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THE ELECTRICAL CONDUCTIVITY OF COD LIVER OIL

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It has been known for many years that photographic plates when placed over cod liver oil are blackened, but there has been wide divergence of opinion as to the cause of this effect on the plate. It has been suggested that the plate is affected by some kind of radiation when the oil is oxidized, but it seems that no experiments have been performed which would either decisively prove or disprove this theory. Kugelmass and McQuarrie[1] have concluded that this phenomenon is merely another example of the "Russell effect." T. Avellar de Loururd[2] claimed to have shown that the blackening is caused by the formation of ozone when the oil is exposed to ultra violet light. Others have claimed that, in the process of oxidation, ultra violet light is excited which, in turn, affects the plate but later experiments have tended to disprove this theory. Some experiments by one of us have suggested the possibility of a radiation in the form of particles which are absorbed by a few centimeters of air. Botcharsky and Foehringer[3] reported that photographic plates were affected by a radiation transmitted through the walls of glass tubes in which were sealed extracts of vitamin A and vitamin B, respectively. Experiments in this laboratory by Wissink[4] have failed to check these results. Consequently, we decided to undertake an investigation to test whether there is any change in the electrical conductivity of the oil when irradiated by a strong source of ultra violet light. While making some preliminary determinations, it was noted that the conductivity of the oil in the apparatus varied rather irregularly before being exposed to the ultra violet. The effect was found also to be the same whether the apparatus was kept in the light or in total darkness. This behavior led us to extend our investigations to the variation of the resistivity of the oil under various conditions.

METHOD AND APPARATUS

The method of resistance measurement consisted in placing the oil in a conductivity cell, to be described later in the paper, in series with a galvanometer and a source of potential and determining the ratio of the current through the cell to the potential impressed across its terminals.

The arrangement of the apparatus for this part of the experiment is shown in figure 1 (a); G represents the galvanometer, which had a sensitivity of 2.1×10^{-10} amperes per mm. deflection at a scale distance

[1] Science, 62:87 (1925).

[2] Compt. Rend. Soc. Biol., 96:1321-1323 (1927).

[3] Nature, 856 (1931).

[4] Thesis, Iowa State College Library.

of 285 cms.; B is a 125-volt storage battery and P is a potentiometer arrangement by which any voltage from 0 to 124 volts may be impressed across the circuit; R is a resistance sufficiently high to protect the galvanometer against excessive current in case of a short circuit in the cell but negligible in comparison to the resistance of the oil; V is a good grade 150-volt D. C. voltmeter and C is the conductivity cell, various forms of which were used during the course of the experiment.

The source of ultra violet light used in the experiment on the photoelectric effect was an iron-nickel arc carrying a current of six amperes. This was enclosed in a metal case in one side of which a heavy brass tube containing a water cell was soldered. The windows in this cell were of quartz so that the passage of the ultra violet light from the arc to the specimen was unimpeded while the heat was absorbed by the water, thus insuring no change in the temperature of the oil because of the presence of the arc.

THE EXPERIMENT

As the experimental study extended to the investigation of several different problems, it may be discussed under five separate headings:

A. The variation of resistance with temperature.

B. The effect of exposure to air on the electrical resistance of the oil.

C. Photo-electric effect.

D. Dependence of resistivity upon vitamin A content.

E. Miscellaneous.

A. THE VARIATION OF RESISTANCE WITH TEMPERATURE

The determination of the resistance of the oil was undertaken by measuring at different temperatures the current flowing through a thin layer of the oil confined between two brass electrodes across which a constant potential difference was impressed.

The original cell constructed for this purpose consisted of two brass electrodes in the form of combs of seven and eight teeth, respectively, so machined that, when fitted together as shown in figure 1 (b), the distances between surfaces was approximately .0064 cm. The area of cross section of the oil traversed by the current was approximately 6.75 cm^2. The cell was surrounded by a water jacket, the temperature of which could be altered as desired. The temperature of the oil was measured by a mercury thermometer graduated to 0.1° C., extending through the top of the jacket and resting on the brass electrodes below.

The results obtained with this apparatus were not sufficiently accurate to be of much value. As it was necessary to clean the apparatus after each trial and, at times, in doing so, to remove the spacers placed between the teeth to prevent short circuits, it was not possible to maintain a constant length of path between electrodes. Also, it was next to impossible to remove every particle of dust and lint from between the teeth when cleaning and these would often cause short circuits or at least decrease the length of the path of the current. However, this arrangement did serve well for preliminary work and in determining the order of magnitude of the resistivity which was found to be about 3×10^{10} ohms cms. at approximately 22° C.

For the succeeding work, the apparatus described in the foregoing paragraphs was replaced by one of simpler construction but capable of giving more accurate results. Two grooves, made accurately .02 inch apart, were machined into two blocks of hard rubber and these blocks were fastened into the ends of a hard rubber box. Two brass plates, .66 cm. by 3 cm., serving as electrodes were then fitted snugly into these grooves as shown in figure 1 (c). The brass container was replaced by an ordinary laboratory calorimeter fitted with a wooden cover and a larger water jacket was made up so that the temperature could be controlled more easily.

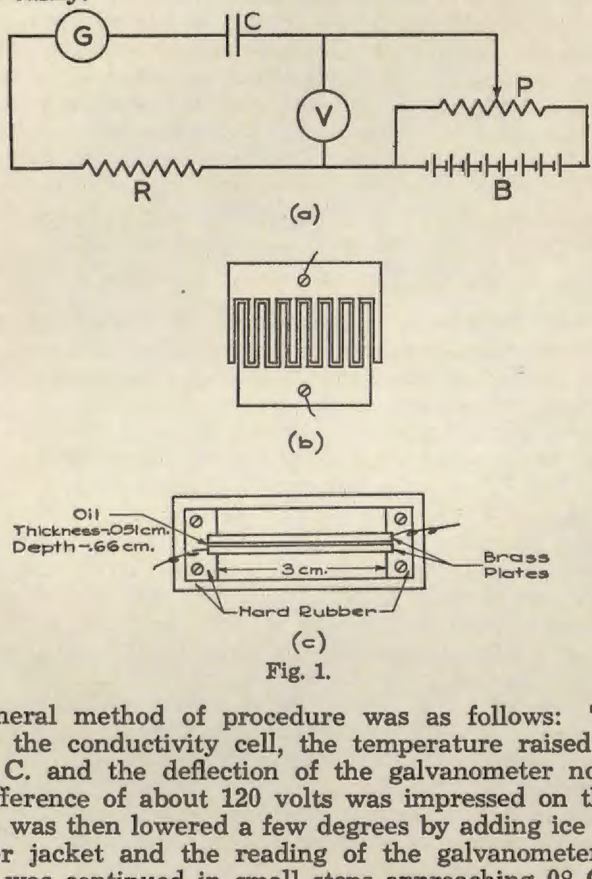

Fig. 1.

The general method of procedure was as follows: The oil was poured into the conductivity cell, the temperature raised to approximately 50° C. and the deflection of the galvanometer noted when a potential difference of about 120 volts was impressed on the cell. The temperature was then lowered a few degrees by adding ice to the water in the water jacket and the reading of the galvanometer was taken again. This was continued in small steps approaching 0° C. The temperature was then raised by approximately the same steps back to the original temperature, thus obtaining values of resistance for both falling and rising temperatures.

The graphs obtained when the resistance was plotted against the temperature closely resembled logarithmic curves. The shapes of the graphs obtained with falling temperature and rising temperature, respectively, were similar but the values of the resistances were usually different. A typical set of data is plotted in graphs I figure 2(a). Curve Ia represents the resistance changes during the first part of the experiment as the temperature fell from about 43° C. to 7° C. The data for curve Ib were taken three or four hours after those for Ia as the temperature rose from 11° C. to 47° C., and those for Ic were, in turn, taken some time after those for Ib as the temperature fell from 47° C. to 8° C. These tests were made on Pure Test cod liver oil on March 25. Similar results were obtained in tests on Super D oil made on March 27 and March 28 as shown in graphs II and III, figure 2 (b), respectively.

It was at first thought that the differences of resistances shown by the earlier graphs of data from succeeding tests taken at short intervals, were probably caused by the lag in the readings of the mercury thermometer but, as the shifts in the curves in these cases seemed to be independent of the direction of the temperature change, it was decided that the errors in the thermometer readings could not account for the resistance differences noted. In order to further satisfy ourselves that this effect was not due to the lag in the thermometer, a copper-constantin thermocouple was substituted for the thermometer in the later experiments and the same results were obtained. The wide variations in the resistances noted in graphs I, II and III where the intervals between tests were comparatively long, proved quite conclusively that the cause must be looked for elsewhere. This effect will be discussed further in the next section.

Later experiments were performed in which the temperature of the oil was increased to approximately 90° C. The resistance-temperature curves shown in Xa and Xb, figure 3 (a), appeared to be approximately logarithmic over the whole range. To test this, the logarithms of the resistances were plotted against the temperatures. The graph then consisted of a series of several straight lines as shown in curves XIa and XIb, figure 3 (a). The dotted portions of these curves were obtained by a comparison with the data secured in several previous experiments over this range of temperatures. The breaks in these curves seemed, in nearly all cases, to be quite sharp, but the slopes of the different sections were not very consistent; that is, on one graph the slope of a given section was greater than that of the preceding section, while on another taken under as nearly as possible the same conditions, the reverse was true. This would seem to indicate a somewhat unstable condition at these higher temperatures. Also, these breaks did not appear at the same temperatures for different trials even though the specimens were taken from the same bottle. Judging from the behavior of the resistance itself as a function of time of exposure as discussed in the next section, the breaks could not necessarily be expected to occur consistently at any one temperature as the effect caused by the contact with the air was large at first and continued more slowly with further contact. In short, the time of change depended upon the previous treatment of the oil as well as upon the temperature.

The results of these experiments seemed to indicate that the change in temperature from 50° to 0° C. and return produced no permanent change in the resistance of the oil. In order to test this point further, a pair of long brass electrodes were inserted through a close fitting hard rubber stopper into a new bottle of oil. In this way, very much less air was admitted to the oil than was the case when the oil was poured into the open cell. When, in this experiment, the resistivity of the oil was

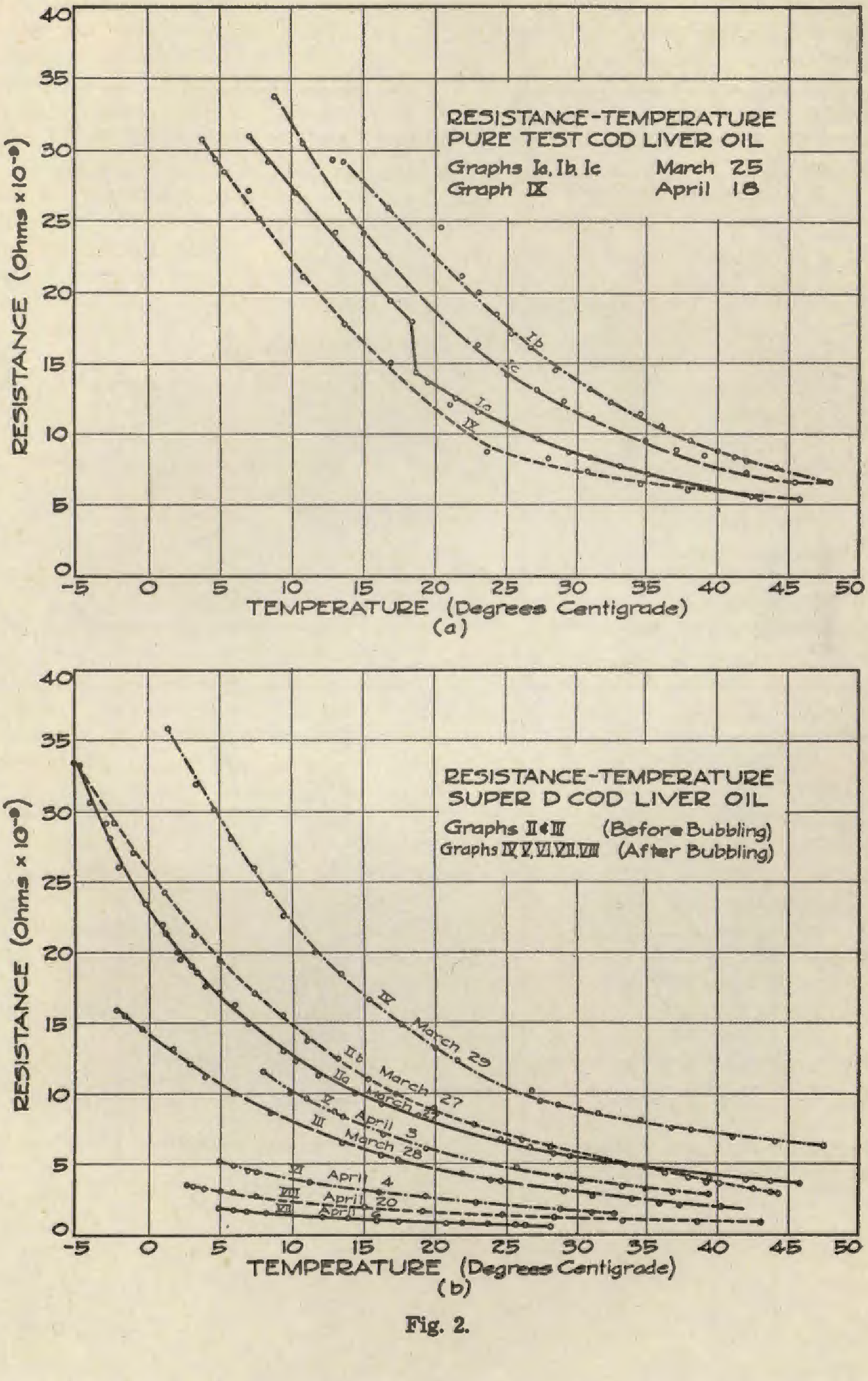
RESISTANCE-TEMPERATURE
PURE TEST COD LIVER OIL
Graphs Ia, Ib, Ic March 25
Graph IX April 18
RESISTANCE (Ohms x 10⁻⁹)
TEMPERATURE (Degrees Centigrade)
(a)
RESISTANCE-TEMPERATURE
SUPER D COD LIVER OIL
Graphs II & III (Before Bubbling)
Graphs IV, V, VI, VII, VIII (After Bubbling)
IV March 29
IIb March 27
IIa March 27
V April 3
III March 28
VI April 4
VIII April 20
VII April 6
RESISTANCE (Ohms x 10⁻⁹)
TEMPERATURE (Degrees Centigrade)
(b)

Fig. 2.

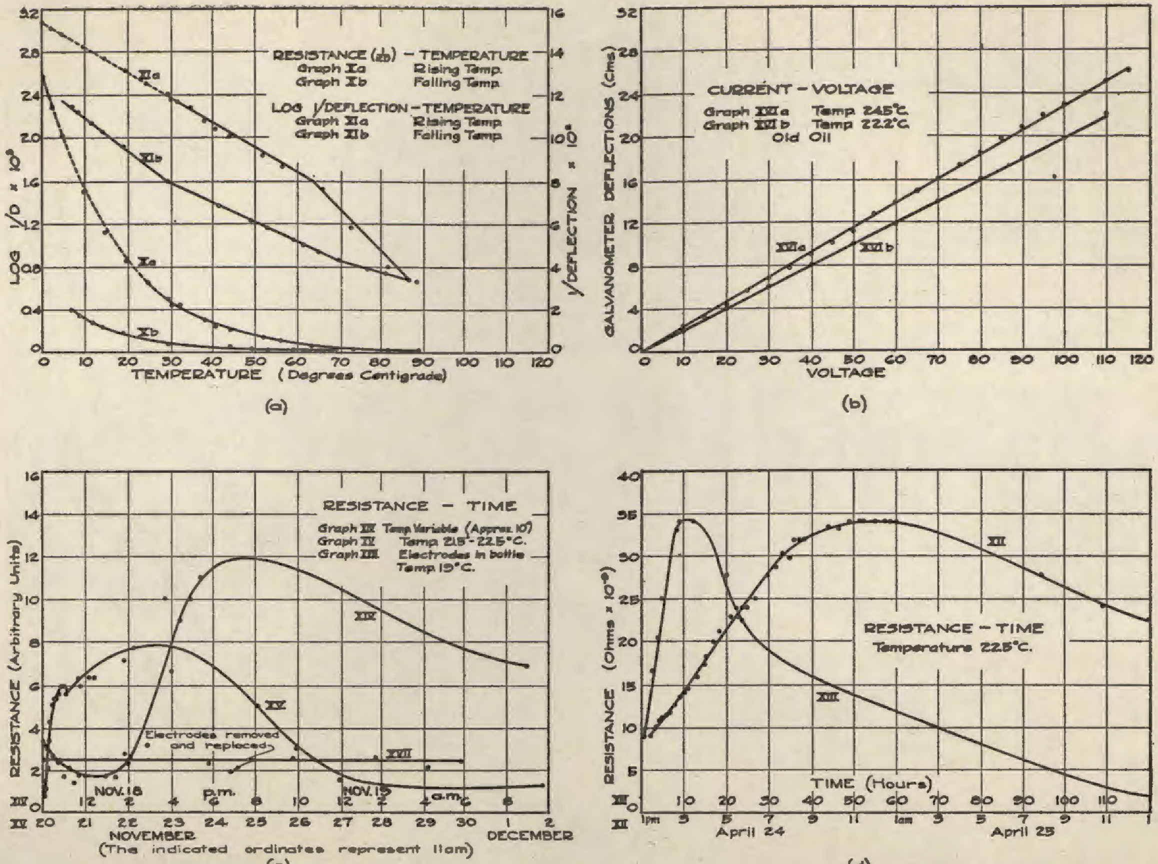
RESISTANCE (1/D) – TEMPERATURE
Graph XIa Rising Temp.
Graph Xb Falling Temp.
LOG 1/DEFLECTION – TEMPERATURE
Graph XIa Rising Temp.
Graph XIb Falling Temp.
LOG 1/D x 10⁸
1/DEFLECTION x 10⁸
TEMPERATURE (Degrees Centigrade)
(a)
CURRENT – VOLTAGE
Graph XVIa Temp. 24.5°C.
Graph XVIb Temp. 22.2°C.
Old Oil
GALVANOMETER DEFLECTIONS (Cms.)
VOLTAGE
(b)
RESISTANCE – TIME
Graph XIV Temp. Variable (Approx. 10°)
Graph XV Temp. 21.5 - 22.5°C.
Graph XVII Electrodes in bottle Temp. 19°C.
RESISTANCE (Arbitrary Units)
Electrodes removed and replaced
NOV. 18
p.m.
NOV. 19
a.m.
NOVEMBER
DECEMBER
(The indicated ordinates represent 11am)
(c)
RESISTANCE – TIME
Temperature 22.5°C.
RESISTANCE (Ohms x 10⁹)
TIME (Hours)
April 24
April 25
(d)

Fig. 3.

determined as the temperature was varied from 0° C. to 50° C., or a few degrees above, no permanent change was found, which confirmed the above conclusion. When the temperature was raised as high as 90° C., a permanent change in the resistivity was found, the resistance then being lower than before the oil was subjected to this high temperature. See graphs X and XI, figure 3 (a). It was inferred from this result that some chemical changes had taken place in the oil at these temperatures. If, however, after this oil had been allowed to cool and a sample then investigated in the usual manner, the shape of the resistance-temperature curve was the same as before but its position was shifted.

A test of a somewhat different nature was carried out on a sample of Super D cod liver oil. This was heated to 90° C. and air was bubbled through it for 35 minutes, the temperature being maintained at 88° C. to 90° C. When the resistance-temperature relation for a sample of this oil was determined, no change in the shape of the graph was found but this graph was found to lie considerably above the graphs obtained for the oil not subjected to this bubbling and high temperature, as is seen by a comparison of graphs II and IV, figure 2 (b). Thus again, while the actual resistance of these two samples was greatly different, the percentage change of resistance with change in temperature in each case was practically the same.

B. EFFECT OF EXPOSURE TO AIR ON THE ELECTRICAL RESISTANCE OF THE OIL

As noted above, it seems that some of the changes in the resistance of the oil were not due to temperature changes alone; because of this effect alone, the resistance of the oil at any temperature should be constant for all specimens taken from the same bottle and also it should not vary from day to day. A very striking example of this change is shown by the break in graph Ia, figure 2 (a), where work was interrupted for one hour but a practically constant temperature was maintained. The resulting resistance change amounted to about 25 per cent of the resistance at that temperature. Also, the rise in resistance as the oil was left in the apparatus exposed to the air as shown in Ib and the subsequent resistance drop with further exposure to air as shown in Ic is significant and led to further investigation as to the variation of the resistance of the oil as a function of the time of exposure to air, that is, possibly as a function of the oxidation of the oil.

These attempts to determine the variation of resistance with exposure to the air were made by allowing the oil to remain in the cell and noting its resistance at frequent intervals, while the temperature was kept constant. The results of a trial made on April 24-25, 1929, are shown in graph XII, figure 3 (d), from which it is seen that the resistance at first increased with time of exposure to air, reaching a maximum in 10 to 12 hours, and then decreased with further exposure. Observations made on April 29 on the same sample, which had been left in the apparatus continually, showed that in five days the resistance had dropped to a value less than that at the beginning of the test. These results are shown graphically in graphs XII and XIII, figure 3 (d), the first part of graph XIII being a reproduction of graph XII plotted to a larger time scale. This point was a little more carefully investigated later. A test made on November 18 showed that, for the first three hours after the oil was taken from the bottle, there was a decrease in the resistance, then an increase for seven or eight hours, and then a decrease, as shown in graph XIV, figure 3(c). A series of determinations extending over a period from November 20 to December 4, are shown in graph XV, figure 3(c). It is to be noted that graph XIV represents less than the first day on graph XV. The variations were somewhat irregular during the latter states as shown in graph XV. These latter results seem inconsistent with those of April 24 near the beginning of the test, as no decrease was then noted. The oil on that date had, however, been in the apparatus for some time and it is probable that the first state noted in the later trials had been passed before the readings were started.

When the experiments mentioned in the foregoing with the electrodes inserted into the bottle of oil were being made, it was noted that whenever the electrodes were removed from the oil, cleaned and reinserted, the resistance for a short time was a little lower than before the removal of the electrodes. This could be accounted for in view of the results obtained on November 18 and 20 by the fact that a little air was carried between the electrodes into the oil, producing a small amount of oxidation. The data obtained with the electrodes immersed in a full stoppered bottle kept at constant temperature over a period of several days are shown in graph XVII, figure 3(c). It is seen that the resistance is quite constant under these conditions. As neither the length nor the cross section of the path of the current could be accurately determined with these electrodes, no attempt was made to calculate the resistivity from the data obtained with them.

That some of the changes noted in the oil did not require large quantities of air present was indicated by the fact that samples taken from the same bottle did not give the same results. For example, the results shown in figure 2(a) were for samples taken from the same bottle but on different dates, graphs I on March 25 and graph IX on April 18. The bottle had been kept stoppered between these dates but was probably only about three-fourths full so that about one-fourth pint of air remained in the bottle above the oil. A new bottle of oil was obtained and its contents divided among twelve smaller bottles which were tightly stoppered, wrapped in black paper to exclude any effects of light on the oil, and stored in a room at ordinary temperature. In this way, only a little of the oil was exposed to the air at any time. However, results obtained from samples from different bottles gave widely differing results. These results were probably due to the oxygen obtained in the pouring from one bottle to another and from bottle to apparatus, and, also, while standing in the apparatus a short time while preparations were completed for a test. It was shown in section A that when an excess of air was introduced into the oil by bubbling at high temperature, the resistance rose to about four times its former value. However, after this aerated oil had been allowed to stand for several days, its resistance dropped back to a value slightly below its former value, as shown in the graphs in figure 2(b).

The results obtained in different trials were so variable that an interpretation is very difficult. It seems from a general survey of the results, that a slight aeration of the oil produces a small decrease in the resistance, while a further aeration causes a very considerable increase. It is possible that the decrease in the resistance with sufficient aeration is caused by the presence of acids produced by oxidation. Also, the breaks in the logarthmic curves described above may be due to the change in the composition of the oil when these acids are formed. The permanent lowering of the resistance produced in the oil when heated to high temperatures may also be due to the same cause.

C. PHOTO-ELECTRIC EFFECT

Two separate methods of investigating the photo-electric effect were employed. In the first, the original set of electrodes described under "apparatus" was employed, figure 1(b). Just enough oil was poured into the cell to fill the spaces between the teeth. As thin a layer of oil as possible was desired as the oil is nearly opaque to ultra violet light. When a constant temperature of the oil had been obtained, a reading was taken on the galvanometer in the circuit shown in figure 1(a), the oil irradiated, and the galvanometer deflection again noted. In the second method, a simple photo-electric cell was employed, consisting of a thin layer of oil spread on an aluminum plate which served as one electrode. The other electrode was a fine copper gauze placed about two millimeters above the plate. A potential difference of 125 volts or approximately 600 volts per centimeter was impressed across the terminals, one of which was grounded. A Dolazalek quadrant electrometer whose sensitivity was 10^{-14} amps per millimeter deflection was employed to measure the current. Ultra violet light was projected onto the oil from above from the iron-nickel arc described previously. In neither of these experiments was there any indication of any photo-electric effect which could be measured on our instruments. It was concluded that there was no appreciable photo-electric emission of the oil due to those wave lengths of ultra violet light transmitted by quartz.

D. THE DEPENDENCE OF RESISTIVITY UPON THE VITAMIN A CONTENT OF THE OIL

A sample of the oil was allowed to stand open to the air for nearly three months, which unquestionably reduced its vitamin A activity considerably. The changes in resistance of this oil showed no marked differences from those noted in the samples left open for four or five days. Also, the oil through which air at high temperature had been bubbled for sufficient time to destroy the vitamin A, and then allowed to stand for a few days, showed no appreciable change in resistance. In neither case was the change very greatly different from that in the case of the oil which had been kept tightly stoppered and in the dark and which was fairly high in vitamin A. It would appear from these data that there is no connection between the electrical resistivity and the vitamin A content of cod liver oil. It should be noted, however, that heating the oil to high temperatures, does cause a permanent reduction in the resistance.

E. MISCELLANEOUS

As there was a possibility that the change in resistances noted might be due to some reaction between the oil and the brass electrodes, new electrodes of both platinum and copper were tried; but the results obtained with these did not differ from those obtained with the brass electrodes.

A variation of the voltage across the cell from five volts to 120 volts in steps of five volts, failed to show any effect due to polarization. This is shown in figure 3 (b).

SUMMARY OF RESULTS

It has been shown by these experiments that:

1. The specific resistance of cod liver oil at room temperature is of the order of 2×10^{11} ohm-cms., but this value depends upon the previous treatment of the oil. This value increases to about 2×10^{18} ohm-cms. at 0° C. and drops to about 2×10^{10} ohm-cms. at 90° C.

2. The resistance varies with the temperature, in all cases decreasing with increase of temperature. There is a logarithmic relation between resistance and temperature over a considerable range in temperature. The changes in slope of the logarithmic graphs do not always occur at the same temperature and are not always in the same direction. The resistance becomes very unstable at temperatures between 80° C. and 90° C. and is permanently decreased when heated to those high temperatures. There is, however, no permanent change due to lowering the temperature to −5° C.

3. The resistance of the oil depends upon the exposure to air decreasing with slight aeration, then upon further aeration increasing to as much as three or four times its original value and eventually decreasing again to its original value or even slightly below this.

4. There is no change in the conductivity of the oil when exposed to ultra violet light of such wave lengths as are passed by quartz.

5. There is no definite relation between the resistance of the oil and its vitamin content.

6. The resistance does not depend on the voltage impressed across the cell; that is, there is no polarization effect.

7. The change in resistance is not due to any chemical action between the oil and the electrodes.

METHODS FOR THE DETECTION OF LIPOLYSIS BY MICROORGANISMS[1]

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From the Dairy Industry Section, Iowa Agricultural Experiment Station

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The ability of a microorganism to hydrolyze fat is of significance in certain changes occurring in food products and also in the classification and identification of species. This character has received relatively little attention; one of the reasons is that methods for its detection have developed more slowly than those revealing changes in carbohydrates and proteins.

Various procedures for the detection of lipolysis by organisms have been suggested. A number of these have been compared at the Iowa Agricultural Experiment Station, particularly in connection with investigations on the lipolytic organisms in dairy products. The detailed methods that have been found most useful are presented herein.

THE NATURAL FAT TECHNIC

In the natural fat technic lipolysis is detected by a change in the appearance of small globules of fat distributed through a medium. Eijkman (7) apparently first noted this change. He poured melted agar over a thin layer of tallow in the bottom of a petri dish and found that the fat under lipolytic colonies became white and more opaque.

A convenient procedure for the natural fat technic is to add a small amount of fat emulsion to each plate before pouring with agar; beef infusion agar is very satisfactory, although various media can be used. The proper fat distribution is readily obtained by preparing a fat emulsion as follows: 3 ml. of a natural fat, 0.5 gm. of agar, and 100 ml. of water are sterilized in a 6-oz., screw cap bottle; after cooling, the fat is dispersed as fine globules by very vigorous agitation. Approximately 0.5 ml. of this emulsion is used per plate. In the case of a high melting point fat it may be necessary to rewarm the mixture before agitation in order to properly disperse it.

Around actively lipolytic colonies the fat globules become opaque through the action of the organisms (plate I). The change in the appearance of the fat globules apparently is due to partial lipolysis since when the plates are flooded with a suitable indicator, free fatty acids are detected. Probably some of these acids are of relatively high molecular weights and, being insoluble in the agar, remain in the fat globules and account for the changed appearance. Various fats can be used in this technic. With those of higher melting points (for example, butter fat) it is necessary to warm the plates in a 45° C. incubator prior to examination since at room temperature the fats are largely solid and rather opaque.

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[1] Journal Paper No. J461 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 119.

With low melting point fats, such as cottonseed oil or corn oil, warming is not necessary because the fats are liquid at room temperature.

In plating various materials for lipolytic organisms, or when plates are spotted with cultures to be tested for lipolysis, the accuracy of the results obtained with the natural fat technic can be confirmed by other methods. Sometimes it is impossible to detect weakly lipolytic colonies by the technic. Hastings (9) employed essentially this procedure in studying lipolysis but used more fat in the medium and, by pouring the plates with hot agar, allowed the fat to come to the surface.

The natural fat technic does not interfere to any extent with the determination of total numbers of organisms and it does not involve flooding the plates with a dye so that colonies are easily picked. The inability to detect weakly lipolytic colonies may at times be a serious objection.

