THE MEDITERRANEAN FLOUR MOTH

(*Ephestia kuehniella Zell.*)

IN

EUROPE AND AMERICA.

APPENDIX

TO THE

Nineteenth Report of the State Entomologist

OF ILLINOIS.

By W. G. JOHNSON, A. M.,

ASSISTANT ENTOMOLOGIST.

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PREFATORY NOTE.

The following article by Mr. Johnson, one of the entomological assistants of the State Laboratory of Natural History, detailed for service in the office of the State Entomologist, contains in part results of work done by him as a graduate student of Stanford University before his connection with this institution, and written up as a thesis for the master's degree. Much of his time has been given to the subject, however, since his engagement here, and a large part of the present paper is based upon results of this later work.

Although the Mediterranean flour moth has not yet been found to infest any mills in this State, its distribution in our vicinity makes it practically certain that it will eventually appear within our limits, and a comprehensive article on it is consequently even more timely than it would be if withheld until after the threatened invasion were an accomplished fact.

It is of great consequence to every miller that he should be not only forewarned of his liability to serious annoyance and heavy loss by the work of this worst of the pests of the flouring mill, but that he should also be thoroughly forearmed with information as to the signs of its presence, the characteristics by which it may be unmistakably recognized, and the measures of prevention and destruction to be used against it.

I have gladly availed myself, therefore, of this opportunity to put the millers of this State and of the country in possession of the essential facts, and to have compiled for the benefit of the working entomologist a complete review of the history and results of previous studies of this insect pest.

S. A. Forbes.

THE MEDITERRANEAN FLOUR MOTH (*Ephestia kuehniella* Zeller) IN EUROPE AND AMERICA.

By Willis Grant Johnson, A. M.

INTRODUCTORY.

Insect injuries in flouring-mills have been known from time immemorial, but not until recent years have they attracted public attention. The mild and equable temperature which is maintained in the modern mill is highly favorable to the development and multiplication of those pests commonly called "mill insects." The most formidable enemy in this group is the Mediterranean flour moth, *Ephestia kuehniella* Zell., an insect unknown to American millers less than seven years ago. The discovery of this terrible scourge in Canada in 1889, in California in 1892, and in New York and Pennsylvania in 1895, has awakened a keen interest in the subject among millers and scientific workers.

Its discovery in California in March, 1892, led me to a careful examination of all available literature on the subject. I found this material so scattered that I have deemed it advisable to bring it together and to embody it substantially in this paper which covers my own observations and experimental work on this insect. Most of these observations were made in California, where also a large part of my experimental work on life history and methods of destruction was carried on. Much additional information has, however, been gained by experimentation and correspondence since my connection with the Illinois State Laboratory of Natural History.

I wish to express here my thanks to Mr. L. O. Howard, U. S. Entomologist, Washington, D. C., through whose kindness I obtained Figures 1, 2, 3, and 5 from the U. S. Department of Agriculture. I also beg to acknowledge, with thanks, the kindness of Mr. James Fletcher, of the Department of Agriculture of Ottawa, Canada, in furnishing me with his exhaustive reports containing articles on this subject, and the courtesy of Dr. P. H. Bryce, Secretary of the Provincial Board of Health of Ontario, Canada, in sending me his excellent Bulletin and circular letter on the flour moth. I am also indebted to Miss E. A. Ormerod, late Consulting Entomologist of the Royal Agricultural Society of England, for her complete accounts of the moth in England; and to Mr. J. Danysz, Director of the Laboratory of Parasitology and of the Cham-

ber of Commerce, Paris, France, for his exhaustive and most important paper on this subject. I desire also to acknowledge here, with thanks, the help and coöperation I have received from the millers of California, New York, Pennsylvania, and Canada; and, finally, to express my appreciation of the favors received from Professor S. A. Forbes, Director of the Illinois State Laboratory of Natural History and State Entomologist, through whose kindness I am able to publish this article in its present form.

The names of all individuals and of firms on whose premises this pest is known to exist, have been omitted by special request, and I have carefully kept the confidence reposed in me. Such suggestions are offered as my experience warrants, and I trust this paper will enable all those interested to become better acquainted with this ravenous pest, and with measures for its control. In discussing the latter I have confined myself to methods which have been tested in large mills.

Before taking up my subject in a formal way it may be well to give, in a paragraph, a brief summary of the life history and habits of this insect.

The small gray moth, with a wing expanse of about seven eighths of an inch, is a sluggish insect, often remaining for hours in one position. The female usually deposits her eggs in spouts and elevators, or on piles of flour in bags, but they may be found in every conceivable place about a mill where there is sufficient food for the larvæ. The eggs hatch in about nine days, and the larvæ feed from five to seven weeks. It is during this period that the mischief is done. The larvæ have a peculiar habit of trailing a silken thread wherever they go, and this waste silk, mixed with flour and dust, often clogs the spouts to such an extent as to stop the machinery. About nine weeks are required for the transformations of the insect, reckoning from the time of the deposition of the egg to the emergence of the adult. It breeds continuously in warm mills, where the temperature is constant, and from four to six broods appear annually. It is usually disseminated in manufactured products, or on empty bags and second-hand machinery. It is comparatively free from the attacks of natural enemies, and when once established in a mill can be checked only by absolute cleanliness and the free use of bisulphide of carbon, sulphur, or steam.

ZOÖLOGICAL POSITION.

There has been much dispute among systematists regarding the zoölogical position of this little moth, and its name has consequently been the subject of much discussion. It belongs to the family of moths known as Phycitidæ, and was first given a scientific name in 1879, since which time it has been known as *Ephestia kuehniella*—a name given it by Prof. Zeller in honor of Prof. Kühn, Director of the Agricultural Institute of the University of Halle, Germany.

Mr. W. H. Patton, of Hartford, Conn., is responsible for the statement* that Dr. F. Karsch has shown that *kuehniella* and *interpunctella* are only dimorphic forms of one species. In 1884, Dr. Karsch gave it as his opinion† that *Tinea zeæ* of Fitch might prove to be a variety of *kuehniella*; and in an article in "Insect Life" for November, 1890,‡ under the caption "Notes upon *Ephestia interpunctella* (Hübn.) Zeller," Mr. Patton gives both *E. kuehniella* and *T. zeæ* as synonyms of *E. interpunctella*. Under the head of "Special Notes," the editors of "Insect Life" (l. c. p. 134) strongly dissent from Mr. Patton's conclusions, stating that they long since adopted *zeæ* as a synonym of *interpunctella*, but that they now fully believe in the distinctness of *kuehniella*, though inclined earlier to a different opinion.

Mr. Geo. D. Hulst, in his monograph of the Phycitidæ of North America,¶ has placed *interpunctella* in the genus Plodia, and left *kuehniella* under Ephestia. The main difference between the two genera, as indicated by Mr. Hulst, is that in Ephestia the palpi are erect, while in Plodia they are porrect.

Mr. Ragonot has shown§ that Mr. A. W. Scott's *Hyphantidium sericarium* evidently belongs to the genus Ephestia and, according to the description, closely resembles *kuehniella*; and he is of the opinion that the former will prove identical with the latter species, since its larval habits are precisely the same. For the present, however, Mr. Ragonot is content to let the species remain as *Ephestia sericaria* (Scott).

Mr. Hulst says (l. c., p. 199) that he has specimens from New Mexico which connect *Ephestia fuscofaciella* Ragonot with *E. kuehniella*, and he is of the opinion that the former may prove only a variety of the latter.

SPECIFIC CHARACTERS.

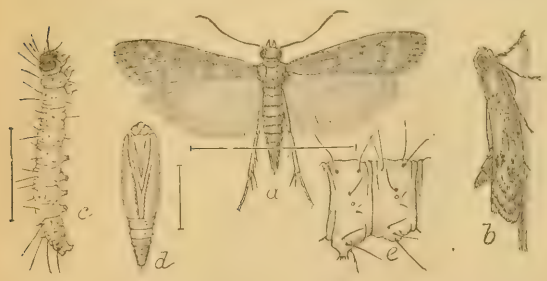

FIG. 1. *Ephestia kuehniella*:—*a*. moth; *b*. female moth, from side, resting; *c*. larva; *d*. pupa; *e*. abdominal joint of larva,—all enlarged, the hair lines representing the natural size. (*b*, *c*, *e*, from "Insect Life;" *a* and *d* after Chittenden).

Ephestia kuehniella (Fig. 1, *a* and *b*) is a delicate moth, from 10 to 14 mm. in length, with a wing expanse varying from 18 to 22 mm.** (about seven eighths of an inch). The females are, as a rule, larger than the males, but the general color and markings on the wings are the same in both sexes. Labial palpi blackish gray; head and thorax some-

*Insect Life, Vol III., p. 158.
†*Entomologische Nachrichten*, May, 1884.
‡Vol. III., p. 152.
¶Trans. Am. Ent. Soc., Vol. XVII., pp. 93-228.
§Ann. Ent. Soc. France (Bull.), 1892, p. CCLXXIV.
**Mr. Hulst gives 24-26 mm. (Trans. Am. Ent. Soc., Vol. XVII., p. 198.)

what lighter; abdomen the same color, with an ocher shade. Front wings medium gray, sprinkled with blackish scales, crossed near the tips by two wavy angular blackish lines; a W-shaped transverse line about one third the way from the base; a black dot in the center, which is sometimes double. (See Fig. 2, *g.*) The hind wings are semi-transparent, of a silvery luster, with a darker border. Both pairs of wings are heavily fringed. (See Fig 1, *a.*)

Fig. 2.—Principal markings and venation of wings. (After Snellen.)

The egg, plainly visible to the naked eye, is elongated oval in outline; greasy whitish in color when first laid, becoming darker as the embryo matures within; and varies considerably in length and breadth, as shown by the following measurements made from four different lots of eggs:

First lot, laid April 12, 1895—Length, 0.432 mm.; breadth, 0.204 mm.
Second lot, laid April 17, 1895—Length, 0.480 mm.; breadth, 0.240 mm.
Third lot, laid May 5, 1895—Length, 0.408 mm.; breadth, 0.228 mm.
Fourth lot, laid June 19, 1895—Length, 0.444 mm.; breadth, 0.216 mm.

