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## ADDITIONAL NOTES ON HEREDITY AND LIFE HISTORY IN THE COCCINELLID GENUS ADALIA MULSANT.


By MIRIAM A. PALMER.


In 1911 an article was published by the writer in the Annals of the Ent. Soc. of America, entitled "Some Notes on Heredity in the Coccinellid Genus *Adalia* Muls." This paper comprised all of the forms of Adalia at that time known to the writer to have been taken in Colo., viz., *melanopleura* Lec., *annectans Crotch*, *coloradensis* Casey, and *humeralis* Say. These forms were all found to interbreed freely, the different types acting as Mendelian units. In the spring of 1916 experiments were begun for the purpose of determining the biological relation between these forms and *A. bipunctata* Linn.

*Adalia bipunctata* Linn. as dealt with in this paper may be described as follows: Head black, with two white spots bordering the eyes. Pronotum pale with black M-shaped design with the broad pale margins, except in rare cases, immaculate instead of the black lateral dot as in *A. annectans*. Elytra brownish red with a rather large rounded black spot in the center of each. Legs black or brownish black. Length 4–5.5 mm., width 3.5–4 mm.

The appearance of the egg and larva in all stages seems indistinguishable from the rest of the *Adalia* group studied.* The color of the egg varied from pale lemon yellow to strong orange. This difference of color seemed to have no real significance, as eggs of both colors were laid by the same female and

*See Annals Ent. Soc. of America, Vol. VII, 1914, p. 228.

sometimes, in the same patch. The orange colored eggs seemed usually to be confined to the first egg patches laid by a female. Length of eggs was about 1.1–1.2 mm.

In the spring of 1916, through the kindness of Prof. R. L. Webster, two shipments of live *A. bipunctata* Linn were received from Ames, Iowa, March 21st and April 1st respectively, seven beetles in each shipment. Later about a dozen of this species were found in Colorado by Mr. L. C. Bragg, and Prof. C. P. Gillette. Owing to the unusual scarcity of the native species only a few of these were secured for the making of the crosses.

The first shipment from Iowa consisted of 6 unfertilized females and one male, the second 5 unfertilized females and 2 males. An *annectans* male was secured and introduced to each of these females. Though they readily mated, in only one instance did it seem to have any result. The eggs either continued to be infertile, or, if the female was already fertilized by a *bipunctata* male, the progeny continued typical *bipunctata*, though they were reared to the second generation.

A large number of beetles were reared from these females, mated with *bipunctata* males, in order to determine whether they were pure strains and what variation might appear. From one of these pairs (Figure 1), 54 beetles were reared in the first generation, all exactly resembling the father and mother, and 71 in the second generation, all true to type except 3, one of which was smaller spotted and two which possessed the lateral dot and lacked the basal white on the pronotum, and had the elytral spots ragged in outline with a slight projection or dot mesad and surrounded by a yellowish halo. From another of these females (Figure 2) mated with the same male there were produced in the first generation 23 beetles exactly resembling the parents, in the second generation, 16 beetles showing exactly the same characters. Another female (Figure 3) with the same male as above produced in the first generation 18 beetles, all normal. Another *bipunctata* female with a *bipunctata* male (Figure 4) produced 39 beetles in the first generation, all true to type, and 15 in the second generation, also true. A number of the first generation from this beetle were put with a number of the first generation from the first mentioned beetle (Fig. 1) and 11 beetles resulted, all apparently typical *bipunctata*. Still another pair of these beetles (Fig. 5) produced in the first generation 9 beetles like the parents excepting that 2 have slightly smaller spots, in the second generation 4 beetles all typical.