THE NILE BLUE SULFATE TECHNIC

Nile blue sulfate has long been used in histology as a fat stain and recently has been employed as an indicator of lipolysis because of its ability to color neutral fats pink and fatty acids blue. As noted by Rettie (13), nile blue sulfate consists of two stains, the oxazine form and the oxazone form. The latter is soluble in fats and fat solvents, giving a pink solution. Thorpe (17) studied the action of nile blue sulfate in the staining of fat and found that while the red dye was not originally present in the solid dye it was apparently formed upon dissolving in water. The amount of red dye could be increased by heating nile blue sulfate in a weak sulfuric acid solution. Nile blue sulfate is the sulfate of diethylaminophenonaphthoxazine and the red dye the corresponding oxazone.

Smith (15) showed that in the presence of nile blue sulfate globules of olein or other neutral fats were red while those of oleic acid were blue, the blue color resulting from the formation of a soap between the fatty acid and oxazine base. The ability of nile blue sulfate to color the various triglycerides and fatty acids was investigated by Boeminghaus (3). Oleic acid gave an intense color compared to various other fatty acids. Kaufmann and Lehmann (11) noted that the unsaturated fatty acids and unsaturated triglycerides stained especially well with nile blue sulfate although certain other saturated compounds also were well stained. Collins and Hammer (5) found that while higher saturated fatty acids and triglycerides did not color well with nile blue sulfate the lower saturated compounds were well colored. Oleic acid and triolein were also well stained.

Turner (18) used nile blue sulfate as an indicator of bacterial lipolysis by adding the dye to a medium containing dispersed fat. Fat globules in the vicinity of lipolytic colonies were stained blue while those at a distance were stained pink. The same investigator (19) compared various methods for the detection of lipolysis and found that the nile blue sulfate medium was very sensitive and gave excellent differentiation; however, the dye was inhibitory for certain species of organisms. Hussong (10), in studying lipolysis by organisms, used a modification of the Turner technic. Collins and Hammer (5, 6) and Hammer and Collins (8) determined lipolysis by a technic similar to that of Hussong.

A convenient procedure for the nile blue sulfate technic is to add to each plate 0.5 ml. of a fat emulsion, such as the one used in the natural fat technic, and pour with beef infusion agar containing nile blue sulfate in the proportion of 1 part of the dye to 10,000 parts of agar. Generally the dye (5 ml. of a sterile 0.2 per cent aqueous solution per 95 ml. of agar) is added to the agar just before pouring the plates, rather than before sterilization, since with the former method a more desirable color is imparted to the medium. Lower concentrations of the dye can also be used.

Examination of the plates for lipolysis is greatly aided by the use of a hand lens or low power binocular. The unhydrolyzed fat is stained pink while with partial hydrolysis the fat globules become blue. The change is from a distinct pink to a distinct blue so there is no difficulty in detecting it. Around colonies of actively lipolytic species there may be a disappearance of the blue dye from the medium due to its absorption by the fatty acids. The method is very useful for studying lipolysis by organisms spotted on plates and can be employed also in plating for numbers of organisms. Since the dye is added to the agar, the picking of desired organisms is not complicated by flooding the plates. The primary disadvantage of the technic is that certain organisms, especially streptococci and micrococci, are inhibited by the dye. In some instances this may be an advantage because of the fact that the medium has a selective action. Thus it is sometimes possible to isolate lipolytic organisms when they constitute only a small percentage of the total flora; it should be emphasized, however, that nile blue sulfate may inhibit both non-lipolytic and lipolytic species.

In order to avoid inhibition of organisms by nile blue sulfate, Turner's technic has been modified (16) by first staining the fat pink with a concentrated solution of the dye and then washing it free of the excess stain. Organisms are grown on a solid medium containing the stained fat in a dispersed state and lipolysis is detected by a change in the color of the fat globules from pink to blue. In attempts to employ this method the fat globules in the vicinity of lipolytic bacteria did not become blue. There was a change in the appearance of the globules which is probably related to the change occurring in the natural fat technic. Since the oxazine form of nile blue sulfate, which reacts with the fatty acids (13, 17), was entirely washed away, no typical blue color on hydrolysis would be expected.

The nile blue sulfate technic is a simple one and the results are easily read. The toxicity of the dye, however, does not permit satisfactory total counts and inhibits certain lipolytic species.

THE MODIFIED NILE BLUE SULFATE TECHNIC

Compounds other than nile blue sulfate have been used to detect the action of bacteria on fat. Sayer, Rahn and Farrand (14) detected lipolysis in a sugar free, litmus agar by a change in the color of litmus, while Waksman and Davidson (20) used various acid indicators for its detection; the fatty acids liberated by lipolytic organisms produced a change in the colors of the indicators.

Carnot and Mauban (4) and later Berry (2) detected lipolytic organisms by growing them on a solid medium containing dispersed fat and, after incubation, flooding the plates with a saturated aqueous solution of copper sulfate. The free fatty acids united with the copper sulfate to form an insoluble blue copper soap which was readily discernible.

Long and Hammer (12) detected lipolysis by flooding plates with nile blue sulfate solution rather than copper sulfate solution.

In the modified nile blue sulfate technic organisms are grown on plates containing a dispersed natural fat; 0.5 ml. of a fat emulsion, prepared in the manner described, is added to each plate and after incubation the plates are flooded for 30 minutes with aqueous nile blue sulfate of an approximate strength of 1 to 1500, rinsed with water, and observed for lipolysis. After rinsing it is an advantage to hold the plates several hours at 45° C. in order to intensify the staining. The unhydrolyzed fat globules are colored pink while partly hydrolyzed globules are blue. Nile blue sulfate is used, rather than copper sulfate, because it gives a sharper differentiation. However, nile blue sulfate stains the medium more or less deeply while copper sulfate does not.

In many trials with various dairy products the total counts obtained with the modified technic were always considerably higher than those obtained with the nile blue sulfate technic ordinarily employed. The lipolytic counts were much higher also with the modified technic. The flooding of the plates after incubation is a disadvantage, however, in that the picking of colonies is complicated. This difficulty can be overcome by special purification of the cultures picked from plates or by pouring a second set of plates for isolation purposes.

The modified nile blue sulfate technic is especially useful since it avoids the inhibitory effect of the dye and is very satisfactory for both total and lipolytic counts. The results appear to be reliable and are easily observed. The chief defect is that the picking of colonies is complicated by flooding the plates.

THE SIMPLE TRIGLYCERIDE TECHNIC

Anderson (1) proposed a technic for detecting lipolysis in which the organisms are grown on a solid medium containing dispersed tributyrin. Since the products of hydrolysis of this compound are soluble, lipolysis can be detected by a disappearance of the globules around lipolytic colonies. Collins and Hammer (5) studied the action of bacteria on simple triglycerides, using nile blue sulfate in the media. They noted that with certain of the simple triglycerides the globules often disappeared because of the solubility of the products of hydrolysis.

The simple triglyceride technic can be carried out conveniently by preparing an emulsion of tripropionin or tributyrin in 0.5 per cent agar and adding some of this to the plates before pouring. Another procedure is to add a few drops of the triglyceride to a tube of melted agar, disperse it by vigorous shaking, and pour the mixture into a petri dish. The amount of triglyceride, whether used as an emulsion or directly, varies with the solubility of the compound. In the prepartion of an emulsion, from 4 to 6 per cent tripropionin or tributyrin is satisfactory. Triacetin cannot be used because of its relatively high solubility and triglycerides higher in the series than tributyrin are unsatisfactory because, in the event of hydrolysis, the fatty acids liberated are only slightly soluble in the agar. After the incubation of poured plates, or of plates on which cultures have been spotted, there is a disappearance of the triglyceride globules around colonies of actively lipolytic species. In order to obtain clear cut results it is necessary to have the triglyceride evenly distributed in small globules and the layer of agar comparatively thin. With large globules the time required for hydrolysis is too long and if there are not enough globules the action is not readily observed. When the agar layer is too thick it may be impossible for a colony to hydrolyze the globules through the entire depth of the layer.

While bacteria capable of hydrolyzing natural fats will produce a clear zone around the colonies when inoculated on a plate containing dispersed tripropionin or tributyrin, certain cultures commonly regarded as non-lipolytic, also will bring about this reaction. Long and Hammer (12) found that certain cultures of *Streptococcus liquefaciens* hydrolyzed tripropionin, tributyrin, or both, but gave no evidence of hydrolyzing either cottonseed oil or butter fat. Recently 32 *Streptococcus lactis* cultures of various origins were studied. None of them gave any evidence of attacking cottonseed oil. Tripropionin was easily hydrolyzed, only two of the cultures failing to attack this compound. Tributyrin was less easily hydrolyzed by *S. lactis* than tripropionin, since only 17 of the 32 cultures tested gave a positive reaction. This agrees with the findings of Collins and Hammer (5) who noted that hydrolysis of the simple triglycerides of the saturated fatty acids became more difficult as the molecular weight increased.

In general, the observations on the simple triglyceride technic indicate that this method is not a satisfactory means of selecting organisms capable of hydrolyzing natural fats because the lower triglycerides are much more easily hydrolyzed than natural fats.

DETECTION OF PROTEOLYTIC AND LIPOLYTIC ORGANISMS

Many of the lipolytic organisms are also proteolytic and in some instances it is an advantage to study proteolysis and lipolysis on one plate. The various technics used for the determination of lipolysis can be modified by the addition of skim milk, a procedure that has long been used to detect proteolysis. This may be conveniently carried out by adding 0.5 ml. of sterile skim milk to each plate and is especially satisfactory in connection with the modified nile blue sulfate technic. The procedure is less useful with the natural fat technic because lipolysis may be difficult to detect when there is no clearing, due to proteolysis, around a colony. With either procedure a count of the acid forming organisms can be obtained in addition to the total, proteolytic and lipolytic counts if sugar enough is present to yield the amount of acid needed to precipitate the casein around a colony. This may require the addition of lactose or glucose to the medium. With certain acid forming species the rapid acid production in the presence of considerable sugar may interfere with the growth of various organisms on the plates.

SUMMARY

Various methods can be used to study the ability of an organism to hydrolyze fat dispersed in a medium. In the natural fat technic hydrolysis is detected by a change in the appearance of globules of fat which become more opaque; with this method it is difficult to detect weakly lipolytic organisms. In the nile blue sulfate technic the dye is added to the medium and lipolysis is readily noted by a change in color of the fat

globules from pink to blue. This technic gives especially clear cut results but the toxicity of the dye definitely limits its usefulness. In the modified nile blue sulfate technic lipolysis is readily detected after incubating the plates by flooding them with a solution of nile blue sulfate; unhydrolyzed fat is pink while partly hydrolyzed fat is blue. The flooding of the plates complicates the picking of colonies.

If globules of tripropionin or tributyrin are dispersed in the medium in place of a natural fat there is a disappearance of the globules in the vicinity of lipolytic colonies because of the solubility of the products of hydrolysis. Since these triglycerides are easily hydrolyzed, a positive test is not always an indication of ability to hydrolyze natural fats.

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PLATE I

Changes in globules of cottonseed oil partly hydrolyzed by *Achromobacter lipolyticum.* The globules around the spot colonies are white and opaque.

PLATE I

THE LIBRIFORM FIBERS IN THE ROOTS OF SWEET CLOVER, MELILOTUS ALBA DESR.

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The libriform fibers, common xylem structures of Angiosperms and so named by Sanio (12) because of their resemblance to the fibers of the bast (formerly called liber), are slender spindle-shaped fibers with walls sparsely pitted and commonly so much thickened that the cell cavity is almost obliterated. Their walls, in common with those of most wood and bast fibers, have been described generally as consisting of three rather easily distinguishable and separable layers. According to the recent terminology used by Kerr and Bailey (4) and Anderson (2), who regard the outermost (middle lamella) of the three layers as an intercellular deposit, the wall of each individual fiber consists of two layers, of which the outer is designated as the primary and the inner as the secondary layer. A close study usually reveals that the secondary and commonly the primary layer are not unit structures but are composed of delicate concentric lamellae that closely fit over and tightly adhere to each other. It is the secondary layer that varies greatly in thickness and when fully developed, commonly constitutes as much as three-fourths or more of the cross sectional area of the fiber.

The layers of the walls of libriform fibers differ from the middle lamella and from each other in both chemical and physical properties. The secondary layer, which has received most consideration because of its functioning apparently as reserve food material, has been variously reported as consisting of hemicellulose, cellulose, and lignin. It is usually pliant, resembling a stiff mucilaginous or gum-like substance, and separates readily from the much more rigid and commonly more lignified primary layer.

The removal of the secondary layer during spring growth, a phenomenon indicating that this layer is reserve food, has been observed a number of times, notably in the roots of the pear, peach, quince, raspberry, and willow, by Le Clerc Du Sablon (5), in the stems of the grape and black locust by Potter (8), and in the stems of the alder, birch, horse-chestnut, ash, and some Gymnosperms by Schellenberg (13). During the process of dissolution, Schellenberg observed that the secondary layer became ramified by canals, a feature suggestive of the corrosive action of diastase on starch grains. In the wood of fruit trees, especially in apple trees, as shown by Murneek (7), Roberts (10), and others, there are fibers of the libriform type with secondary layers of reserve carbohydrates. Murneek refers to these reserve carbohydrates in the walls as hemicellulose.

A survey of the literature shows that the libriform fibers are especially prominent in the stems of the legumes. Sanio (11, 12) found libriform tissue well developed in a large number of the Papilionaceae, among which were *Medicago arborea, Cytisus laburnum, Gleditsia triacanthos,* and *Caragana arborescens*. In the stems of *Robinia pseudo-acacia* and of species of Wistaria, Strasburger (14) observed that the fibers of the xylem had a much thickened inner layer which reacted to tests for cellulose. Potter (8) noted libriform fibers in the stems of *Vicia faba*, and in the roots of some species of Lupinus and Phaseolus.

In all libriform fibers investigated by Potter the secondary layer responded to tests for cellulose. In the roots of *Trifolium repens*, the secondary layer of the fiber walls according to Erith (3), is pliant and becomes red in the presence of chlor-zinc-iodide. Sanio (11) found the secondary layer in the walls of the libriform fibers of the legumes commonly gelatinous and was of the opinion that libriform fibers with gelatinous secondary layers are characteristic of the Papilionaceae.

MATERIAL AND METHODS

The investigation centered mainly on the primary and secondary layers of the libriform fibers, only casual attention being given to the middle lamella since in this investigation it was found to have no features of particular significance. The investigations included the structure, chemical constitution, and physical properties of the walls of the fibers, and the modifications the walls undergo during the second season's growth.

The libriform fibers investigated were chiefly those in the roots of the common strain of biennial white sweet clover. The observations on other biennial strains, including the biennial yellow sweet clover, were sufficient to show that the biennial types are very similar in the structure and history of their libriform fibers. In the roots of the annual white sweet clover, although the libriform fibers are similar in structure and properties to those of the biennial types, they are relatively few, their formation being limited to the early period of growth and apparently have no important function in the life of the plant aside from the rôle they play in the early contraction of the root and hypocotyl. Roots of the biennials in the first season's growth furnished fibers in various stages of development, and thus suitable for structural, physical, and chemical studies of fiber development, while roots in the second year's growth afforded fibers for the study of the modifications their walls undergo the second season.

The conclusions concerning the chemical nature and physical properties of the libriform fibers were based largely upon their reactions observed under the microscope. The sections were made mostly free-hand and from fresh material. Some microtome sections of imbedded material were employed in studying the minute structure of the fiber walls and for making some of the photomicrographs.

The microchemical studies of the fiber walls were based upon their color reactions, and solubility. In identifying the substances by means of positive color reactions the reagents used were as follows: Ruthenium red and methylene blue for pectins; phloroglucin and HCl for lignin; and chlor-zinc-iodide and iodine with H_2SO_4 for cellulose. Safranin and hematoxylin, which were used in making permanent mounts, also served in the recognition of cellulose and lignin.

The use of the solubilities of substances as an aid in their identification involved also the color reactions of the substances. It was based upon the comparative color reactions of fibers treated and untreated with the solvents of the respective substances, whose identifications were in question. In case of pectin which ruthenium red and methylene blue had indicated was present in the fiber wall, the color tests were repeated on fibers that had been boiled in ammonium oxalate or in weak H_2SO_4 for three or four hours and then washed in water. In the identification of lignin by its solubility fibers which had been boiled in ether-alcohol, then in one per cent NaOH, chlorinated, and then boiled in two per cent sodium sulphite to remove the lignin, were compared with fibers not previously treated as to color reactions for lignin. In the identification of hemicellulose and cellulose by their solubilities both color reactions and changes in thickness of wall layers of fibers previously treated with Schweitzer's reagent or with various concentrations of H_2SO_4 were considered in the comparisons.

In the study of such features as length, surface markings, shape, and structure of the fibers that required lengthwise views, long longitudinal sections were used, which after being boiled in one per cent NaOH, in Schultz's maceration fluid, or in five or ten per cent H_2SO_4, were separated into their individual fibers. In studying the lamellae and fibrillar structure of the wall layers, the fibers were swollen in high concentrations of H_2SO_4 (60 per cent or higher) in the presence of iodine. The swelling of the fibers was followed under the microscope and controlled by varying the concentration of the acid or by displacing it when the layers were satisfactorily swollen.

In sweet clover plants beyond the seedling stage the hypocotyl and radicle, readily distinguishable in the seedling stage, become so fused and similar histologically that it is not necessary to refer to the hypocotyl separately from the root system. The root system consists of a large commonly branched taproot and relatively small lateral roots. In the biennial sweet clovers the root system approximates its maximum size and the libriform fibers reach their maximum number and thickness of walls the first season. During the second season the changes in the tissues of the root have to do almost entirely with the removal of storage materials and cell wall modifications.

THE LIBRIFORM FIBERS OF SWEET CLOVER DURING THE FIRST SEASON

GENERAL FEATURES

In the roots of the biennial sweet clover, the libriform fibers are quite variable in different plants, but constitute at the end of the first season's growth, from a fourth to more than one-half of the volume of the xylem (figs. 1 and 2). As shown in cross-sectional views of the roots, the xylem is divided radially by rays into wedge-shaped masses which consist largely of libriform fibers arranged in groups of various sizes (fig. 1). Interspersed among and alternating with the groups of libriform fibers are the tracheal elements and some parenchyma. The libriform fibers are typically spindle-shaped with a range in length from one to three or more millimeters and an average width of approximately seven microns at their widest place. The individual fibers of the fiber bundles are not only joined laterally but also lengthwise by their overlapping ends, and thus constitute tough flexible strands that transverse the entire length of the root. Throughout the length of the fiber bundles there are included here and there small isolated groups of parenchyma cells. By the development and expansion of these isolated parenchyma tissues the fiber strands are partially separated into smaller anastomosing strands with sinuous courses, the result being that the system of fiber strands is shortened and the root and hypocotyl thereby lengthwise contracted and pulled farther into the soil where they have better protection against unfavorable weather conditions.

STRUCTURE OF THE LIBRIFORM FIBERS

In fully developed libriform fibers of the sweet clover, like those characteristic of roots at the end of the first season, the two layers, primary and secondary, are readily recognizable (fig. 9). The middle lamella is thin and appears in untreated sections as scarcely more than a line of junction between the opposite primary layers. The primary layer is relatively thin as compared with a fully developed secondary layer but its thickness is a number of times that of the middle lamella. Its maximum thickness is attained early in the fiber's development, is practically the same in all fibers, and is uniformly maintained throughout the first season and during the second season until near the flowering period of the plant (fig. 3 and 5). The secondary layer, which, unlike the primary layer, is quite variable in thickness, commonly is 75 per cent or more of the cross-sectional area of the fiber wall, and so much thickened that the cavity of the fiber is almost obliterated and the protoplasm reduced to an almost indetectable quantity (fig. 5).

In fibers suitably swollen and stained, a fibrillar structure is revealed in both wall layers and also in the middle lamella. The primary layer consists of a single lamella, one layer of fibril strands in thickness. The fibril strands are arranged spirally with the coils almost at right angles to the long axis of the fiber and so closely joined that they are visible only when forced apart by the swelling of the fibers. The fibrils of the primary layer are oriented about those of the secondary layer much after the fashion of the cord about a fagot, and when the secondary layer expands lengthwise in swelling, the coils of the fibrils of the primary layer are separated sufficiently to become recognizable.

In secondary layers fully thickened, a number of lamellae, sometimes as many as 10, can be recognized when the layer is suitably swollen and stained (fig. 6). The thickness of this layer depends upon growth conditions. In libriform fibers in the process of development, as in those near the cambium during the growing season and in old fibers where storage materials are being removed, there is a wide range in the thickness of the secondary layer. The thickness of this layer depends also upon the nutritional conditions of the plant. Frequent mowing and close pasturing, which hinder the manufacture and deposition of carbohydrates, affect not only the number of libriform fibers formed but also the thickness of their secondary layer.

The secondary layer is pliant like rubber or a stiff gelatinous material and is commonly distorted by folding inward when the size of the lumen permits, which is most likely because of its inability to expand in the direction of the primary layer. Some of the folding of this layer so frequently observed in cross sections may be due also to the pressure of the knife in sectioning (fig. 4). The ease with which it is separated from the more rigid primary layer indicates that the two layers are joined very loosely, if joined at all. The secondary layer, although rather resistant, swells much more readily in hydrating agents than either the primary layer or middle lamella (fig. 9). In high concentrations of swelling agents, as 60 per cent H_2SO_4 or in Schweitzer's reagent, the secondary layer swells and bursts through the more resistant primary layer at intervals along the surface of the fiber and expands into large, rounded swellings, which often cause the fiber to resemble a chain of beads (fig. 7). In cases of short sections of fibers exposed to high concentrations of the hydrating agents, the secondary layer expands lengthwise beyond the ends of the primary layer and forms large, rounded swellings that give the sections the resemblance of dumb-bells, and this again clearly demonstrates its greater response to the hydrating reagents (figs. 8, 9, and 10).

Each of the component lamellae of the secondary layer is composed of strands of fibrils which in all the lamellae are parallel with the long axis of the fiber and almost at right angles to those of the primary layer (fig. 8). The fibrils are very minute and their detection is difficult unless the layer is partially hydrated in the presence of iodine in which the fibrils become somewhat colored.

The wall layers of the libriform fibers of sweet clover are like those of wood and bast fibers as described by Ritter (9), Ludtke (6), and Anderson (1), in that the lamellae are composed of fibrillar strands, the chief features of distinction being in the relative orientation of the fibral strands in the different layers and lamellae.

REACTIONS OF THE WALLS OF THE LIBRIFORM FIBERS TO HISTOLOGICAL STAINS, MICROCHEMICAL COLOR REAGENTS, AND SOLVENTS

In fibers stained with different stains, as safranin and hematoxylin, the primary layer shows some affinity and the secondary a decided affinity for the cellulose stains. The decided cellulose nature of the secondary layer is also well shown by its swelling and turning blue in the presence of such reagents as chlor-zinc-iodide, and combinations of H_2SO_4 and iodine. The primary layer, besides showing no great affinity for cellulose stains, behaves much like the middle lamella in reacting slowly and sometimes not at all in old fibers when treated with Schweizer's and other hydrating agents. In tests for lignin and pectin-like substances with phloroglucin followed by HCl and with ruthenium red or methylene blue, the reaction was strong in the middle lamella, especially in old fibers, a little less pronounced in the primary layer and weak to almost not detectable at all in the secondary layer.

Fibers boiled an hour in five per cent H_2SO_4 or HCl showed no change in thickness in either of the layers or in the reactions to the various tests. Boiled for an hour in one per cent NaOH or in chloral hydrate the fibers no longer reacted to the tests for pectin, but separated readily and still reacted to the cellulose and lignin tests. After being boiled in 10 per cent NaOH, fibers usually reacted to neither the pectin nor lignin tests, but to tests for cellulose, the primary layer now turning blue in chlor-zinc-iodide almost immediately while the secondary layer changed from a brownish to a blue after several minutes, but neither layer showed any reduction in thickness. Moreover, after the process for the removal of the lignin by boiling in ether-alcohol, then in one per cent NaOH followed by chlorination and boiling in two per cent Na_2SO_4, both layers of the fiber walls showed no reduction in thickness and the primary layer reacted promptly to the cellulose tests. In Schweitzer's reagent for two days, the secondary layer was much swollen, if not dissolved, but the primary layer was not much affected unless previously subjected to the process for the removal of lignin.

From the preceding reactions of the libriform fibers the following conclusions were drawn. The primary layer consists of cellulose impregnated with other subtsances, chiefly lignin. The secondary layer is either cellulose or a very resistant type of hemi-cellulose. That the layers maintain their thickness upon the removal of impregnated substances is in accord with the present conception that the secondary materials in cell walls are between the cellulose micellae and do not disturb their arrangement. The middle lamella in the libriform fibers of sweet clover apparently has its usual composition, consisting principally of lignin and calcium pectate.

Attempts to entirely dissolve the primary and secondary layers showed them remarkably resistant to both alkalies and acids, although the resistance was noted to vary considerably with the age and stage of the development of the fibers. Boiling them for 30 minutes in 40 per cent NaOH caused much swelling but did not dissolve either of the layers. In the autoclave at two atmospheres of pressure for an hour the secondary layer disappeared usually in 30 to 35 per cent H_2SO_4 while the primary layer usually endured concentrations up to 40 per cent of the acid. The resistance to hydrolysis of the primary layer can be attributed to the presence of lignin. In resistance to hydrolysis the secondary layer is like ordinary cellulose but in functioning as a wall reserve it has the nature of hemicellulose. It is evident that methods of chemical analysis in which weak hydrolyzing agents are used do not include the carbohydrates stored in the secondary layer. Roberts (10) has called attention to a similar situation in apple trees where the reserves in the form of wall thickenings were found to resist remarkably high concentrations of acids.

THE MODIFICATIONS OF THE LIBRIFORM FIBERS AND ACCOMPANYING TISSUES DURING THE SECOND SEASON

During the second season while the biennial sweet clover is developing its flowering shoots and maturing seeds, transformations occur in the tissues of the roots which consequently lose their flexibility and become woody and rigid. This may be interpreted as an adaptation which enables the plant to support its reproductive shoots in an erect position. The processes bringing about the change in texture has to do with the digestion of the secondary layer of the libriform fibers and the thickening and lignification of the primary layer of the fibers and also of the walls of other tissues. The progress of these processes is most rapid during the latter part of the season when the seeds are ripening.

The digestion of the secondary layer is first noticeable in the libriform fibers near the cambium. In some of the fibers the secondary layer is almost entirely removed while in others it is only reduced in thickness and left usually much folded and shrunken away from the primary layer. The digestion proceeds centripetally until nearly all the fibers have their secondary layer to some degree digested. This process of digestion is accompanied or soon followed by a decided increase in the thickness of the primary layer and its strong lignification. At the same time the libriform fibers undergo their modifications there is a thickening and lignification of the walls of the ray cells and of other parenchyma, the process in these tissues beginning also in the region of the cambium and proceeding centripetally. These are the cell wall modifications that replace the fleshy flexible nature of the root during the first season by the woody rigid texture present at the end of the second season. The transformation culminates in the death of the root.

That the wall reserves are used mostly in making the transformations that occur within the root is indicated by the fact that their digestion and accompanying cell wall modification occur mostly after the new lateral roots and flowering shoots of the second season have reached their full size. The early disappearance of the starch from the roots suggests that it is depended upon for the development of the new lateral roots and for the initial development at least of the flowering shoots.

The digestion of the wall reserves begins as early as that of the starch but takes place much more slowly and is most pronounced near the end of the second season. The first noticeable anatomical changes in the interior of the root at the opening of the second season's growth are the transformation of some xylem parenchyma cells in the region of the cambium into tracheal vessels and the partial digestion of the secondary layer of some of the adjacent libriform fibers. This close association of the formation of vessels with the change in adjacent libriform fibers suggests that at the very start of the second season's growth the wall reserves are called upon to some extent to support the anatomical changes within the root. But their tardy removal suggests that the wall reserves are set aside in the main to support the anatomical changes in the root that culminate in its rigidity, an adaptation probably necessary to enable the root to properly support the flowering shoot and also to permit all the food made by the flowering shoots to be applied to the development of the reproductive structures.

SUMMARY

PERTAINING TO THE FIRST SEASON

The libriform fibers constitute from a fourth to more than one-half of the volume of the roots of the biennial sweet clovers.

With the middle lamella considered as intercellular, the layers constituting each fiber wall are two, and are designated as primary and secondary layers.

The secondary layer is quite variable in thickness and when fully developed is so extremely thickened that the cell lumen is a minute cavity with an almost indetectable amount of protoplasm. It normally is found upon close inspection to consist of a number of thin concentric layers or lamellae closely joined or cemented together and each composed of fibrillar strands oriented with their long axis parallel with that of the fiber. It reacts for cellulose, requires high concentrations of alkalies and acids to hydrolyze it, but it is digested by the plant enzymes and apparently used in the formation of tissue structures, in which capacity it plays the part of a wall reserve of the nature of hemicellulose.

The primary layer, one lamina in thickness, contains, in addition to its framework of cellulose, much lignin and is more resistant to hydrolyzing agents than the secondary layer. After treatments to remove lignin it reacts typically for cellulose. Its fibrillar strands are spirally coiled with the turns of the spiral running almost at right angles to the long axis of the fiber and also to the long axis of the fibril strands of the secondary layer.

PERTAINING TO THE SECOND SEASON

During the second season the secondary layer of the libriform fibers is subjected to a process of digestion which begins near the cambium and proceeds centripetally until most of the fibers have been affected, some having their secondary layer considerably reduced in thickness, and others having lost it entirely or being left with only a thin folded remnant of it.

Associated with the digestion and removal of the secondary layer there occur other modifications in which the primary layer of the libriform fibers and also the walls of the xylem ray cells and other parenchyma cells are considerably thickened and strongly lignified. These processes culminate as the seeds are ripening and in the death of the root. As a result of these changes in cell walls the fleshy flexible nature characteristic of the root of the biennial sweet clovers during the first season is replaced by the woody rigid character possessed by the root at the end of the second season.

The libriform fibers, therefore, serve two purposes, namely, as storage places of carbohydrates in the form of a wall layer and later as strengthening fibers that give rigidity to the root when the flowers and seeds are being borne.

Owing to the highly resistant nature of the wall reserves of the libriform fibers they are not included in the common chemical methods of carbohydrate analyses.

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EXPLANATION OF PLATE I

Fig. 1. Cross section of a root showing relative amount of the libriform tissue,—the black areas in the xylem.

Fig. 2. Portion of a cross section of a root in which the grouping of the libriform fibers is shown, and in which the amount of libriform tissue is proportionately very large, being three-fourths or more of the volume of the xylem.

Fig. 3. Libriform fibers in cross section showing the primary and the extremely thickened secondary layer.

Fig. 4. Cross sectional views of libriform fibers in which the secondary layer in some cases is folded and partially separated from the primary layer.

Fig. 5. Cross sectional view of fibers in which some pits are visible.

Fig. 6. Cross sectional view of a libriform fiber in which the lamellae of the wall layers are recognizable.

Fig. 7. Lengthwise view of a libriform fiber much swollen in H_2SO_4, showing the secondary layer broken through the primary except at the constrictions.