This variation in size occurs also in eggs of the same lot. The general average length is 0.441 mm., and the breadth 0.222 mm. The surface is irregular and has a crumpled appearance.

The larva (Fig. 1, *c*) when first hatched is very small, being only 1.083 mm. long, with a body diameter of 0.19 mm; head slightly larger, measuring 0.247 mm.; flesh-colored, varying from a whitish to a pinkish tint; head reddish brown; legs and prolegs a little lighter colored than body; body sparsely hairy, hairs longest on the posterior segments, often measuring there 0.342 mm., but about 0.114 mm. on the other segments. When full grown the larva varies from 12 to 14 mm. in length; form cylindrical, somewhat slender, with a rather uniform diameter of about 2 mm.; color as earlier, the pinkish tint more pronounced in some than in others. Three pairs of true legs, and a well-developed caudal pair; abdominal legs long, cylindrical, with a circular fringe of hooklets at the crown. Piliferous warts black or brown, rather minute but prominent; lateral ones more conspicuous in front of the first spiracle, the subdorsal ones, one each side of the mesothorax, almost completely encircled by a narrow black ring interrupted only at its upper margin. Each segment has six bristle-bearing dots, four of which are conspicuous and two smaller; a transverse reddish-brown patch on the segment next the head, divided, from front to back, by a faint central line; surface of body rather smooth.

The chrysalis (Fig. 1, *d*) varies from 9 to 10.5 mm. in length, and from 2.5 to 3 mm. in width. Reddish brown above, the head and thorax being darker than the rest of the body, much lighter below, the shade becoming lighter from the head back, approaching a yellowish tint on the wing-pads and abdomen; posterior part slightly curved and cylindrical; tip of the last segment considerably darker than the rest of the body and furnished with 9

or 10 stout brownish bristles, with their points curved, encircling the margin of the upper surface. Eyes prominent, usually of the same color as the head but sometimes darker; spiracles distinct.

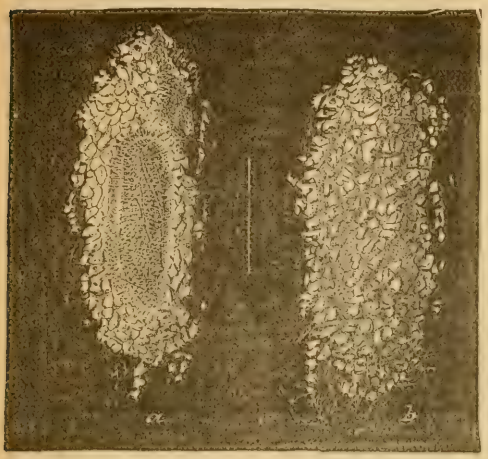

FIG. 3.—*a*, cocoon from below, showing pupa through the thin silk attaching the cocoon to a beam; *b*, same from above. Enlarged. (From "Insect Life")

The cocoon (Fig. 3, *a* and *b*) varies in length from 10 to 14 mm., and from 4 to 6 mm. in width. It is composed of very delicate whitish silk spun by the larva, and is often intermingled with particles of meal, flour, dirt, or other material. It is perfectly smooth within, and is usually attached to some surface by a very thin layer of silk, so that the pupa can be plainly seen when the cocoon is removed from its place of attachment, as represented in the accompanying illustration.

GENERAL REVIEW.

Although this moth was first discovered in a flouring-mill in Germany in 1877, it was not made known to science until 1879, when Prof. Zeller noted the outbreak and described and named the species (1)* from specimens from the infested mill, sent him by Prof. Kühn, Director of the Agricultural Institute, University of Halle, Germany. Prof. P. C. T. Snellen refers to this paper of Zeller's in 1881 (2).

The insect was next observed in a noodle factory in Belgium in 1884, and was reported by Mr. Alfred Preudhomme de Borre, July 5 of the same year (5). He supposed it to have been introduced into that country with American cereals. Many substances were used to rid the mill of the infestation, but they proved useless. The most noticeable improvement in the situation resulted from scrupulous cleanliness.

In May, 1884, Mr. Maurice Girard read a paper before the Entomological Society of France (3) on the ravages of the flour moth, which had appeared in a flouring-mill at Lodelinsarte, Belgium, and gave a short description of the adult insect and larva. In the discussion which followed this paper Mr. E. L. Ragonot said that he had in his collection specimens of *Ephestia kuehniella* from North Carolina, Mexico, and Chili. In this same year Dr. F. Karsch, in an article entitled "*Ephestia kuehniella*, Zeller: Eine Nord Amerikanische Phycide am Rhein," (4) notes the appearance of this moth at several places along the lower

* The full-face parenthetical figures in this paper refer to the bibliographical list appended.

Rhine. The ground color of the front wings of the typical specimens bred by Zeller was pure yellow or nearly brownish, while those bred by Karsch were glossy lead-gray, but Karsch considers them one species. The only moth he found in American literature that approached *kuehniella* was Fitch's *Tinea zeæ*, which is the same as *Plodia interpunctella*; but Fitch's description of the latter species did not agree with that of Zeller's species. Dr. Karsch thought, nevertheless, that *zeæ* might prove to be a variety of *kuehniella*.

In an editorial note in the *Entomologische Nachrichten* for 1885 (pp. 46, 47), the statement is made that this pest had appeared in some mills near Bremworde. The burning of sulphur and the application of bisulphide of carbon were found useless, and the mills were stopped and thoroughly cleaned. It is asserted that the insect, in that locality, is of American origin, and was introduced with American wheat. The same periodical, for the same year (pp. 239, 240), contains another note, reviewing a communication from Prof. Landois to the *Braunschweiger Tageblatt*, in which the statement is made that this pest is by far the most annoying and dangerous insect affecting wheat or flour.

Professor P. C. T. Snellen published in 1885 (7) an illustrated article of considerable importance on this insect, which included a summary of Prof. Zeller's article already referred to, and a comparison of *kuehniella* with other European species of Ephestia.

Mr. A. Seigel, German Consul-General at New York City, being asked by some of his countrymen to find out what he could regarding *Ephestia kuehniella* in this country, and to ascertain if possible the means employed for its destruction, addressed a letter on the subject to Dr. J. A. Lintner, State Entomologist of New York, under date of February 2, 1885, who replied that he had no knowledge of the pest as an American insect, and that if it existed in the United States it was as yet unknown, as no such habits had been manifested in any of our flouring-mills by any species akin to *Ephestia kuehniella*. He refers to *Plodia interpunctella*, and suggests several remedies for the destruction of the flour moth; viz., bisulphide of carbon, sulphur, and trapping. This, I believe, is the first published statement in American literature (8) regarding this pest.

The next note I find on this insect is by Mr. W. Thompson, of Stoney Stratford, Bucks, England (9). Larvæ found feeding on rice cones were given him by a friend in October, 1886, from which moths emerged during November and December. At first the insect was thought to be *Myelois ceratoniæ* and was so reported; but specimens sent to Mr. Barrett in April, 1887, were identified by him as *Ephestia kuehniella*. In the same volume of the same journal (10) Mr. J. W. Tutt gives a short account of the feeding habits of this insect, and records the breeding of the adult moth from larvæ given him by Prof. T. D. A. Cockerell, collected originally from a cargo of flour at the London docks. In June, 1887, larvæ from this same source were exhibited by Prof. Cockerell at a meeting of the South London Ento-

mological Society. In the first published account of this exhibition (11) it is stated that the larvæ were in flour shipped from America to Trieste, and thence to London; but later (20) Prof. Cockerell states that although the larvæ just referred to were in flour from America, they were supposed to have come from some badly infested Trieste flour stored in the same warehouse.

In the same year Mr. C. G. Barrett (12) reports breeding moths of *Ephestia kuehniella* from larvæ sent him by Prof. Zeller in 1879; refers to the moths of this species sent him by Mr. Thompson for determination, noted above; and briefly describes the moth, noting ready means of distinguishing it from that of other species of Ephestia and from *Myelois ceratoniæ*.

November 2, 1887, Mr. Sidney T. Klein read notes of his observations on the habits of *Ephestia kuehniella*, at a meeting of the Entomological Society of London (13). He discovered in May a colony of these larvæ in some large warehouses in the east end of London, where the insect spread rapidly in spite of the fact that the building was fumigated with sulphur and the ceilings, walls, and floors were hot-limed. One entire warehouse was "literally smothered with larvæ, and several hundred pounds' worth of damage was done." Chickens introduced into the warehouse gorged themselves with the larvæ. Some interesting observations are reported concerning the habits of the larva, and it is said that a small hymenepterous parasite (*Bracon brevicornis* Wesm.) destroyed the pest by September. The same author gives elsewhere (14) full details concerning a lot of flour from Trieste infested with larvæ of the flour moth, referring again to the parasite, and in another connection (15) has an item concerning the introduction of the flour moth into England. The County of Middlesex Natural History and Science Society published a note by Mr. Archibald Geikie (17), in which he reported the complete destruction of *Ephestia kuehniella* by the same little braconid mentioned by Mr. Klein, figuring the male and female. He said, in substance, that he had noticed a black spot on the back of the flour moth larvæ which he had not observed before, but paid no attention to it, thinking it a normal phenomenon in the development of the insect. Some weeks later he was astonished to find on the sacks of flour, which had been covered with Ephestia larvæ, a great number of little black insects, and he was of the opinion that the black spots he had seen were nothing else than the eggs of *Bracon brevicornis*.

I will not call in question the correctness of this inference, as I know nothing about the life history of the European braconids, but will simply say in this connection that our two American species, *Bracon gelechiæ* Ashm. and *B. hebetor* Say, do not lay their eggs *within* the body of their host. I have made many observations on this point, and have always found the egg either *on* the body of the larva or attached to some material very near it. Mr. E. B. Poulton, of London, England, has, however, shown by experiment (21) that these black spots are simply testicles in the process of evolution. Mr. J. Danysz, of Paris, France, who seems to have overlooked Mr. Poulton's paper, has arrived

at the same conclusion (**55**). In my own work I have found this a very convenient method for separating the sexes of the larvæ, and in no case has it been misleading.