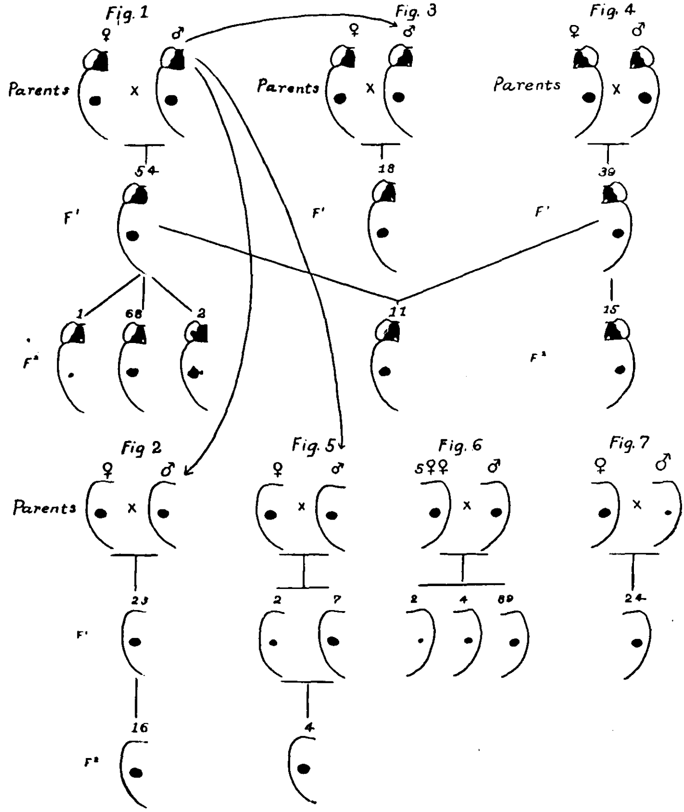


Fig. 1. Pair of *bipunctata* beetles, from Iowa, and their progeny.
Fig. 2. Pair of *bipunctata* beetles, from Iowa, and their progeny. (Male same as Fig. 1.)
Fig. 3. Pair of *bipunctata* beetles, from Iowa, and their progeny. (Male same as Fig. 1.)
Fig. 4. Pair of *bipunctata* beetles, from Iowa, and their progeny.
Fig. 5. Pair of *bipunctata* beetles, from Iowa, and their progeny.
Fig. 6. Five *bipunctata* females and 1 male, from Iowa, and their progeny.
Fig. 7. One female from Fig. 6 mated with a *bipunctata* male, from Colorado, and progeny.

One of these *bipunctata* females (Figure 8) previously unfertilized, mated with the same *annectans* male, as had been offered without result to the above females, produced in the first generation 3 *bipunctata* beetles with moderately small spots. One of these, a female, was mated with its *annectans* father and produced 3 small-spotted *bipunctata* and 2 typical *annectans*. Another of this lot of first generation females was mated with an *annectans* male from out of doors (Figure 9) and the first egg patch resulted in 3 *bipunctata*, 2 fairly small-spotted and one with a dot mesad of the elytral spots. The second egg patch gave 1 *bipunctata* normal, 1 *bipunctata* with spots reduced to dots, and 1 *annectans*. The original female (Figure 8) was then mated with a small-spotted *bipunctata* male (Figure 11) and 16 large-spotted *bipunctata* resulted.

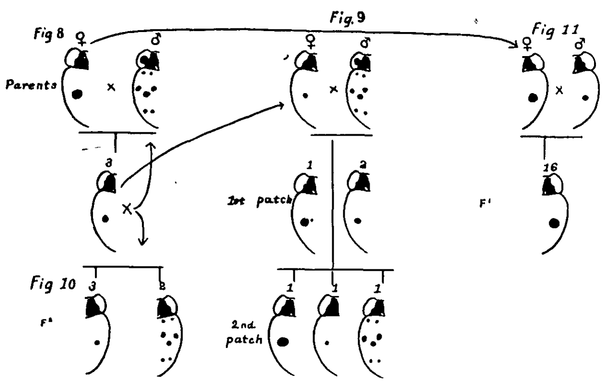


Fig. 8. *Bipunctata* female from Iowa mated with *annectans* male, and progeny.
Fig. 9. Female of F¹. generation of Fig. 8 mated with *annectans* male, and progeny.
Fig. 10. Female of F¹. generation of Fig. 8 mated with *annectans* male (father).
Fig. 11. *Bipunctata* female of Fig. 8 mated with *bipunctata* male from Colorado.

The 5 other females from Iowa were put together in one cage with a *bipunctata* male (Figure 6) and from the eggs 95 beetles were reared, all *bipunctata*, 2 small-spotted, 4 medium-spotted, and the rest of the same size of spots as the parents. One of the females was separately mated with a *bipunctata* male with small spots (Figure 7), and there resulted 24 *bipunctata* with spots the same size as the mother.