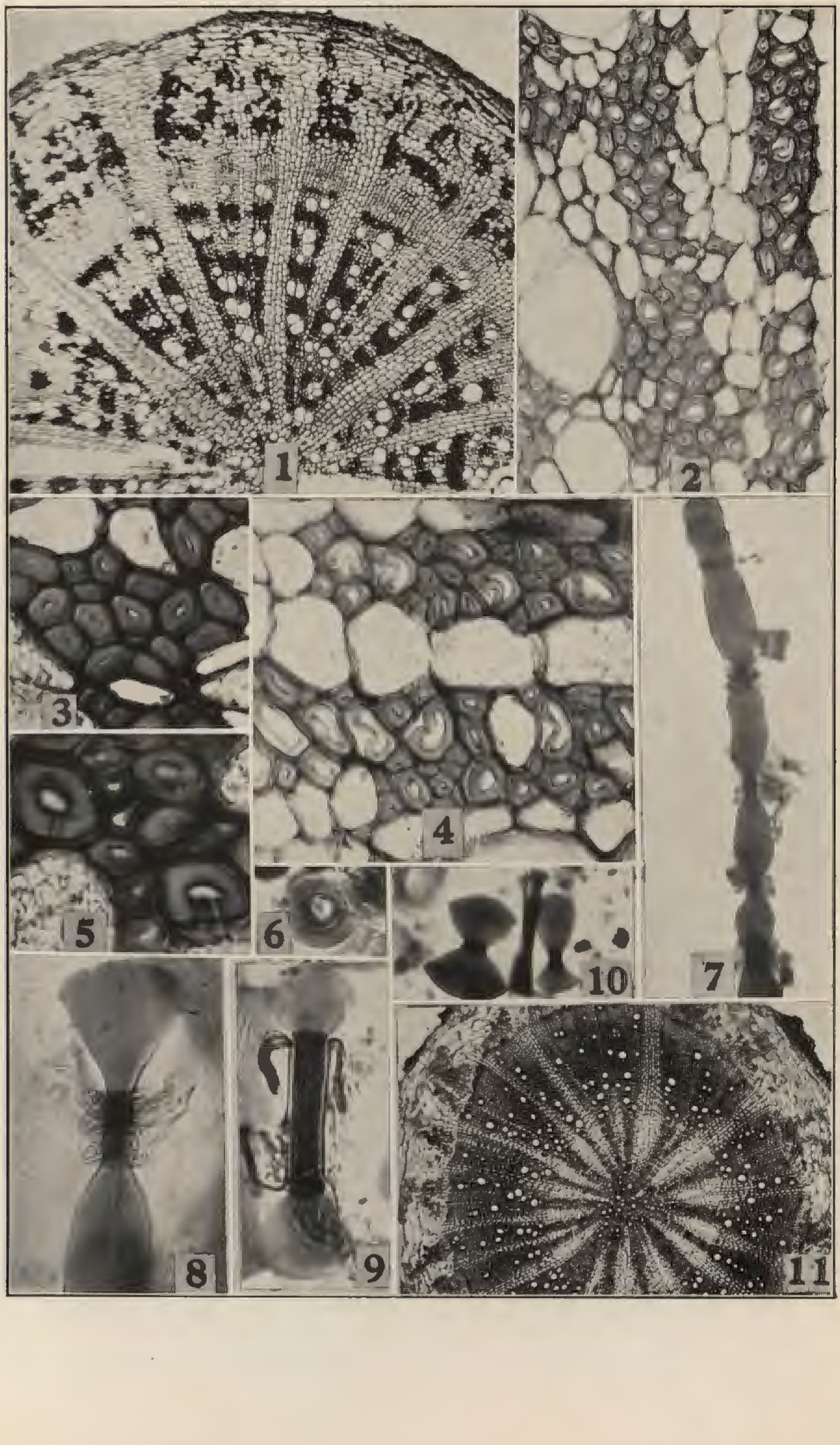
Fig. 8. Lengthwise view of a much swollen section of a libriform fiber showing, (a) the fibrillar structure of the primary layer resembling a cord wrapped about the secondary layer, and (b) that the secondary layer consists of fibrils running parallel with the long axis of the fiber.

Fig. 9. Lengthwise view of a section of a fiber in which the middle lamella, primary layer, and secondary layer are present.

Fig. 10. Other lengthwise sections of fibers swollen in H_2SO_4, showing a very great difference in the swellings of the primary and secondary layers.

Fig. 11. Cross section of a root at the flowering stage of the plant, in which the transformations in the fiber and parenchyma tissues are well along. In the dark portion of the xylem, the libriform fibers have lost in part or entirely the secondary layer and the primary layer has been thickened and strongly lignified. The walls of the ray cells and the other parenchyma cells have been thickened and lignified.

PLATE I



FRACTIONATION OF OXIDIZED CORNSTALK LIGNIN[1, 2]

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The hypohalogen oxidation of lignin for the purpose of recovering the oxidized product has in recent years received the attention of several workers (1, 4, 5). The reaction proceeds to a definite endpoint and the amount of oxidizing solution used can be quantitatively determined by means of sodium thiosulfate using starch paste as an indicator. Using an alkaline iodine oxidizing solution Walde (4) found that ammonia lignin from cornstalks required about 160 cc. of 0.1N iodine per gram sample. This oxidized lignin contained iodine and carboxyl groups, and was designated as iodo-carboxy-lignin.

Cornstalk ammonia lignin was prepared in this investigation. Oxidation values were determined for various conditions of oxidation, and the oxidized products were isolated. The various lignins were fractionated, methylated and saponified to obtain a more homogeneous product.

EXPERIMENTAL

PREPARATION OF CORNSTALK AMMONIA LIGNIN

Since the various parts of the cornstalk contains approximately the same amount of lignin (2) the whole cornstalk was taken as a source of lignin. The stalks were allowed to air dry and were then put through a hammer mill. The ground stalks were subjected to an acid hydrolysis to remove the hemicellulose. The stalks were covered with 0.1N HCl and were hydrolized at a pressure of 20 pounds per square inch for two hours. The pulp remaining after this treatment was washed free of chlorides, and amounted to 62 percent of the original stalks, expressed on an air dry basis. The acid hydrolyzed stalks were placed in a steel bomb and covered with concentrated ammonium hydroxide. The bomb was closed and was heated by a steam jacket surrounding it so the pressure inside the bomb was 150 pounds per square inch. After six hours the bomb was allowed to cool and the insoluble pulp removed from the ammoniacal liquor by filtration. The ammoniacal liquor was heated to 50° C. and then acidified with concentrated HCl, which caused the lignin to precipitate. The lignin was allowed to settle overnight, the supernatant liquor decanted off and the remaining suspension filtered with suction. It was washed and dried, and on analysis was found to contain 5.14 per cent ash.

To remove the ash the product was dissolved in a dilute NaOH solution and then filtered with suction, first over macerated filter paper and then twice over filter paper. After warming, acidifying, filtering and

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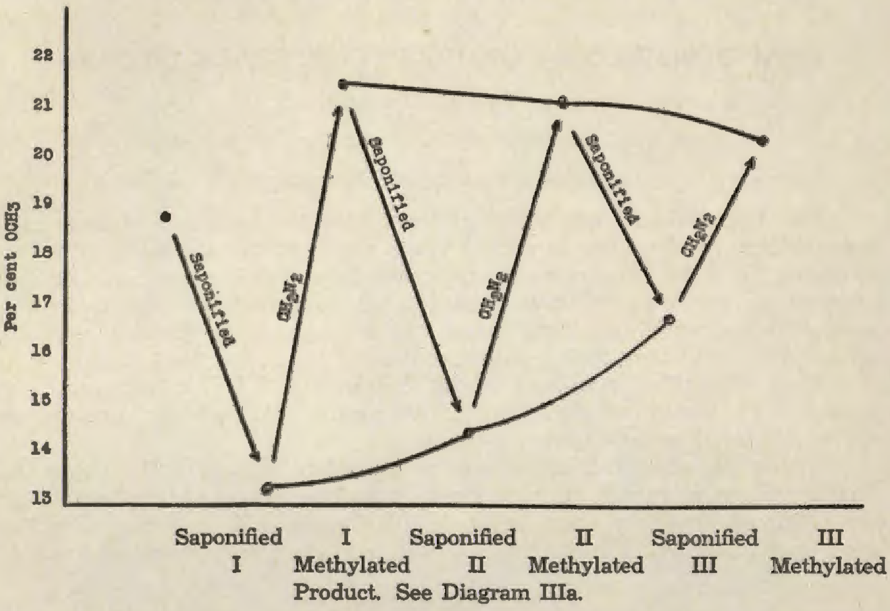
[1] A part of the thesis submitted to the Graduate Faculty of Iowa State College in partial fulfillment of requirements for the Degree of Doctor of Philosophy.

[2] Supported in part by a grant from the Industrial Science Research funds of Iowa State College for the study of lignin.

Graph I. Change in methoxyl content by saponification and methylation.



washing as before, the product now contained but 0.37 per cent ash, and had a methoxyl content of 13.98 per cent.

OXIDATION VALUES

Alkaline iodine oxidation values were determined using a 0.2N iodine solution. The method consists essentially in dissolvng a weighed sample of lignin in alkali, adding a slight excess of 0.2N iodine-potassium iodide solution, and after the oxidation is complete, acidifying and titrating the excess iodine with a standard solution of sodium thiosulfate. Cornstalk ammonia lignin gave oxidation values from 168 to 177 by the above method. An alkaline bromine oxidation gave values between 710 and 890, showing that the alkaline bromine oxidation proceeded much farther than the alkaline iodine oxidation. A neutral bromine oxidation using a sodium bicarbonate solution instead of an alkaline solution resulted in oxidation values of 201 to 203. From this it is seen that a neutral bromine oxidation oxidizes lignin to approximately the same degree as an alkaline iodine oxidation.

METHYLATION OF AMMONIA LIGNIN

Cornstalk ammonia lignin has a methoxyl content of 13.98 per cent and like other isolated lignins contains free hydroxyl groups which can be methylated. Using dimethyl sulfate and caustic according to the method of Urban (3) the methoxyl content was raised to 30.43 per cent. Methylation with diazomethane in an ether solution increased the methoxyl content of the original ammonia lignin to 24.43 per cent.

PREPARATION OF OXIDIZED LIGNIN

Cornstalk ammonia lignin was oxidized with a sodium hypobromite solution and the oxidized product recovered. The product obtained by this method was designated as bromo-carboxy-lignin II, abbreviated Br. C.L.II, to differentiate it from another bromo-carboxy-lignin prepared directly from the acid hydrolyzed stalks and which was designated as bromo-carboxy-lignin I, or Br.C.L.I.

For the preparation of bromo-carboxy-lignin II 30 grams of ammonia lignin were added to 1.5 liters of a solution containg 150 g. of Na_2CO_3, being heated and stirred for several hours to insure complete solution. A stream of carbon dioxide was passed through the solution for four hours, causing much of the lignin to precipitate. A 10 cc. portion was tested for oxidation value to determine the exact amount of oxidizing reagent needed. The lignin solution was cooled to 6° C. and the calculated amount of an approximately 0.5N NaOBr solution was slowly added, the addition taking one-half hour. The oxidizing solution was made up in the ratio of 15 g. of Na_2CO_3, 1 g. of NaOH, 20 cc. of bromine and sufficient water to make the volume to 1 liter. The calculated amount needed was 1,005 cc., so 1,200 cc. were added to maintain a slight excess. Ten minutes after the addition of the oxidizing solution the reaction was practically complete, as the excess oxidizing power was the same then as it was thirteen hours later. Since the quantity of lignin and the amount of oxidizing solution used by the reaction was known the oxidation value of the reaction could be calculated. This was 160

Diagram I. Dioxane separation of Br.C.L.I.

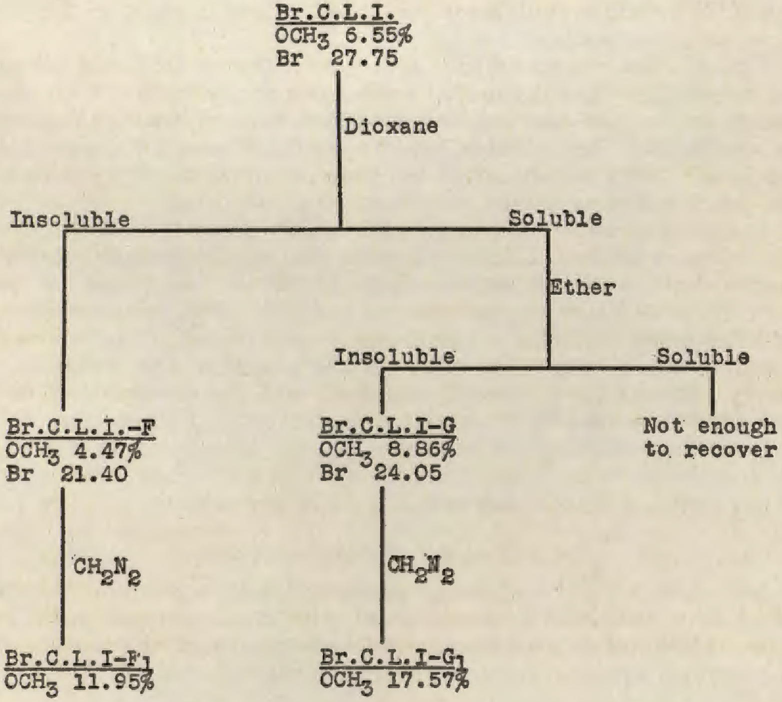
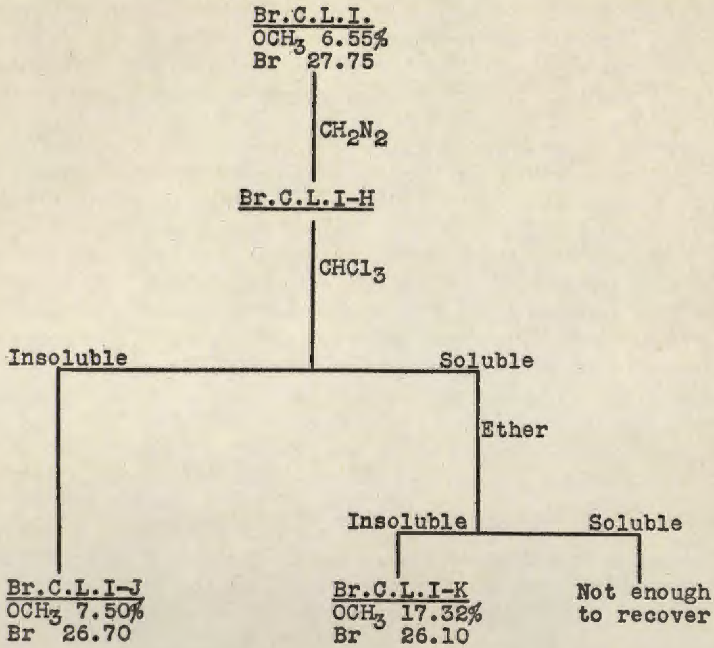


Diagram II. Chloroform separation of diazomethane methylated Br.C.L.I.



cc. of 0.1N bromine equivalent per gram, which is close to the alkaline iodine oxidation value.

The solution was acidified with concentrated HCl and allowed to stand overnight. The lignin had settled compactly in that time, the supernatant liquor was decanted and the lignin filtered, washed free of halogens and deried. The yield of air dry Br.C.L.II was 32 g., containing 5 per cent ash. This was dissolved in dilute caustic, filtered three times and again precipitated, washed free of halogens and dried.

A similar product was prepared directly from the acid hydrolyzed stalks, designated Br.C.L.I. In this case the acid hydrolyzed stalks were extracted with a dilute NaOH solution, filtered, and carbon dioxide passed in for 24 hours to saturate the solution. The calculated quantity of oxidizing solution plus a small excess was added. The solution was allowed to stand overnight, although the reaction was complete in 15 minutes. It was then filtered, acidified, and the precipitated oxidized lignin filtered, washed and dried. Anaylsis: Ash 5.3 per cent. The air dried sample was dissolved in dilute caustic, filtered three times, acidified, and the oxidized lignin filtered, washed and dried. Analysis: Ash 0.09 per cent, OCH_8 6.55 per cent, Br 27.75 per cent.

METHYLATION OF OXIDIZED LIGNIN

Both bromo-carboxy-lignins prepared by the sodium bicarbonate method were subjected to methylation with diazomethane and dimethyl sulfate. Methylation was repeated in each case until the methoxyl content remained constant for two successive methylations.

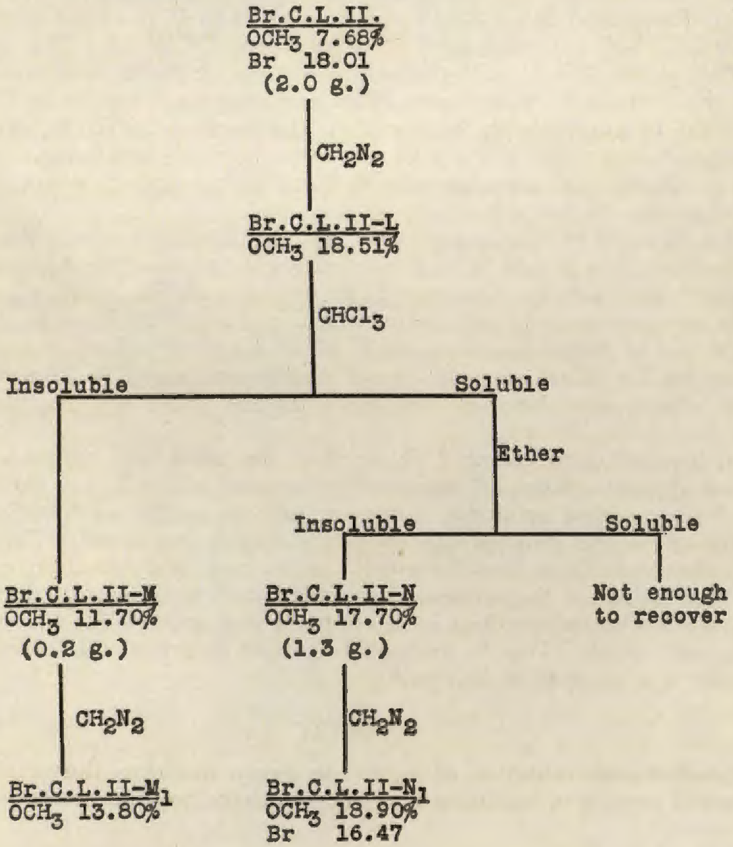
Br.C.L.I, with the analysis OCH_3 6.55 per cent, Br 27.75 per cent and ash 0.090 per cent was methylated with diazomethane in an ether solution three times. This methylated product had the analysis OCH_3 16.08 per cent, Br 26.78 per cent. The same Br.C.L.I, when methylated twice with alkali and dimethyl sulfate according to Urban's method, gave a product with the analysis OCH_3 16.80 per cent, Br 25.5 per cent.

Br.C.L.II, with the analysis OCH_3 7.68 per cent, Br 18.01 per cent and ash 0.0 per cent, after one methylation with diazomethane had the analysis OCH_3 17.87 per cent. The second methylation brought this value up to OCH_3 18.60 per cent, while the third checked the second at OCH_3 18.51 per cent, and had a bromine content of 16.70 per cent. With dimethyl sulfate and alkali this Br.C.L.II, after two methylations contained OCH_3 18.73 per cent, after the third methylation OCH_3 19.47 per cent, and after the fourth OCH_3 18.42 per cent, with a bromine content of 15.77 per cent.

FRACTIONATION

Br.C.L.I was separated into two fractions by means of dioxane. This is shown in Diagram I. The two products were methylated with diazo-

Diagram III. Chloroform separation of diazomethane methylated Br.C.L.II



methane and the methoxyl content of the two fractions after methylation were 11.95 per cent and 17.57 per cent for the insoluble and soluble fraction respectively.

Methylated Br.C.L.I can be separated into two fractions by means of chloroform and the soluble portion recovered by pouring into ether. This is shown in Diagram II. From an inspection of the methoxyl contents it would appear that Br.C.L.I-G_1 on Diagram I, which is soluble in dioxane, insoluble in ether and methylated with diazomethane, is very similar to Br.C.L.I-K on Diagram II, which is a diazomethane methylated product soluble in chloroform but insoluble in ether.

Diazomethane methylated Br.C.L.II can also be separated into two fractions by means of chloroform. This is shown in Diagram III. Br.C.-L.II-N of Diagram III appears similar to Br.C.L.I-G_1 of Diagram I and Br.C.L.I-K of Diagram II from the methoxyl analysis, although it has a much lower bromine content.

SAPONIFICATION

Br.C.L.II-N_1 of Diagram III, OCH_3 18.90 per cent, was subjected to a saponification with 10 per cent NaOH for two hours. Not all the product dissolved by that treatment, so the insoluble portion, amounting to 15 per cent of the original and containing 11.80 per cent OCH_3, was filtered off. The filtrate was acidified, which precipitated the first saponified product, designated *Saponified I* and amounted to 45 per cent of the original Br.C.L.II-N_1. It contained 13.18 per cent OCH_3 and 16.0 per cent Br. This product was methylated three times with diazomethane, after which the methoxyl content was 21.30 per cent, as is shown in Diagram IIIa. This is considerably higher than the methylated Br.C.L.II-N_1 before saponification but since a 15 per cent residue containing only 11.80 per cent OCH_3 had been separated from it by saponification, this increased methoxyl content could be expected.

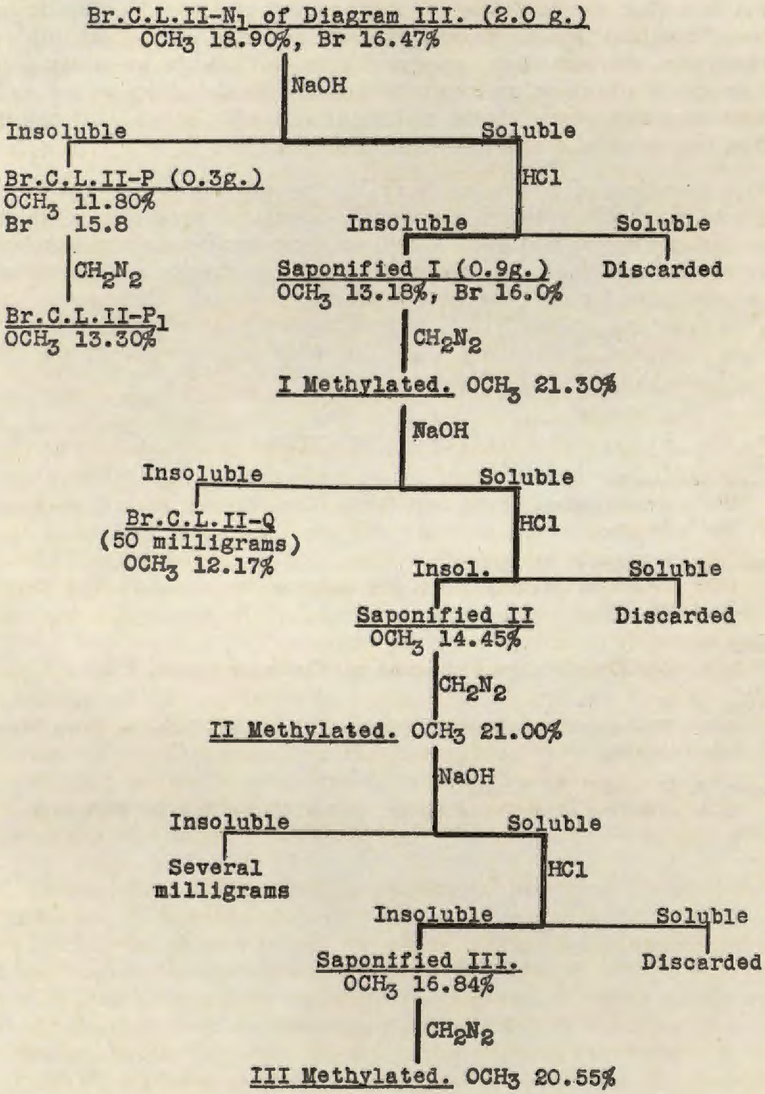
This *Saponified I*, diazomethane methylated product was designated *I Methylated* (see graph I), and was subjected to another saponification yielding *Saponified II* containing 14.45 per cent OCH_3, and an insoluble residue amounting to 50 milligrams and containing 12.17 per cent OCH_3. Methylation of *Saponified II* gave *II Methylated*, which contained 21.00 per cent OCH_3. This series is given diagrammatically in Diagram IIIa and the changes in the methoxyl contents are presented graphically in Graph I.

An inspection of Graph I shows that the methoxyl contents of the methylated products are all practically the same, about 21 per cent OCH_3. With the saponified products, however, an increasing methoxyl content is observed as the number of saponifications is increased. This shows clearly that something besides esterification and saponification is taking place, and indicates that repeated saponification and methylation would lead to a methylated product with about 21 per cent OCH_3 which would not saponify at all. Due to the small amount of product *III Methylated* the series was stopped at this point.

SUMMARY

1. Hypohalogen oxidation of ammonia lignin modifies the original hydroxyl groups in lignin so that diazomethane will increase the meth-

Diagram IIIa. SIaponification and methylation of Br.C.L.II-N_1 of Diagram III.



oxyl content of the oxidized lignin as much as dimethyl sulfate. Ammonia lignin from cornstalks with 13.98 per cent OCH_3 with methylates to 24.43 per cent OCH_3 with diazomethane and to 30.43 per cent OCH_3 with dimethyl sulfate.

2. The presence of a carboxyl group in oxidized lignin is indicated by the fact that the methylated product saponifies with caustic and on remethylation the methoxyl content returns to the original value. However, the structure apparently is not stable in caustic, for on resaponification the methoxyl content does not drop as far as in the first saponification. With subsequent methylation and saponification the same effect is more pronounced.

3. Fractionation of bromo-carboxy-lignins with solvents by three different methods yielded apparently identical products with respect to the methoxyl content. Whether these products are homogenous or not is not clear, for the methylated products on treatment with caustic yield a soluble and insoluble fraction. However, the soluble fraction on methylation and saponification yields more insoluble material, indicating that the reactions involved are causing further changes in the lignin molecule.

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THE FERMENTATION OF XYLOSE BY THE COLON-AEROGENES GROUP OF BACTERIA[1]

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The early investigations of Harden and associates (Harden 1901 et seq.) demonstrated fundamental differences between the two sections of the colon-aerogenes group. Many investigations have since been directed toward further elucidation of the mechanisms of dissimilation by which hexoses are converted into the various products. Consequently, studies generally have been limited to investigation of the fermentation of glucose or simpler compounds considered to be probable intermediates such as glyceric acid (Virtanen and Peltola, 1929; Antoniana, 1933), glyceraldehyde (Virtanen and Hausen, 1931), methylglyoxal (Neuberg and Gorr, 1925), pyruvic acid (Aubel, 1924), and dioxyacetone (Virtanen, Karström and Turpeinen, 1929). The present investigation of the dissimilation of xylose has been carried out to contribute to our knowledge of the fermentation of pentoses by the colon-aerogenes bacteria.

EXPERIMENTAL

Comparative fermentations of xylose and glucose were carried out in liter flasks filled with medium and incubated at 30° C. for 7 days. With calcium carbonate as the buffer, the residual carbon dioxide in the liquor was determined in the following manner. After completion of the fermentation, the flask was connected to a reflux condenser leading to an ordinary soda-lime train for the gravimetric determination of carbon dioxide. A quantity of dilute (25%) sulphuric acid, slightly in excess of the total calcium carbonate originally added, was allowed to drop slowly into the flask and the contents slowly brought to boiling. The liberated carbon dioxide was transferred to the soda-lime tubes by drawing a slow stream of CO_2-free air through the apparatus for one hour. The initial CO_2 content was calculated from the accurately weighed $CaCO_3$ added. The difference between the quantity of CO_2 collected and that added as carbonate represents the CO_2 produced by the fermentation.

Other methods are described in previous papers. (Reynolds and Werkman, 1937, Reynolds, Jacobsson and Werkman, 1937.)

In all experiments the carbon and oxidation-reduction balances give evidence of the substantial accuracy of the analyses.

Identity of the cultures used was: *Escherichia coli,* number 26 of the American Type Culture Collection, and *Aerobacter indologenes,* strain described by Burkey (1928). Cultures were examined for purity microscopically and by plating both before and after completion of fermentation.

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[1] Supported by the Industrial Science Research Fund of Iowa State College.

Typical results obtained from glucose and xylose fermentations by *A. indologenes* (table 1) show that there are no great differences in the final products of the two sugars. Some points, however, are worthy of consideration.

Scheffer (1928) has formulated a scheme of dissimilation of glucose by Aerobacter (see also Kluyver, 1936). He proposed a primary cleavage to methylglyoxal. The intermediately formed methylglyoxal stabilized as lactic acid, or was either dehydrogenated to hydrogen and pyruvic acid or hydrolyzed to formic acid and hydrated-acetaldehyde. Acetylmethylcarbinol was formed by the condensation of one mole of the hydrated acetaldehyde with a mole of the non-hydrated, the latter arising through decarboxylation of pyruvic acid. Ethyl alcohol resulted from the reduction of intermediately formed aldehyde.

The data in table 1 on the fermentation of glucose can be shown to fit substantially the Scheffer-Kluyver scheme. In extension of their scheme Reynolds and Werkman (1937) and Reynolds, Jacobsson and Werkman (1937) have shown that acetic acid plays the rôle of an intermediary compound. The acid accumulates during the early phases of dissimilation and is later converted into 2,3-butylene glycol by reduction *via* acetylmethylcarbinol.

Scheffer attributed the formation of small quantities of succinic acid from glucose by Aerobacter to the protein (peptone) in his substrate. In agreement with such a conception, we have found that the fermentation of glucose by *A. indologenes* in a medium containing only ammonium salts as a nitrogen source yields no succinic acid. Under similar conditions, however, xylose gives rise to appreciable quantities of succinic acid. The acid was isolated and identified by its melting point and that of the paratoluidide. The finding of succinic acid as a product of fermentation of xylose by *A. indologenes* is in agreement with Fred and Peterson (1920) and Breden and Fulmer (1931). An explanation of the formation of the 4-carbon acid from xylose and not from glucose is not apparent.

In connection with the rôle of succinic acid in fermentation by Aerobacter, it has previously been shown that *A. indologenes* causes a decrease in that acid when its sodium salt is added to a glucose fermentation. (Reynolds, Jacobsson and Werkman, 1937). Disappearance of succinic acid was accompanied by increases in 1-carbon compounds and in 2,3-butylene glycol. The results suggested that the acid was broken down according to the Thunberg-Wieland series (Neuberg and Simon, 1933) yielding acetaldehyde which condensed to acetylmethylcarbinol, the latter being subsequently reduced to glycol. It is not impossible, that in the fermentation of glucose by Aerobacter, succinic acid is a normal intermediate which, like acetaldehyde, does not ordinarily accumulate. On the other hand, the presence of succinic acid as a product of the fermentation of xylose may be due to the properties of the particular type of fragment resulting from initial cleavage of the pentose molecule, possibly the 2-carbon fraction, assuming the initial cleavage is to 3- and 2-carbon compounds.