In 1887, Mr. R. Adkin, of London, made two contributions to the literature of the flour moth (**18, 19**) which I have not seen. In an article published in 1892 (**45**) he states that the pest is still present in England, and that it is of sufficiently frequent occurrence in granaries, mills, bakeries, etc., to be regarded as an established insect pest.

In 1889, Miss E. A. Ormerod reports the appearance of the flour moth in very destructive numbers in England (**23**) and refers (**24**) to a new outbreak in a mill in the north of England in 1888, the larvæ getting into the spouts and machinery and, by their webs, stopping the flow of the flour. Some of this infested flour was found, on examination, to be little more than a webbed mass full of living larvæ, chrysalids, and dead moths. The mill was stopped and thoroughly cleaned, steam was introduced into every part of the place, and the walls and floor beneath were washed with "paraffine" (kerosene). The owner of this infested mill thought the insect came to him in empty sacks returned from some baker, perhaps coming originally from London in this way. In 1890 (**32**) Miss Ormerod reports the pest as still present in England, in one instance being kept in check by frequent fumigation, sulphur being the chief substance used. She gives the results of some inquiries regarding the presence of this insect in other countries, with a short abstract of matter in her Twelfth Report concerning the nature of the attack. Several paragraphs are quoted from Mr. Fletcher's Report for 1889 (**29**) and from a Bulletin by Dr. Bryce (**26**), both of which are referred to on another page of this article. In her Fourteenth Report (**38**) Miss Ormerod says that the flour moth may be regarded as thoroughly established in England and quietly extending itself, and that it is still doing serious damage in the mills from which it was first reported, although expensive preventive measures have been taken to keep it in check. The fact that this insect is present in widely distant parts of England is evidence of the root the insect has taken in that country.

There is no record of damage by this pest in North America prior to 1889, at which time it appeared in destructive numbers in a large flouring-mill in Ontario, Canada. The owner tried every means known to him to destroy the insect, but every effort failed, and he finally appealed to Mr. James Fletcher, Dominion Entomologist, for help. The matter was then brought officially before the notice of the Ontario Government, and the investigation was placed in the hands of Dr. P. H. Bryce, Secretary of the Provincial Board of Health of Ontario, who published the results of his investigation (**26**) in October, 1889.

The manager of the mill suspended work, and took down the machinery and subjected it to steaming. The whole mill was then thoroughly cleaned and fumigated with sulphur; the walls and ceilings were scraped and swept; elevator spouts, loose wooden

work, paper bags, and many hundred dollars' worth of goods were burned; elevator cups and belts were boiled for hours in water; and those parts of the machinery not easily accessible, were flamed by means of a kerosene torch. All this was not sufficient, and September 19 the Local Government passed an Order in Council, compelling the manager of the mill to take more stringent steps for the suppression of the pest. In compliance with an order from Dr. Bryce, the miller constructed a tight steam box and subjected every piece of machinery, even millstones and iron rollers, to a thorough steaming. After two months' loss of time, and loss of fixtures and machinery, the mill started up again.

In his Bulletin (**26**), Dr. Bryce gives details concerning the habits and appearance of this insect in its various stages, and adds an account of its depredations in the past, drawing largely from Miss Ormerod's Twelfth Report. He suggests preventive and remedial measures in case the moth appears again in other mills.

Mr. Fletcher accompanied Dr. Bryce a part of the time during these investigations. They visited many stores and mills to find out whether the moth had spread, but in one case only was the insect found, and here, only such quantities of farinaceous foods were kept as would be sold out during the week to consumers. In his Report for 1889 (**29**), Mr. Fletcher says, "There was a general opinion among all those visited, that this insect was only the ordinary meal worm, *Asopia farinalis*, which may generally be found in small numbers in neglected meal or flour barrels, but which seldom does sufficient harm to be classed as an injurious insect." He further adds that "the present species may be considered a much more formidable enemy, and if allowed to multiply and spread through our large American flouring-mills, will be a calamity of enormous magnitude." A few months later the state of affairs in the infested mill was found to be very serious. Mr. Fletcher gives a brief summary of recent literature on this insect, with Dr. Riley's excellent figures of *Plodia interpunctella* and *Ephestia kuehniella* and comparison of the two species, adding information suggested by his own notes and observations.

In spite of the measures taken the year previous, the moth spread to other mills, and many local dealers in flour and grain had the pest on their premises. A printed circular letter was issued by Dr. Bryce, October 15, 1890 (**33**), offering to millers and produce men the coöperation of the Board of Health for the eradication of the pest A copy of the Provincial Act (47 Vic, chap. 38, sec. 39 and 40) is printed in this circular, according to which, among other provisions, any medical officer or sanitary inspector may at any reasonable time inspect a mill and examine the goods being manufactured for sale as food, and may condemn and order to be destroyed any food-products which may be found unfit for use. In addition to this, the person exposing them for sale shall be liable to a penalty not exceeding one hundred dollars for each parcel of grain, bread, or flour. In conclusion, Dr. Bryce reprints, from his former Bulletin, the remedies to be used in combating the pest.

In his Report for 1890 (37) Mr. Fletcher reviews his previous account of *Ephestia kuehniella*, and quotes several important letters from the manager of the first infested mill. The indifference on the part of those most interested is very noticeable, for one would naturally suppose that millers and produce dealers would have taken a little trouble to understand this matter, and to assist in carrying out measures which would be for their special benefit. A great many millers suffered severely for thinking there was nothing to fear when the moths first appeared on their premises. Mr. Fletcher says, "the steps taken by the Provincial Board of Health, and the milling company on whose premises the moth worked such havoc in 1889, have proved very satisfactory and were entirely successful. A few straggling moths were seen in the mill during the summer of 1890, but constant watching and scrupulous cleanliness finally rid the mill of the infestation." Mr. Fletcher gave an earlier account of this outbreak in Canada in a Report of the Entomological Society of Ontario (30).

The appearance of this moth in North America in 1889 in such destructive numbers called forth a timely article by Dr. C. V. Riley and Mr. L. O. Howard (27), in which the known facts regarding this pest are brought together in a condensed form.* Mr. Howard visited the Canadian mills the latter part of August, 1889, and accompanied Mr. Fletcher on a tour of inspection to the worst-infested establishment. The entire building was still completely overrun by this insect, notwithstanding the thoroughgoing measures which had been taken for its destruction. The principal studies on *kuehniella* mentioned in this article were, however, made upon material brought to Dr. Riley by Professor Panton, of the Guelph Agricultural College, during the summer of 1889; on material in the National Museum, containing specimens from Eufaula, Ala.; on five specimens from Europe sent by Mr. Ragonot; and on others from Germany, forwarded by Professor Zeller in 1883. The various stages of *Ephestia interpunctella* are figured in comparison with those of *kuehniella*, in order that both may be readily recognized, the early stages being quite similar.

In his excellent monograph of the North American Phycitidæ (36) Mr. G. D. Hulst cites some of the literature of *Ephestia kuehniella* and a short description of the species, indicates its distribution, and says that his specimens from New Mexico were taken in August and September. He refers to Zeller's original description and to Dr. Bryce's pamphlet, and quotes several paragraphs from the latter.

In August, 1892, Prof. T. D. A. Cockerell, then of the Institute of Jamaica, reported the appearance of this insect in Kingston, Jamaica. He found some oatmeal badly infested with larvæ which he supposed to be those of the Mediterranean flour moth, and accordingly issued a circular letter giving a short history of this pest, which was afterwards published in several daily papers in Kingston (40). April 1, 1893, Prof. Cockerell wrote me as

* I have made liberal use of the reviews contained in this paper, although I have carefully examined all the articles mentioned in it.

follows: "I hasten to make a correction on *Ephestia*. I wrote you October 27, [1892] that we had found larvæ of *E. kuehniella* here, but, although the larvæ seemed to be indeed that species, when the moths emerged they appeared different. So I sent some to M Ragonot, in Paris, and I have just heard from him that they are *Ephestia desuetella* Walker."

Several articles on this pest have appeared in French publications. The first, by P. Brocchi (22), in 1888. It contains a brief summary of the past history of this insect, and gives several methods, both preventive and remedial, for its arrest and destruction. Several papers on this subject have been written by Dr. C. Decaux, of France, referred to in the bibliography appended (41, 42, 43).

Mr. E. L. Ragonot (49) refers to the question of the origin of *Ephestia kuehniella*, calling attention to the fact that a species of the family Phycitidæ, discovered in the district of Wollombi, New South Wales, and described by Mr. A. W. Scott, in the Proceedings of the Zoölogical Society of London, 1859, under the name of *Hyphantidium sericarium*, belongs evidently to the genus Ephestia, and, according to the description, closely resembles *E. kuehniella*, but the plate shows two supplementary lines in the basillary space and another in the middle of the space, the imperfect crossing being replaced by a round dot. This slight difference he is inclined to lay at the door of the artist, and thinks that the species may prove to be identical with *Ephestia kuehniella*, the more particularly as its larval habits are precisely the same For the present, however, he is content to let the species remain as *E. sericaria* (Scott).

The most important publication that has yet appeared on this subject is by Mr. J. Danysz, of Paris, France, Director of the Laboratory of Parasitology and of the Chamber of Commerce. It is an illustrated article (54) of about sixty pages, and was published in 1893. It contains a summary of the more important articles previously published on this subject, a careful review of what has been said in regard to the origin and spread of the moth observations on its life history, and a discussion of the remedies used in various places for its suppression. As noted in the articles to which reference has already been made, European authors, excepting Miss Ormerod, have hitherto regarded this insect as of American origin, having been imported into Europe with American cereals. It will also be remembered that Dr. Riley and Mr. Howard, in their article on this moth which was published in "Insect Life" (Vol. II., pp. 166–171), protested against this haphazard conclusion, but with little effect upon the European authors who have since discussed this matter. Mr. Danysz concludes, after a careful review of the arguments brought forth by European writers, that it is unsafe to point to any one country as the original home of this insect. He is inclined to think that it was originally a very widespread species, and that it comes into prominence as a pest in flouring-mills at in-

tervals when circumstances favor. He places no reliance upon the idea that it is being, or has been, imported in numbers from America into Europe.