From the *bipunctata* beetles taken in Colorado there were also a considerable number of beetles reared. These were taken in Denver on two occasions, ten on April 19th by Mr. L. C. Bragg, and three on April 28 by Prof. C. P. Gillette. The first lot consisted of 6 females and 4 males and the second lot were all males and small-spotted. From one female (Fig. 12) mated with a *bipunctata* male 29 beetles were reared in the first generation, all apparently normal except that one was smaller-spotted, and 6 in the second generation, all apparently normal *bipunctata*. Another female (Figure 13) mated with a *bipunctata* male produced in the first generation 11 beetles, 4 with spots the same size as the parents and 7 smaller-spotted and in the second generation 16 beetles like the grand-parents.

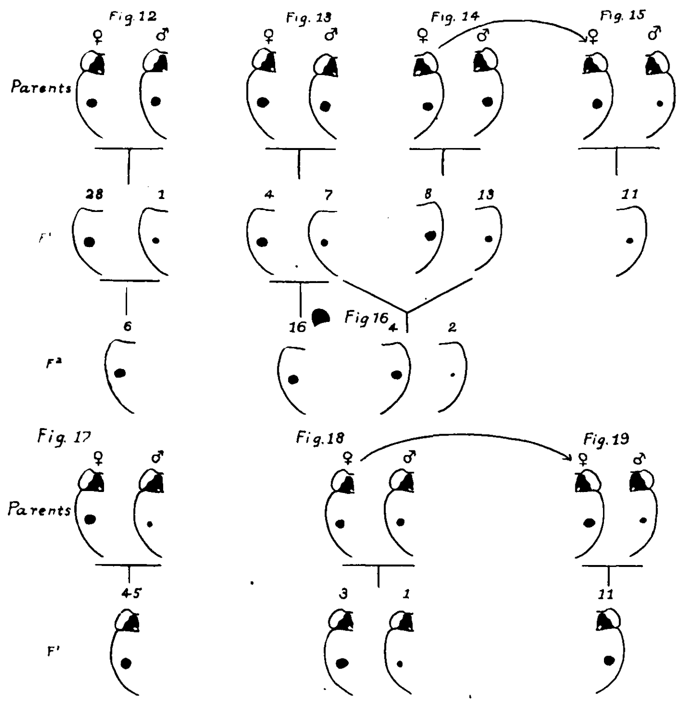


Fig. 12. Pair of *bipunctata* beetles from Colorado, and progeny.
Fig. 13. Pair of *bipunctata* beetles from Colorado, and progeny.
Fig. 14. Pair of *bipunctata* beetles from Colorado, and progeny.
Fig. 15. Pair of *bipunctata* beetles from Colorado, and progeny, (female the same as Fig. 14).
Fig. 16. Progeny of $F^1$. or $F._1$ of Fig. 13 and 14.
Fig. 17. Pair of *bipunctata* beetles, from Colorado, and progeny.
Fig. 18. Pair of *bipunctata* beetles, from Colorado, and progeny.
Fig. 19. Pair of *bipunctata* beetles, from Colorado, and progeny, (female the same as Fig. 18).

Another female (Figure 14) mated with a large-spotted male produced in the first generation 21 beetles, 13 more or less small-spotted and 8 fairly large-spotted. This female was then mated with a small-spotted male (Figure 15) from Denver and from this union 11 *bipunctata* were produced, all rather small-spotted. From a cage containing the small-spotted beetles of the first generation of the last two females (Figures 13 and 14) eggs were reared (Figure 16) which resulted in 6 *bipunctata*, 2 of which had *very* small spots. From another pair (Figure 17) there were reared 45 large-spotted *bipunctata* in the first generation. Another of these females, (Figure 18) mated with a *bipunctata* male medium-spotted, produced *4 bipunctata*, 3 normal and one rather small-spotted; mated later (Figure 19) with a small-spotted *bipunctata* male it produced 11 beetles, all with good-sized spots.