Results obtained from simultaneous fermentations of xylose and glucose by *Esch. coli* are collected in table 2.

TABLE 1. *Anaerobic dissimilation of glucose and xylose by Aerobacter indologenes*

Sugar fermented and products in millimoles per liter.

Substrate	Sugar fermented	Carbon dioxide	Hydrogen	Formic acid	Ethyl alcohol	Acetic acid	Lactic acid	Acetylmethylcarbinol	2,3-Butylene glycol	Succinic acid	Pctg. recovery carbon	Redox index
Glucose	123.8	189.0	34.2	34.6	82.5	1.1	3.68	0.89	79.4	0	97.0	.943
Xylose	99.73	113.3	19.0	26.2	55.8	11.27	5.16	0.91	44.0	5.43	98.5	.977

Medium = 2.0% sugar, 0.1% $(NH_4)_2HPO_4$, 0.5% $NaHCO_3$

TABLE 2. *Anaerobic dissimilation of glucose and xylose by Escherichia coli*

Sugar fermented and products in millimoles per liter.

Substrate	Sugar fermented	Carbon dioxide	Hydrogen	Formic acid	Ethyl alcohol	Acetic acid	Lactic acid	Succinic acid	Pctg. recovery carbon	Redox index
Glucose	73	41.2	39.2	4.25	27.0	22.05	87	3.56	95.5	0.97
Xylose	55.1	2.47	2.0	1.68	9.74	9.68	58.5	16.05	103	1.05

Medium = 2.0% glucose, 0.5% Bacto-peptone, 1.0% calcium carbonate.

In the work of Scheffer and Kluyver, a scheme has been proposed to explain the mechanism of glucose dissemination by *Esch. coli.* Methylglyoxal, resulting from preliminary cleavage of the hexose molecule, stabilizes as lactic acid or is split into formic acid and acetaldehyde. The aldehyde serves as a precursor of ethyl alcohol and acetic acid. A direct 4- and 2-carbon splitting of the hexose molecule to give, intermediately, the dialdehyde of tartaric acid which subsequently undergoes rearrangement to succinic acid, is proposed to explain the formation of the 4-carbon acid. The proposed mechanism is based on the following assumptions:

1. If succinic acid is formed synthetically from intermediate 2-carbon compounds, each mole of succinic acid will be accompanied by two moles of 1-carbon compounds, i. e., formic acid or carbon dioxide. Then the total number of 1-carbon compounds will be equal in moles to the sum of (1) two times the succinic acid, (2) ethyl alcohol and (3) acetic acid.

2. If succinic acid is formed from a 4-carbon compound arising through a direct 4- and 2-carbon cleavage of the hexose molecule, then neither succinic acid nor the 2-carbon compound accompanying its formation will require simultaneous production of 1-carbon compounds. The sum of 1-carbon compounds will then be equal to the difference between the sum of 2-carbon compounds and succinic acid.

Results obtained by Scheffer on completed fermentations are in agreement with the latter assumption. Direct proof for such a mode of formation is lacking and absence of any evidence of the intermediary formation of such a compound as the dialdehyde of tartaric acid brings into question the proposed mechanism.

As with Aerobacter, it can be shown that the data in table 2 for the fermentation of glucose by *Esch. coli* comply satisfactorily with the Scheffer-Kluyver scheme. The mechanism, however, is not adequate to explain all of the data obtained from the fermentation of xylose.

Qualitatively, the products obtained from the two sugars are the same. Quantitatively the most marked difference is in the much greater yield of succinic acid from xylose as compared with glucose.

The substrate-product ratio for the fermentation of xylose by *Esch. coli* (table 2) shows that lactic acid was formed at a rate only slightly greater than one mole for each mole of xylose fermented. The data are difficult to explain on any basis other than an initial cleavage of the pentose molecule into 3- and 2-carbon compounds, the 3-carbon fraction being converted into lactic acid. Other products, including succinic acid, would be the result of further conversions of the remaining 2-carbon fragment. The data favor the suggestion that *Esch. coli* can form succinic acid by synthesis from intermediate 2-carbon compounds.

DISCUSSION

Previously, this laboratory has reported the isolation of phosphoglyceric acid resulting from the action of members of the colon group on glucose, and conversion of the phosphoglyceric acid to pyruvic. (Werkman et al., 1936; Stone and Werkman, 1936). In view of these results it is reasonable to suppose that the chemistry of the primary reactions in the dissimilation of glucose by the coli-aerogenes group is similar to that proposed for muscle glucolysis by the Embden-Meyerhof scheme. Experimental data dealing with the primary reactions involved in the bacterial decomposition of pentoses are lacking. It is, however, logical to assume that a preliminary phosphorylation precedes cleavage of the molecule to shorter carbon-chain fragments. Results reported here, particularly those obtained from the fermentation of xylose by *Esch. coli* indicate that the primary cleavage results in 3- and 2-carbon fragments. The results are best explained on the basis of the intermediate formation of pyruvic acid by way of phosphoglyceric acid, the pyruvic being subsequently reduced to lactic acid. The fermented xylose liquor gave a positive reaction for pyruvic acid when tested by the method of Simon and Piaux (1924), giving further support to pyruvic acid as an intermediate. The remaining products, including large quantities of succinic acid, must be formed through further conversions and synthesis from the remaining 2-carbon fraction.

In the fermentation of xylose by *A. indologenes*, the quantitative and qualitative similarity of the products with those derived from glucose indicates that primary cleavage results in similar intermediates in both cases. The previously reported results on the intermediary character of acetic acid in this fermentation, and results indicating that *A. indologenes* causes a hydrolytic cleavage of pyruvic acid to formic and acetic acids (Mickelson, Reynolds and Werkman, 1936) make it probable that a similar mechanism acts in the formation of acetylmethylcarbinol and 2,3-butylene glycol from xylose. In addition, the data indicate that succinic acid plays the rôle of an intermediate in the fermentation of xylose by *A. indologenes*.

CONCLUSIONS

The products formed in the fermentation of xylose and glucose by members of the colon-aerogenes group are, with one exception, qualitatively the same, but vary quantitatively. *A. indologenes* forms succinic acid from xylose, but not from glucose.

Data reported support an initial cleavage of the pentose molecule by *Esch. coli* and *A. indologenes* into 3- and 2-carbon fragments.

Esch. coli forms much larger quantities of succinic acid from xylose than from glucose.

It is probable that succinic acid formed from xylose by *Esch. coli* results through synthesis from intermediate 2-carbon precursors.

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EFFECT OF LONG CONTINUED TREATMENT ON THE ORGANIC MATTER, NITROGEN AND PHOSPHORUS CONTENT OF CLARION LOAM. I. CONTINUOUS CORN[1]

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In spite of all the experiments which have shown the injurious effects of continuous cropping and the experiences of many farmers which have demonstrated the undesirability of the practice, there are still those who crop the land continuously to the same crop with no provision or at least with entirely inadequate provision for the return of the necessary fertility constituents to permit of the continued satisfactory use of the land for the growing of crops.

It has been found that the fertility of the soil can be maintained only if the organic matter content is kept up and some provision is made to return the plant food constituents removed by the crops grown. The cultivation and consequent aeration of the soil stimulates microbiological action and results in a rapid loss of organic matter and hence the alternation of non-cultivated with cultivated crops cuts down the rate of decomposition and tends to conserve the organic matter supply of the soil. There is also a greater return of crop residues with some crops than with others, and legume residues are especially valuable as sources of organic matter. It appears, therefore, that under a rotation of crops which includes a legume, fertiliy losses may be much reduced over those which occur under continuous cropping. It also appears that fertilization of the soil may lessen the rapidity of fertility losses and under continuous cropping the effects of soil treatments may be particularly significant.

The purpose of the work reported here was to study the losses of fertility under continuous cropping to corn with various soil treatments on plots at the Agronomy Farm of the Iowa Agricultural Experiment Station which have been under investigation since 1914. It was planned to determine the changes in organic matter, nitrogen, phosphorus, available phosphorus and pH in the soil on these plots from 1917 to 1936; to determine the effects of manure and limestone additions on these constituents; and also to determine the number of samples that should be taken from experimental plots one-tenth acre in size in order to insure significant and satisfactory results.

HISTORICAL

Blair and Prince (5) studied the effect of manure, nitrogen fertilizers and a mineral mixture consisting of superphosphate and muriate of potash on the supply of organic matter, nitrogen and phosphorus in soils. The amounts of organic matter and nitrogen in the soil were increased only on those plots which received manure in combination

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with the mineral mixture. Under all other treatments of the soil there was a loss of these constituents. In an earlier report of the same experiment (4, 8) it was noted that the nitrogen content of the soil was difficult to maintain under continuous cropping, even with additions of fertilizer.

Bear and Salter (3) concluded that the organic matter content of the soil could be maintained and increased by the use of fertilizers without plowing under green manure crops or crop residues other than the stubble left after the crops were harvested.

Bear (2) studied the effect of quicklime on the organic matter and nitrogen in the soil and noted that in every case the soils treated with quicklime and fertilizer contained a smaller amount of nitrogen and carbon than the soils receiving corresponding fertilizer treatments without the quicklime.

Salter (10) studied the influence of the carbon-nitrogen ratio of organic matter additions on the accumulation of the organic matter in the soil. The data indicated that additions of materials having a narrow carbon-nitrogen ratio resulted in a large accumulation of organic matter in the soil, whereas, materials having a wide ratio did not have anything like as great an effect.

Snider (13) studied the effect of long-continued soil treatment and crop rotation upon the nitrogen and organic matter contents of the soil. He reported that on lightly limed soils the total nitrogen and organic matter were maintained at a higher level than on untreated or highly limed soils.

White (18) found that where lime was used with manure or a complete mineral fertilizer, the temporary decrease in organic matter, resulting from stimulated bacterial action, was offset by the increased amount of crop residues.

White and Holben (19) studied the effect of caustic lime on soil treated with barnyard manure. They found that in 40 years soil treated with lime and manure produced 13,120 pounds of dry matter and 214 pounds of nitrogen more than soil treated with manure alone. They estimated that lime applied to manured soil had stimulated the decay of 2,000 pounds of organic matter beyond that occurring in soil treated with manure alone. This resulted in an increased yield of crops sufficient to bring about an accumulation of 4,245 pounds of crop residues, thus leaving a balance of 1,345 pounds of organic matter in excess of that in the soil receiving the manure treatment without lime.

Turk and Millar (16) studied the effect of various kinds and combinations of crop residues with and without lime and fertilizer additions on the organic matter and nitrogen content of some of the lighter soils of Michigan. They reported that greater losses of organic matter occurred with materials of low nitrogen content. This bears out the contention that it is necessary to add nitrogen to soil in order to increase the organic matter content to an appreciable extent.

Karraker (7) compared the effect of certain management practices on the amount of nitrogen in a soil. He found that soils left bare showed a loss of 530 pounds of nitrogen in the surface 18 inches over a period of 11 years; that with soils kept in continuous bluegrass, the nitrogen content remained about the same or showed a slight increase;

and that soils kept in continuous bluegrass and white clover showed a gain of 405 pounds of nitrogen.

Salter and Green (11) considered the effects of different crops and cropping systems on the soil and attempted to differentiate between the effects of cultural practices and the influence of the residues left by a crop. They assumed that the average effect of a given crop in a single year was proportional to the content of organic carbon and nitrogen in the soil at the beginning of the year. The losses of nitrogen and organic carbon from the soil under the different cropping systems arranged in decreasing order were continuous corn, continuous wheat, continuous oats, the 5-year rotation and the 3-year rotation. They estimated that about 10 per cent of the total nitrogen added in manure remained in a residual form in the soil and about 5 per cent of the organic carbon added remained undecomposed.

Metzger (9) showed that there was a close relationship between the total nitrogen content of the soil and crop production over a period of 25 years, and that there was a similar relationship between the organic carbon in the soil and crop production.

Snyder (14) observed that over a 4-year period there were greater losses of nitrogen under continuous wheat than under continuous corn, oats or barley. With clover in the rotation, and manure added, he was able to increase the nitrogen content of the soil. All soils under continuous crops lost humus, whereas, soils under a rotation and manure gained 0.2 to 0.5 per cent humus. He also found that the greatest losses of humus occurred in soils rich in nitrogen and humus and that the ntirogen content of soils becomes stabilized as the humus content decreases.

EXPERIMENTAL

The continuous corn experiment consists of five plots, each 28 feet wide, 155 feet long and separated by a 7-foot border. The plots were laid out on Clarion loam at the Agronomy Farm in 1914. The soil treatments made were as follows:

Plot No.	Treatment
906	Check.
907	8 tons manure once in 4 years.
908	8 tons manure once in 4 years plus sufficient limestone to neutralize the acidity of the soil.
909	Limestone sufficient to neutralize the acidity of the soil.
910	Check.

The manure was added at the rate of 8 tons per acre in 1914 and every fourth year thereafter. Limestone was added in 1914 and thereafter when necessary to neutralize the acidity of the soil.

Composite soil samples were taken from each plot in 1917. These samples were made by mixing 5 small samples taken from near the corners and center of each plot. In 1936 each plot was divided into four sections 7 feet wide and 155 feet long. Three samples of soil were taken from each of the 4 sections of all plots. The samples were taken 50 feet apart, starting at random from 5 to 35 feet from one end of the plots. The soils were air-dried, ground and mixed thoroughly before any determinations were made. The pH, organic matter, total nitrogen, total phosphorus and soluble phosphorus were determined in duplicate on each sample. The results were calculated on a moisture-free basis.

The pH of the soils was determined electrometrically by the quinhydrone electrode. Total nitrogen was determined by the Gunning-Hibbard method (1). Inorganic carbon determined by the Schollenberger method (12) was subtracted from the total carbon determined by the wet combustion method (20) and the result multiplied by the factor 1.724 to give the organic matter. Total phosphorus was determined by the modified magnesium nitrate method (6), and the soluble phosphorus was determined by the 0.002 N sulfuric acid method (15).

RESULTS

1. *Loss of Organic Matter, Nitrogen and Phosphorus and Changes in Available Phosphorus and pH of Soils from 1917 to 1936.*

The results obtained in the determinations of organic matter, total nitrogen and phosphorus of the soil samples in 1917, the averages of those samples in 1936, and the changes in available phosphorus and pH are given in table 1.

TABLE 1. *Percentages of nitrogen, phosphorus and organic matter and pH changes and soluble phosphorus of soils samples in 1917 and 1936*

	Date	Check 906	Manure 907	Manure + lime 908	Lime 909	Check 910
Organic matter	1917	4.7959	4.2866	4.0169	2.8468	2.5011
Content	1936	3.8912	4.0187	3.0866	2.8815	2.1375
Difference		−0.9047	−0.1679	−0.9303	+0.0347	−0.3636
Nitrogen	1917	0.2221	0.1940	0.1901	0.1471	0.1322
Content	1936	0.1731	0.1701	0.1503	0.1327	0.1080
Difference		−0.0508	−0.0239	−0.0398	−0.0144	−0.0242
Total phosphorus	1917	0.0441	0.0413	0.0405	0.0335	0.0344
Content	1936	0.0354	0.0352	0.0346	0.0310	0.0284
Difference		−0.0087	−0.0061	−0.0059	−0.0025	−0.0060
Parts per million of available	1917	35.00	35.00	24.50	25.00	24.10
phosphorus	1936	22.55	23.88	33.75	19.76	Trace
Difference		−12.45	−11.12	+9.25	−5.24	−24.10
pH	1917	5.99	6.01	5.90	6.14	6.14
	1936	5.92	6.21	7.40	7.04	6.01
Difference		−0.07	+0.20	+1.50	+0.90	−0.13

The results obtained on the 1917 soils are from one composite sample, whereas, the figures for the 1936 results are the average of 12 samples. The results for the determinations on individual samples in 1936 are given in table 2.

TABLE 2. *Organic matter, nitrogen, phosphorus and pH of Soils Samples in 1936*

Plot No.	Section	Pctg. organic matter			Pctg. total nitrogen			Pctg. total phosphorus			p.p.m. soluble phosphorus			pH		
		Position of samples			Position of samples			Position of samples			Position of samples			Position of samples		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
906	A	3.6413	3.5920	3.8417	0.1528	0.1571	0.1651	0.0358	0.0349	0.0350	16.0	29.0	16.0	5.73	7.03	5.61
	B	3.3759	4.3033	4.2148	0.1490	0.1702	0.1856	0.0335	0.0350	0.0363	16.3	28.1	28.9	5.78	6.34	5.63
	C	3.5980	3.9339	4.1443	0.1714	0.1734	0.1770	0.0356	0.0384	0.0375	15.6	41.9	17.3	5.55	6.90	5.31
	D	4.0231	3.9442	4.0835	0.1881	0.1827	0.1800	0.0352	0.0360	0.0319	15.6	31.7	14.2	5.44	6.29	5.54
907	A	4.1636	4.2921	4.2420	0.1747	0.1689	0.1724	0.0339	0.0344	0.0321	20.8	26.0	15.6	5.71	6.03	5.82
	B	4.0420	3.8965	3.9763	0.1694	0.1747	0.1661	0.0366	0.0383	0.0387	22.0	21.7	17.3	6.25	6.44	5.95
	C	4.1887	3.8741	4.1156	0.1808	0.1691	0.1760	0.0349	0.0335	0.0355	28.9	23.1	18.9	6.75	6.59	6.27
	D	4.0979	3.4635	3.8717	0.1735	0.1524	0.1637	0.0355	0.0353	0.0333	52.0	23.0	17.3	5.86	6.58	6.31
908	A	3.4857	2.9739	2.6998	0.1577	0.1378	0.1631	0.0340	0.0321	0.0373	32.5	31.0	59.1	6.99	7.01	7.73
	B	3.8377	1.9873	3.5265	0.1744	0.1130	0.1591	0.0379	0.0290	0.0371	44.6	27.1	28.9	7.62	7.57	7.35
	C	2.8079	2.9419	3.3310	0.1735	0.1356	0.1592	0.0379	0.0317	0.0349	43.3	27.4	26.0	7.86	7.38	7.31
	D	3.6146	2.3198	3.5132	0.1630	0.1095	0.1580	0.0375	0.0294	0.0359	35.1	27.7	22.2	7.51	7.55	6.97
909	A	3.5606	2.1249	3.5196	0.1540	0.1067	0.1509	0.0331	0.0266	0.0348	20.8	23.6	20.8	6.59	7.27	7.05
	B	3.7919	2.5665	2.9118	0.1625	0.1148	0.1380	0.0334	0.0279	0.0324	24.6	21.7	17.3	7.10	7.26	7.14
	C	3.2957	1.6324	3.2108	0.1479	0.1030	0.1468	0.0322	0.0254	0.0361	20.4	17.3	20.8	7.23	7.39	6.95
	D	3.0034	2.2022	2.7577	0.1424	0.1041	0.1216	0.0318	0.0269	0.0318	18.9	18.0	13.0	7.17	7.05	6.28
910	A	2.3250	1.6861	2.9947	0.1033	0.0802	0.1350	0.0279	0.0237	0.0336	trace	trace	trace	6.10	6.01	5.82
	B	2.2920	1.7372	2.5614	0.1589	0.0851	0.1233	0.0271	0.0244	0.0296	"	"	"	5.91	6.08	5.54
	C	2.1731	2.5416	1.6863	0.1048	0.1174	0.0811	0.0287	0.0308	0.0265	"	"	"	5.94	5.69	6.26
	D	2.4346	1.0955	2.1228	0.1146	0.0888	0.1034	0.0314	0.0278	0.0297	"	"	"	5.95	7.11	5.69

The organic matter and nitrogen contents of the soils in 1917 were highest in the soil of plot 906 and lowest in that of plot 910, due mainly to the slope of the land, although there was some difference because of the variation in rate of decomposition of organic matter in the differently treated soils. The phosphorus content of these soils in 1917 was highest in the soil from plot 906 and lowest in the samples from plot 909, while in 1936 it was highest in the soil from plot 906 and lowest in that from plot 910.

In 1917 the available phosphorus of the soils was highest in the soils from plots 906 and 907, and lowest in that from plot 910. In 1936 the available phosphorus content was highest in the soil from plot 908, and only a trace was found in the soil from plot 910.

The pH of the soil from all plots was about the same in 1917, ranging from pH 5.90 to pH 6.14. But in 1936 the pH of the soils which had received lime (plots 908 and 909) was increased considerably over that of the soils which had not been treated with lime. The soil treated with manure was slightly less acid and the two check soils were slightly more acid in 1936 than in 1917.

2. *Crop Yields.*

The yields of corn calculated on a 15 per cent moisture content from 1915 to 1936, inclusive, are given in table 3.

TABLE 3. *Corn yields, bushels per acre, continuous corn, 1915–1936*

Year	No. 906	No. 907	No. 908	No. 909	No. 910
	Check	Manure	Manure + lime	Lime	Check
1915	38.6	36.8	41.2	19.2	10.5
1916	36.0	35.6	39.6	30.8	14.0
1917	48.7	50.6	51.8	47.2	40.0
1918	25.7	37.1	38.6	31.4	24.3
1919	38.6	55.7	60.0	42.8	37.1
1920	41.4	50.0	64.2	50.0	45.7
1921	34.2	48.5	50.0	42.9	35.7
1922	38.6	48.5	52.8	45.7	32.8
1923	30.0	51.3	52.5	43.8	36.3
1924	28.5	35.7	34.2	30.0	22.8
1925	50.6	53.3	57.3	45.3	25.3
1926	32.5	32.5	35.0	28.8	17.5
1927	33.3	34.7	37.3	32.0	25.9
1928	47.6	48.5	44.8	35.0	28.7
1929	39.6	44.7	45.2	36.3	30.4
1930	25.9	27.0	30.9	29.0	28.1
1931	35.8	45.5	64.7	35.1	29.7
1932	44.5	50.0	48.8	40.6	31.7
1933	44.3	49.3	47.5	35.6	26.9
1934	16.8	17.4	15.8	17.0	14.0
1935	52.6	59.1	62.7	60.4	40.4
1936	18.3	19.3	22.3	20.9	15.0
Average	36.4	42.3	45.3	36.4	27.4

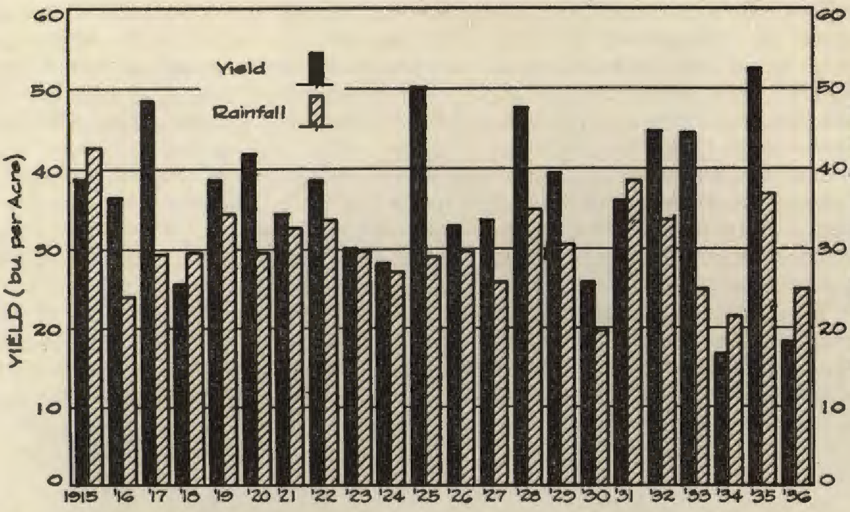

Figure 1. Relation of yield to rainfall. (Plot 906 for 1915-1936).

The yields on all plots varied considerably from year to year mainly because of weather conditions, but the relative yields on the variously treated plots were much the same in any one year.

The annual rainfall for the period from 1915 to 1936, inclusive, and the relation of yield to rainfall are shown for plot 906 in fig. 1.

The data in the graph show a fairly close relation between the average annual rainfall and the corn yield, but this was not always true. For example, the total rainfall in 1918 was practically the same as in 1917, but the yield of plot 908 was considerably reduced. Undoubtedly this was due to the distribution of the rainfall in 1918. The average yields of the different plots show the same trend of yield for the plots as was shown by the individual crops.

3. *Sampling Technique.*

One of the objectives of this work was to determine the number of samples which would be required for a test of significance between the differences in organic matter, nitrogen, phosphorus and pH at the different samplings.

There are two methods of procedure sometimes employed in uniformity trials which may be adapted for this purpose. The first method consists in taking a number of samples for analysis from each plot and determining the coefficient of variability (standard deviation divided by the mean difference). From the relationship of the coefficient of variability to probability the number of observations necessary for a test of significance can be calculated. The other method consists of making frequency distributions of the averages of the combinations of 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 observations made on one of the constituents on the 12 samples from a plot that showed a large variation, and then selecting the smallest number, the average of combinations of which comes sufficiently close to being the same as the average of the 12 individual samples. Both methods are based on certain assumptions. In the first method the magnitude of the difference for significance must be assumed or an infinite number of samples may be necessary to prove significance and in the second method it is assumed that the number of observations made are in excess of that required for an adequate test of variability.

For the estimation of the number of samples that should be taken to show significance in the difference between variates by the first method, values were calculated for organic matter, nitrogen, phosphorus and pH for each of the five plots and the results obtained are presented in table 4.

To illustrate the second method of determining the number of observations necessary to sample the soil adequately, combinations of 2, 3, 9 and 10 samples were made on the results obtained for organic matter in plot 909. The distribution of the averages of these combinations is shown in figs. 2, 3 and 4.

DISCUSSION OF RESULTS

Since there was only one sample taken from each plot in 1917, the data do not permit of a test of the significance of the differences between the 1917 and 1936 determinations. However, the differences between the various soils are fairly consistent for both samplings and it is believed that they are large enough to be of some practical value even though a test of significance cannot be made.

If it is assumed that the variation of the soil in organic matter, nitrogen and phosphorus in 1917 was the same as that found in 1936, the significance of the losses of these constituents can be tested. A test of

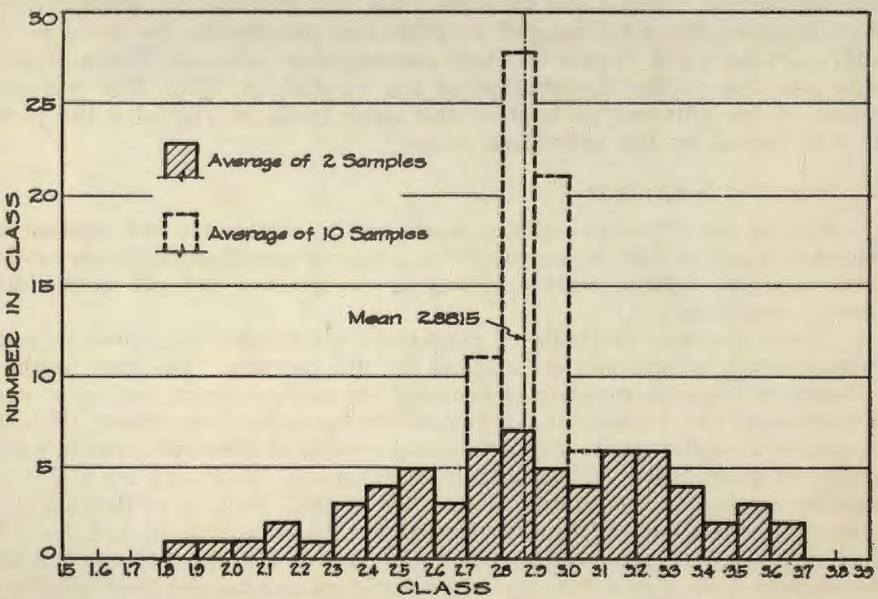

Figure 2. Distribution of averages of combinations of 2 and 10 samples per plot for organic matter of soil in plot 909.

TABLE 4. *Coefficient of variability and the number of samples necessary to show significance*

	Plot No.														
	906			907			908			909			910		
	s/mD*	No. samples		s/mD	No. samples		s/mD	No. samples		s/mD	No. samples		s/mD	No. samples	
		5% pt.	1% pt.		5% pt.	1% pt.		5% pt.	1% pt.		5% pt.	1% pt.		5% pt.	1% pt.
Organic matter	0.308	4	5	1.33	16	26	0.606	6	9	18.8			1.40	18	30
Nitrogen	0.25	3	5	0.304	4	5	0.54	5	8	1.5	20	34	0.97	10	16
Phosphorus	0.19	3	4	0.32	4	5	0.54	5	8	1.38	18	30	0.47	5	7
pH	8.2			1.69	26	44	0.19	3	4	0.347	4	6	2.5	52	87

* Coefficient of variability.

this kind was made based on the above assumption and it was found that the losses in organic matter between 1917 and 1936 were highly significant in the soils of plots 906 and 908, that significant losses in nitrogen and phosphorus occurred in all soils, except that of plot 909, that significant differences in the soluble phosphorus existed in all soils, except that of plot 909, and that there was no significant differences in the pH of the soils in 1936 from that in 1917, except in the soils treated with lime (plots 908 and 909). Where the mean difference was fairly large and the standard deviation was small, the differences were significant or highly significant. In several cases where the differences were found to be highly significant they would have been significant even with a larger standard deviation than that found in 1936. This would permit of a larger variation in the soils sampled in 1917 than probably existed. Even though this test is based on certain assumptions there are indications that the differences are significant.

The soil in plot 906 showed a large loss of organic matter, nitrogen and phosphorus, a considerable decrease in available phosphorus, and a slight decrease in pH. A relatively large loss of organic matter would be expected over a 19-year period since the organic matter content was relatively high in 1917, and no addition of organic material was made, except in the crop residues. The pH of this soil was 5.99 in 1917 and 5.92 in 1936, and it is high enough to allow considerable decomposition, yet there is not as much as would be expected at a higher pH. The loss of nitrogen was also relatively large and correlated with the loss of organic matter. The loss of phosphorus from the soil in this plot (906) was quite large, but it cannot be assumed that the phosphorus

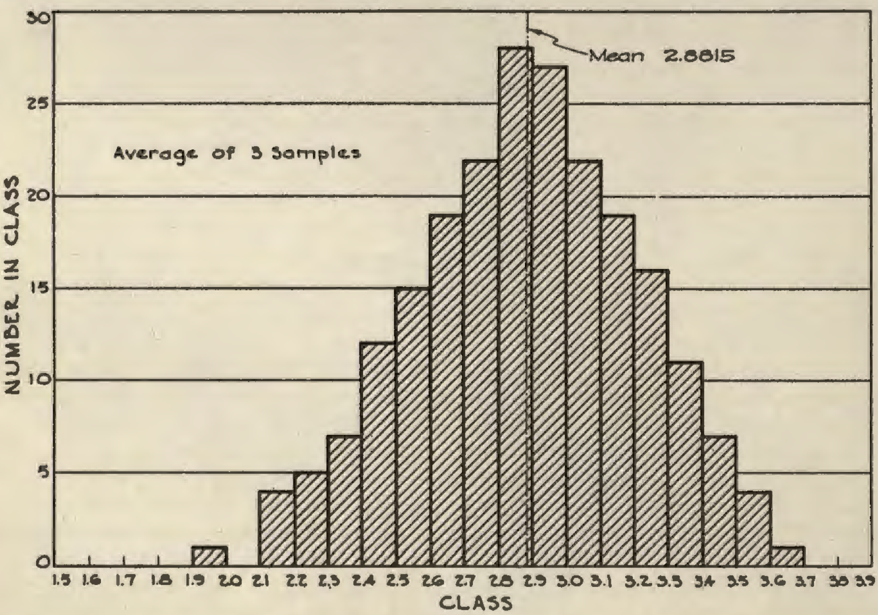

Figure 3. Distribution of averages of combinations of three samples per plot for organic matter of soil in plot 909.