Mr Danysz has also written an interesting article (**55**) upon the pigment spots (embryonic testicles) of the larva of *Ephestia kuehniella.* While searching for the natural enemies of this insect, his attention was drawn to the published note of Mr. Archibald Geikie (**17**), referred to on p. 13. Mr. Danysz then segregated a number of Ephestia larvæ with the black spots upon their backs in the hope of securing some of the parasites, but his expectations were disappointed, for they all transformed successively to chrysalids and adults without presenting any abnormal features, while of the parasites he did not secure a single specimen. His close watch of the black spot, however, furnished him with a very interesting observation. By dissection he found that the pigment spot in question consisted of two reddish brown reniform corpuscles placed in the cellular tissue above the digestive tube, and that these same organs, a little modified, were easily recognizable in both the chrysalis and adult, so united in the latter, however, as to form a single ovoid body, connected by two long canals with the genital armature. The fact that larvæ with black spots always produce males, left no doubt that these organs were testicles in the process of development—a conclusion already reached by Mr. E. B. Poulton in the fall of 1888. (See p 14.)

In this same year (1893) Dr. F. Decaux published (**56**) a short illustrated article on *Ephestia kuehniella* in which he reviews its habits and suggests means for its destruction; and Prof. Lawrence Bruner, of the University of Nebraska, published a short illustrated article (**61**), which is principally a compilation from published reports on this insect, and was intended as a timely warning to millers and dealers to be on the lookout for it. In January, 1894, Mr Gerald McCarthy published (**62**) a notice of the Mediterranean flour moth's presence in North Carolina, saying that it is likely to become a serious pest in that state.

In December, 1892, I sent out a circular letter regarding the flour moth, calling attention to its appearance in destructive numbers on the Pacific coast. This is, I believe, the first authentic record of its occurrence in the United States. The notice naturally interested the general public and several California papers (**46**) printed it. During the same month another newspaper (**47**) printed a reporter's account of an interview with me concerning this insect, and I published myself (**48**) a short account of its past history and appearance in California, with a review of the remedies used elsewhere for its suppression. I furnished an article of the same general character, for the January (1893) issue of "Milling", which was reprinted in another monthly journal (**50**) devoted to the same interest. The most important articles I have contributed on this subject appeared in the "American Miller" in 1895 (**67, 68, 72, 73**). In the March number (**67**) I gave a brief summary of former publications, a short sketch of the insect's life history, a preliminary account of my experiments, a review of the remedies used in various

places, especially in California, and quotations from a large number of correspondents on this subject. In the May number (**68**) I announced the discovery of the pest in New York State, which is the first record of its occurrence in destructive numbers in mills in the United States east of the Rocky Mountains. In the October number (**72**) I gave a brief account of the methods now used in California and New York for keeping the flour moth in check, together with other notes and observations. In the November issue (**73**) I announced the discovery of a new parasite (*Bracon hebetor* Say) of this insect, and added a new locality. The facts which led to the discovery of the parasite are discussed somewhat in detail, suggestions are made for its colonization, and extensive notes regarding the new Canadian outbreak are given.

Mr. F. H. Chittenden, Assistant Entomologist to the United States Department of Agriculture, in an article entitled "The more Important Insects Injurious to Stored Grain," gives a short, somewhat popular account (**71**) of the Mediterranean flour moth. The article is illustrated, and contains the most perfect representation of the adult moth ever published. It is reproduced by permission on p. 9 of this paper. Mr. Chittenden also contributed some valuable notes previously unpublished.

In December, 1895 (**74**) I called attention to the fact that I had discovered *Bracon hebetor* Say feeding upon the larvæ of the Mediterranean flour moth, and further stated that I had bred a single specimen, a male, from the same lot of larvæ, which differed in many respects from typical specimens of *hebetor*, but was thought by Mr. Ashmead to be a small variety of the same species. *B. gelechiæ*, although not found on the flour moth, is mentioned, as it is closely related to *B hebetor*; and reference is also make to the European parasites of this insect, *B. brevicornis* and *Chrymelus rubiginosus*.

I note next a communication from a Pennsylvania miller, Mr. E. Burns, who states (**75**) that he has been troubled with the flour moth in his mill for the last three years. He has been fighting it, principally, by keeping an extra sweeper, which adds about $500 per year to the running expenses of the mill. He says he tried sweeping his mill with steam some years ago, and found it worked well in the summer, when all the doors and windows were open, but as soon as cold weather set in he could not use this method, as the "steam on the cloths of the purifiers makes all good middlings run over the tail end of the machine." This information adds a new locality for the flour moth, as it has not heretofore been recorded from Pennsylvania.

Comments upon this outbreak and a few notes concerning the flour moth, with illustrations were published (**76**) by me in January, 1896; and in February I replied (**78**) to a query from a milling firm in Melbourne, Australia, who had forwarded me for examination a sample of flour matted together in a way to suggest the work of the flour moth. No insects were found in it. An illustration accompanying my reply shows a sample of wheat flour felted together by the flour moth.

Prof. William Trelease, of the Shaw School of Botany, St. Louis, exhibited at the February (1896) meeting of the Academy of Science of St. Louis (**79**) specimens of a curious silk fabric taken from the ceiling of a corn-storing loft in San Luis Potosi, Mexico, by Dr. Francis Eschauzier. Although specimens of the insect responsible for the silk were not secured, it was presumed that it was made by larvæ of the Mediterranean flour moth.

Besides the articles already mentioned, several reviews and notices have appeared in other publications, principally in "Insect Life," all of which are mentioned in the list at the end of this paper.

DISTRIBUTION AND DISSEMINATION.

As has been already stated, *Ephestia kuehniella* was first brought to the attention of scientists in 1877. Prof. Zeller, two years later, when he described it, stated on insufficient grounds that in all probability the insect came from North America. It was supposed to have been introduced in Belgium, in 1884, on American cereals. Regarding its appearance in mills near Bremworde in 1885, it is stated positively that the insect was introduced in that locality on American wheat. This being in the Belgium and Bremworde mills at the time of the outbreak, seemed to suggest to those concerned that the pest must be of American origin. The fact of the case is, that the pest was not known in North America in destructive numbers prior to 1889, at which time it appeared in Canada. The moth has been known much longer in Europe than in America, but the extreme readiness with which Europeans attribute new pests to this country, has been exhibited more than once.

Miss Ormerod did not find *Ephestia kuehniella* listed in Grote's check list of the moths of North America for 1882, and was therefore of the opinion that the pest came to England from Europe or the East, rather than from America. Mr. Sydney Klein, in the "Mark Lane Express," 14th November, 1887, in speaking of the English outbreak, says the pest was introduced into the London warehouse where he carried on his observations, in some meal shipped from Fiume, on the Adriatic, in 1885. I might state here, that Mr. Klein mentions this pest as the scourge of the Mediterranean ports, but does not give any date as to its first appearance there.

In 1890 Miss Ormerod made inquiries regarding the distribution of the moth, and received a letter from Dr. Lindeman, of Moscow, stating that he was not aware of its being present in Southern Russia, and that it had not been observed in Central Russia up to that time.

Mr. J. Danysz, of Paris, has made a careful study of the outbreak in France, and states that its first occurrence there is recorded prior to its first appearance in England. He does not think it safe to point to any one country as the original home of the pest, and places no reliance upon the idea that the insect was

introduced into Europe from America. He calls attention to the fact that Halle, Germany, where the pest was first observed in 1877, is an inland town, as is also the place where the moth was first observed in France, and concludes that circumstances will not sustain the theory of the original importation of the insect into either Germany or France. A practical miller assures Mr. Danysz that he has known of the pest in the neighborhood of Paris for the last fifty years, and that he remembers a case of serious damage as early as 1840. Another miller asserts that he knew of a serious outbreak of this insect in a flouring-mill in Constantinople in 1872; that it was very troublesome for two years, and then disappeared.

Dr. Selmar Schonland, Curator of the Albany Museum, Grahamstown, Cape Colony, wrote Miss Ormerod in 1890, that inquiry had been made regarding a moth, or rather, larva, which was doing considerable damage in flouring-mills in King Williamstown. I do not know whether this was *Ephestia kuehniella* or not, but judging from the account of the damage done, I am inclined to think it was.

Regarding the introduction of the pest into Canada, Mr. Fletcher says there is some doubt as to the time when the first specimens came, and also concerning their origin; but evidence seems to point to a consignment of goods imported from Mediterranean ports in 1887. Mr. Geo. P. Hulst, in his monograph of the Phycitidæ of North America, in speaking of the flour moth, says: "I do not know that it has given trouble in California, if indeed it exists there (1890). It has, however, developed very rapidly in Europe, becoming a very great evil. The 'Ontario Bulletin' speaks of its having come from Europe, though there is no reason why it should not have come from the Pacific coast." With reference to the present Canadian outbreak, so far as I can learn, the pest seems to have been in local mills for some time past, and as these mills are in an inland town, it would be a difficult matter to trace the moth to its original source.

Notwithstanding the fact that this insect was not noticed in North America until 1889, evidence seems to point to its presence in this country some years earlier. Mr. Danysz has traced its occurence in America as far back as 1880. As stated by Dr. Riley and Mr. Howard, specimens from Alabama, indistinguishable from *Ephestia kuehniella*, were in the Natural Museum collection at the time of the Canadian outbreak. Dr. Riley states also that he had seen specimens from North Carolina in Mr. Ragonot's collection in Paris. It is also recorded from Colorado and New Mexico, and was found in a Mexican exhibit at the World's Fair in Chicago; and it has been found in Chili and probably occurs in Australia and South Africa. However long the pest may have existed in North America, no record of any damage is recorded prior to 1889; and the California outbreak, first observed by me, is positively the first record of any destruction by this pest in the United States.

The moth seems to have appeared in great numbers in certain localities for a time, and then disappeared. Prof. Zeller wrote Dr. Riley in 1883 that the insect had apparently died out at Grünhof; and, as stated above, Mr. Danysz was informed by a practical miller that it appeared in destructive numbers in a flouring-mill in Constantinople in 1872, and disappeared after two years. This might seem to indicate that the insect is a passive creature, and if not disturbed, and allowed to multiply for a time, would finally disappear altogether; but so far as I can learn, it has never disappeared from a given locality or mill only after the most energetic fighting.