All of these *bipunctata* beetles were evidently pure strains, as no other forms appeared in the progeny though large numbers were reared and most were carried through the second generation. The size of the spots evidently varies and seems to act merely as a fluctuating variation, though it appeared oftener in some strains than in others. It probably acts the same as the size of the spots in *annectans* discussed in the former paper of 1911. The marking on the pronotum, too, seems to vary so that the white lateral area may be broken into (Figure 1), so as to form the black lateral dot.

In the early part of May an *annectans* female (Figure 20) was taken on the campus and soon laid a patch of eggs, fertilized before capture. From this egg patch there developed 16 beetles, viz., 3 *annectans*, 4 *melanopleura* with white area on the pronotum, 2 *melanopleura*, normal, with lateral dot on the pronotum, 4 *bipunctata* with very small spots, and 3 *coloradensis* with considerable variation, 2 with the typical white area on the pronotum and one with it broken by a black lateral dot, more posteriorly placed than in *annectans*. A few second generation individuals were reared from most of these forms. The *annectans* beetles produced 1 *annectans*. The *melanopleura* with white area mated with each other, produced 3 normal *melanopleura* with lateral dot; one of the males mated with an *annectans* female produced 4 beetles, 2 *annectans* and 2 normal *melanopleura* with lateral dot. These results seem to signify that the lack of the lateral dot may occur in *melanopleura* as a fluctuating variation, as these specimens could not have been influenced by the other element of the hybrid as they were either *annectans* or else *humeralis* hybrids, both of which have always proved to be recessive to every character of *melanopleura*.

*The bipunctata* specimens produced 1 *annectans* and 1 *humeralis*, which signifies that there were two kinds of *bipunctata* hybrids, viz., both *annectans* and *humeralis*. One pair of *coloradensis* specimens, one with white area and one with

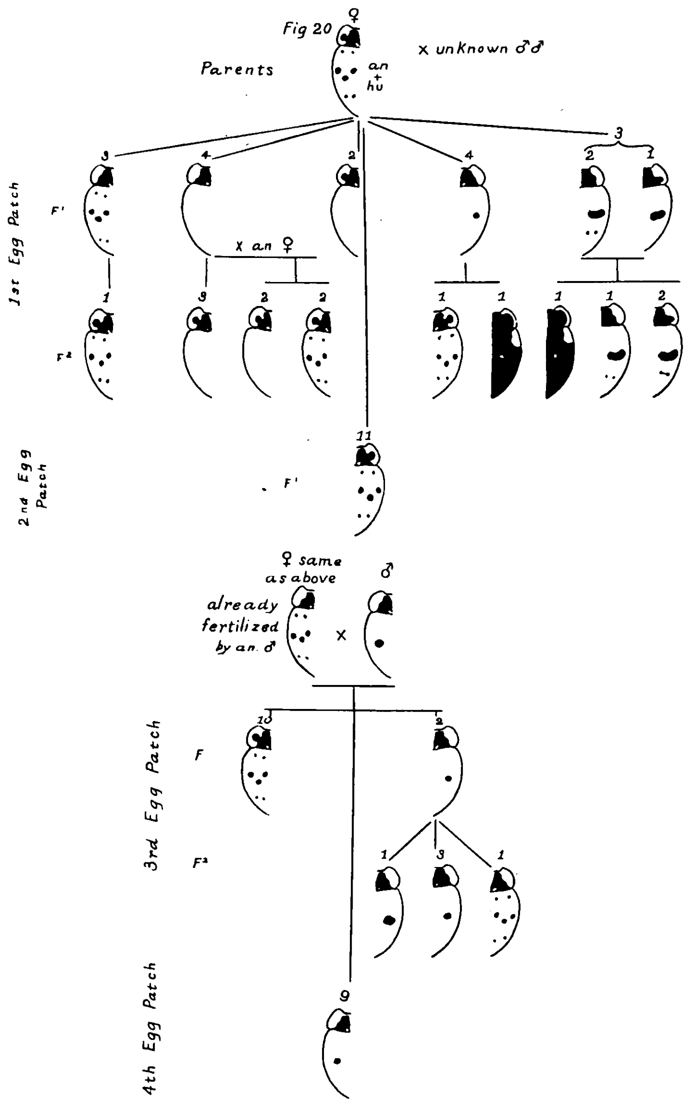


Fig. 20. *Annectans* female captured out doors, already fertilized, and progeny, 3rd and 4th egg patches laid after fertilization of the female by a *bipunctata* male taken in Colorado.