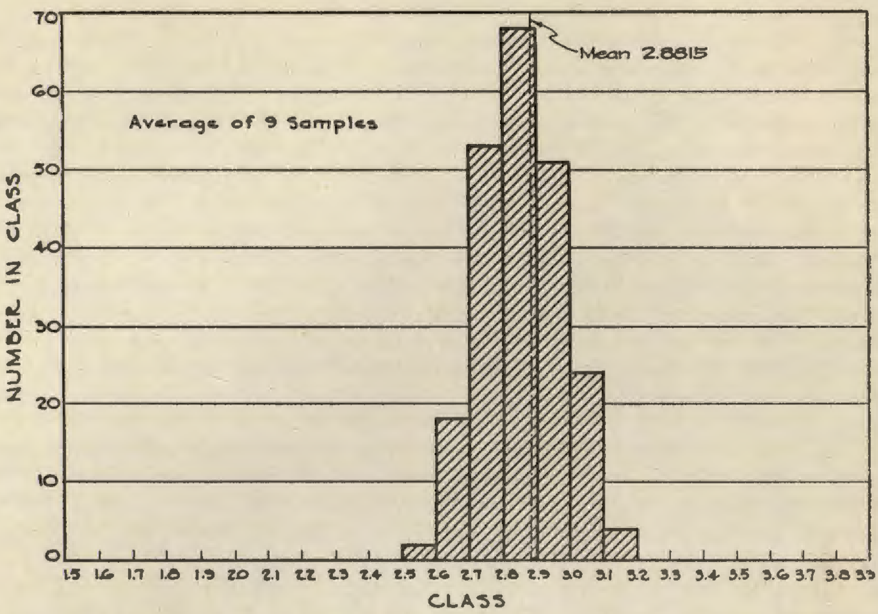

Figure 4. Distribution of averages of combinations of nine samples per plot for organic matter of soil in plot 909.

removed in the crop harvested during the 19-year period was all removed from surface soil. There was a large decrease in the amount of available phosphorus in this soil, which was largely independent of the amount of total phosphorus present. The pH of the soil was slightly lower in 1936 than in 1917, but the change was probably insignificant.

There was a loss of both organic matter and nitrogen in the soil of plot 907 from 1917 to 1936, but this loss was not as great as in the soil of plot 906. The net loss of organic matter should be small in this soil over a period of years because of the large amount added in manure and crop residues. The microbiological activity in the soil would be increased because of the large number of microorganisms introduced with the manure and the large amount of readily available organic matter. However, the pH of the soil was 6.01 in 1917 and 6.21 in 1936 and the microbiological activity would not be as great as in a neutral soil. Likewise, the net loss of nitrogen would be small because of the relatively large addition of nitrogen in the manure. The loss of nitrogen was also correlated fairly closely with the loss of organic matter in this soil. The loss of phosphorus in this soil was not large considering the total crops harvested from the plot, and also because there was some addition of this constituent in the manure. There was a rather large decrease in available phosphorus in this soil, but the decrease was not as large as in the check soil, plot 906.

The soil of plot 908 showed a relatively large loss of organic matter during the period from 1917 to 1936. Since this plot received larger crop residues than any of the other plots, and a total amount of 48 tons of manure per acre during the time the experiment has been in operation, it was not expected that the net loss from this soil would be so great. However, the pH of the soil was 7.4, and this high pH, together with the large number of microorganisms introduced into the soil with the manure undoubtedly account for the large decomposition of organic matter in the soil of this plot. The loss of nitrogen in this soil was quite large as would be expected since the loss of organic matter was also relatively large. This loss of nitrogen would have been larger, no doubt, if none had been added in the manure. Also, the increased bacterial numbers probably caused more nitrogen to be fixed or held in the soil than would have been the case with a less active microflora. The net loss of phosphorus from the soil in plot 908 was no larger than would be expected from the amount present in the crops removed and that added in the manure. The available phosphorus was increased considerably in the soil of this plot. This increase in availability of phosphorus may be attributed to the combined effect of manure and lime.

In the soil of plot 909 there was an apparent tendency toward the conservation of the constituents determined. The analyses showed a slight increase in the organic matter content in 1936 over that in 1917, but the amount was small and hardly significant. Since this soil was treated with lime, it would be assumed that there should have been a considerable loss of organic matter on account of the higher pH and increased bacterial action. However, the content of organic matter was so low in the beginning that the decomposition would not be rapid. The inference drawn is that while the lime stimulated decomposition, this was offset by the fact that the organic matter present was apparently in an advanced stage of decomposition and hence the rate of decomposition was very low. The loss of nitrogen from the soil in this plot was fairly small as would be expected since there was only a slight change in the organic matter content. The increased pH may have stimulated nitrogen fixation in this soil and as a result of this increased fixation the net loss of nitrogen was small. The loss of phosphorus in this soil for the 19-year period was small and probably less than that removed in the crops harvested. This small loss of total phosphorus suggests another interpretation of the small loss of organic matter and nitrogen from the soil of this plot. Van Slyke (17) calculated that about 4.0 pounds of phosphorus was removed by the grain in a 25-bushel crop of corn. The total yield of corn on this plot was 722.6 bushels for the 19-year period and would contain then 115.6 pounds of phosphorus. The analysis showed a loss of only 50 pounds. Here again the analyses represent the phosphorus in the surface soil and the phosphorus removed in the crop was probably not all removed from this layer. However, the data suggest the sample taken in 1917 was not representative of the soil of this plot. The same conclusion, namely, that the samples were not representative, may be drawn from the analyses for organic matter and nitrogen. In other words, the amounts of organic matter, nitrogen and phosphorus were probably higher in 1917 than appears from the analyses of the samples taken this year and a greater loss should have been shown as a result of the treatment with lime.

The loss of organic matter and nitrogen from the soil of plot 910 was quite large, yet not as large as expected. The organic matter in this soil also may have been in an advanced stage of decomposition and the rate of decomposition very slow. The available phosphorus was greatly reduced in this plot during the 19-year period, only a trace being present in the soil samples in 1936. The loss of total phosphorus in this soil was little more than would be expected by the crops removed.

Because of the ordered arrangement of the plots in the field, no test of significance of the differences brought about by treatments can be made. However, the effects of the manure and lime on the organic matter, nitrogen, total and available phosphorus and on the pH are quite obvious, especially in the case of plots 907 and 908.

The manure added to plot 907 tended to conserve the organic matter, nitrogen and total phosphorus content of this soil. There was more organic matter decomposed in the soil of plot 907 than that in plot 906, but this was offset by the manure added and the larger amount of crop residues returned. The manure additions tended to conserve the nitrogen and the net loss of nitrogen in this soil was less than half that observed in the soil of plot 906. The smaller loss of phosphorus in this soil than in the adjoining check soil was undoubtedly caused by the addition of this constituent in the manure. The pH of the soil treated with manure was increased 0.2 over that of the adjoining check soil.

The effects of manure when added with lime, as shown by the analyses of the soil in plot 908, were quite different than when the manure was added alone. The loss of organic matter was large in this plot in spite of the application of a total of 48 tons of manure per acre and the return of relatively large amounts of crop residues. The loss of nitrogen was larger in this soil than in that treated with manure alone and parallels the decrease in the organic matter content. The effect of manure alone or lime alone was to decrease the availability of phosphorus, but with manure and lime together the effect was to increase the available phosphorus content considerably. The pH of the soil was increased more where both manure and lime were added than where either material was added alone.

The losses of organic matter, nitrogen and phosphorus in the soil of plot 910 were similar to those obtained in the soil of plot 906, but were not quite as large, since the tota lamounts of these constituents in this soil were much lower than in the soil of plot 906. The organic matter was probably present in an advanced stage of decomposition and the rate of loss less than in the soil of plot 906. The acidity of this soil, the low content of total phosphorus and organic matter were no doubt contributing factors in the decrease in available phosphorus.

In the beginning of the experiment higher yields were obtained on plots 906, 907 and 908 than on plots 909 and 910. This corresponds to the original fertility of the plots. At the end of 22 years the average yield of plot 907 was greater than that for plot 906 or plot 909.

The highest yield was obtained on plot 908 in the beginning of the experiment, and except for slight variations the yield on this plot was highest each year, the average yield for the 22-year period being higher than the yield on any other plot.

The yield on plot 910 was lower in the beginning of the experiment than that on any other plot and continued to be low throughout the experiment. During the last ten years, even though the yield was sometimes fairly high, the quality of corn was very poor.

The results of the determination of the number of samples required for significance by the first method mentioned require some explanation. The purpose of this work was not to determine the number of samples necessary to prove significant mean differences alone, but to estimate the number of samples needed to test significance where the mean difference was large enough to give a significant test with 12 samples. In the soil of plot 909 the change in the organic matter content was only 0.0337 per cent, and it is obvious that an infinite number of samples would be needed here to give a significant test. With a large standard deviation and a small mean difference, the number of samples will be large.

The loss of organic matter was large in the soil of plots 906 and 908. With the standard deviation found in 906, only 5 samples were necessary to give a proof of significance, whereas, in plot 908, 9 samples were necessary. The mean difference in organic matter content in the soil of plot 908 in 1917 and 1936 was greater than in plot 906, but the standard deviation was larger in plot 908 than in plot 906, hence a larger coefficient of variability was obtained and therefore a larger number of samples was necessary.

The number of samples for organic matter, nitrogen, phosphorus and pH necessary to give a highly significant test, where the mean difference was large, ranged from 4 to 9, and for significance the number ranged from 3 to 6. In the cases where the mean difference was small and where the standard deviation was large the number ranged from 16 to an infinite number.

These results indicate that 9 samples would be sufficient for all the plots to provide representative samplings and to give a test of significance where the changes were large. For the plots showing a small change it is quite obvious that those differences are not significant and it is useless to take a large number of samples just to prove them significant. This number (9 samples) was selected because it appeared in a plot with a large mean difference, yet where the variation was great. Also it is assumed that the standard deviation for other plots to be samples will be about the same or less than for the organic matter of plot 909, and that the mean differences will be rather large. This method does not show the exact number of samples that should be taken, but it is a means of making an estimation by observing the variation in sampling.

The second method for estimating the number of samples for an adequate test of the variability of the soil in these plots does not give the exact number but it serves as a basis for obtaining a fair estimate of the number required. The results of the determinations of the organic matter content of the soil of plot 909 were used to illustrate the principle of this method because the variability of the soil in this plot was large. If the number of samples needed for an adequate test is determined for a soil of large variability the number found will be large enough for all plots with an equal or smaller amount of variation.

The range of the content of organic matter for the soil of plot 909 for the 12 samples was from 1.63 per cent to 3.80 per cent and the mean was 2.8815 per cent. Sixty-six combinations of two samples each can be made from these 12 samples. By taking the averages of these combinations, the range was found to vary from 1.88 per cent to 3.68 per cent and the averages were well scattered in this range. Only seven of these combinations had averages which were between 2.8 and 2.9 per cent. Therefore, the chance of drawing two samples with an average in this range is very small. The average of two samples is very likely to be as low as 2.3 or as high as 3.5 and there is some chance that it may be outside this range. Therefore, results based on two samples from this plot would not be reliable since they do not give a sufficient test of the variation within the plots.

Two hundred twenty combinations of 3 samples each can be made from 12 samples. The averages of combinations of 3 samples ranged from 1.9 per cent to 3.7 per cent. Only 28 of these combinations had averages which were between 2.8 and 2.9 per cent and only 72 of the 220 were between 2.7 and 3.0 per cent. The chance of drawing 3 samples with an average in even the latter range is small.

Two hundred twenty combinations of 9 samples each can be made from 12 samples. The averages of combinations of 9 samples ranged from 2.5 per cent to 3.2 per cent. Sixty-eight of these combinations had averages which were between 2.7 and 2.8 per cent and 172 had averages between 2.7 and 3.0 per cent. In other words, approximately 8 out of 10 combinations of 9 samples had averages between 2.7 and 3.0 per cent.

Sixty-six different combinations of 10 samples each were made from the 12 samples taken and each of these was averaged. The lowest average was 2.7 per cent and the highest was 3.1 per cent. The tendency was for the average of 10 samples to be near the mean (2.8 per cent) of the 12 samples as would be expected. The chance of taking 10 samples from this plot and getting about the same information as was found with 12 samples is fairly high, and the information added by the other 2 samples is probably not enough to make the extra sampling worth while.

SUMMARY AND CONCLUSIONS

A composite sample of soil was taken from each plot of the continuous corn experiment at the Agronomy Farm of the Iowa Agricultural Experiment Station in 1917. The composites were made by mixing thoroughly 5 small samples taken from near each corner and the center of each plot. In 1936 a different sampling technique was employed. The method followed consisted in dividing each plot into 4 parts and taking 3 samples 50 feet apart in each of these sections, starting at random from 5 to 35 feet from one end of the plots. The 12 samples taken from each plot were analyzed separately to determine the variability of the soil in the plots.

The samples taken in 1917 and those taken in 1936 were analyzed for organic matter, nitrogen, total phosphorus, available phosphorus and pH. Although the data do not permit of a test of the significance of the differences between the content of these constituents found in the soils sampled in 1917 and those sampled in 1936 these differences appear to be of considerable practical importance. The results obtained may be summarized briefly as follows:

1. The organic matter, nitrogen and phosphorus in the soils in all plots decreased from 1917 to 1936, except in the soil which received a treatment of lime alone, where the organic matter was increased slightly.

2. The largest decrease in organic matter occurred in the soil which had received applications of manure and lime. In all but one case the loss in organic matter was greatest in those soils which contained the greatest amount of this constituent at the beginning of the experiment. Only in the soil which received lime alone was it found that this did not hold true.

3. The addition of manure to the acid soil reduced the loss of organic matter and nitrogen.

4. The addition of manure and lime to the acid soil decreased the loss of nitrogen.

5. The addition of manure alone or lime alone decreased the amount of available phosphorus in the soil, whereas the addition of both manure and lime increased the amount present.

6. The results indicate that lime tended to conserve the organic matter, nitrogen and phosphorus of the soil which received lime alone, although the results were not conclusive.

7. Considerable variability in the soil within the plots was found. Two methods were employed to estimate the number of samples necessary to sample adequately the soil of all plots and to give a test of significance of the differences.

8. It was estimated by these methods that 9 samples from each plot would be necessary to sample adequately the soil of plots which showed as much variation as was found in these continuous corn plots.

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SOME TINGITIDAE (HEMIPTERA) FROM OCEANIA

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The present paper is based largely upon specimens of Tingitidae kindly sent to the writers by the late C. F. Baker of the Philippine Islands and Dr. L. B. Uichanco, Head of the Department of Entomology, University of the Philippines, as well as some other miscellaneous material from Oceania kindly sent by various collectors. These collections contain more than 250 specimens, representing 16 genera and 35 species. Of the 35 species, 7 are described below as new. The holotypes and allotypes are in the Drake collection.

Phatnoma pacifica Kirkaldy

Phatnoma pacifica Kirkaldy, Proc. Linn. Soc., N. S. W., Sidney, XXXIII, 1908, p. 363.

Phatnoma pacifica Hacker, Mem. Queens. Mus., IX, 1928, p. 176, Pl. XX, fig. 4.

One male, Los Banos, Luzon, Philippine Islands, Dec. 1, 1926, collected by E. B. Jamora. This specimen agrees with Hacker's figure of the species.

Serenthia sedalis Drake

Serenthia sedalis Drake, Philip. Jour. Sci. XXXIV, 1927, p. 312.

One specimen, Mt. Makiling, Luzon, Philippine Islands, collected April 14, 1931, at an elevation of 150 meters by L. B. Uichanco.

Monanthia sauteri Drake

Monanthia sauteri Drake, Ohio Jour. Sci., XXIII, 1923, p. 103.

Los Banos, Luzon, Philippine Islands, 1 specimen, May 10, 1915, collected by C. S. Banks; 7 specimens, June 28, 1922 and January 15, 1929, collected on *Cordia myxa* L. (Boraginaceae) by L. B. Uichanco, and one example April 22, 1930 by V. J. Madrid.

Monanthia evidens Drake

Monanthia evidens Drake, Philip. Jour. Sci., XXXII, 1927, p. 53.

Twelve specimens from Los Banos, Luzon, Philippines, elevation 50 meters, collected on *Ehretia acuminata* R. Br., May 15, 1934, by L. B. Uichanco. This species was known heretofore only from the holotype (female) from Imugan, Neuva Vizcaya, P. I. The male (allotype) is very similar to the female in general appearance, color and structure and differs only in being of slightly smaller size.

Monanthia seorsa, sp. nov.

Ovate, greyish brown, with fuscous markings. Head black, the spines short, curved, testaceous, the median tubercular. Body beneath black. Rostral channel moderately wide, rather deep, open behind, the laminae yellowish brown. Rostrum long, brown, dark at apex, extending to end of sulcus. Antennae rather short, moderately slender; segment I short, moderately stout, black-ferruginous; II shorter and more slender, dark reddish brown; III slender, testaceous, two and one-half times as long as four; IV dark fuscous, strongly swollen towards tip.

Pronotum moderately convex, concealed by the closely overlapping paranota, except in front and behind; triangular projection fuscous; lateral carinae as exposed behind testaceous, divaricating; median carina sharply raised, brownish behind; triangular exposed portion in front slightly elevated, the anterior margin subtruncate; paranota very broad, resting closely upon dorsal surface of pronotum, the outer edges meeting on disc and there concealing median carina, thence posteriorly with margin raised moderately. Elytra extending a little beyond apex of abdomen; costal area moderately wide, irregularly biseriate, the transverse nervures thickened, placed in groups of two to three and these groups connected with stout, transverse nervelets; subcostal area broad; discoidal area large, extending very deeply, broadly and concavely into the subcostal area at the apex, the anterior and hind margins of the concave projection strongly raised and dark fuscous. Legs rather short; femora mostly black, very granular, the tibiae and tarsi testaceous, the tips of the latter dark.

Length, 3.00 mm.; width, 1.44 mm.

Holotype (male) and allotype (female) Taiwan (Formosa). The paranota and costal area separate this species at once from its nearest allies.

Monanthia seorsa inflata, n. var.

Differs from typical *seorsa* in having humeri more prominent, the outer portion of paranota behind the disc much more strongly raised and inflated, and the anterior and posterior margins of the concave projection of discoidal area considerably more raised than in the female of *seorsa*. Other structures and color like *seorsa*.

Length, 3.30 mm.; width, 1.68 mm.

Holotype (female) Los Banos, Luzon, Philippine Islands, April 21, 1930, collected by F. Villaneuva. Two paratypes, one female taken with type, and the other female taken from same locality, April 22, 1930, by V. J. Madrid.

Monanthia sessoris, sp nov.

Uniformly greyish testaceous, sparsely clothed with very fine, short, pale, recumbent hairs. Rostral laminae testaceous, slightly divaricated posteriorly, widely separated behind; rostrum brownish, black at tip, extending a little beyond apex of channel. Body beneath brown, rather densely clothed with short pale hairs. Head dark, with five slender, testaceous, suberect spines. Antennae with first two segments short, brownish, the others wanting. Legs slender, yellowish brown, the tips of tarsi dark.

Pronotum moderately convex; median carina strongly raised, composed of one row of rather large, rectangular areolae; hood small, faintly produced forward at middle; paranota broad, resting tightly upon dorsal surface of pronotum, the outer margin practically touching median carina; lateral carinae as exposed behind nearly parallel. Costal area broad, biseriate (a few extra cells on one side), the areolae large and hyaline; subcostal area narrower, biseriate; discoidal area extending considerably beyond middle of elytra, bounded by a raised nervure, narrowed both at base and apex, broadest near middle, there five areolae deep. Wings slightly clouded, iridescent, a little longer than abdomen.

Length, 2.85 mm.; width, 1.20 mm.

Holotype, female, Mt. Makiling, Luzon, Philippine Islands. The strongly elevated median carina and fine hairs on nervures are very distinguishing characters.

Monanthia uichancoi, sp. nov.

Color and form very similar to *M. evidens* Drake but differs from it in being slightly smaller and especially in the character of paranota, presence of lateral carinae, and the much more elevated hind portion of median carina. Paranota with transverse nervure above humeri and inner nervure along outer margin of cells black and very sharply raised so as to form carina-like ridges, the areas within the angles formed by the ridges, both in front and behind, moderately impressed. Lateral carinae exposed on triangular process, distinct but not strongly raised, pale in color and divaricating posteriorly. Median carina strongly raised on triangular process, there uniseriate. Hood small, more sharply raised than in *evidens* Drake.

Elytra narrower than in *evidens;* discoidal area very similar in form to *evidens.* Antennae slender, pale testaceous, basal segment short, brownish black, slightly stouter and shorter than II; III tending to be a little longer in male than in female.

Holotype (male), allotype (female) and nine paratypes, Calamba, Luzon, Philippine Islands, at an elevation of 25 meters, Nov. 10, 1929, collected by L. B. Uichanco. This species is named in honor of Mr. L. B. Uichanco who has taken a very active and unusually keen interest in the insects of the Philippine Islands.

Physatochila marginata (Distant)

Teleonemia marginata Distant, Ann. Soc. Ent. Belg., LIII, 1909, p. 121.

Cysteochila (Parada) marginata Horvath, Ark. Zool., XVII, 1925, p. 3.

Physatochila marginata Bergroth, Rev. Russ. Ent., XVII, 1917, p. 105.

Baguio Benguet, Philippine Islands, 2 examples, C. F. Baker. This is not a very typical species of the genus *Physatochila.*

Cysteochila bakeri Drake and Poor

Cysteochila bakeri Drake and Poor, Philip. Jour. Sci., LXII, 1937, p. 9.

Mt. Makiling, Luzon, female, C. F. Baker. This specimen bears the same data as the type.

Cysteochila abundantis Drake and Poor

Cysteochila abundantis Drake and Poor, Philip. Jour. Sci., LXII, 1937, p. 8.

Mt. Makiling, Luzon; Tangcolan, Bukidnon; and 2 examples from Tigao, Mindanao, Philippine Islands, C. F. Baker; Nilchiri, Coondor, 1902, 1 specimen, collected by M. Maindron. One specimen, Pasonanca, Zamboanga, Philippine Islands, April 9, 1936, by L. B. Uichanco. This is one of the most common members of the genus in the Philippines.

Cysteochila elongata Distant

Cysteochila elongata Distant, Ann. Soc. Ent. Belg., XLVII, 1903, p. 49.

Takao, Taiwan (Formosa), 1 male. The writers propose the name *Baeochila* subgen. nov. for *elongata*. This subgenus has a rather large hood which distinguishes it from typical *Cysteochila*. The metasternal canal is distinct. The rostral sulcus is open behind.

Cysteochila javensis, sp. nov.

Moderately large, elongate-ovate, brownish, with greyish white markings. Pronotum convex above, coarsely pitted; tricarinate, each carina uniseriate; median carina slightly more elevated, the areolae moderately large; lateral carinae faintly converging behind, concealed by paranota in front; paranota moderately large, tumid, embrowned above; hood small, faintly produced forward in front.

Head with five short, blunt, testaceous spines. Segments I and II of antennae short, pale brown, the first slightly longer and stouter; III long, slender, testaceous; IV wanting. Bucculae yellowish brown, closed in front. Rostrum extending to metasternum, brownish, black at apex; rostral laminae testaceous, the channel wide and chordate on metasternum. Elytra brownish, the basal portion and a small area at apex of discoidal area greyish white; costal area narrow, uniseriate, the transverse nervelets infuscate, subcostal area biseriate; sutural area impressed, widest a little behind middle, there four areolae deep; sutural area more widly reticulate behind. The principal nervures and sides of paranota and hood sparsely clothed with pale hairs.

Length, 2.80 mm.; width, 1.00 mm.

Holotype (female), and 1 paratype, Pekalongan, Java, 1907, F. Muir.

This species differs from *C. bakeri* D. & P. in having a smaller hood and paranota, narrower costal area and duller color; from *C. lecta* D. & P. by its narrower costal area and more inflated and more elevated paranota.

Perissonemia recentis Drake and Poor

Perissonemia recentis Drake and Poor, Philip. Jour. Sci., LXII, 1937, p. 5.

Singapore, Straits Settlements, female, collected by C. F. Baker. This specimen was undoubtedly collected with the type and bears the same data.

Perissonemia torquata Drake and Poor

Perissonemia torquata Drake and Poor, Philip. Jour. Sci., LXII, 1937, p. 2.

Butuan Mindanao, Philippine Islands, female, taken by C. F. Baker. This specimen agrees with the holotype.

Perissonemia borneensis (Distant)

Teleonemia borneensis Distant, Rec. Ind. Mus., III, 1909, p. 166, Pl. X, figs. 1, 1a.

Perissonemia borneensis Drake & Poor, Philip. Jour. Sci., LXII, 1937, p. 4.

Sandakan, Borneo, female; Singapore, Straits Settlements, male and female, C. F. Baker; Zamboanga, Mindanao, Philippine Islands, male, C. F. Baker; Island Sibuyan, male, C. F. Baker; Malaba, male, 1902, taken by M. Maindron.

Perissonemia illustrus Drake and Poor

Perissonemia illustrus Drake & Poor, Philip. Jour. Sci. LXII, 1937, p. 4.

Imugan, N. Vizcaya, Philippine Islands, 3 examples, C. F. Baker. These specimens were collected with the type series.

Perissonemia vegata, sp. nov.

Small, brownish black, the pronotum in front and a conspicuous spot on each side at the base of triangular process covered with whitish exudation. Head very dark brown, the spines much reduced. Eyes dark. Rostrum dark brown, black at apex, extending between intermediate legs. Body beneath dark brown. Legs dark brown, the tarsi lighter. Antennae moderately long; segments I and II dark ferruginous, the first segment twice as long as and considerably stouter than the second; III testaceous, twice as long as IV, the latter black.

Pronotum black, strongly convex above, coarsely pitted, the paranota wanting; collar raised, reticulate, truncate in front; median carina sharply raised, non-reticulate; lateral carinae indistinct, perhaps faintly discernible behind; triangular process reticulate, truncate at apex. Elytra constricted beyond middle, brownish black, at the base and constriction brownish; costal area extremely narrow, very indistinctly areolate; subcostal area triseriate; discoidal area widest beyond middle, there five aerolae deep; sutural area much more widely reticulated, the areolae considerably clouded with fuscous. Wings longer than abdomen, clouded with fuscous.

Length, 2.85 mm.; width, 1.00 mm.

Holotype, female, Sandakan, Borneo, C. F. Baker. This species belongs to the subgenus *Ulonemia* Drake and Poor. It may be separated at once from *borneensis* (Distant) by the extremely narrow costal area and the much darker and more tumid pronotum.

Perissonemia tasmaniae, sp. nov.

Allied to *P. recentis* D. & P. but much more slender, pronotum not so strongly convex, carinae slightly more elevated and thicker. Brown, costal area and pronotum tinged with pale testaceous. Head brown, with five short blunt yellowish spines, the median erect and the others porrect. Antennae brown, moderately slender; segment I stouter than and nearly twice as long as II; III slender, long; IV wanting. Eyes black. Pronotum moderately convex, closely and finely pitted. Carinae sharply raised, with distinct aerolae behind; lateral carinae divaricating anteriorly. Paranota narrow, moderately reflexed, uniseriate; collar raised, reticulate, the front margin truncate.

Elytra moderately narrowed posteriorly, faintly constricted beyond middle. Costal area narrow, uniseriate; subcostal area broader, mostly biseriate, triseriate at widest point; discoidal area elongate, narrowed at both base and apex, widest near middle, slightly tinged with yellow at apex. Sutural area finely reticulate. Wings almost as long as elytra.

Length, 3.00 mm.; wdth, 0.84 mm.

Holotype (male), Launceston, Tasmania, Aug. 20, 1918. This species is more delicately reticulate than *P. recentis* and lacks the conspicuous color markings.

Leptoypha hospita Drake and Poor

Leptoypha hospita Drake & Poor, Philip. Jour. Sci., LXII, 1937, p. 12.

Allotype, male: Color and form very similar to holotype (female) but a little more slender. Island of Penang, C. F. Baker, type locality.

Eteoneus virtutis Drake and Poor

Eteoneus virtutus Drake & Poor, Philip. Jour. Sci., LXII, 1937, p. 13.

Mt. Makiling, Luzon, Philippine Islands, male and female, collected by C. F. Baker. These specimens bear the same label and were probably collected with the type.

Melandiola similis Hacker

Melandiola similis Hacker, Mem. Queens. Mus., IX, 1927, p. 21.

One specimen, Botany Bay, N. S. Wales, Australia, collected by H. Petersen.

Tingis buddleiae Drake

Tingis buddleiae Drake, Proc. Ent. Soc. Wash., XXXII, 1930, p. 168.

Forty-nine examples, Los Banos, Luzon, Philippine Islands, at an elevation of 50 meters, May 2, 1934, collected on *Buddleia asiatica* by V. J. Madrid.

Belenus dentatus (Fieb.)

Monanthia (Phyllontochila) dentata Fieber, Ent. Monog., 1844, p. 71, Pl. VI, figs. 2-4.

Belenus dentatus Distant, Ann. Soc. Ent. Belg., LIII, 1909, p. 116.

Los Banos, Luzon, Philippine Islands, female, collected by F. Muir, and 1 specimen collected July 10, 1932 by S. P. Capco, at an elevation of 5 meters; and at Mt. Makiling, Luzon, P. I., C. F. Baker.

Phyllontocheila philippinensis Distant

Phyllontocheila philippinensis Distant, Ann. Mag. Nat. Hist., IX, 1902, p. 355.

Los Banos, Luzon, P. I., 12 specimens, Sept. 15, 1915, C. S. Banks; 2 specimens Sept. 20, 1915, 2 Sept. 29, 1915, 1 Sept. 30, 1915, 1 Oct. 11, 1915, collected by A. Lipayon; 2 specimens Aug. 9, 1915, A. L. Leodoro; and 3 specimens Oct. 24, 1931, by M. de la Cruz.