There is not much doubt but that the moth existed in widely separated places a long time before 1877. As stated above, Mr. Danysz has collected some important information on this point from practical millers in France. I have been informed by a thoroughly reliable miller in San Francisco, whose name I withhold by request, that he came in contact with this pest in 1858. At that time he was employed in a large flouring mill at Rastdorf, near Kiel, Schleswig Holstein, Germany, where the moth was very abundant during the month of June. He is positive about his identification of the insect, having had much experience fighting it in his California mills since 1889.

The foregoing facts indicate that *Ephestia kuehniella* was thoroughly established in Germany twenty years or more before it came into Prof. Zeller's hands for description, and it is therefore unlikely that the pest was introduced into that country from North America. From all I have been able to gather on this point I am of the opinion that its original home, if ever ascertained, will not be North America.

It has been recently discovered that this moth lives in the nests of a wild bumblebee in California, and Mr. D. W. Coquillett, of the U. S. Department of Agriculture, is reported by Mr. F. H. Chittenden as having stated that it also occurs in the hives of the honey-bee. The question naturally presents itself, has the moth found that it can perpetuate its species in a bumblebee's nest or a beehive, and transferred its attack from the mill to these more natural and primitive food houses, or *vice versa?* The theory that the transfer has been from the bumblebee's nest and the beehive to the mill would afford a plausible explanation of the appearance of the moth in mills in isolated places, and at times when it was least expected. The origin of the California outbreak might be thus explained; but I have myself no faith in this theory concerning the present infestation, and will not discuss the matter further from this standpoint.

I will now state as briefly as possible the facts I have gathered regarding its occurrence on the Pacific coast. I have been told by prominent millers in California, that it has been less than fifteen years since oatmeal was bought in the Eastern States, shipped to California, and sold cheaper than it could be manufactured there. I do not infer from this that the moth came through this channel, but simply introduce the statement to indicate the commercial

relations that existed a short time ago between the Pacific coast and the Eastern States. Had we known positively that the moth existed in the United States east of the Rocky Mountains during this period, we might have been a little hasty in accounting for its presence in California. I am reported as having stated* that the pest was probably introduced into California on second-hand machinery brought from a Chicago mill which was in communication with the Ontario mills. I had been informed that the machinery in question came direct from Chicago to San Francisco, being stored in the mill where the pest soon afterwards appeared in great numbers, flying in and out of cylinders connected with the apparatus. I have since ascertained that the machinery, although purchased in Chicago by a California firm, changed hands several times in San Francisco before it reached the mill where my first observations were made, being in the meantime in a mill—since burned down—where the pest was known to exist. This seems to indicate that the moth was introduced into the former mill from a neighboring one and not from Chicago.

A prominent miller in San Francisco informs me that his mill was overrun by this pest in the early part of 1889, soon after the introduction of a large quantity of rice from Sicily. He is of the opinion that the moth came to him with this rice. This is not certain, since it was observed about the same time in neighboring mills in which rice was not kept. After interviewing the owners of many larger mills in California, I found that the pest, in all cases, was first noticed during the early months of 1 89. This indicates that the introduction must have been a general one, as the outbreak occurred at the same time in widely separated mills.

The manager of the mill which has been the principal seat of my observations, tells me that he purchased the machinery mentioned above from an oatmeal company in San Francisco, which has since discontinued business, and transferred them to his premises. They were bought in the spring of 1890, and were stored in the attic of his mill. About three months later he noticed some moths flying in and out of cylinders connected with the apparatus, and fearing they might be the same pest that had appeared in Canada, he took immediate steps for their extermination, closing the end of the cylinders and burning sulphur inside. He says, regarding this outbreak: "This entirely destroyed the moths in the cylinders, but about six months later a more energetic fight was required, the mill being then thoroughly swept and fumigated with sulphurous fumes, with good results."

I have positive proof that the moth is established in mills in the following California localities: San Francisco, Oakland, Sacramento, Port Costa, Stockton, and Woodland. It is only a matter of time—unless millers keep the pest in check more effectually than at present—before every miller in that state will have *Ephestia kuehniella* to combat.

There is a good deal of uncertainty about the origin of the flour moth in New York State. From what I can ascertain by correspondence, the pest is pretty generally distributed throughout

* "San Francisco Call," Dec. 6, 1892.

the southwestern part of that State. It seems to have been first observed in the early part of 1893, and has been spreading from mill to mill until it is now established in mills in several counties. I cannot find any printed account of its presence there previous to my own announcement of it in March, 1895.

Dr. J. A. Lintner, the State Entomologist, stated, in a letter written in February, 1885, that he had no knowledge of the flour moth as an American insect, and that if it existed in the United States it was unknown to him. I cannot venture even the slightest hint as to the source of this outbreak in New York. Suffice it to say that the pest is well established in several interior counties in the southwestern part of the State, and, from present accounts, is spreading to others. The latest information I have on this subject is contained in a communication to the "American Miller" for December, 1895, (p. 910) from a Pennsylvania miller living in the vicinity of the New York outbreak.

Considering the ease with which the flour moth is carried from place to place, it is not surprising that we hear so much concerning its ravages. The eggs, larvæ, and pupæ are transferred long distances in manufactured products, and the conveyances themselves very often become sources of infestation. Ships, canal boats, freight cars, or even wagons that carry large quantities of grain, flour, or other farinaceous products, afford excellent breeding beds for this pest, which is usually transferred to the warehouse, mill, store, or private residence with the material. The fact that the adult moth is capable of living from seven to nine days after maturity, seems to indicate that it may fly a considerable distance; and in large cities where many mills are operated, it is quite possible that the parent insect often finds lodgment in such places after long flights. The moth, however, is not a rapid flyer, and alights quite often, the distance between flights depending on the surroundings. In a California mill I have seen the adults fly the full length of the building (a hundred and ten feet) before lighting. In the open air no doubt the flight would be much longer.

Owing to the minuteness of the eggs, and to the fact that the larvæ are almost always concealed, these two stages are the most readily transferable. Eggs deposited on sacks of flour and on other manufactured products in the mill, are carried away unnoticed with the material, and the pest is thus given a large local distribution, finding lodgement in warehouses, grocery stores, livery and feed stables, hotels, and private dwellings. Mills in the vicinity of such places are liable to become infested from them, by the return of old bags or barrels.

The pest is sometimes transferred long distances in second-hand machinery. In April, 1894, a Stockton, Cal., miller wrote me as follows: "Referring to yours of the 3d inst., relative to the Mediterranean flour moth, would state that I have known of it for some years, and for the past eighteen months we have had it with us here. Although its presence is not at all desirable, still we have suffered no damage or inconvenience from it, unless, perhaps, we have had to exercise a little more vigilance in keeping the mill thoroughly clean. We introduced it here by purchas-

ing a machine that was for a short time in one of the San Francisco mills. We have not used sulphur nor done anything to eradicate it, excepting to increase our endeavor towards cleanliness." An instance of this same nature is given on p. 28, the moth being introduced on some apparatus bought from a local firm in whose mill the pest had a firm foothold.

As a rule, the moth is transported carelessly on bags and machinery. The former is, however, the commonest and greatest source of danger, and extreme care should be taken lest the pest is introduced in this manner. All bags which have been used for transporting grain, flour, or meal should have no entry to a mill until subjected to a thorough fumigation with bisulphide of carbon or with steam. Preventive measures are treated in detail on subsequent pages of this paper.

CHARACTER AND EXTENT OF INJURIES.

The larvæ of the Mediterranean flour moth would not be such a pest to millers were it not for the strange peculiarity they have of trailing little silken threads as soon as they begin to crawl. This silk is usually mixed with flour and dust, and looks and feels like a handful of cobwebs rolled loosely together in a flour bin. The mass of flour and web represented in Fig. 4 gives a fairly good idea of its condition. This particular material was taken from a spout in a New York mill last April, from which a photograph was made and reproduced. It is this waste silk that troubles millers most. When hundreds and thousands of these larvæ are at work in a spout, elevator, or other portions of machinery, this silk accumulates rapidly, piles up in tangled masses, clogs the machinery, and very soon stops it entirely. Then the whole plant must be taken apart and cleaned.

Fig. 4.—A mass of flour webbed together by the flour moth larvæ. (Original).

One of my California correspondents sent me the following note on this subject:

"We find more trouble with the pest in the spouts and elevator legs than in any other portion of the mill, since these parts of the machinery are kept closed and the moth can breed there

without being disturbed. Some of the elevator legs have been so closed up that there was scarcely room for the elevator to travel, and many of the spouts have been so completely choked up that it was necessary to take them down and remove the web, larvæ, and pupæ before the stream of stuff could pass through them."

The magnitude of the attack depends somewhat on the time of the year and upon the nature of the products manufactured. In the eastern states, and also in California, the larvæ are most abundant during the summer months, but in California the climate is so even that but little variation is noticed at different times of the year.

The larvæ are particularly found of products manufactured from rice, and in mills where this is the principal cereal handled that department is worse infested than others. Buckwheat flour is also a favorite, and the larvæ will pass over oatmeal and wheat flour in order to get to this product; but in mills where rice and buckwheat are not handled, they attack any cereal product. The parent insect may deposit her eggs in any part of the mill where the young larvæ can find food, but in the great majority of cases the eggs are laid where the conditions are most favorable for the development of the young larvæ. The spouts and elevators are therefore worse infested than other parts of a mill. In a mill where flour is stored in sacks, the female pushes her ovipositor through the meshes of the sacks and places her eggs within the flour. I have carefully observed this point, and have found that three fourths of the eggs are deposited in this way, when such places are chosen for their deposition. Such flour may be perfectly free from larvæ when sent out from the mill, but in a few days the young creatures hatch from the eggs within it, and the flour is soon matted together and is unfit for use. The larvæ get into most manufactured products in this manner, the eggs of the moth being usually packed with the material.

