiments *P. tomentosa* was more reliable than Elberta peach in the field and as reliable as Montmorency cherry in the greenhouse as an index plant for necrotic ring spot virus.

Samples of seventeen varieties of plums, five varieties of ornamental *Prunus*, one variety of apricot and six varieties of cherries cultivated in southwest Iowa nurseries were indexed for necrotic ring spot virus. Of these thirty-two species and varieties, twenty-seven were found to contain virus. Infection ranged from 0 to 70 per cent in twenty-six of the species and varieties. In only one, Early Richmond, was virus present in 100 per cent of the trees. A total of 496 individual trees were indexed in this experiment. Average infection for all samples was found to be 37 per cent (confidence interval, 32 to 42 per cent, $P = 0.95$).

Two samples of Wild Black Cherry and two samples of Wild Plum were indexed. Infection in the Wild Black Cherry samples was found to be 50 and 55 per cent (confidence intervals, 17 to 83 per cent and 36 to 70 per cent). Infection in the samples of Wild Plum was found to be 14 and 55 per cent (confidence intervals, 3 to 37 per cent and 30 to 79 per cent).

These data indicate that most of the *Prunus* species and varieties cultivated in southwest Iowa nurseries and two of the wild species growing near the nurseries are infected with necrotic ring spot. Isolation of virus-free sour cherry nursery stock from these infected *Prunus* is necessary. The possibility of Wild Plum rootstocks as sources of virus contamination for cultivated plum is also indicated.

One hundred and sixty-one *P. Mahaleb* L. trees composing a seed orchard near Gustine, California, and twenty-five samples of budwood from a *P. Mahaleb* orchard near Zillah, Washington, were indexed. Seven per cent of the California orchard trees and 85 per cent of the samples from the Washington orchard were found infected. Three samples from fields of *P. Mahaleb* seedlings were indexed; these samples were found to contain 14, 35, and 18 per cent infection (confidence intervals, 6 to 27, 15 to 59, and 12 to 24 per cent, respectively).

The data definitely establish that virus is present in *P. Mahaleb* orchard trees and that some of the seedlings being shipped into southwest Iowa nurseries are infected with necrotic ring spot virus and constitute one means of introducing this virus into sour cherry nursery stock in that area. The possibility of spread of virus in the *P. Mahaleb* seedling bed is suggested.

In an attempt to determine the rate of spread of necrotic ring spot in sour cherry nursery stock in southwest Iowa, random samples of trees

in three fields were indexed at two different dates. Two of these fields were isolated by a distance of at least one-fourth mile from other *Prunus*; the other was surrounded by sour and sweet cherries known to contain 32 per cent ring spot (confidence interval, 14 to 48 per cent).

According to the chi-square test, in the unisolated field there was a significant increase in percentage of infected trees during the time interval between indexing dates. In this field percentage of infected trees increased from 9 to 37 per cent during a 46-day interval. In the isolated fields the percentage of infected trees increased from 2 to 8 per cent in 46 days in one, and from 18 to 20 per cent in 1 year in the other.

It seems that spread of necrotic ring spot virus may occur in sour cherry nursery stock propagated in southwest Iowa and that isolation of sour cherry fields by one-fourth mile from other *Prunus* may help ensure their continued freedom from contamination by necrotic ring spot virus.

FUNDAMENTAL ASPECTS OF DEPRECIATION THEORY ¹

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Increased interest in depreciation has arisen because of the high income tax rates and excess profits taxes during and following World War II. This is evidenced by (1) the controversies between tax agencies and companies concerning the exact amounts of depreciation to be allowed and (2) the concern of both government and business over the indirect effects of depreciation policies upon the modernization of industrial properties. Prior to 1934 when T.D. 4422 was issued depreciation was of more interest to those few individuals concerned with public utility rate making than to the average businessman. Depreciation is now of concern to all people who own properties which have a net taxable income. An understanding of the general principles upon which estimates of depreciation are based will assure the taxpayer the payment of a minimum income tax in so far as cost-depreciation affects it. It also will provide a better estimate of the financial position of his business with regard to the investment in long-lived properties. Recent literature on depreciation has contained so many assertions based upon implicit assumptions and vague generalities that this study of the underlying principles of depreciation has been undertaken. The principal objective of the study has been to integrate and explain the ideas on depreciation which already exist in diverse places and whenever possible to compare alternative proposals for estimating depreciation. It is an effort to clarify the basic issues which underly much of the present controversy about depreciation.

A survey of the historical development of the idea of allocating the cost or value of a property over the life of the property reveals that when the word depreciation was introduced it was used in either the sense of cost or of value and was ambiguous from the beginning. Since that time depreciation has been used to connote the physical condition of a property without regard to the allocation of either cost or value. Much confusion in discussions of depreciation has arisen because the exact meaning of the word depreciation was never specified in the discussion. Of prime importance in any discussion of depreciation in either of the above specific meanings is the meticulous qualification of the word depreciation throughout the discussion.

A clear statement of the objectives of any depreciation policy will do much to facilitate a choice of a method whereby these objectives can

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