posterior lateral dot, produced 4 beetles, 1 *humeralis* and 3 *coloradensis;* 1 of the latter with white area and 2 with posterio-lateral dot. This dot seems in this case to be a fluctuating variation, for the appearance of the *humeralis* in the progeny proves the parents both to have been *coloradensis* hybrids with *humeralis;* in other words, each presented a single strain of *coloradensis* and neither one seems to be a Mendelian dominant. Evidently from these last two cases, the *annectans* mother of all these must have been an *annectnas humeralis* hybrid and must have been mated with several males very nearly at the same time. These males must have born *annectans*, *melanopleura*, *bipunctata and coloradensis.*

After 9 days the above female laid another patch of eggs from which 11 beetles were reared, all *annectans*, which seems to signify that the *annectans* male was the last one which mated with the female and the most of the eggs in the first patch had already been fertilized by the former males. The second patch, however, was fertilized entirely by the *annectans* male, the fresher spermatozoa evidently taking precedence over the older ones.

This female was then mated with a *bipunctata* male and the next egg patch, laid within 3 or 4 days produced in the first generation 10 *annectans* and 2 *bipunctata* with small spots, in the second generation from the *bipunctata* beetles there were reared 1 normal *bipunctata*, 3 with fairly small spots and one *annectans*.

A fourth patch of eggs laid 6 days later was reared and 9 beetles matured, all *bipunctata* with small spots. These beetles emerged during the latter part of June, but up to the 15th of August, when the experiment was discontinued, they had neither laid any eggs nor been seen in copulation. They were, however, seemingly in perfectly healthy condition and probably would have hibernated and laid in the spring, or they might have begun breeding September 1st. The latter supposition is based on the theory that the inactivity may have been due to the period of cessation during July and August mentioned by D. E. Fink in his bulletin 1915 of the Virginia Experiment Station. A period of great difficulty in rearing *Coccinellids* at this season of the year has been noted in Colorado by the writer, but has been heretofore attributed rather unsatisfactorily to various other causes.

In this case every one of the forms under consideration appeared from the eggs of a single female, but hybrids of *bipunctata* were discovered only with *annectans* and *humeralis*.

On the 25th of May an egg patch was obtained from another *annectans* female (Figure 21), taken out of doors already fertilized. Though, for 5 days before laying the eggs, it had been mated with a *bipunctata* male, the one used in Figure 1, 2, 3, and 5, no trace of *bipunctata* appeared in the progeny. Thirteen beetles matured, 3 *annectans*, 4 normal *melanopleura* with lateral dot, 3 *melanopleura* with white area, and 3 *coloradensis* with a lateral dot placed more posteriorly than the

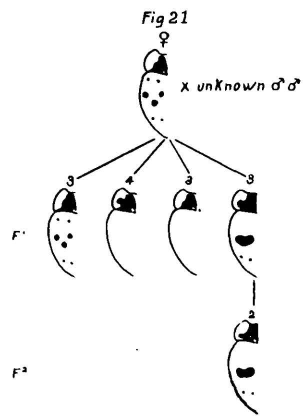


Fig. 21. *Annectans* female captured, already fertilized, and progeny.

lateral dot of the other forms. In the second generation from the *coloradensis* cage, 2 beetles were reared and they were both *coloradensis* with the posterior lateral dot.

Judging from this case together with the similar results with the *coloradensis* progeny of the former *annectans* female, it is evident that *coloradensis* often possess a lateral dot, more posteriorly placed than in other forms, instead of the broad white area as given in the former paper of 1911. Both these patterns are mentioned in the original description by Casey. The above-mentioned lateral dot seems in this case to have bred true, but considered with the case in Figure 20 it can hardly be considered more than a fluctuating variation, since in that case a pair of *coloradensis humeralis* hybrids, one with the dot and one with the white area produced progeny both with and without the dot.