Hormisdas vicarius Drake

Hormisdas vicarius Drake, Philip. Jour. Sci., XXXII, 1927, p. 56.

Betis, Pampanga, Philippine Islands, Nov. 28, 1928, 16 specimens collected by L. B. Uichanco on *Urena lobata* L. var. *sinuata* (L.) (Malvaceae).

Stephanitis nitoris Drake and Poor

Stephanitis nitoris Drake and Poor, Philip. Jour. Sci., LXII, 1937, p. 17.

Mt. Makiling, Luzon, Philippine Islands, 1 example, C. F. Baker (same label as type); Los Banos, Luzon, P. I., Sept. 26, 1926, 5 specimens, taken by S. M. Cendana; 15 specimens, Feb. 20, 1935, V. J. Madrid, on *Uvaria rufa*.

Stephanitis globulifera Matsumura

Tingis globulifera Matsumura, Senchu-Zukai, II, 1905, p. 36, Tab. 19, fig. 16.

Stephanitis globulifera Horvath, Ann. Nat. Mus. Hung., X, 1912, pp. 321, 330.

Tokyo, Japan, May 30, 1931, 8 specimens taken by L. Gressitt.

Stephanitis nashi Esaki and Takeya

Stephanitis nashi Esaki & Takeya, Mushi, IV, 1931, p. 54.

Tokyo, Japan, May 17, 1931, several specimens, L. Gressitt; Canton, China, 1 example. This species infests the pear tree.

Stephanitis fasciicarina Takeya

Stephanitis (Stephanitis) fasciicarina Takeya, Mushi, IV, 1931, pp. 70-72, Tab. 7, fig. 2, Tab. 8, fig. 6.

Moji, Japan, Sept. 11, 1906, and Tokyo, Japan, Sept. 25, 1915. This species is very closely allied to *S. querci* Bergroth and differs only slightly from it in having a smaller and lower hood and less elevated median carina. The costal area of elytra usually has one less row of areolae in its widest part. A series of *S. querci* from the Philippines shows some variation in these characters but they do not seem to integrate with paratypes and a series of other specimens of *fasciicarina* from Japan.

Stephanitis subfasciata Horvath

Stephanitis subfasciata Horvath, Ann. Mus. Nat. Hung., X, 1912, p. 325.

Pekalongan, Java, May, 1901, 1 example, F. Muir, collector.

Stephanitis typica Distant

Cadamustus typicus Distant, Ann. Soc. Ent. Belg., XLVII, 1903, p. 47; Fauna Brit. Ind., Rynch., II, 1904, p. 132, fig. 95.

Stephanitis typica Horvath, Ann. Mus. Nat. Hung., X, 1912, p. 325.

Los Banos, Luzon, Philippine Islands, Feb. 26, 1919, numerous specimens, collected on *Anona muricata* Linn., L. B. Uichanco; numerous other specimens from Los Banos by various collectors; three specimens from Butuan, Agusan, P. I., Apr. 22, 1932, L. B. Uichanco. This is one of the most common and most widely distributed tingitids in the Philippine Archipelago.

THE RHYNCHOPHORA OF IOWA

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In 1876, Mr. J. D. Putnam published his "List of Coleoptera found in the vicinity of Davenport, Iowa," "Coleoptera collected at Monticello, Iowa, June 12, 1872," and "Coleoptera collected near Frederick, Monroe Co., Iowa, August, 1869." Mr. H. F. Wickham, in 1888, published "A list of the Coleoptera of Iowa City and vicinity." In 1895, a supplement to this list was published. In 1911, Wickham published "A List of the Coleoptera of Iowa" in which are found 221 species of Rhynchophora reported from various collections and records in literature.

The chief problem of this study has been the determination of specimens found in the Iowa State College and Iowa Insect Survey collections. With Mr. Wickham's 1911 list as a working basis, the project was begun two years ago of bringing together all the records published by the various authors dealing with Iowa species. As the work progressed, it became evident that numerous new records were present in the material studied. All available published records have been carefully checked, and every determination, new or old, was compared with material in the National Museum at Washington by the author in December, 1936.

Over 10,000 specimens, comprising nearly 2000 individual county distribution records, have been studied in the various collections. Four hundred sixty-two species have been definitely shown to occur within the state, while published records of 48 others from surrounding states tend to indicate their probable occurrence within our borders.

The county records are listed under each species. The genera and species are arranged according to Leng's "Catalogue of the Coleoptera of America, north of Mexico." Corrections in a number of the original citations given by Leng have been made. Synonymy has been included in a few cases upon verification by Mr. L. L. Buchanan.

LIST OF IOWA RHYNCHOPHORA WITH DISTRIBUTIONAL DATA

Family Brentidae

Eupsalis minuta Drury. Exot. Ins., 1, 1770, p. 90, t. 42, f. 3, 7. (nec 1837, 1773, p. 95 auct.)

County records: Des Moines, Henry, Jefferson, Johnson, Kossuth, Lee, Linn, Monroe, Story, Van Buren, Wapello.

[1]The author takes this opportunity of acknowledging the special debt to Dr. H. H. Knight, under whose direction and aid this project has been pursued; to Dr. Hendrickson, whose prairie insect material has produced a number of very fine records which are included in this work; to Drs. Drake, Harris and Wellhouse for their kind help and interest in the problem; to Mr. H. E. Jaques, whose unselfish cooperation made the Iowa State Insect Survey records available for study; and to Mr. L. L. Buchanan of the United States National Museum whose aid in determining the species of Apion, Curculio, and Cryptorhynchus made their study the more valuable.

Eupsalis minuta var. **lecontei** Power. Ann. Soc. Ent. Fr., 1878, p. 494.

County records: Henry, Story, Worth.

Recognition of this variety is hardly necessary since the male beak is extremely variable in this species. The larger males necessarily tend to have enlarged beaks.

Family Platystomidae

Ormiscus saltator Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 397.

County records: Dickinson, Johnson.

The Dickinson specimens were collected by Mr. L. L. Buchanan and are now in the U. S. National Museum collection. It has been rarely collected.

Eurymycter fasciatus. (Olivier). Entomologie, 4, 1795, p. 9.

County records: Clayton, Davis, Muscatine, Story.

Allandrus bifasciatus Leconte. Proc. Am. Phil. Soc., 1876, p. 396.

County records: Johnson.

Two specimens were collected at Iowa City by Mr. Buchanan. A new state record.

Piezocorynus moestus Leconte. Ann. Lyc. Nat. Hist. N. Y., 1, 1824, p. 172.

County records: Johnson.

Wickham ('11) reported this species from Iowa City, thereby indicating that the specimens were in his personal collection. However, no specimens from Iowa were seen by the author in the Wickham collection which is now deposited in the National Museum. In fact, no specimen of the genus has been seen with an Iowa label. This record, from the distribution indicated in Leng ('20), could be more logically Leconte's *P. mixtus* or Gyllenhal's *P. dispar.*

Euparius marmoreus (Olivier). Entomologie., 3, 1795, p. 12.

County records: Appanoose, Buena Vista, Davis, Des Moines, Dickinson, Henry, Jasper, Jefferson, Lee, Louisa, Monroe, Page, Story, Wapello, Washington, Wright.

In 1888, C. A. Gillette took the species at lights and Raymond, in 1890, took them from milkweed. Wickham denoted its distribution as general throughout the state.

Brachytarsus alternatus (Say). Jour. Acad. Nat. Sci., 5, 1826, p. 250.

County records: Clayton, Davis, Dickinson, Henry, Louisa, Plymouth, Washington.

Brachytarsus sticticus Boheman. Schoenh. Gen. Curc., 1, 1833, p. 172.

County records: Boone, Bremer, Buena Vista, Clayton, Des Moines, Dubuque, Henry, Iowa, Jackson, Jasper, Jefferson, Johnson, Lee, Louisa, Polk, Pottawattamie, Story, Van Buren.

This is the *B. variegatus* Say reported from Iowa by Wickham ('11). Common throughout the state.

Brachytarsus tomentosus (Say). Jour. Phil. Acad. Sci., 5, 1826, p. 251.

County records: Cass, Cherokee, Davis, Decatur, Des Moines, Dickinson, Emmet, Henry, Jackson, Keokuk, Kossuth, Linn, Osceola, Plymouth, Worth.

Brachytarsus paululus Casey. Col. N. A., 1884, p. 194.

County records: Benton, Cass, Cherokee, Dickinson, Henry, Jackson, Mahaska, Plymouth, Worth.

This species was determined almost exclusively from size since its vestiture is almost identical with *B. tomentosus* Say. The two specimens from Cass County, collected by the author, are 1.4 mm. in length, the other specimens are about 1.8 mm. The vestiture seems a little more dense, which, together with the size difference, provides the only distinguishing character. It is probable that biological study will prove its synonymy with *B. tomentosus.*

Brachytarsus limbatus (Say). Jour. Phil. Acad. Sci., 5, 1826, p. 250.

County records: Dickinson, Johnson.

The specimens are in the U. S. National Museum, those from Dickinson having been collected in 1935 by Gould Warren, the Johnson county specimens by Mr. Buchanan in 1916 and 1917.

Brachytarsus plumbeus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 406.

County records: Johnson.

Reported from Iowa City by Wickham ('11). No specimens have been seen from Iowa which are densely clothed with ashgray pubescence, not mottled, and measuring 3.2 mm.

Family Belidae

Ithycerus noveboracensis (Forst.). Nov. Spec. Ins., 1771, p. 35.

County records: Bremer, Clayton, Hancock, Henry, Johnson, Marshall, Polk, Story.

This is the "New York Weevil" of economic literature and is one of the largest curculionids occurring in the state. Ewing's specimen from Marshall County was taken from hickory. The Polk County specimen carries a label notation "5/24/79 from Polk Co. injuring apple. C. F. Clarkson."

Family Curculionidae

Eugnamptus striatus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 5.

County records: Des Moines.

One specimen with the label "Burlington, Ia." was kindly sent from the Kansas University collection by Mr. Lyman Henderson. The strial punctures are large and approximate, the intervals convex throughout the elytra and distinctly less wide than the punctures. It is quite probably this species in spite of its occurrence so far outside of the previously recorded type locality, Florida.

Eugnamptus collaris (Fabricius). Syst. Eleuth., **2**, 1801, p. 410.

County records: Cedar, Dickinson, Hancock, Henry, Jackson, Johnffison, Jones, Kossuth, Story.

Eugnamptus collaris var. **nigripes** Pierce. Proc. U. S. Nat. Mus., **55**, 1913, p. 367.

County records: Story.

A specimen collected June 28, 1892, was taken "On *Quercus alba.*" A specimen from the Wickham collection with an Iowa label is in the National Museum.

Eugnamptus collaris var. **fuscipes** Pierce. Proc. U. S. Nat. Mus., **55**, 1913, p. 367.

County records: Boone, Hancock, Johnson, Kossuth, Lee.

Two specimens from Lee County were collected from sycamore by Harris and Johnston.

Eugnamptus collaris var. **ruficeps** Pierce. Proc. U. S. Nat. Mus., **55**, 1913, p. 367.

County records: Johnson, Story.

These two records disprove Blatchley's assumption that "This variety enjoys a limited southern distribution and, consequently, it should be elevated to the rank of a species." There are no structural differences.

Eugnamptus sulcifrons Gyllenhal. Schoenh. Curc., **5**, (1), 1839, p. 343.

County records: Boone, Linn, Madison, Polk, Story.

These specimens exhibited a distinct frontal sulcus, but otherwise look very much like *E. collaris.*

Eugnamptus angustatus (Herbst). Kafer, **7**, 1797, p. 140.

County records: Johnson, Linn.

Reported from these two localities by Wickham ('11). No specimens were seen in the National Museum.

Rhynchites bicolor (Fabricius). Syst. Ent., 1775, p. 131 (nec 98-388, Leng).

County records: Adair, Allamakee, Blackhawk, Bremer, Buena Vista, Cass, Cherokee, Clay, Crawford, Dickinson, Franklin, Green, Hamilton, Henry, Ida, Iowa, Lee, Linn, Lyon, Monona, Muscatine, Osceola, Plymouth, Story, Union, Washington, Winnebago, Woodbury, Worth.

This species, the "Rose Weevil," is common on wild rose throughout the state.

Rhynchites aeneus Boheman. Nov. Col. Spec., 1829, p. 22.

County records: Dickinson, Plymouth, Pottawattamie, Story, Woodbury.

Found by Hendrickson ('28) on the stem of Resin weed *(Silphium lacinatum* L.*)* and a pair mating on *Brauneria purpurea* Britton.

Rhynchites hirtus (Fabricius). Syst. Eleuth., 1801, p. 421.

County records: Muscatine.

A single specimen was collected by Mr. Denning on the above date in a wooded area near Muscatine, Iowa. The closest previous record seems to be from Michigan.

Rhynchites cyanellus Leconte. Proc. Am. Phil. Soc. 15, 1876, p. 8.

One specimen with the label "Ia." from the collection of C. V. Riley deposited in the U. S. National Museum. Harrington ('91) reported it feeding and copulating on willow.

Rhynchites aeratus Say. Curc., 1831, p. 3.

County records: Dickinson, Woodbury.

Eight specimens of this species, seven of which were taken in Dickinson County by Mr. Buchanan, are in the U. S. N. M. collection.

Attelabus analis Illiger. N. Mag. Lieb. Ent. (Schneider's), 5, 1794, p. 616.

County records: Johnson.

Pierce ('13) reports it from a Wickham specimen.

Attelabus nigripes Leconte. Ann. Lyc. Nat. Hist. N. Y., 1, (6), 1824, p. 171.

County records: Dickinson, Henry, Johnson, Monroe.

Might be confused with a small *Rhynchites bicolor*.

Attelabus pubescens Say. Jour. Phil. Acad. Nat. Sci., 5, 1826, p. 252.

County records: Clayton, Crawford, Johnson, Story.

Reported by Wickham ('11) under the name *A. rhois* Boh., a synonym.

Pterocolus ovatus (Fabricius). Syst. Eleuth., 2, 1801, p. 426.

County records: Johnson, Dickinson.

A nice series of this peculiar weevil which Mr. Buchanan collected at Lake Okoboji, Ia., are now in the National Museum collection. He found them feeding on oak sprouts.

Apion erraticum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 44.

County records: Johnson.

Reported by Wickham ('11).

Apion impunctistriatum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 48.

County records: Cherokee, Clinton, Decatur, Dickinson, Henry, Johnson, Jones, Muscatine, Plymouth, Sioux, Story, Washington.

Apion melanarium Gerstaecker. Stett. Ent. Zeit., 15, 1854, p. 261.

County records: Bremer, Buchanan, Cherokee, Clarke, Des Moines, Dickinson, Emmet, Harrison, Henry, Jackson, Keokuk, Lee, Louisa, Plymouth, Polk, Story, Van Buren, Wapello, Washington, Winnebago, Worth.

Apion sp. 1.

A specimen in the National Museum collected at Lake Okoboji, Iowa, August 22, 1916, by Mr. L. L. Buchanan has been placed by him near *virile.* This is one of nearly a dozen undetermined species of Apion from Iowa. Mr. Buchanan is planning to monograph the genus in the near future and these species will be fully considered at that time.

Apion robustum Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 45.

County records: Davis, Dickinson, Harrison, Johnson, Jones, Linn, Sioux.

Apion pennsylvanicum Boheman. Schoenh. Curc., **5,** (1), 1839, p. 417.

County records: Lee, Johnson, Story, Washington.

Apion sp. 2.

A specimen collected by H. C. Knutson in Johnson County, June 20, 1934, has been placed by Mr. Buchanan near *A. pennsylvanicum.*

Apion occidentale Fall. Trans. Am. Ent. Soc., **25,** 1898, p. 126.

County records: Cherokee, Dickinson, Plymouth.

Apion sp. 3.

Fourteen specimens of Iowa material are grouped with a specimen notation "near *occidentale.*" It is possible that two species are present in this material.

Apion punctinasum Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 46.

County records: Dickinson.
First recorded from the state by Buchanan ('22).

Apion tenuirostrum Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 62.

County records: Dickinson, Story, Wright.
Buchanan ('22) records it from Dickinson and Wright counties.

Apion sp. 4.

A specimen from Lake Okoboji, July 22, 1916 collected with two others by Buchanan are noted to have "simple claws; no mucro on anterior tibia; near *tenuirostrum.*"

Apion smithi Wagner. Deutsche Ent. Zeitschr., 1909, p. 767.

County records: Henry, Washington.

Apion modestum Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 58.

County records: Dickinson, Henry.
This is a homonym of *A. modestum* Kirby, 1817, p. 234, which Wagner ('10) considers, in turn, a synonym of *A. loti* Kirby, 1808, p. 58.

Apion walshi Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 57.

County records: Johnson.

Apion minor Smith. Trans. Am. Ent. Soc., **11,** 1884, p. 56.

County records: Dickinson, Johnson, Story.

Apion turbulentum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 56.
County records: Dickinson, Story.

Apion griseum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 59.
County records: Bremer, Buchanan, Cedar, Des Moines, Dickinson, Henry, Johnson, Lee, Louisa, Monroe, Muscatine, Story, Van Buren.
Seemingly common throughout the eastern half of the state.

Apion porcatum Boheman. Schoenh. Curec., 5, (1), 1839, p. 374.
County records: Des Moines, Lee.

Apion centrale Fall. Trans. Am. Ent. Soc., 25, 1898, p. 151.
County records: Dickinson, Johnson, Palo Alto, Story.
Buchanan ('22) first records the species from Iowa.

Apion rostrum Say. Jour. Acad. Nat. Sci., Phila., 5, 1826, p. 253.
County records: Story, Taylor.
Infests the seed pods of Baptisia in Iowa.

Apion nigrum Herbst. Kafer, 7, 1797, p. 132 (nec p. 122, Leng).
County records: Story.
Reported by Wickham ('11).

Apion varicorne Smith. Trans. Am. Ent. Soc., 11, 1884, p. 60.
County records: Boone, Clinton, Dickinson, Humboldt, Lyon, Plymouth, Van Buren, Winnebago.
Reported by Buchanan ('22) for the first time.

Apion decoloratum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 52.
County records: Henry, Johnson, Story.
Fall ('98) reports it on Desmodium at Iowa City. Found in the seed pods of Meibomia.

Apion emaciipes Fall. Trans. Am. Ent. Soc., 25, 1898, p. 166.
County records: Delaware.
A new state record.

Apion carinatum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 52.
County records: Dickinson.
Recorded by Buchanan ('22).

Apion attenuatum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 62.
County records: Plymouth, Story, Winneshiek.
A new state record.

Apion notabile Buchanan. Proc. Ent. Soc. Wash., 24, 1922, p. 83.
County records: Dickinson.
A note to be found on the pin states that it is "apparently equal to *spinipes* Fall (L. B. '32)."

Apion commodum Fall. Trans. Am. Ent. Soc., 25, 1898, p. 154.

One specimen labelled as this species is in the synoptic collection at the National Museum.

Apion sp. 5.

A specimen with the note "(runs to *commodum*)" which was collected by Mr. Buchanan at Lake Okoboji, July 24, 1916, was separated from the rest of the *commodum* specimens.

Apion sp. 6.

A specimen bearing the note (near *turbulentum*)" is in the National Museum collection. It was collected by Mr. Buchanan at Lake Okoboji, July 16, 1917.

Apion sp. 7.

This specimen from Washington, Iowa, was collected by Dr. Hendrickson and listed in his 1930 work as Apion sp. 1. It was again checked by Mr. Buchanan for the author, and the additional label states "Not found in N. W. coll." It is probably a new species.

Apion sp. 8

Two specimens, including Hendrickson's ('30) sp. 2 and 4, have been rechecked by Mr. Buchanan who finds nothing comparable in the N. M. collection.

Apion sp. 9.

One specimen, perhaps from the series designated as sp. 3 by Hendrickson ('30), carries the notation on the pin, "Apion sp. (claws virtually simple)." It is in the N. M. collection.

Apion sp. 10.

Four specimens which were collected Sept. 27, 1893, have the accession catalog number "889" on each pin. Referring to this number, one finds that the specimens were collected "9/27/93 by F. A. Sirrine, I. A. C. (Iowa Agricultural College), taken from seeds of *Dalea alopeuroides.*" Belongs to group III.

Phyxelis rigidus (Say). Curc., 1831, p. 11 (nec p. 12, Leng).

County records: Clayton, Delaware, Fayette, Floyd, Hancock, Henry, Howard, Johnson, Kossuth, Mahaska, O'Brien, Palo Alto, Story, Washington, Winneshiek.

Undoubtedly very common throughout the state. Occasionally reported attacking potatoes in Iowa.

Anametis granulata (Say). Curc., 1831, p. 12.

County records: Buchanan, Cerro Gordo, Clayton, Dickinson, Fremont, Greene, Hamilton, Henry, Iowa, Jackson, Johnson, Jones, Kossuth, Louisa, Plymouth, Sioux, Story, Webster, Winnebago.

Common throughout the state.

Panscopus maculosus Blatchley. Rhynch. N. E. U. S., 1916, p. 105.

County records: Story.

Collected on Wahoo (*Evonymus atropurpureus* Jacq.) at Ames, May 25, 1934, by Mr. Hansberry.

Panscopus aequalis (Horn). Proc. Am. Phil. Soc., 15, 1876, p. 55.

County records: Johnson, Story.

Reported from Ames and Iowa City by Wickham ('11). These records are probably of the preceding species although it is reported from Kansas.

Aracanthus pallidus Say. Curc., 1831, p. 9.

Reported from Iowa by Leng ('20). No Iowa specimens have been seen by the author.

Tanymecus confusus Say. Curc., 1831, p. 9.

County records: Appanoose, Boone, Bremer, Calhoun, Cherokee, Clay, Clayton, Davis, Des Moines, Henry, Iowa, Jackson, Jefferson, Jones, Louisa, Muscatine, Plymouth, Sioux, Story, Van Buren, Wapello, Winneshiek.

Very common throughout the state.

Pandeleteius hilaris (Herbst). Kafer, 7, 1797, p. 58.

County records: Appanoose, Clayton, Johnson, Linn, Louisa, Story.

Hormorus undulatus (Uhler). Proc. Acad. Nat. Sci., Phila., 7, 1855, p. 416.

County records: Delaware, Hancock, Story.

Graphorinus vadosus Say. Curc., 1831, p. 8.

County records: Sioux.

Hendrickson's ('30) record remains unique for the state. It resembles a great deal the following species.

Epicaerus imbricatus Say. Jour. Acad. Nat. Sci. Phila., 3, 1824, p. 317.

County records: Blackhawk, Cherokee, Dallas, Davis, Des Moines, Dickinson, Dubuque, Fayette, Hardin, Henry, Iowa, Lee, Monroe, Muscatine, Plymouth, Ringgold, Sioux, Story, Union, Washington, Woodbury.

Walsh ('64) reports that "it infests apple and cherry trees and gooseberry bushes in Iowa." Common throughout the state. It is the "imbricated snout beetle" of literature.

Pantomorus godmani (Crotch). Proc. Zool. Soc. Lond., 1867, p. 389.

County records: Johnson, Story.

Commonly referred to as "Fuller's Rose Weevil."

Pantomorus tessellatus (Say). Jour. Acad. Nat. Sci. Phila., 3, 1824, p. 318.

County records: Lee, Pottawattamie.

Two specimens from Lee county and Pottawattamie county are less densely squamose than another specimen from Lee county, but all are clothed with silver white scales and present a much more robust appearance throughout than the specimen of *P. godmani,* which is brownish in coloration and with the thorax much narrower behind.

Pantomorus tessellatus var. pallidus (Horn). Proc. Am. Phil. Soc., **15,** 1876, p. 94.

County records: Pottawattamie.

This specimen was undoubtedly collected at the same time that the above specimen was taken, and resembles the more dense specimen from Lee county mentioned above. It is determined as such in the National Museum collection.

Lepidocricus minor (Buch.) Proc. U. S. N. M., **76,** 1929, p. 6.

County records: Hamilton, Iowa, Johnson, Keokuk, Story.

The Johnson record is that of Wickham ('11) for *L. herricki.* According to Buchanan ('29), *herricki* enjoys a more southern distribution.

Lepidocricus oblongus (Buch.). Proc. U. S. N. M., **76,** 1929, p. 8.

County records: Dickinson, Osceola, Palo Alto, Story.

Perhaps only a variety of the preceding.

Barypeithes pellucidas (Boheman). Schoenh. Curc., **2,** 1834, p. 507.

County records: Story.

A new state record.

Otiorrhynchus (Tournieria) ovatus (L.). Syst. Nat., 1758, p. 384.

County records: Allamakee, Boone, Bremer, Butler, Cerro Gordo, Clayton, Emmet, Des Moines, Dickinson, Floyd, Hancock, Henry, Jackson, Johnson, Kossuth, Linn, Story, Winneshiek.

Known as the "Strawberry crown-girdler."

Cercopeus chrysorhoeus (Say). Curc., 1831, p. 13.

County records: Johnson, Story.

Aphrastus taeniatus Say. Curc., 1831, p. 9.

County records: Blackhawk, Boone, Fremont, Henry, Iowa, Johnson, Story.

Sitona flavescens (Marsham). Ent. Brit. etc., 1802, p. 311.

County records: Boone, Franklin, Kossuth, Pocahontas, Story.

This is the "yellow clover curculio".

Sitona hispidulus (Fabricius). Gen. Ins., 1777, p. 226.

County records: Boone, Butler, Delaware, Des Moines, Fayette, Henry, Jefferson, Kossuth, Lee, Louisa, Lucas, Mills, Scott, Story, Union, Washington, Wapello.

Known as the "clover root curculio." A new state record.

Sitona lineellus Bonsdorff. Hist. Nat. Curc. Suec., 1785, p. 30.

County records: Boone, Kossuth, Lucas, Winnebago.

Recorded from Kossuth and Winnebago by Hendrickson ('30).

Sitona scissifrons Say. Curc., 1831, p. 10.

County records: Buchanan, Dickinson, Hamilton, Hancock, Kossuth, Osceola, Palo Alto, Plymouth, Story, Winneshiek, Woodbury, Wright.

Sitona scissifrons Say, according to Mr. Buchanan, is the name to be given to this species instead of *S. tibialis* Hbst.

Hypera (Antidonus) punctata (Fabricius). Syst. Ent., 1775, p. 150.

This species is so common throughout the state on clover that little needs to be said of it. Known as the "clover-leaf beetle", it has been a serious pest in certain years past. It was not numerous during the extremely dry seasons of 1935 and 1936.

Hypera eximius (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 414.

Common on Rumex throughout the state. Pupating cocoons were collected at Le Mars, Iowa on June 13, 1936, the adults emerging on June 18, 1936. Not reported by Wickham ('11), but recorded from Iowa by Titus ('11).

Hypera (Erirhinomorphus) rumicis (Linn.). Syst. Nat., 1758, p. 379.

Buchanan ('23) reported this weevil from Iowa City where it had been collected May, 1917 from Polygonum. Its distribution seems to be identical with the above species, and, aside from the difference in color pattern, it is identical with *H. eximius.*

Hypera (Erirhinomorphus) comptus (Say). Curc., 1831, p. 12.

County records: Dubuque, Jefferson, Lee.

Reported from Iowa by Titus ('11). Csiki ('34) considers it a variety of *rumicis* L. The type of the scale makes this conclusion impossible.

Hypera trivittatus (Say). Curc., 1831, p. 12.

County records: Story.

One specimen, badly denuded, with the scales deeply emarginate but not cleft as in *nigrirostris,* seems to fit the description of this species.

Hypera (Dapalinus) nigrirostris (Fabricius). Syst. Ent., 1775, p. 132.

County records: Common throughout the state.

Listronotus sordidus (Gyllenhal). Schoenh. Curc., **2**, (1), 1834, p. 280.

County records: Story.

Known only from the published records of Wickham ('11).

Listronotus tuberosus Leconte. Proc. Phil. Acad. Sci., 1876, p. 130.

County records: Johnson, Story.

The specimen from Story county has been the only one of this distinct species seen by the author. On Sagittaria and Carex.

Listronotus squamiger (Say). Curc., 1831, p. 11.

County records: Jackson, Story.

Listronotus inaequalipennis (Boheman). Schoenh. Curc., **6**, 1842, p. 189, (nec 1840, Leng).

County records: Des Moines.

Known only from the Wickham ('11) records. Henderson (i. litt.) places it as a synonym of *squamiger.*

Listronotus caudatus (Say). Jour. Acad. Sci., **3**, 1824, p. 311 (nec 1823, Leng).

County records: Cherokee, Dickinson, Franklin, Jackson, Jefferson, Johnson, Story.

Mr. Sooter collected two specimens from *Scirpus sp.* at Lost Island, Ruthven, Iowa.

Listronotus appendiculatus (Boheman). Schoenh. Curc.,**6**, 1842, p. 192 (nec 1840, Leng).

County records: Johnson, Muscatine, Story.

Listronotus nebulosus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 133.

County records: Linn, Story.

Listronotus frontalis Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 133.

County records: Linn, Story.

Listronotus latiusculus (Boheman). Schoenh. Cur., 1842, p. 199 (nec 1840, Leng).

County records: Blackhawk, Des Moines, Dickinson, Johnson, Louisa, Mahaska, Story, Winneshiek.

Harris ('26) discusses this species as a pest of carrots at Burlington, Iowa, during the summer of 1925.

Hyperodes solutus (Boheman). Schoenh. Curc., **6**, (2), 1842, p. 197 (nec 1840, Leng).

County records: Bremer, Clayton, Cherokee, Decatur, Dickinson, Henry, Iowa, Jackson, Jefferson, Johnson, Lee, Mitchell, Osceola, Pocahontas, Story, Winnebago.

Swept in numbers from swamps and slough vegetation.

Hyperodes grypidioides (Dietz). Trans. Am. Ent. Soc., **16**, 1889, p. 35.

County records: Polk, Story.

Hyperodes indistinctus (Dietz). Trans. Am. Ent. Soc., **16**, 1889, p. 32.

County records: Johnson, Linn.

Blatchley ('16) considers this species synoymous with *H. solutus.*

Hyperodes interpunctatulus (Dietz). Trans. Am. Ent. Soc., **16**, 1889, p. 36.

County records: Lee, Story.

Hyperodes ulkei (Dietz). Trans. Am. Ent. Soc.,**16**, 1889, p. 37.

County records: Polk, Story.

Hyperodes tenebrosus (Dietz). Trans. Am. Ent. Soc., **16,** 1889, p. 38.

County records Decatur, Dickinson, Keokuk, Plymouth, Story.

Hyperodes montanus (Dietz). Trans. Am. Ent. Soc.,**16,** 1889, p. 39.

County records: Bremer, Dickinson, Guthrie, Lee, Story.