It has been reported by some European writers that the larvæ attack the bolting-cloth, but I have made no similar observations. I have found many larvæ on and about the screens in mills, but have never seen one attack the cloth. In my breeding cage experiments I have no difficulty whatever in this direction. All my cages are covered with fine Swiss muslin, and I have no trouble in keeping the larvæ within. To see whether, in confinement, they would attack bolting cloth, I procured some of this material from a miller in California, and covered two cages with it. The larvæ matured, and pupated in most cases in the top of the cage, usually forming their cocoons on the under surface of the cloth, but in no case was it punctured by them. I am of the opinion that in the cases reported the injury to the bolting-cloth was due to that cosmopolitan creature, the cadelle (*Tenebrioides mauritanica*). I have seen both larva and adult of this insect cutting bolting-cloth, and have found it in every mill I have inspected. In California it is known as the "bolting-cloth beetle."

The Ephestia larvæ thrive best on the more glutinous cereals, but they infest all manufactured foods prepared from wheat, oats, rice, Indian corn, and buckwheat, and will attack the grain

itself, to a limited extent, when the manufactured products are not available. While a resident of California, being suspicious of all breakfast foods purchased for my table, I closely inspected every package, and found flour-moth larvæ in oatmeal, corn meal, rolled wheat, and germea bought at a local grocery store. They also feed on crackers, and have been found in bumblebees' nests and in beehives, feeding probably upon the wax and bee-bread. Mills in which several kinds of cereals are prepared for food are not troubled equally in all departments. For instance, where wheat flour, oatmeal, and buckwheat flour are manufactured, the oatmeal is more infested than the wheat flour, and the buckwheat worse than the oatmeal. The manager of a California mill wrote me with reference to this subject as follows: "I have observed that they seem to thrive best in buckwheat flour. I have never been able to understand why they should prefer this flour, but we have to be exceedingly careful of this food, or in a short time it will become full of webs spun by the larvæ." The manager of a Canadian mill wrote Mr. Fletcher the following: "If this insect strikes a mill where a variety of cereal products are manufactured, it will work its way into every product, though it likes glutinous substances best. It attacked every thing we made, from pot-barley to fine farina and milk food in tins" In a mill, where rice foods are the principal product manufactured, the manager tells me the rice is more attacked than any other cereal. He said they were much troubled with the larvæ in food put up in tin cans lined with tissue paper, very often having the goods returned, marked "wormy."

DEVELOPMENT.

By a long series of experiments, conducted in California and Illinois, I have ascertained that the life cycle of *Ephestia kuehniella* under the most favorable conditions, from the time the egg is deposited until the adult moth emerges, is about nine weeks.

Mr. Danysz has found that the period of development in France is about the same, insects in his experiments having completed the life cycle in from two to two and a half months. Professor Landois is of the opinion that during warm weather, in Germany, the larva of the flour moth develops into the adult within four weeks. In speaking of the outbreak in warehouses in London, Mr. Klein says: "The larvæ, which were full-fed in about three weeks, then made their way to the surface." It is hardly safe to assume that this represents the full life cycle of the larvæ, as the exact date of hatching was not recorded.

In connection with the Canadian outbreak, Mr. Fletcher says: "There are probably two normal broods of the flour moth, one emerging in the spring, and another in the autumn; but in a jar kept constantly under observation in my office, which was heated during the winter, there have been, I judge, three distinct broods; although from the fact that some retarded individuals have been emerging the whole time, and no special study made of them, it is very difficult to keep track of the separate broods."

Mr. F. H. Chittenden has estimated, from experiments recently conducted by him in Washington, that in the warmest weather the life cycle is about five weeks. In my experimental work during midsummer, under the most favorable conditions, in California and Illinois, I have been unable to get a full grown larva in less than five weeks from the time it emerged from the egg.

The number of annual broods of this insect depends largely upon the geographical location and upon the condition of the mill. In California, where the climate is even, the amount of damage done and inconvenience caused varies but little with the time of year. In the Eastern States, however, the insect is most troublesome during the summer months; although in exceptionally warm mills it is very annoying even in midwinter. I have shown by a series of carefully planned experiments that there are from five to six annual broods in California, and probably the same number in some of the Southern States and in Eastern States where the mills are well heated during the winter months. In most cases, however, in the East, four broods seem to be the average, appearing most abundantly from April to December. Brood after brood have appeared successively in my cages for the past two years.

From a long series of experiments, I have selected five representing the life cycle of this insect, the eggs being deposited in April, August, and October. The results are given in the following table:

EXHIBIT OF OBSERVATIONS ON LIFE CYCLE.

Experiment.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Source of material	California	California	New York	New York	New York
Experiment conducted in	California	Illinois	Illinois	Illinois	Illinois
Adults found pairing	Aug. 1, 1892	Oct. 25, 1894	April 11, 1895	April 11, 1895	April 29, 1895
First eggs deposited	Night of Aug. 1, 1892	Night of Oct. 25, 1894	Night of April 11, 1895	Night of April 11, 1895	Night of April 29, 1895
Total No. of eggs deposited	217	220	271	259	227
First eggs hatched	Afternoon of Aug. 8, 1892	Forenoon of Nov. 3, 1894	Forenoon of April 21, 1895	Noon of April 21, 1895	Afternoon of May 7, 1895
First fully matured larvæ	Forenoon of Sept. 27, 1892	Forenoon of Dec. 18, 1894	Forenoon of May 26, 1895	Afternoon of May 26, 1895	Forenoon of June 12, 1895.
Cocoon begun & completed	Sept. 28, 1892	Dec. 20, 1894	May 28, 1895	May 27, 1895	June 13, 1895
First adult moth emerged	Morning of Oct 9, 1892	Noon of Jan. 1, 1895	Morning of June 12, 1895	Morning of June 12, 1895	Noon of June 28, 1895

From the above table we see (1) that the period of incubation for the eggs varies from seven to nine and a half days, with an average of eight and two fifths days; (2) that the feeding stage of the larvæ varies from thirty-five to forty-nine and a half days, with an average of forty days; (3) that usually from one to two days elapse after the larvæ are full grown before the cocoon is spun; (4) that the chrysalid stage lasts from ten and a half to fifteen days, with an average of thirteen days; and (5) that the period from the time the eggs are deposited to the emergence of the moths varies from fifty-nine and a half to sixty eight and a half days, with an average of sixty-three and three fifths days, or about nine weeks.

Copulation takes place, in most cases, the same day the adult emerges, usually in the early morning, lasting from four to five hours, but oftentimes extending over a period of eight to ten hours. A single female will pair several times, and a male that was seen pairing on two different occasions on two successive days, on being removed to another cage, in which a freshly emerged female was placed April 11, 1895, paired again the same afternoon. The eggs deposited by this female that same night, hatched just ten days later, thus proving their fertility. The female has a peculiar habit of resting with the anterior end of her body somewhat elevated, the wings slightly spread, between which she projects the tip of her abdomen, as shown in the illustration at *b* on page 9. Oftentimes she also extends her ovipositor from an eighth to a quarter of an inch (not represented in the figure), giving the abdomen the appearance of ending in a long spike. The female will assume this attitude for several days, or until copulation takes place. I have had as many as twenty five females in a cage at a time, where they often remained five or six days in this characteristic position before any males emerged. They are rather sluggish while pairing, and can be easily transferred from one cage to another without being separated.

The female usually deposits her first lot of eggs the night after the first copulation, and so far as my observations and experiments go, they are laid at night only. The egg-laying period of a single individual lasts five or six days, during which time an average of about two hundred and forty eggs are deposited. In mills they are usually deposited singly, but may often be found in chains of eight to ten. The largest number I have succeeded in getting from a single female is two hundred and seventy-one, and the smallest one hundred and twenty. The total number deposited by each individual in the above experiments is listed in the table. The female lives only two or three days after the eggs have been deposited; and the average life of the male after pairing is from six to seven days.

Professor H. Landois, of Münster, Germany, ascertained by an anatomical examination that the eight ovaries of an *Ephestia kuehniella* contained respectively, 66, 79, 80, 84, 85, 87, 92, 95 eggs, an aggregate of 668.

I have dissected a great many fully matured females, some immediately after pairing and others just before, but have not obtained any such results as those tabulated by Professor Landois The greatest number of eggs I have obtained by dissection is 342, and the least number 187. I have also carefully examined a series of females after death, immediately after the eggs had been deposited, to see if any undeveloped eggs were left in the ovaries, and in five cases found they were completely spent, while I found seven eggs each in three others, fourteen in another, and twenty-six in another. This would seem to indicate that the total number of eggs in the ovaries does not represent in all cases the total number that may be laid by a single individual. As stated above, the greatest number of eggs I have yet obtained from a single female is 271 (No. 3), and an examination of the parent insect later showed that the ovaries were spent.

A correspondent of mine in California was asked by me to conduct a series of experiments in his mill during the month of November, 1892, to ascertain the exact time required for the incubation of the flour-moth eggs, and on December 5 I received the following reply: "The eggs hatch in my mill, under the most favorable conditions, in a trifle less than nine days." This is in accordance with my own experiments. Mr. James Fletcher says that caterpillars emerged in December, in a warm office, about nineteen days after the eggs were laid. I cannot account for this difference in time, as eggs deposited December 4, 1894, kept in my office where the temperature ranged from 38° to 72° Fah. hatched in exactly nine days. As has been shown by Mr. Danysz the development of the embryo is greatly retarded by a continuous low temperature, and it is possible that the eggs in Mr. Fletcher's office may have been exposed to a lower temperature than 38° Fah. for a considerable length of time, which would, possibly, explain the difference in the period of development. Another point to be taken into consideration is the fact, that the female is from five to six days in depositing her eggs, and that there is a difference of as many days in the hatching of the first laid and the last-laid eggs of the same generation.