Conclusions: (1) *Bipunctata-annectans* hybrids were formed both in the laboratory and in state of nature. More difficulty was experienced, however, in securing crosses than in the previous experiments with only the native forms, but this may have been partly accidental. They would mate readily enough, but in only comparatively few instances were the eggs affected. The hybrids when formed seemed just as healthy and fertile as the other hybrids.

(2) *Bipunctata-humeralis* hybrids were formed out of doors and these, too, were fertile.

(3) The appearance of the *bipunctata-annectans* and the *bipunctata-humeralis* hybrids was identical in these cases. *Bipunctata* dominated completely in the markings of the pronotum and also in the spots of the elytra unless the smaller size of the spots was a modification. The spots were no smaller though than those that occasionally appeared in what seemed to be pure strains of *bipunctata*. Evidently in the *bipunctata-annectans* hybrid the size of the spot is determined by the marking of the smaller spotted parent, black being recessive in these beetles (see paper of 1911). Except in rare cases the smaller spotted parent is most liable to be *annectans*. Since *bipunctata* seems to be small spotted in some cases there is no constantly reliable character whereby to distinguish the hybrid except that it is very likely to be more or less small-spotted.

Why the size of the spot should be reduced in the *bipunctata-humeralis* hybrids is far from clear. In these experiments it could hardly have been due to mere fluctuation of the *bipunctata* element or the results would not have been so constant. For example: In the case of Figure 20, first, third and fourth egg patches 15 hybrids were obtained from the *annectans-humeralis* female crossed with a *bipunctata* male. The chances are that half of these were *bipunctata-annectans* and half were *bipunctata-humeralis* hybrids, which should be enough to show some variation, but the dot seems to be of practically uniform size in all.

(4) *Bipunctata*, in the hybrid form, was reared from the same patch of eggs as were also *melanopleura* and *coloradensis*, and this seems very good if not indeed, conclusive evidence that they are able to interbreed with these forms too, though the exact hybrids were not all produced.

(5) In *melanopleura*, *coloradensis* and *bipunctata* there were discovered variations in the markings of the pronotum, viz.: in all these forms the lateral dot may be either present or absent. So *melanopleura* with the white area on the pronotum are not necessarily *melanopleura-coloradensis* hybrids as supposed in the paper of 1911 or *melanopleura-bipunctata*, as might be expected. Vice versa, since *bipunctata* sometimes possess the lateral dot it would not be surprising to find *melanopleura-bipunctata* hybrids bearing it and so not differing in appearance from typical *melanopleura*. The lateral dot in *coloradensis* being differently placed and not coinciding with the regular dot, the white area would be expected to appear in the hybrid.

In *melanopleura* the presence of the lateral dot is infinitely the more common form, in *coloradensis* it seems to be rather uncommon, and in *bipunctata* it is extremely rare.

In 1914 a second article was published by the writer in the Annals of the Ent. Soc. of Am. entitled "Some Notes on Life History of Ladybeetles." As the writer had not then taken *bipunctata* in Colorado, it was not included in those experiments. In order to complete this record a few life history notes were taken on this species in connection with the foregoing experiments.

Life cycle records were taken as follows:

Egg stage (6 records) 3–7 days.
Larva stage (2 records) 9–10 days (in hot weather).
Pupa stage (2 records) 4–5 days (in hot weather).
Egg to adult 16–30 days.

Adult stage; no records taken except on hibernating beetles, a number of which lived and mated and laid eggs in the laboratory until August 15, when the experiment was discontinued and they were killed and pinned up. Judging from this the hibernating form must be able to live 12 months more or less. The life cycle records vary greatly according to the temperature of the weather. In the spring each stage took about twice as long as in the warmest part of the summer with the thermometer from 87 to 93 degrees.

One satisfactory egg record was taken and in 3 months and 15 days this female laid 1,180 eggs. The beetles laid from 12 to 35 eggs in a patch and would sometimes lay 2 patches a day and would also often skip several days and then lay again.

Before being fertilized the beetles would lay only a few scattered eggs but in a day or so thereafter they would lay plentifully and in good patches. Fertilization seemed to last several weeks, but not for the season. One female observed was found to be laying infertile eggs 35 days after being isolated from a male. The spermatozoa of the later male seem always to take precedence over all former, so that the eggs which have not been already fertilized produce the characters of the last male. The earliest egg patch was obtained April 1st and the earliest beetles emerged May 1st.