Hyperodes delumbis (Gyllenhal). Schoenh. Curc., 1834, p. 283 (nec 34-203, Leng).

County records: Bremer, Cass, Delaware, Fayette, Henry, Linn, Osceola, Polk, Story, Wapello.

Undoubtedly the most common species of the genus in the state. Flies to the lights during the spring and summer in numbers.

Hyperodes sparsus (Say). Curc., 1831, p. 11.

County records: Allamakee, Boone, Bremer, Dickinson, Floyd, Fremont, Henry, Jefferson, Kossuth, Lee, Louisa, Lucas, Story, Van Buren, Washington, Worth.

Hyperodes obscurellus (Dietz). Trans. Am. Ent. Soc., **16,** 1889, p. 45.

County records: Kossuth.

Determined by Mr. Buchanan for Hendrickson ('30).

Hyperodes echinatus (Dietz). Trans. Am. Ent. Soc., **16,** 1889, p. 46.

County records: Clayton, Story.

One specimen with an Ames, Iowa label notes that it is a "Purslane leaf-miner."

Hyperodes vitticollis (Kirby). Ins. Rich. Bor. Amer., **4,** 1837, p. 200.

County records: Bremer, Johnson.

The Bremer county record is in the Casey collection.

Hyperodes humilis (Gyllenhal). Schoenh. Curc., **2,** (1), 1834, p. 284.

County records: Plymouth, Story.

Hyperodes porcellus (Say). Curc., 1831, p. 11.

County records: Jefferson, Story.

Hyperodes sp. 1.

Two specimens, one from Ames, Iowa and the other from Montrose, Iowa are included here, and should be placed under group one with those having the second funicular joint much longer than the first.

Hyperodes sp. 2.

One specimen collected by the author at Ames, Iowa, last May 21, runs to "dorsalis," but there are conflicting characteristics which make its definite determination impossible.

Hyperodes sp. 3.

One specimen collected May 31 at Lost Island Park, Ruthven, Iowa, by the author posses a striking resemblance to the female"*delumbis*" specimens. However, each interval of the elytra has long setae, whereas, in *delumbis* specimens, only the alternate intervals are with setae.

Hyperodes sp. 4.

A series of six specimens of this striking species include Appanoose, Cass, Dickinson, Story (2), and Winneshiek counties. It is large enough for a Listronotus, but the second funicular joint is but little longer than the first, a character that would tend to place it in the first group of the Hyperodes.

Hyperodes sp. 5.

An Ames specimen collected by Mr. Glawe on June 29, 1930, does not seem to key to any of the known Hyperodes species. It looks much like a minute Listronotus except for the subequal first joints of the funicle. Mr. Henderson, who is monographing the genus, thinks it may be a new species.

Hyperodes sp. 6.

A specimen from the collection of Dr. Harris bears an Ames label and was collected June 21, 1928. It has the general appearance of *H. sparsus* and *H. delumbis* combined. The thorax gives an appearance of being granulated, the elytral intervals each having a row of short, clubbed setae, and the hind tibia clothed on the inner surface with long silken hairs.

The six species listed above have occupied the study of the author for long periods of time, and seemingly without tangible conclusions. Undoubtedly, Mr. Henderson's work on the genus will provide the necessary explanations.

Hylobius pales (Herbst). Nat. Ins. Kaf., 7, 1797, p. 31, t. 99, f. 10. (nec Boh. 34-340, Leng.)

County records: Story.

A unique addition to the state weevil list collected by the author along the Skunk river south of Ames.

Euclyptus ferrugineus (Leconte). Proc. Phil. Soc. Am., 15, 1876, p. 174.

County records: Johnson.

No specimens were seen by the author in the collections studied. The species measures but 1.5 mm., which perhaps accounts for its rarity.

Dorytomus mucidus (Say). Curc., 1831, p. 14.

County records: Henry, Johnson, Pottawattamie, Scott, Story, Van Buren.

Swept from willow in early spring.

Dorytomus laticollis Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 164.

County records: Johnson, Story.

Dorytomus parvicollis Csy. Vol. 4, Coleop. Mem., 1892, p. 367.

County records: Story, Winneshiek.

It is doubtful if the more strongly toothed femora is sufficient for a specific differentiation.

Dorytomus indifferens Casey. Col. Not., 4, 1892, p. 375.

County records: Story, Boone.

Dorytomus fusciceps Casey. Col. Not., 4, 1892, p. 377.

County records: Lee (?).

The paratype (U.S.N.M. Paratype 36694) is labelled "Iowa." It is unlike any specimens of the preceding species.

Dorytomus brevicollis Lec. Proc. Am. Phil. Soc., 15, 1876, p. 165.

County records: Story.

Dorytomus squamosus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 166.

County records: Story, Van Buren.

Recorded by Casey ('92) from Iowa.

Grypidius equiseti (Fabricius). Syst. Ent., 1775, p. 130 (nec 98-403, Leng).

County records: Johnson, Story.

Notaris puncticollis (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 163.

County records: Dickinson, Story.

Notaris bimaculatus (Fabricius). Mant. Ins., 1, 1787, p. 98.

County records: Dickinson, Story, Winnebago.

Reported by L. L. Buchanan from Spirit Lake and Lake Okoboji, Iowa in 1923.

Pachyphanes discoideus (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 169.

County records: Henry, Iowa, Johnson, Story, Winnebago, Winneshiek.

Pachyphanes amoenus (Say). Curc., 1831, p. 26.

County records: Johnson, Story.

Reported by Wickham ('11).

Pachyphanes lineolatus Casey. Coleop. Not., 4, 1892, p. 385.

County records: Lee (?).

A specimen in the Casey cabinets with the labels "Iowa" and "B."

Desmoris scapalis var. compar Dietz. Trans. Am. Ent. Soc., 21, 1894, p. 123.

County records: Dickinson, Poweshiek.

Desmoris pervisus Dtz. Trans. Am. Ent. Soc., 21, 1894, p. 125.

County records: Adams, Appanoose, Benton, Cedar, Delaware, Dickinson, Dubuque, Hancock, Story, Union.

Taken on sunflower at Ames by Hendrickson ('30).

Desmoris constrictus (Say). Phil. Ac. Nat. Sci., 4, 1824, p. 313.

County records: Carroll, Cherokee, Dickinson, Iowa, Kossuth, Lucas, Plymouth, Pocahontas, Story, Winneshiek.

Collected in great numbers from *Helianthus sp.* at LeMars, Iowa, and at lights during July.

Desmoris sordidus (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 173.

County records: Clinton, Dickinson, Lyon, Poweshiek, Union, Webster.

Desmoris fulvus (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 172.

County records: Adair, Cherokee, Clarke, Monroe, Plymouth, Story, Winneshiek.
Suggestive of *Smicronyx vestitus*.

Desmoris flavicans (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 171.

County records: Lee (?).
Reported from Iowa by Casey ('92).

Desmoris fiducialis Casey. Col. Nat., 4, 1892, p. 399.

County records: Lee (?).
A specimen from Iowa (Keokuk?) described by Casey under this name bears such a likeness to *D. fulvus*, that it is doubtful if it is not that species.

Smicronyx squalidus Casey. Col. Not., 4, 1892, p. 407.

County records: Cherokee, Dickinson, Hancock, Johnson, Plymouth, Story, Union, Wayne, Winneshiek.

Smicronyx ovipennis Leconte. Proc. Phil. Soc. Am., 15, 1876, p. 170.

County records: Adams, Johnson, Plymouth.

Smicronyx connivens Casey. Col. Not., 4, 1892, p. 398.

County records: Cherokee, Iowa, Story.

Smicronyx congestus Casey. Col. Not., 4, 1892, p. 401.

County records: Story.

Smicronyx sculpticollis Casey. Col. Not., 4, 1892, p. 403.

County records: Grundy.
The Dietz ('94) records are only from "Iowa."

Smicronyx vestitus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 172.

County records: Cherokee, Des Moines, Osceola, Plymouth, Sac, Story, Winneshiek.

Smicronyx perfidus Dietz. Trans. Am. Ent. Soc., 21, 1894, p. 161.

County records: Cherokee, Plymouth.

Smicronyx maculatus Dietz. Trans. Am. Ent. Soc., 21, 1894, p. 162.

County records: Benton, Union, Winneshiek.

Smicronyx corniculatus (Fahreus). Schoenh. Curc., 7, (2), 1843, p. 309 (nec p. 319, Leng).

County records: Bremer, Cass, Franklin, Henry, Story.

Smicronyx griseus Lec. Proc. Am. Phil. Soc., **15**, 1876, p. 171.

County records: Boone.

One specimen in the Harris collection seems to fit this species more closely than any other.

Stenopelmus rufinasus Gyllenhal. Schoenh. Curc., **3**, (1), p. 469 (nec 35-409, Leng).

County records: Des Moines, Scott.

A large series of specimens collected by Stoner at Dubuque were examined at the National Museum. This is an aquatic species, and from the records, seems to confine itself to the Mississippi River valley.

Endalus limatulus (Gyllenhal). Schoenh. Curc., **3**, (1), 1836, p. 319.

County records: Buchanan, Dickinson, Plymouth, Story.

Mr. Hansberry reports it ovipositing on *Juncus sp.* at Independence, June 19, 1934.

Endalus ovalis Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 177.

County records: Dickinson.

Hundreds were sifted from the seeds of the river sedge by Dr. Hayden.

Tanysphyrus lemnae (Paykull). Mon. Curc., 1792, p. 78.

County records: Henry, Johnson.

Onychylis nigrirostris (Boheman). Schoenh. Curc., **7**, (2), 1843, p. 184.

County records: Johnson, Linn.

Anchodemus angustus Lec. Proc. Phil. Soc. Am., **15**, 1876, p. 181.

County records: Hamilton, Johnson.

Collected by the author under boards along the edge of Goose Lake on Oct. 16, 1936. The long swimmerette hairs on the front tibia are distinctive.

Lixellus filiformis Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 182.

County records: Dickinson, Linn.

Lissorhoptrus simplex (Say). Curc., 1831, p. 29.

County records: Boone, Jackson, Linn, Story, Washington, Worth.

This is the "Rice Weevil."

Lissorhoptrus apiculatus (Gyllenhal). Schoenh. Curc., **3**, (1), 1836, p. 320.

County records: Dickinson, Wapello.

These specimens are in the U. S. N. M. collection.

Bagous restrictus Lec. Proc. Phil. Soc. Am., **15**, 1876, p. 187.

County records: Johnson, Linn, Story.

Bagous americanus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 185.

County records: Story.

Bagous mammillatus (Say). Curc., 1831, p. 28.

County records: Dickinson.

Bagous sellatus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 184.

County records: Story.

This is the *Bagous* sp., at "*Andropogon furcatus—Spartina Michauxiana* consocies, June 26, 1926" of Hendrickson ('30).

Bagous planatus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 185.

County records: Henry.

Bagous obliquus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 185.

County records: Dickinson, Johnson.

Bagous transversus Lec. Proc. Phil. Soc. Am., 15, 1876, p. 188.

County records: Des Moines, Dickinson, Henry.

Bagous bituberosus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 188.

County records: Johnson.

Pnigodes setosus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 189.

County records: Story.

Thysanocnemis fraxini Lec. Proc. Am. Phil. Soc., 15, 1876, p. 214.

County records: Jefferson, Johnson, Plymouth, Story.

Thysanocnemis punctata Csy. Syn. Notes, Bal., Tych., 1910, p. 129.

County records: Lee (?).

Described from Iowa by Casey in 1910, this species is perhaps one extreme variation of the above species. It is a single specimen type, as is the case in the majority of Casey's types.

Thysanocnemis bishoffi Blatch. Rhyn. N. E. U. S., 1916, p. 241.

County records: Franklin, Louisa, Plymouth, Story.

Thysanocnemis balaninoides Schffr. Jour. N. Y. Ent. Soc., 1908, p. 217.

County records : Louisa, Story.

Thysanocnemis ocularis Casey. Syn. Notes, Bal., Tych., 1910, p. 129.

County records: Story.

Thysanocnemis helvola Lec. Proc. Am. Phil. Soc., 15, 1876, p. 214.

County records: Plymouth, Story.

Tychius sordidus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 217.

County records: Lee (?).

Recorded by Wickham ('11).

Tychius sordidus var. nimius Csy.

County records: Lee (?).

Described from Iowa by Casey ('10).

Tychius tectus Leconte. Proc. Am. Phil. Soc.,15, 1876, p. 217.
County records: Dickinson, Lyon, Plymouth, Story, Winnebago, Worth.

Tychius aratus Say. Curc., 1831, p. 26 (nec Gyll. 34-414).
County records: Dickinson, Story.

Myrmex myrmex Herbst. Natursystem, etc., 7, 1797, p. 56.
County records: Clayton, Johnson, Lee.

Myrmex chevrolatii Horn. Proc. Am. Phil. Soc., 13, 1873, p. 450.
County records: Cerro Gordo, Clayton, Dickinson, Johnson, Lee, Linn.

Oopterinus perforatus (Horn). Proc. Am. Phil. Soc., 13, 1873, p. 453.
County records: Story.

Magdalis perforata Horn. Proc. Am. Phil. Soc., 13, 1873, p. 453.
County records: Story.

Magdalis austera Fall. Trans. Am. Ent. Soc., 1913, p. 29.
County records: Story.

Magdalis olyra (Herbst). Jablonsky, Nat. Ins., 7, 1797, p. 7.
County records: Johnson, Muscatine, Story.

Magdalis pandura (Say). Curc., 1831, p. 7.
County records: Boone, Clayton, Fayette, Henry, Jasper, Johnson, Story.

Magdalis inconspicua Horn. Proc. Am. Phil. Soc., 13, 1873, p. 456.
Reported by Blatchley ('16) from Iowa.

Magdalis salicis Horn. Proc. Am. Phil. Soc., 13, 1873, p. 435.
County records: Clayton, Henry, Lee, Story.

Magdalis barbita (Say). Curc., 1931, p. 6.
County records: Henry, Tama.

Magdalis armicollis Say Jour. Ac. Nat. Sci., 1824, p. 312.
County records: Boone, Butler, Clayton, Emmet, Fayette, Hancock, Henry, Johnson, Monroe, Sioux, Story, Wineshiek.
This is the "elm weevil" and varies greatly in size and color.

Magdalis armicollis var. pallida (Say). Curc., 1831, p. 7.
County records: Johnson, Story.

Curculio caryae (Horn). Proc. Am. Phil. Soc., 13, 1873, p. 460.
County records: Jefferson.

Curculio rectus (Say). Curc., 1831, p. 16.

County records: Cherokee, Howard, Johnson, Story, Winneshiek.

Curculio nasicus (Say) Curc., 1831, p. 16.

County records: Dickinson, Howard, Johnson, Story.

Curculio pardalis (Chttn.). Proc. Ent. Soc. Wash., 10, 1908, p. 25.

County records: Dickinson, Henry, Story.

Curculio confusor (Hamilton). Desc. n. sp. Col., 1893, p. 309.

County records: Story.
The single specimen bears the note "on Quercus alba."

Curculio iowensis (Casey). Can. Ent., **42**, 1910, p. 122.

County records: Lee.
A species described by Casey from Keokuk, Iowa, the type locality, from a single female specimen. It was reduced to a variety of *confusor* by Leng ('20), but placed as a distinct species by Chittenden ('27).

Curculio baculi (Chitt.). Proc. Ent. Soc. Wash., 10, 1908, p. 20.

County records: Dickinson, Henry, Muscatine, Story.

Curculio obtusus (Blanchard). Bul. Brook. Ent. Soc., 7, 1884, p. 107.

County records: Story.

Curculio strictus (Casey). Ann. N. Y. Ac. Sci., 9, 1897, p. 660.

County records: Dickinson, Harrison, Muscatine, Page, Story.
The determination label by Mr. Buchanan states that there is a possibility that more than one species is present in the above records.

Curculio numenius (Chttn.). Ent. Amer., 8, 1927, p. 178.

County records: Dickinson, Story.
Buchanan's Iowa specimens from Dickinson county were included by Chittenden ('27) in his description of the species.

Tachypterellus quadrigibbus magnus List. Bull. Colo. Agr. Exp. Sta. No. 385, 1932, p. 10.

County records: Story.

Anthonomus scutellaris Leconte. Proc. Ac. N. S. Phila., 1858, p. 79.

County records: Story, Johnson.

Anthonomus profundus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 198.

County records: Henry, Jefferson, Johnson, Story.

Anthonomus nebulosus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 107.

County records: Story.
A new state record.

Anthonomus virgo Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 206.

County records: Iowa.
Hendrickson ('30) records this unique species from Iowa.

Anthonomus haematopus Boheman. Schoenh. Curc., 7, (2), 1843, p. 222.

County records: Dickinson, Johnson, Story, Worth.

Reported from Iowa City under the name of *A. sycophanta* Walsh. *A. bolteri* Dtz., reported also by Wickham, is a variety according to Leng ('20). The author could scarcely detect even that difference in U.S.N.M. material.

Anthonomus suturalis Lec. Ann. Lyc. Nat. Hist. N. Y., 1, 1824, p. 171.

County records: Henry, Iowa, Jefferson, Story.

Anthonomus flavicornis Boheman. Schoenh. Curc., 7, (2), 1843, p. 231.

County records: Henry, Linn.

Anthonomus corvulus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 201.

County records: Johnson.

Reported by Wickham ('11). No specimens were seen.

Anthonomus subguttatus Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 213.

Recorded by Dietz and Wickham.

Anthonomus signatus Say. Curc., 1831, p. 25.

County records: Story.

Anthonomus consimilis Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 216.

A specimen from "Iowa" which was determined by Mr. Dietz for Col. Hubbard & Schaeffer is now in the U.S.N.M. collection.

Anthonomus musculus Say. Curc., 1831, p. 15.

County records: Jefferson, Johnson, Linn, Story.

Anthonomus nigrinus Boheman. Schoenh. Curc., 1843, p. 230.

County records: Page

Anthonomus scutellatus Gyllenhal. Schoenh. Curc., 3, (1), 1836, p. 342.

County records: Johnson, Story.

Anthonomus orchestoides Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 226.

County records: Henry.

Anthonomus squamosus Leconte. Proc. Am. Philos. Soc., 15, 1876, p. 202.

County records: Dickinson, Lyon, O'Brien, Poweshiek, Sioux, Story, Wright.

Anthonomus tectus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 203.

County records: Johnson, Sioux, Story.

Anthonomus molochinus Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 231.

County records: Dickinson.

A series in the U.S.N.M. collection. Looks much like *A. tectus*.

Anthonomus rufipes Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 204.
County records: Adair, Dickinson, Humboldt, Story.

Anthonomus disjunctus Leconte. Proc. Am. Phil. Soc.,15, 1876, p. 204.
County records: Dickinson, Henry, Mahaska, Story.

Anthonomus robustulus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 205.
County records: Audubon, Clinton, Dickinson.

Anthonomus ungularis Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 206.
County records: Henry.

Anthonomus nubiloides Fall. Bull. Brook. Ent. Soc., 23, 1928, p. 239.
County records: Johnson.
The specimen is labelled *nubilus* Lec. in the U.S.N.M. collection, and is perhaps the record from which Wickham reports that species.

Anthonomus decipiens Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 206.
County records: Bremer, Dickinson, Dubuque, Henry, Jefferson, Johnson, Keokuk, Lee, Story.

Anthonomus ligatus Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 245.
County records: Dickinson.

Anthonomopsis mixtus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 206.
County records: Dickinson, Henry, Johnson, Plymouth, Story, Woodbury.

Pseudanthonomus crataegi (Walsh). Proc. Ent. Soc. Phila., 6, 1867, p. 266.
County records: Henry, Howard, Johnson, Linn, Plymouth, Story.

Pseudanthonomus facetus Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 252.
Reported by Angell ('93) and Wickham ('11).

Chelonychus longipes Dietz. Trans. Am. Ent. Soc., 18, p. 256.
County records: Dickinson, Hancock.
This is the first record of the species in the state.

Elleschus ephippiatus (Say). Curc., 1831, p. 25.
County records: Boone, Bremer, Cerro Gordo, Dickinson, Jefferson, Johnson, Pottawattamie, Story.

Orchestes ephippiatus Say. Curc., 1831. p. 16.
County records: Cherokee, Dickinson, Fremont, Scott, Story.

Orchestes niger Horn. Proc. Am. Phil. Soc., 13, 1873, p. 462.
County records: Dickinson, Muscatine, Story.

Orchestes illinoisensis Fall. Trans. Am. Ent. Soc., 39, 1913, p .64.
County records: Boone, Lee.

Orchestes canus Horn. Proc. Am. Phil. Soc., 17, 1878, p. 620.

County records: Henry, Johnson, Story.
The Story specimen carries the notation "on apple."

Orchestes mixtus Blatchley. Rhyn. N. E. U. S., 1916, p. 282.

County records: Johnson.
One specimen in the U.S.N.M. collection fits this species.

Orchestes pallicornis Say. Curc., 1831, p. 16.

County records: Boone, Johnson, Story.

Orchestes rufipes Lec. Proc. Am. Phil. Soc., 15, 1876, p. 208.

County records: Dickinson.
These records are in the U.S.N.M. collection.

Acalyptus carpini (Herbst). Ent. Syst., 1, (2), 1792, p. 409.

County records: Howard.
One specimen in the U.S.N.M. collection from Elma, Iowa.

Prionomerus calceatus (Say). Curc., 1831, p. 15.

Four specimens with the label "I." in the I.S.C. collection. One specimen "coll. C. V. Riley," "Iowa" in the U.S.N.M. collection.

Piazorhinus scutellaris (Say). Proc. Ac. N. S. Phila., 1826, p. 252.

County records: Johnson.

Nanophyes pallidulus (Gravenhorst.). Verg. Uber. d. Zool. Syst. Gott., 1807, p. 203.

County records: Johnson.
One specimen in the U.S.N.M. collection from the Wickham material.

Gymnetron tetrum (Fabricius). Ent. Syst., 1, 1792, p. 406 (nec 01-448).

County records: Johnson, Linn, Madison, Pottawattamie, Story.
Common in mullein seeds.

Gymnetron plagiellum Gyllenhal. Schoenh. Curc., 4, (2), 1838, p. 759.

Pierce ('19) notes the species in Iowa.

Gymnetron netum (Germar). Mag. Ent., 4, 1821, p. 312.

County records: Henry, Muscatine, Story.
Determined by Buchanan as this species.

Miarus hispidulus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 221.

County records: Linn, Story.
A label *"on Quercus alba"* is pinned with the Story specimen.

Cleonus plumbeus Lec. roc. hil. Soc. Am., 15, 1876, p. 150.

County records: Story.
Wickham ('11) reports it without definite record.

Cleonus frontalis Lec. Proc. Phil. Soc. Am., **15**, 1876, p. 150.

County records: Dickinson, Plymouth.
A new state record.

Lixus caudifer Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 156.

County records: Lee (?).
Probably a Keokuk, Iowa, specimen, now in the Casey collection.

Lixus rubellus Rand. Bost. Jour. N. H., **2**, (1), 1838, p. 41.

County records: Dickinson, Palo Alto.
The specimens are in the U.S.N.M. collection.

Lixus marginatus Say Curc., 1831, p. 13.

County records: Bremer, Henry, Lee, Page, Plymouth, Van Buren.

Lixus musculus Say. Curc., 1831, p. 14.

County records: Johnson, Story, Washington, Winneshiek.

Lixus parcus Lec. Proc. Am. Phil. Soc., **15**, 1876, p. 157.

County records: Johnson.
Specimen in the U.S.N.M. collection.

Lixus concavus Say. Curc., 1831, p. 14.

County records: Cherokee, Jackson, Johnson, Lee, Plymouth, Story, Webster.
This is the "rhubarb curculio." Common on *Rumex spp.*

Lixus mucidus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 158.

County records: Cherokee, Iowa, Johnson, Story.

Lixus laramiensis Casey. Ann. N. Y. Acad. Sci., **6**, 1891, p. 204.

County records: Story.
This is a Lixus sp. 1 of Hendrickson ('30), reported from *Spartina* consocies.

Lixus sylvius Boheman. Schoenh. Curc., 1843, p. 430 (nec 1844, Leng).

County records: Clayton, Henry, Mahaska, Story.
A new state record.

Lixus scrobicollis Boheman. Schoenh. Curc., **3**, (1), 1836, p. 84.

County records: Jefferson, Page.

Lixus fimbriolatus Boheman. Schoenh. Curc., **3**, (1), 1836, p. 42 (nec 1826, Leng).

County records: Dickinson, Hancock, Henry, Johnson, Lyon, Monroe, Pottawattamie, Story, Winnebago.

Lixus tricristatus Chittenden. Proc. U. S. N. M., **77**, Art. 18, 1930, p. 12.

County records: Dickinson, Johnson, Montgomery, Story.
The type resembles *scrobicollis.*

Lixus nitidulus Casey. Ann. N. Y. Acad. Sci., **6**, 1891, p. 210.

County records: Story.
Reported by Hendrickson ('30).

Lixus terminalis Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 157.

County records: Bremer, Clayton, Des Moines, Fayette, Fremont, Henry, Jefferson, Keokuk, Mills, Page, Story, Van Buren, Washington.

Lixus planicollis Chittenden. Proc. U. S. N. M., **77**, Art. 18, 1930, p. 13.

County records: Johnson.

Lixus flexipennis Chittenden. Proc. U. S. N. M., **77**, Art. 18, 1930, p. 15.

County records: Dickinson.

Lixus buchanani Chittenden. Proc. U. S. N. M., **77**, Art. 18, 1930, p. 16.

County records: Dickinson.
Type locality—Lake Okoboji, Iowa.

Sternechus paludatus Casey. Ann. N. Y. Acad. Sci., **8**, 1895, p. 830.

County records: Story.
This specimen agrees with Casey's type. A new state record.

Baris striata (Say). Curc., 1831, p. 17.

County records: Audubon, Buena Vista, Des Moines, Dickinson, Guthrie, Hamilton, Johnson, Linn, Osceola, Palo Alto, Plymouth, Polk, Story, Winnebago, Winneshiek.
Very common on giant ragweed.

Baris umbilicata (Leconte). Proc. Acad. N. S. Phila., 1868, p. 363.

County records: Boone, Dickinson, Dubuque, Johnson, Lee, Plymouth, Story, Winneshiek.

Baris transversa (Say). Curc., 1831, p. 18.

County records: Boone, Cherokee, Henry, Iowa, Johnson, Story, Webster, Winneshiek.
The Webster couny specimen is identical with Casey's *B. gravida.*

Baris callida Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 481.

County records: Greene, Henry, Story, Winneshiek.

Baris subovalis (Leconte). Proc. Ac. Nat. Sci., Phila., 1868, p. 363.

County records: Story.

Baris dolosa Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 490.

County records: Bremer, Buena Vista, Cherokee, Clayton, Des Moines, Dickinson, Henry, Jackson, Jefferson, Johnson, Lee, Linn, Louisa Lucas, Plymouth, Story, Wapello, Winneshiek.
Casey's type male specimen is from Keokuk, Iowa (Casey '92).

Baris xanthii Pierce. Ent. News, **18**, 1907, p 379.

County records: Clayton, Floyd, Henry, Jefferson, Scott, Union.

Baris tumescens (Leconte). Proc. Acad. N. S. Phila., 1868, p. 362.

County records: Story, Delaware.

Baris interstitialis (Say). Jour. Ac. N. S. Phila., **3**, 1824, p. 314.

County records: Cherokee, Dickinson, Lee, Plymouth, Sioux, Story, Winneshiek.

Baris deformis Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 496.

County records: Boone, Clinton, Des Moines, Dickinson, Emmet, Henry, Jefferson, Johnson, Story.

Baris confinis (Leconte). Proc. Acad. N. S. Phila., 1868, p. 362.

County records: Buena Vista, Chariton, Cherokee, Clayton, Delaware, Dickinson, Henry, Jefferson, Lee (?), Linn, Lucas, Plymouth, Story.

Baris subsimilis Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 499.

County records: Lucas, Story.

Baris socialis Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 499.

County records: Bremer, Clayton, Lee, Plymouth, Story, Washington.

Reported by Blatchley ('16).

Baris aperta Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 500.

County records: Dallas, Dickinson, Henry, Jackson, Lee, Linn, Louisa, Palo Alto, Page, Plymouth, Story, Van Buren, Webster, Winneshiek.

Baris aerea (Boheman). Schoenh. Curc., **8**, (1), 1844, p. 141.

County records: Appanoose, Buena Vista, Clayton, Dubuque, Henry, Story.

Baris novella Casey. Mem., **9**, 1920, p. 337.

County records: Henry, Story.

Cosmobaris scolopacea (Germar). Ins. sp. nov., 1824, p. 202.

County records: Butler, Clayton, Louisa, Woodbury.

These records include the species described by Hayes as *C. squamigera* and *C. sionilli,* which are to be treated as synonyms.

Stictobaris cribrata (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 296.

County records: Plymouth.

A new state record.

Glyptobaris rugicollis (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 297.

County records: Henry.

Onychobaris millepora Casey. Ann. N. Y. Acad. Sci., **6**, 1892, p. 526.
County records: Plymouth, Story, Winneshiek.

Onychobaris subtonsa Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 295.
County records: Bremer, Clayton, Henry, Plymouth, Story, Winneshiek.
Collected in Plymouth county in association with *O. millepora*.

Onychobaris pectorosa Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 295.
County records: Johnson, Plymouth, Story.
Reported from Johnson county by Wickham ('11).

Madarellus undulatus (Say). Jour. Ac. N. S. Phila., **3**, 1824, p. 315.
County records: Henry, Johnson, Monroe, Story.

Madarellus inconstans Casey. Mem., **9**, 1920, p. 354.
County records: Lee (?).
Described by Casey from Iowa. It is perhaps only a variety.

Aulobaris nasuta (Leconte). Proc. Ac. N. S. Phila., 1868, p. 295.
County records: Davis, Lee (?), Muscatine, Washington.

Aulobaris pusilla (Leconte). Proc. Ac. N. S. Phila., 1868, p. 363.
County records: Ringgold, Washington.

Aulobaris scolopax (Say). Curc., 1831, p. 26.
County records: Van Buren.
This single specimen is in the U. S. N. M. collection.

Aulobaris ibis (Leconte). Proc. Ac. N. S. Phila., 1868, p. 365.
County records: Johnson, Story.

Aulobaris dux Casey. Ann. N. Y. Ac. Sci., **6**, 1892, p. 546.
County records: Wapello.

Pseudobaris farcta (Leconte). Proc. Ac. N. S. Phila., 1868, p. 362.
County records: Johnson.

Pseudobaris sobrina Blatchley. Rhyn. N. E. U. S., 1916, p. 373.
County records: Henry.

Pseudobaris angusta (Leconte). Proc. Ac. N. S. Phila., 1868, p. 363.
County records: Clayton, Decatur, Dickinson, Henry, Jefferson, Linn, Story.

Pseudobaris nigrina (Say). Curc., 1831, p. 26.
County records: Clayton, Des Moines, Dickinson, Henry, Linn, Story, Washington, Winnebago.