The active or feeding stage of the larva depends upon the temperature of its surroundings, and upon the kind and amount of food. Larvæ hatched from eggs October 9, 1894, were divided into two lots and placed in breeding-cages with wheat flour for food. One cage was placed in the insectary where the temperature varied from 28° to 78° Fah., and the other was kept in a warm office at a temperature of 48° to 82° Fah. Larvæ in the former lot were fully matured November 26, or in about seven weeks, and in the latter November 13, or just five weeks from the time they emerged from the eggs. In other experiments conducted to test the effect of the amount and kind of food on the larvæ, I have had varied results. Larvæ feeding on coarse corn meal, for example, did not mature as quickly as those in the same room fed on wheat or buckwheat flour. As already stated the average active period of the larva is about forty days; but under the most favorable cir-

cumstances this stage is reduced to about five weeks. Mr. James Fletcher writes that moths kept in a breeding cage in his study, continued to emerge and lay eggs until December 15. He then adds in a foot-note, that larvæ from these eggs were full grown March 21. This makes a period of ninety-five days, and would seem to indicate that in Canada the development of the larva is very much slower than in California, or in Illinois and New York, during the winter months, as in no case have I observed the larval period to last longer than forty-nine and a half days.

When the larvæ reach maturity they have the peculiar habit of migrating to some isolated corner for pupation, and will then leave their feeding quarters provided an outlet is afforded. It is difficult to confine them in a breeding-cage at this period, and in my cages many larvæ have escaped by working their way out underneath the stout rubber bands which held the muslin over the cage. After maturity the larva will often crawl about for one or two days, without taking any food, before finding a suitable place for its quiescent stage. The cocoon, in which the chrysalid rests, is made of fine silk, often intermingled with particles of flour or meal. These cocoons are sometimes found in great masses in the most remote parts of a mill. The adult moths emerge in about two weeks, and deposit their eggs for succeeding generations.

Mr. Sidney T. Klein, in a paper read before the Entomological Society of London, refers to the peculiar migratory habits of the flour moth as follows:

"Their migratory habits, when full-fed, were very extraordinary; nothing seemed to keep them within bounds. I had a colony of some thousands in my house, in order to make experiments how to exterminate them; but I found that my breeding-cages, with the finest meshed wire, were useless to restrain them. I then placed them under a large glass shade on a polished surface with no perceptible outlet; but it was no use; the corners and ceiling of my room were within a week studded with their cocoons, and every day specimens of the larvæ were discovered in different parts of the house, from top to bottom; in fact, they increased and wandered to such an alarming extent that I had to give up keeping them."

In the same paper, speaking of the creatures in the warehouse where he made his observations, Mr. Klein says:

"When full-fed the larvæ made their way to the surface, and could be seen in myriads crawling along the floor and up the walls of the warehouse, till they reached the angle where the roof met the walls. There they spun compact silken cocoons, in which they turned to the pupa state."

HISTORY OF THE CALIFORNIA OUTBREAK.

In March, 1892, the president of one the largest milling firms on the Pacific coast invited me to visit one of his mills which, he said, was literally overrun with worms and moths. I inspected the mill the latter part of March, and procured a large number

of the moths and larvæ which were responsible for the annoyance. I recognized the insect as the Mediterranean flour moth, and gave the proprietor the necessary warning; but to make sure that my determination was correct I sent specimens of both larva and adult to Prof. J. H. Comstock, of Cornell University, Ithaca, New York, for identification, and at the same time forwarded specimens to Dr. C. V. Riley, United State Entomologist, at Washington, D. C., for comparison with those in the National Museum. The material sent to Prof. Comstock was referred to Mr. M. V. Slingerland, Entomologist to the Cornell University Experiment Station, who replied that there was no doubt about the insects' being that terrible pest, the Mediterranean flour moth. In the absence of Dr. Riley from Washington, my letter was acknowledged by Mr. L. O. Howard, Acting Entomologist, who wrote in reply that my determination was unquestionably correct, further stating that the Department had received no prior information regarding the occurrence of this species on the Pacific coast.

I made frequent visits to the mill during the summer, and each time found the insect more abundant than on my previous examination. After considerable correspondence with the the proprietor, who had become greatly alarmed, I deemed it advisable to send out an emergency circular to various papers on the Pacific coast, in which due warning should be given to millers and dealers of the presence of this formidable enemy. Accordingly, December 1, 1892, I sent out from the Department of Entomology, Leland Stanford, Jr., University, Palo Alto, California, the following circular, which is the first authentic record of the presence of this pest in mills in the United States:

"Notes on the Mediterranean Flour Moth, *Ephestia kuehniella* Zeller.

(*Emergency Circular.*)

"This moth was first found in a flouring-mill in Germany during 1877, and was brought to the attention of Prof. Kuehn, of the Agricultural Institute of the University of Halle, who sent specimens to Prof. Zeller, of Gruenhof, for determination. The insect proved to be new to science, and was described and named *kuehniella* by Professor Zeller, in honor of Dr. Kuehn.

"The moth was little known until 1884 and 1885, when it appeared in some mills in Belgium and did much damage. Several articles appeared in English periodicals in 1887, concerning its ravages in Europe. It caused a great deal of trouble, and in many instances mills were closed. Very little was known about the pest in this country until 1889, when it appeared in Ontario, Canada. Much damage was done; mills were closed, and in one case the loss was estimated at one thousand pounds.

"The fact that such an unwelcome pest has established itself on the Pacific coast is to be regretted. The announcement that it is in our midst should be a signal of alarm to every miller and grain dealer in this region. Notwithstanding its comparatively recent appearance, it has caused much trouble to millers and flour dealers. Every possible means should be taken to eradicate this ravenous pest from our midst. Not only are our mills in danger, but our commerce is at stake, and public health imperiled."

After the publication of this note, I received many letters of inquiry from various parts of the country regarding this pest. I pushed my experimental work in the laboratory, and made good my opportunity of studying this creature in the mill. I endeav-

ored to trace it to its original source, but the more material and facts I gathered on this point, the more complicated the matter became, and I finally concluded it was unsafe to assume that the moth came at any stated time from any given locality.

My first correspondent, on whose premises the moth was first discovered, has given me much valuable information on this subject, and if all millers on the Pacific coast had taken as firm a stand, and fought as persistently as he has for the past three years, the Mediterranean flour moth would not now be so widely distributed. May 24, 1892, he wrote me as follows: "I desire to say that you are correct regarding the moth, and I know that it is a great pest. We have endeavored to exterminate it, and have succeeded in keeping it in check somewhat by constant sweeping and cleaning, and by burning sulphur in the building; but we must now adopt some other means, as it seems to be gaining during this warm weather."

I visited the mill again June 4, 1892; making a thorough inspection, and found a frightful state of affairs. Only a few moths were seen in the basement, but on the other floors I found a very different state of things. In some parts the moths were found upon every piece of machinery and apparatus, and could be seen in great numbers upon the sacks in which large quantities of flour, meal, and grain were stored. Hundreds were clinging to the sides of the mill and about the windows. An occasional moth would take wing when disturbed, but as a rule they were quiet. They were even in the dark chambers of the reels. The larvæ were found in every crack and angle about the machines and wood-work, around bolt heads, in nail holes, and in every crevice where masses of flour had collected. They were particularly abundant in the spouts and elevator legs. I scooped down a handful of the dust that had accumulated in one of the spouts, and upon careful examination found thirty-five larvæ, varying from one eighth to one half inch in length. All the spouts and elevators carrying the more glutinous cereals were in a similar condition. The larvæ were also seen on piles of boxes containing breakfast foods. In fact, in the most isolated places I could find eggs, larvæ, pupæ, and adults.

I made frequent visits to the infested mills during the summer of 1893, and each time found the insect on the increase, and spreading from mill to mill. In April, 1894, I wrote the manager of the mill where I made my first observations, inquiring about the present condition of the place, as compared with one year ago, and received the following reply: "Following up my previous letter to you regarding the flour moth, and in answer to your specific questions in the letter just received from you, I would state that our mill is still infested to some extent, and we are still fighting it, keeping one man constantly employed for that purpose. The condition of the mill, however, as compared with a year ago, is very much improved. We have the pest so in subjection that we are really not suffering any inconvenience from it, nor any loss, with the exception of the wages of the man em-

ployed to fight it, and the cost of the material used in the warfare, which is immaterial." During the same month I made a tour of inspection to the worst-infested mills in the State and found that the moth had generally a firmer foothold, and was more troublesome, than the year previous. In answer to a query of August 16, 1895, the president of the firm in whose mill I made my first observations, says: "The flour moth is still with us. It is hardly equal to death, but discounts taxes in the inconvenience it gives us. The outlook, as compared with a year ago, is about the same as regards the probability of becoming entirely rid of it; but it affords me great pleasure to tell you that I have it in subjection, and that it is not now injuring us nearly so much as formerly." As regards the present distribution of the pest, he says in the same letter: "The insect is increasing in this State. I believe that every mill in California, and in all probability every mill on the Pacific coast, unless it may be some very new mill, is infested by these moths. One of the newest mills in this State, which is now shut down, was more afflicted with these moths than any other mill we have with us. They were so numerous they choked up every spout and elevator, and before the mill had run six months it was necessary to shut down and employ a force of men to take down all the spouts and elevators and clear away the accumulations from them."

My recent discovery of a hymenopterous parasite of the larva, *Bracon hebetor* Say, gives encouragement that the pest may be at least somewhat checked by this little insect. This is the first reported case of parasitism of this insect in this country, and is treated in detail on a subsequent page. Judging from the wide distribution of the flour moth on the Pacific coast, it is safe to predict that the worst has not yet been recorded. It is only by the most persistent and energetic fighting that the pest can be kept in check in any locality; but in California the climate is so equable and so mild that the propagation of the species goes on continuously, and I am in doubt if it ever can be entirely eradicated there. Here is what one of my correspondents says on the subject: "I think I see in this little insect a very serious pest, and that it will be only a question of time when it will be impossible to obtain a barrel of flour that does not contain either the eggs or larvæ of this insect. This would not, however, militate so much against the manufacture of flour as it would against cereals or breakfast foods, or meals, as they are called in millers' parlance. The moth cannot live very long in a sack of flour, owing to its being so densely packed that there is no room for it to move about, and it thus soon dies; but in coarse meals and coarser grain, the moth and larva can move, spin their web, lay their eggs, and multiply; and this I fear will eventually destroy the popularity of breakfast foods, and ruin to a great extent a large trade that has been built up in this country." Millers throughout California have become very much alarmed, and agree with my correspondent, that if something, either natural or arti-

ficial, does not check this advancing enemy very soon, the successful operation of large mills will be seriously, if not permanently, injured.

DISCOVERY IN NEW YORK STATE.