A few feeding records were taken on both *bipunctata-annectans* and *annèctans* larvae. These were taken in very warm weather, the thermometer being 87° to 93° each day. The larvae, accordingly ate their maximum and finished their life cycle in the minimum time. In colder weather they ate much less per day and the period of development was according prolonged. These experiments were conducted with the greatest care. The larvae were put into separate cages and the lice which were given for feed were counted as carefully as possible. Young of *Myzus circumflexus* were used for the first feed in each instance and after that *Chaitophorus negundinis* was used entirely. A check tube was kept to ascertain the number of lice dying naturally in a day, but it seemed to be of little account, as practically no lice seemed to die except from some disease or from capsid injury, and this turned the dead bodies brown, so that they could be easily distinguished in the larval cages. Some of the larvae had already filled up on the unhatched eggs of their patch before isolation, which of course did not count in the food record, also whenever there was any doubt as to the number of lice eaten the smaller alternative was taken. The young lice that may have been born after being put in the cage were not regarded, as they would not increase the bulk materially. The only difference they could make would be to add to the number left over and subtracted, which would reduce the number in the record, instead of exaggerating it. In these ways every precaution was taken against getting too large a count. The records are as follows:

| | | | | | | | | | | | | Length | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total | Larva | Adult |
| bi. larva | H | 10 | M 7 | M 45 | 23 | M 60 | 100 | 80 | P | | 325 | 7 mm. | 5 mm. |
| " " | H | 5 | M 8 | M 30 | 50 | M 95 | 92 | 100 | 30 | P | 407 | 6.9 mm | 5 mm. |
| an. larva | H | 5 | M 8 | M 43 | M 18 | 84 | 72 | 4 | P | | 234 | 7 mm. | 4.9 mm. |
| " " | H | 10 | M 13 | M 30 | 37 | M 38 | 94 | 100 | 7 | P | 323 | 7 mm. | 5 mm. |
| " " | H | 2 | M 16 | M 23 | M 46 | 67 | 75 | 0 | P | | 243 | 7 mm. | 4.5 mm. |

H—hatched. M—molted. P—pupated. bi.—bipunctata. an—annectans.

The *bipunctata* specimens in this experiment were really *bipunctata annectans* hybrids.

The *annectans* larvae, it will be observed, have eaten less than the *bipunctata* individuals, but this is probably only accidental, as the larvae of the same species seem to vary greatly, and these specimens were all the same size, and should therefore be of equal capacity. It is interesting to notice that the one that ate the most lice was slightly the shortest when full grown.

These results seem to differ somewhat from those given by Mr. Clausen, in California, in his paper of 1916.* The difference is probably due to climatic conditions influencing the rapidity of development, as the totals, it will be seen, do not differ any more from these results than has been found as a common variation between individuals of the same species even under the same conditions. During the spring when the weather was cool the beetles ate much less per day and the life cycle periods were much longer. Though no counts were made at this time there is no doubt but that they would not disagree materially with the records of Mr. Clausen.

Perhaps the following observation on *Hippodamia convergens* might also be added. On July 18, 1916, this species was found by the writer congregated in heaps of hundreds in grassy crevices in the solid granite top of a foot-hill, 38 miles north-west of Ft. Collins, at an altitude of a little over 8,000 feet.

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*Life-history and Feeding Records of a Series of California Coccinellidae by Curtis P. Clausen, University of California Publications, Technical Bulletins Entomology, Vol. I, No. 6, pp. 251–299, June 17, 1916.

Two other such cases were reported during the same summer and fall, about ten and fifteen miles from Ft. Collins, the one on the granite top of Horse Tooth Mountain, altitude 7,160 feet, and the other at about the same elevation. In the latter case the beetles were said to be massed on a small pine tree. Another mass was reported to have been found on a bare mountain-top west of Denver at about the same time of year as the former instances. In March, 1917, on the plains two miles west of Ft. Collins, Mr. L. C. Bragg observed hundreds of *convergens* coming out from hibernation from under rocks and stones near the road side.