Trichobaris trinotata (Say). Curc., 1831, p. 17.

County records: Fayette, Henry, Jasper, Jefferson, Johnson, Muscatine, Story.

This is the "potato stalk borer."

Pachygeraeus laevirostris (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 309.

County records: Buchanan, Des Moines.

Centrinaspis picumnus (Herbst). Nat. Ins., 7, 1797, p. 30.

County records: Davis, Des Moines, Henry, Johnson, Muscatine, Story, Van Buren, Washington.

Centrinaspis perscillus (Gyllenhal). Schoenh. Curc., 3, (2), 1836, p. 762.

County records: Buena Vista, Dickinson, Henry, Pocahontas, Polk, Poweshiek, Story, Warren.

Centrinaspis perscitus (Herbst). Natursyst., 7, 1797, p. 28.

County records: Henry, Scott.

Centrinaspis penicellus (Herbst). Natursyst., 7, 1797, p. 29.

County records: Cherokee, Crawford, Dickinson, Fremont, Linn, Palo Alto, Plymouth, Pottawattamie, Sioux, Story.

Centrinaspis falsus (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 315.

Reported by Wickham ('11).

Odontocorynus scutellum-album (Say). Curc., 1831, p. 21.

County records: Bremer, Dickinson, Iowa, Johnson, Louisa, Story, Winneshiek.

Odontocorynus iowensis Csy. Mem., 9, 1920, p. 428.

County records: Dickinson, Johnson, Winneshiek.

The type specimen is from Johnson County.

Odontocorynus denticornis Casey. Ann. N. Y. Acad. Sci., 6, 1892, p. 597.

County records: Clayton, Dickinson, Henry, Jasper, Kossuth, Plymouth, Page, Pocahontas, Story, Winnebago, Woodbury.

Odontocorynus rufobrunneus Casey. Mem., 9, 1920, p. 413.

County records: Bremer.

Compared with U. S. N. M. material and Casey's type.

Odontocorynus salebrosus Casey. Ann. N. Y. Acad. Sci., 6, 1892, p. 598.

County records: Dickinson, Hancock, Henry, Humboldt, Iowa, Sioux, Sioux, Story, Warren, Winnebago.

Centrinopus alternatus Casey. Ann. N. Y. Acad. Sci., 6, 1892, p. 602.

County records: Cherokee, Dallas, Decatur, Henry, Keokuk, Story, Winnebago, Winneshiek, Woodbury.

A new state record.

Nicentrus lineicollis (Boheman). Schoenh. Curc., 8, (1), 1844, p. 221.

County records: Boone, Linn.

Nicentrus ingenuus Casey. Ann. N. Y. Acad. Sci., **6**, 1892, p. 610.

County records: Jefferson, Story.

Nicentrus simulans Casey. Mem., **9**, 1920, p. 449.

County records: Fremont, Linn.
Described from Iowa by Casey ('20).

Nicentrus vacunalis Casey. Mem., **9**, 1920, p. 450.

County records: Fremont.
The type is from Riverton, Iowa.

Centrinites strigicollis Casey. Ann. N. Y. Acad. Sci., **6**, 1892, p. 616.

County records: Jefferson, Johnson, Story.

Anacentrus (Oligolochus) bracata (Casey. Ann N. Y. Acad. Sci., **6**, 1892, p. 627.

County records: Bremer, Henry, Johnson, Linn, Story.

Anacentrinus deplanata (Casey). Ann. N. Y. Acad. Sci., **6**, 1892, p. 630.

County records: Bremer, Dallas, Hancock, Lee, Plymouth, Story.
Found in the axils of mullein leaves where they overwinter in the adult form.

Anacentrinus oblitus (Casey). Ann. N. Y. Acad. Sci., **6**, 1892, p. 634.

County records: Cherokee, Dickinson.

Sibariops confusa (Boheman). Schoenh. Curc., **3**, (2), 1836, p. 740.

County records: Des Moines, Johnson, Jones, Lucas, Story, Washington.
A new state record.

Sibariops confinis (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 317.

County records: Henry, Johnson, Lee (?), Story, Washington.

Sibariops civica Casey. Mem., **9**, 1920, p. 491.

County records: Lee (?).
The type is described from Iowa.

Cylindrida prolixa (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 317.

County records: Dickinson, Johnson, Pocahontas, Pottawattamie, Story, Washington.

Dirabius rectirostris (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 315.

County records: Buchanan, Buena Vista, Dickinson, Hancock, Johnson, Jones, Palo Alto, Story, Winnebago.

Idiostethus tubulatus (Say). Curc., 1831, p. 20.

County records: Bremer, Delaware, Dickinson, Emmet, Jefferson, Jones, Kossuth, Linn, Muscatine, Story, Washington.

Idiostethus puncticollis Casey. Mem., **9**, 1920, p. 500.

County records: Johnson, Story.

Probably a synonym of *tubulatus*, of which Casey had no specimen.

Idiostethus subcalvus (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 622.

County records: Lee.

One specimen in the U. S. N. M. collection determined by Buchanan.

Haplostethops ellipsoideus (Casey). Ann. N. Y. Acad. Sci., **6**, 1892, p. 652.

County records: Delaware, Henry, Lee (?), Story.

Haplostethops caviventrus Blatchley. Jour. N. Y. Ent. Soc., **30**, 1922, p. 119.

County records: Calhoun, Dickinson, Johnson.

Determined as such in the U. S. N. M. collection.

Idiostethus dispersus Casey. Ann N. Y. Ac. Sci., **6**, 1892fi p. 652.

County records: Henry, Story.

Stethobaris ovata (Lec). Proc. Ac. N. S., 1858, p. 363.

County records: Story.

Zaglyptus striatus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 237.

County records: Story.

A new state record.

Oomorphidius erasus (Leconte). Trans. Am. Ent. Soc., **7**, 1860, p. 217.

County records: Fremont.

Catapastus conspersus (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 318.

County records: Clayton, Johnson, Lee, Lucas, Plymouth, Story.

Barinus cribricollis (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 422.

County records: Story.

Barinus squamolineatus Casey. Calif. Acad. Sci., 1886, p .256.

County records: Allamakee, Buchanan, Des Moines, Johnson, Lee, Palo Alto, Story.

Barinus linearis (Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 422.

County records: Johnson.

Barilepton filiforme Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 319.

County records: Dickinson.

Eunyssobia echidna (Leconte). Proc. Am. Phil. Soc., **15**, 1876, p. 320.

Reported by Wickham ('11) without locality.

Gelus oculatus (Say). Jour. Acad. Nat. Sci., Phila., **3**, 1824, p. 308.

County records: Clayton, Henry, Johnson, Lee, Louisa, Story, Van Buren, Washington.

Cylindrocopturus binotatus (Lec.). Proc. Am. Phil. Soc., **15,** 1876, p. 263.

County records: Cherokee, Dickinson, Plymouth, Story, Winneshiek.

Cylindrocopturus adspersus (Leconte). Proc. Am. Phil. Soc., **15,** 1876, p. 262.

County records: Winneshiek.

Cylindrocopturus operculatus (Say). Jour. Ac. N. S. Phila., **3,** 1824, p. 308.

County records: Cherokee, Decatur, Dickinson, Fremont, Keokuk, Plymouth, Story.

Cylindrocopturus sparsus (Casey). Ann. N. Y. Acad. Sci., **9,** 1897, p. 673.

County records: Dickinson, Iowa.

Cylindrocopturus nanulus (Lec.). Proc. Am. Phil. Soc., **15,** 1876, p. 261.

County records: Lee (?).
Reported from Iowa by Casey ('97).

Cylindrocopturus quercus (Say). Curc., 1831, p. 20.

County records: Blackhawk, Linn, Johnson, Washington.

Acoptus suturalis Leconte. Proc. Am. Phil. Soc., **15,** 1876, p. 264.

County records: Howard.

Psomus politus Casey. Col. Not. **4,** 1892, p. 459.

County records: Dickinson.
A new state record.

Mononychus vulpeculus (Fabricius). Syst. El., **2,** 1801, p. 450.

County records: Dickinson, Johnson.

Craponius inequalis (Say). Curc., 1831, p. 20.

County records: Story.
A new record.

Acanthoscelis curtus (Say). Curc., 1831, p. 29.

County records: Story.
A new state record.

Acanthoscelis acephalus (Say). Jour. Ac. N. S. Phila., **3,** 1824, p. 309.

County records: Clayton, Monroe, Story, Union.

Auleutes asper (Leconte). Proc. Am. Phil. Soc., **15,** 1876, p. 270.

County records: Clarke.

Auleutes nebulosus (Lec.). Proc. Am. Phil. Soc., **15,** 1876, p. 271.

County records: Winnebago.

Hypocoeliodes wickhami Dietz. Trans. Am. Ent. Soc., **23,** 1896, p. 416.

County records: Calhoun.

Acollodes saltoides Dietz. Trans. Am. Ent. Soc., 23, 1896, p. 416.

County records: Bremer, Dickinson, Story.

Coeliodes flavicaudis Boheman. Schoenh. Curc., 8, (1), 1844, p. 397.

County records: Boone, Butler, Cherokee, Clay, Clayton, Dickinson, Jefferson, Linn, Plymouth, Scott, Story, Van Buren, Winnebago.

Ceutorhynchus rapae Gyll. Schoenh. Curc., 1837, p. 547.

County records: Boone, Des Moines, Dickinson, Harrison, Henry, Howard, Johnson, Lee, Palo Alto, Plymouth, Story, Winneshiek, Woodbury.
Known as the "cabbage curculio."

Ceutorhynchus sericans Lec. Proc. Am. Phil. Soc., 15, 1876, p. 275.

Reported from Iowa without record by Wickham ('11).

Ceutorhynchus sulcipennis Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 274.

County records: Benton, Blackhawk, Boone, Cedar, Deleware, Fremont, Hancock, Hardin, Iowa, Johnson, Kossuth, Linn, Louisa, Lucas, Mills, Palo Alto, Story, Webster, Winnebago.

Ceutorhynchus cyanipennis Germar. Ins. Spec. Nov., 1, 1824, p. 235.

County records: Des Moines, Dickinson, Emmet, Humboldt, Johnson, Osceola, Story.

Ceutorhynchus neglectus Blatch. Rhyn. N. E. U. S., 1916, p. 447.

County records: Boone, Cass, Cherokee, Dickinson, Johnson, Plymouth, Story, Winneshiek.

Ceutorhynchus pauxillus Dtz. Trans. Am. Ent. Soc., 23, 1896, p. 442.

County records: Des Moines, Plymouth.
A new state record.

Ceutorhynchus squamatus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 277.

County records: Cedar, Cherokee, Des Moines, Dickinson.

Ceutorhynchus septentrionalis Gyllenhal. Schoenh. Curc., 4, (1), 1837, p. 492.

County records: Calhoun, Henry, Johnson, Lee, Mahaska, Story.

Ceutorhynchus puberulus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 279.

County records: Buchanan, Dickinson, Johnson.

Ceutorhynchus zimmermanni Gyllenhal. Schoenh. Curc., 1837, p. 492.

County records: Johnson.
Reported by Wickham ('11).

Perigaster lituratus (Dietz). Trans. Am. Ent. Soc., 23, 1896, p. 457.

An Iowa paratype of Buchanan's *longirostris*, a synonym of this species, is in the U. S. N. M. collection, Cat. No. 43532. It was collected by Shimek.

Perigaster cretura (Herbst). Natursyst., 7, 1797, p. 70.

County records: Johnson, Story.

Phytobius sulcicollis Fahreus. Schoenh. Curc., 7, (2), 1843, p. 346.

County records: Blackhawk, Bremer, Clayton, Dickinson, Henry, Johnson, Linn, Louisa.

Phytobius squamosus (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 281.

County records: Johnson.

Mecopeltus fuliginosus Dietz. Trans. Am. Ent. Soc., 23, 1896, p. 497.

County records: Linn, Story.

Rhinoncus pericarpius (Linn.). Syst. Nat., 1758, p. 380 (nec Fab. 01-451, Leng).

County records: Clay, Dickinson, Fremont, Hancock, Harrison, Iowa, Jefferson, Kossuth, Linn, Mills, Palo Alto, Pottawattamie, Winnebago.

Recorded by Wickham under the name of *R. occidentalis* Dtz., a synonym.

Rhinoncus pyrrhopus Boheman. Schoenh. Curc., 8, (2), 1845, p. 172.

County records: Adair, Adams, Benton, Cerro Gordo, Floyd, Henry, Ida, Jackson, Jefferson, Johnson, Jones, Linn, Polk, Pottawattamie, Plymouth, Sac, Story, Winneshiek.

Rhinoncus longulus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 284.

County records: Boone, Cedar, Clinton, Louisa, Mahaska, Story. Not reported by Wickham.

Amalus haemorrhous (Herbst). Natursyst., 6, 1795, p. 399.

County records: Cherokee, Hancock, Humboldt, Plymouth, Winneshiek.

First records from Iowa by Hendrickson ('30).

Litodactylus griseomicans (Schwarz). Proc. Ent. Soc. Wash., 2, 1892, p. 165.

County records: Dickinson, Hamilton.

Eubrychiopsis lecontei (Dietz). Trans. Am. Ent. Soc., 23, 1896, p. 475.

County records: Dickinson.

Conotrachelus juglandis Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 226.

County records: Clayton, Story.

Conotrachelus albicinctus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 226.

County records: Dickinson, Story.

Conotrachelus seniculus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 227.

County records: Appanoose, Clayton, Emmet, Henry, Howard, Jefferson, Johnson, Keokuk, Louisa, Madison, Page, Story, Union, Wapello.

Conotrachelus elegans (Say). Curc., 1831, p. 18.

County records: Bremer, Story.

Conotrachelus nivosus Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 229.

County records: Cherokee, Plymouth, Story.

Conotrachelus crataegi Walsh .Proc. Bost. Soc. Nat. Hist., **9**, 1864, p. 311.

County records: Fayette, Henry, Story.
Known as the "quince curculio."

Conotrachelus naso Leconte. Proc. Am. Phil. Soc., **15**, 1876, p. 231.

County records: Buchanan, Clayton, Henry, Johnson, Story.
The Johnson county specimen was labelled *affinis* by Wickham.

Conotrachelus posticatus Boh. Schoenh. Curc., **4**, (2), 1837, p. 406.

County records: Dickinson, Johnson, Story.

Conotrachelus recessus (Casey). Can. Ent., **42**, 1910, p. 130.

County records: Story.
Describey by Casey as *Loceptes recessus* and discovered by Buchanan to be a Conotrachelus species. It is extremely small.

Conotrachelus geminatus Dejean. Cat. Col. Dej., **3**, 1837, p. 322.

County records: Des Moines, Iowa, Johnson, Muscatine, Story.
Dr. Harris found them burrowing in stems of *Polygonum nitella.*

Conotrachelus cribricollis (Say). Curc., 1831, p. 28.

County records: Dallas, Muscatine, Story.

Conotrachelus anaglypticus (Say). Curc., 1831, p. 18.

County records: Bremer, Clay, Dickinson, Henry, Johnson, Kossuth, Story, Winneshiek.

Conotrachelus leucophaeatus Fahreus. Schoenh. Curc., **4**, (1), 1837, p. 417.

County records: Cherokee, Story, Woodbury.

Ryssematus lineaticollis (Say). Jour. Ac. Nat. Sci., Phil., **3**, 1824, p. 313.

County records: Appanoose, Des Moines, Dickinson, Guthrie, Hamilton, Howard, Humboldt, Lee, Linn, Muscatine, Plymouth, Story, Winneshiek.

Casey's *R. grandicollis* records are included under this species, his type being considered as only a large specimen of *lineaticollis.*

Ryssematus aequalis Horn. Proc. Am. Phil. Soc. 13, 1873, p. 464.

County records: Cherokee, Dickinson, Henry, Jefferson, Johnson, Plymouth, Wapello, Winneshiek.

Ryssematus palmacollis (Say). Curc., 1831, p. 16.

County records: Plymouth.
A tentative determination.

Chalcodermus aeneus Boheman. Schoenh. Curc., 4, (1), 1837, p. 388.

County records: Boone.

Chalcodermus collaris Horn. Proc. Am. Phil. Soc., 13, 1873, p. 467.

County records: Story.

Microhyus setiger Lec. Proc. Am. Phil. Soc., 15, 1876, p. 238.

County records: Story.

Tyloderma foveolata (Say). Desc. Curc., 1831, p. 19.

County records: Clay, Clayton, Henry, Ida, Johnson, Jones, Osceola, Page, Scott, Warren, Winneshiek.

Tyloderma fragariae (Riley). 3rd Ann. Rept. Ins. Mo., 1871, p. 42.

County records: Blackhawk, Johnson, Lee, Story, Wapello.
This is the "strawberry crown-borer."

Tyloderma variegata (Horn). Proc. Am. Phil. Soc., 13, 1873, p. 468.

County records: Palo Alto.

Tyloderma aerea (Say). Curc., 1831, p. 29.

County records: Henry, Howard, Story.

Tyloderma aerea var. **nigra** Casey. Bull. Brook. Ent. Soc., 7, 1884, p. 56.

County records: Story.

Eurhoptus pyriformis Lec. Proc. Am. Phil. Soc., 15, 1876, p. 245.

County records: Boone, Johnson.

Acalles pectoralis Lec. Proc. Am. Phil. Soc., 15, 1876, p. 245.

County records: Story.

Cryptorhynchus parochus (Herbst). Jablonsky, Nat. Ins., 1797, p. 55.

County records: Henry, Story.

Cryptorhynchus bisignatus Say. Curc., 1831, p. 19.

County records: Johnson, Story.

Cryptorhynchus pumilus Boheman. Schoenh. Curc., 4, (1), 1837, p. 122.

An Iowa specimen from the Wickham collection in the U. S. National Museum collection.

Cryptorhynchus fuscatus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 251.
County records: Boone, Johnson.

Cryptorhynchus obliquus Say. Curc., 1831, p. 28.
County records: Johnson.

Cryptorhynchus obtentus (Hbst.). Jablonsky, Nat. Ins., 7, 1797, p. 38.
County records: Story.

Cryptorhynchus tristis Lec. Proc. Am. Phil. Soc., 15, 1876, p. 255.
County records: Johnson, Woodbury.

Thecesternus humeralis (Say). Jour. Acad. Nat. Hist., Phila., 5, 1826, p. 254.
County records: Common throughout the state.

Acamptus echinus Casey. Ann. N. Y. Ac. Sci., 6, 1892, p. 445 (nec 95-837, Leng).
County records: Mahaska.

Dryophthorus americanus Bedel. Rhynchophora, 1885, p. 192.
County records: Henry, Johnson, Jones.
This is the *D. corticalis* of Say, which name was preoccupied in the genus.

Cossonus platalea Say. Curc., 1831, p. 24.
County records: Henry, Johnson, Story.

Cossonus subareatus Boheman. Schoenh. Curc., 8, (2), 1845, p. 266.
County records: Wapello.

Cossonus impressifrons Boheman. Schoenh. Curc., 4, (2), 1838, p. 1001.
County records: Henry, Jones, Lee, Monroe.

Cossonus corticola Say. Curc., 1831, p. 24.
County records: Henry.

Hexarthrum ulkei Horn. Proc. Am. Phil. Soc., 18, 1873, p. 446.
County records: Des Moines.

Rhyncolus carinatus Blatchley. Rhynch. N. E. U. S., 1916, p. 545.
County records: Story.
A new record for the state.

Stenoscelis brevis (Boheman). Schoenh. Curc., 8, (2), 1845, p. 282.
A Wickham specimen with the antennal funicle 6-jointed instead of 7-jointed is in the U. S. N. M. collection.

Rhodobaenus 13-punctata (Illiger). N. Mag. Lieb. Ent., 5, 1794, p. 613.
Common on ragweed and cocklebur throughout the state.

Rhodobaenus 13-punctata var. pulchellus (Gyllenhal). Schoenh. Curc., 4, (2), 1838, p. 941.

Also common throughout the state.

Calendra aequalis (Gyllenhal). Schoenh. Curc., 4, (2), 1838, p. 941.

County records: Boone, Clayton, Decatur, Dickinson, Harrison, Henry, Kossuth, Lyons, Muscatine, Pottawattamie.
A common species and the largest Calendra in Iowa.

Calendra ochreus (Leconte). Proc. Acad. Nat. Sci., Phila., 1858, p. 80.

County records: Johnson,Pottawattamie, Story.
This is in part a synonym of *aequalis*, according to Blatchley ('16), and perhaps the above records are such.

Calendra striatipennis (Chittenden). Jour. N. Y. Ent. Soc., 14, 1906, p. 180.

County records: Dickinson, Story, Winnebago.

Calendra pertinax (Olivier). Ent., 5, 1807, p. 90.

County records: Dickinson, Harrison, Howard, Johnson, Story, Washington.

Calendra setiger (Chittenden). Proc. Ent. Soc., Wash., 7, 1906, p. 55.

County records: Decatur, Story.

Calendra robusta (Horn). Proc. Am. Phil. Soc., 13, 1873, p. 419.

County records: Dickinson.
C. multilineatus Satterthwait is a synonym of this species. A paratype from the Shimek collection is an Iowa specimen.

Calendra costipennis (Horn). Proc. Am. Phil. Soc., 13, 1873, p. 420.

County records: Clayton, Dickinson, Pottawattamie.

Calendra soltaui (Chittenden). Proc. Ent. Soc. Wash., 7, 1906, p. 178.

County records: Johnson, Story (?).

Calendra parvula (Gyllenhal). Schoenh. Curc., 4. (2), 1838, p. 961.

County records: Cass, Henry, Pocahontas, Story.
Very common throughout the state.

Calendra minima (Hart). 16th Rept. Ill. St. Ent., 1890, p. 65.

County records: Henry.

Calendra retusa (Gyllenhal). Schoenh. Curc., 1838, 4, (2), p. 949.

County records: Story.

Calendra destructor (Chittenden). Proc. Ent. Soc., Wash., 7, 1906, p. 174.

County records: Henry, Monroe.

Calendra zeae (Walsh). Pract. Ent., 2, 1867, p. 117.

County records: Des Moines, Henry, Johnson, Louisa, Monroe, Story, Van Buren.

Calendra scoparia (Horn). Proc. Am. Phil. Soc., **13**, 1873, p. 424.
County records: Humboldt, Story.

Calendra callosa (Olivier). Ent., **5**, 1807, p. 92, pl. 28, fig. 416.
County records: Clayton, Monroe, Sioux, Story.

Calendra melanocephala (Fabricius). Syst. Eleuth., **2**, 1801, p. 435.
County records: Boone, Des Moines, Henry, Humboldt, Jasper, Johnson, Jones, Scott, Story, Washington.

Calendra sayi (Gyllenhal). Schoenh. Curc., **4**, (2), 1838, p. 943.
County records: Dickinson, Story.

Calendra venatus (Say). Curc., 1831, p. 22.
County records: Clayton, Henry, Johnson, Keokuk, Plymouth, Story.

Calendra vestitus (Chittenden). Proc. Ent. Soc. Wash., **6**, 1904, p. 134.
County records: Henry.

Calendra incongrua (Chittenden). Proc. Ent. Soc. Wash., **7**, 1905, p. 61.
Satterthwait ('31) reports it from Iowa.

Calendra robustior (Chittenden). Proc. Ent. Soc. Wash., **7**, 1905, p. 62.
County records: Humboldt.

Calendra robustior var. **costifer** Chitt. Proc. Ent. Soc. Wash., **31**, 1924, p. 152.
County records: Dickinson.
Paratype No. 26895 U. S. N. M. collection.

Calendra jugosa Chittenden. Proc. Ent. Soc. Wash., **31**, 1924, p. 151.

Type No. 26892 U. S. N. M. collection. It was described without locality. It is an Iowa specimen from the Wickham collection.

Sitophilus granaria (L.). Syst. Nat., (10th ed.), 1758, p. 378.

This is the "granary weevil" and is generally distributed throughout the state.

Sitophilus oryzae (L). Amoen. Acad., 6, 1763, **p.** 395.

The "rice weevil" has been reported from various parts of the state.

SCOLYTOIDEA

Family Scolytidae

Scolytus quadrispinosus Say. Proc. Ac. Nat. Sci., Phila., **3**, 1824, p. 323.
County records: Johnson, Story (?).

Scolytus muticus Say. Proc. Ac. Nat. Sci., Phila., **3**, 1824, p. 323.
County records, Story.

Scolytus rugulosus Ratz. Die Forstinsekten, etc., 1837, p. 187.
County records: Wapello.

Chramesus hicoriae Leconte. Proc. Ac. Nat. Sci., Phila., 1868, p. 168.
County records: Johnson, Story.

Phthorophloeus limnaris (Harr.). Rept. Inj. Ins., ed. 2, 1852, p. 78.
County records: Johnson.

Phthorophloeus frontalis (Olivier). Ent. 4, 1795, p. 13.
County records: Des Moines.

Leperisinus aculeatus (Say). Proc. Ac. N. S., Phila., 1824, p. 322.
County records: Des Moines, Johnson, Story.

Hylurgopinus rufipes (Eich.). Desc. of Scolytidae, 1868, p. 147.
County records: Johnson.

Pterocyclon fasciatum Say. Proc. Ac. N. S., Phila., 5, 1825, p. 255.
County records: Story.

Monarthrum mali (Fitch). 3rd Ann. Rept. N. Y. St. Agr. Soc., 1856, p. 326.
County records: Johnson.

Xyloterinus politus (Say). Proc. Acad. Nat. Sci., Phila., 1826, p. 256.
County records: Story.

Trypodendron retusum (Leconte). Proc. Acad. Nat. Sci., Phila., 1868, p. 158.
County records: Johnson.

Pseudopityophthorus minutissimus (Zimmerman). Syn. Scholytidae, 1868, p. 143.
County records: Johnson.

Pityophthorus rhois Swaine. Can. Bark. Beetles, 1, 1917, p. 26.
County records: Story.

Pityophthorus puberulus (Leconte). Proc. Acad. Nat. Sci., Phila., 1868, p. 157.

Pityogenes carinulatus (Leconte). Trans. Am. Ent. Soc., 5, 1874, p. 70.
County records: Story.

Pityogenes knechteli Swaine. Can. Bark. Beetles, 2, 1918, p. 106.
County records: Plymouth.

Ips calligraphus (Germar). Ins. sp. nov., 1, 1824, p. 461.
County records: Story.

Ips pini (Say). Jour. Acad. Nat. Sci., Philaa., 5, 1826, p. 257.

County records: Johnson (?).

Ips. n. sp.

A Scolytid taken at the lights by the author was unfortunately in such condition that Mr. Blackman could be certain only of the genus. Of the species, he says "Unknown to me and I do not believe it has been described from North America."

Orthotomicus caelatus (Eich). Desc. Scolytidae, 1867, p. 402.

County records: Story.

Xyleborus pubescens Zimmerman. Trans. Am. Ent. Soc., 1, 1868, p. 145.

County records: Johnson.

Xyleborus celsus Eich. Desc. Scolytidae, 1867, p. 400.

County records: Johnson.

Lymantor decipiens Leconte. Proc. Am. Phil. Soc., 17, 1878, p. 624

County records: Story.

Pseudothysanoes drakei Blackm. Miss. Agri. Exp. Sta. Tech. Bull., 9, 1920. p. 48.

County records: Story.

SPECIES OF PROBABLE OCCURRENCE IN IOWA

Apion obsoletum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 44.

This species is reported from Michigan, Missouri and Dakota. Blatchley ('16) adds Nebraska.

Apion extensum Smith. Trans. Am. Ent. Soc., 11, 1874, p. 47.

Originally reported from Dakota. Blatchley reports it from Indiana.

Trachyphloeus asperatus Boheman. Schoenh. Curc., 7, (1), p. 116 (nec 1844, Leng).

Blatchley gives it doubtful occurrence throughout the middle states.

Lepyrus palustris (Scopoli). Ent. Carn., 1763, p. 33.

Blatchley gives it as occurring in Indiana, New York, to Wisconsin, Colorado and Manitoba, south to Louisiana.

Hyperodes rotundicollis (Dietz). Trans. Am. Ent. Soc., 16, 1889, p. 44.

Blatchley states that it ranges from N. Y. to Nebraska and Colorado, south to Texas.

Pseudanthonomus seriesetosus Dietz. Trans. Am. Ent. Soc., 18, 1891, p. 251.

Blatchley gives D. C., Mich, and Nebr. as its range.

Ampeloglypter longipennis Casey. Ann. N. Y. Ac. Sci., 6, 1892, p. 549.

It ranges from Penn. and Md. to Nebr., according to Blatchley.

Barilepton quadricolle Lec. Proc. Am. Phil. Soc., 15, 1876, p. 423.

Blatchley records it from Mich., s. Ill., and Nebr.

Cylindrocopturus longulus (Lec). Proc. Am. Phil. Soc., 15, 1876, p. 263.

Reported from New England to Canada, Utah and California.

Auleutes tenuipes (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 270.

Blatchley gives its range from New England and Canada to Mo., Ga., and Texas.

Auleutes cruralis (Leconte). Proc. Am. Phil. Soc., 15, 1876, p. 270.

Blatchley records it from Newfoundland and L. Superior to Utah, south to Pa. and Texas.

Ceutorhynchus decipens Leconte. Proc. Am. Phil. Soc., 15, p. 275.

Canada and New England to Mich., south to N. C. and west to Kansas, Utah, Colo., and Calif., is the range given by Blatchley.

Ceutorhynchus ovalis Dietz. Trans. Am. Ent. Soc., 23, 1896, p. 438.

Its type localities are Illinois and Minnesota.

Calendra maidis (Chittenden). Proc. Ent. Soc. Wash., 7, 1905, p. 59.

Reported from Mich., Kansas, Texas and Alabama.

Calendra inaequalis (Say). Curc., 1831, p. 23.

Satterthwait ('31) reports in in the larval form from Ala., Fla., Minn., Md., N. Y., Pa., and S. C.

Calendra cariosa (Olivier). Ent. Carn., 1807, p. 27.

Larvae were reported from Ill., Mo., Nebr., and Kansas.

Calendra oblita (Lec). Proc. Am. Phil. Soc., 15, 1876, p. 425.

Larvae were reported from Mich., Wisc., Kans., Md., Tex., and Ariz.

DOUBTFUL IOWA RHYNCHOPHORA RECORDS

Apion floridanum Smith. Trans. Am. Ent. Soc., 11, 1884, p. 49.

Recorded by Wickham ('11) from Iowa. Undoubtedly an incorrect determination by Smith.

Listronotus callosus Lec. Proc. Am. Phil. Soc., 15, 1876, p. 130.

Reported from Ames and Eldora by Wickham ('11). Its range is much more southern.

Anthonomus nubilus Leconte. Proc. Am. Phil. Soc., 15, 1876, p. 205.

Reported from Iowa City by Wickham ('11). A specimen in his collection is really Fall's *nubiloides*.

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