In response to my article on the flour moth in the March (1895) number of the "American Miller," I received several interesting letters pertaining to the same subject. One of these revealed a new locality for the pest; the first positive record of its appearance in mills in the United States east of the Rocky Mountains. The letter, dated March 10, 1895, came from the head miller (name and the exact locality omitted by request) of a firm in southwestern New York, and reads as follows:

"Your article which appeared in the 'American Miller' of this month has no doubt been read with a great deal of interest. Of course it can only be appreciated by those who have been afflicted with the flour moth in their mills. I have had charge of some of the best and largest mills in this country, and have never had any trouble with this insect until about a year ago, at which time it took possession of the entire plant in about two weeks' time. I was forced to shut down and take out elevator spouts. The covers were removed from the spouts, and the birds' nests, as we call them, were taken out by the bushel. I would not have believed it had any one informed me, but such was actually the case. I have been a contributor to the milling press now and then, but have not dared to say anything about it on account of being scored by those who have been fortunate enough to escape their presence. I have tried everything to get rid of them, and I think I have succeeded fairly well by using metal spouts throughout the mill."

Upon receipt of this interesting communication, I immediately wrote the miller asking for samples of the material containing the larvæ, and March 20 I received two packages of flour literally filled with the worms, pupæ, and several dead adult moths. The material was placed in a breeding-cage, and the following day (March 21) three adult females emerged, leaving no doubt about the identity of the species. Two more females emerged the 25th; and the first male appeared April 10. With this material I conducted a series of experiments, mentioned later in this paper. The letter accompanying this material is of general interest, and I quote it in full:

"Your favor of the 13th instant is received and noted. I mail you two samples of the webs, as per request, one taken from an elevator leg, and the other from a hopper in a porcelain roller mill, grinding fine purified middlings. I will answer your question as to how they originated in this mill, as near as I can. This mill has been run by the [————] Milling Company for years on a system as nearly perfect as any mill can be run. About eighteen months ago this firm surrendered to the First National Bank of this city, and one of the stockholders became office manager. This gentleman, not being acquainted with the

art of manufacturing flour, attempted to cut down expenses. He looked upon the sweeper in a mill as a sort of luxury and dispensed with his services. The mill run night and day and soon became filthy. In about four months' time the moths made their appearance; in fact they got so bad the head miller was forced to resign. I was then engaged, by correspondence, for one year. Had I known the condition the mill was in at that time, I should not have accepted; but, as it is, I have done the best I could. I have succeeded fairly well in getting rid of the pest, and I expect to drive them out entirely."

The remainder of this interesting letter is quoted under the heads of remedies and distribution.

I made the first public announcement of this pest in New York, in a short article in the "American Miller" for May, and special editorial mention of it was made in the same issue, warning millers to be on their guard in that and adjoining states.

I made an especial effort to account for the presence of the flour-moth pest in this mill; but, after a large amount of correspondence, I only ascertained that it had been established for some years in mills at several places in southwestern New York, and, possibly, in parts of Pennsylvania. Some mills in this region were forced to shut down and clean out spouts and elevators nearly two years before the pest came to my attention. The infested district in New York is inland, and to say that the moth came originally from Canada, or from any other specified source, would be pure assumption. The moth is still present in New York; but the head miller who first made known its presence to me assures me, in a letter dated September 14, 1895, that it is not nearly so abundant in his mill as formerly, and that he has it under control.

NEW OUTBREAK IN CANADA.

It will be remembered that the Mediterranean flour moth appeared in destructive numbers in Ontario, Canada, in the year 1889, and after encountering a determined and energetic fight, practically disappeared, little or nothing having been heard of it since in that region. In the November (1895) number of the "American Miller" I recorded its occurrence in the Province of Quebec, Canada, and gave other notes concerning it. My attention was called to this outbreak by Mr. Edward R. Taylor, manufacturing chemist, Cleveland, Ohio, who wrote me September 23, 1895, as follows: "I take the liberty to forward you a letter and sample of flour infested with what appears to me to suit the description of the Mediterranean flour moth. If you will kindly examine the material and report to the party concerned it will be greatly appreciated." The letter was from a Canadian miller, dated September 19, 1895, and read as follows: "I mail you to-day a sample of flour containing a little pest that has appeared in our mill this year for the first time, and is consequently a stranger to me. You will find in the sample several small flies, with their young in the mat enclosed. They are to be found in great quantities in our spouts, in every conceivable corner, and so abundant

in purifiers and bolts that it is becoming a serious matter. Any information you can give me, publicly or privately, will be thankfully received."

A careful examination of the material left no doubt as to the species' being *Ephestia kuehniella.* In my reply I asked for additional information regarding the pest, and for a fresh lot of material, as the sample sent was in bad condition when received, having been crushed during transit. I received the following answer, dated October 2: "Replying to your favor of the 26th ult., would say that the pest came into our mill from a neighboring mill during the past summer. We have made no particular attempt to exterminate it. Our mill is a new one, put in only a year ago, and consequently the moth is a new thing with us; but we learn that it was in the neighborhood last year. With thanks for your kind attention we will await the 'American Miller' for further particulars." The sample of infested flour accompanying this letter was placed in a breeding-cage, from which I took two adult females October 15. The specimens did not vary in any particular from typical specimens from California and New York. As to the source of this infestation I have nothing to say. The whole subject of the distribution of this pest is in such an unsettled state that I will not venture to give an explanation of its origin in any given locality.

NATURAL ENEMIES.

In the struggle for existence the flour moth is not entirely free from the attacks of natural enemies, but has many pronounced advantages in the fact that it is entirely concealed in silken tunnels during its larval or feeding state. There are two weak points, however, in its life history; namely, the quiescent or pupal state, and the period immediately after the larva has reached maturity, when its migratory instincts are so strong that it will expose its delicate body for several hours as it crawls about hunting a suitable place for pupation. Nature has taken advantage of these vulnerable points, but, on the whole, interposes but feeble checks on the multiplication of the species.

The reducing agents of the flour moth fall naturally under two heads, predaceous enemies and parasitic enemies, the former including insects, birds, and mammals; and the latter, insects alone. Such data as we have are presented here chiefly as an indication of the practical inefficiency of the natural enemies of this species.

Birds.—Mr. Sidney T. Klein delivered a colony of the larvæ of the flour moth, which he had been keeping in his room for experimental purposes, over to the tender mercies of about fifty game and Plymouth-rock hens kept in his garden, and the greediness with which these larvæ were eaten by the fowls suggested a ready means for the extermination of myriads of those in the warehouse where he had been making observations. Mr. Klein says: "A great number of hens was therefore requisitioned from the neighborhood in the east end, and it was encouraging to see the enormous quantities consumed. But the hens began to flag after ten minutes of gorging, and, although they were kept in the warehouse for

several weeks, the insects still continued to increase and spread to other granaries." An outbreak of this pest very rarely occurs where chickens could be utilized for its destruction, and they are therefore of little practical value in this connection.

Mammals.—I have here to relate a curious instance where a common house mouse, *Mus musculus*, devoured several hundred pupæ of the flour moth in one evening. April 11, 1895, I removed a male and a female flour moth, still pairing, from a stock cage, and placed them in a separate cage in order to obtain the eggs for experimental purposes. The eggs were laid and hatched in due season, the first young appearing April 21, and the larvæ were supplied with an abundance of wheat flour and catmeal for food. The larvæ matured and were all pupated by June 5, the brown chrysalids being plainly seen through the sides of the glass cage. By actual count there were two hundred and fifty-four pupæ in the cage at this time. A mouse discovered this cage sometime during the night of June 12, cut through the Swiss muslin that covered it, and devoured every pupa within. Little or none of the flour and meal in the cage had been eaten. Of course, millers and dealers can turn mice to no good account as enemies of the flour moth, and this instance is introduced simply as a record of the evident relish of one mouse for insect pupæ.

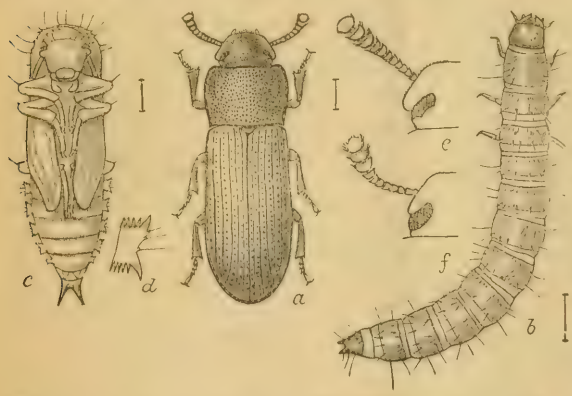

FIG. 5.—*Tribolium confusum*: *a*, adult beetle; *b*, larva; *c*, pupa,—all enlarged; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of *T. ferrugineum*,—all greatly enlarged. (After Chittenden.)

Predaceous Insects.—Those insects popularly known as "flour weevils" are foremost in this group. They are known to science as *Tribolium ferrugineum** and *T. confusum.* The two species are so closely related that they can with difficulty be separated, and, to the ordinary observer, they are one and the same thing. Their habits are similiar, and the injuries occasioned by them far outnumber those of any other insect that attacks grains and farinaceous foods. Both species are cosmopolitan, and have a wide geographical distribution.

* In speaking of the flour moth larvæ Professor Zeller says: "Simultaneously with these larvæ I received the little beetle *Tribolium ferrugineum*, which multiplied so rapidly that during the summer I sometimes found large masses of its yellowish larvæ. I eagerly destroyed them, fearing they would, at least, be disadvantageous to the larvæ and pupæ of the flour moth. Now, it seems to me that this beetle was unjustly held in suspicion by me, and that it and its larvæ, at most, would help to devour the moths reared for propagation, and dying soon after mating." From this it appears that Prof. Zeller did not observe the weevil feeding upon the larvæ or pupæ of the flour moth. In the same paragraph, however, he says: "I rather suspicion the Ephestia larvæ of devouring little by little, not only their dead parents, but also the pupæ which have fallen out of the web." I have myself seen the flour-moth larvæ attack and devour pupæ of their own kind in a breeding-cage where the pupæ had been uncovered.

They have long been known to infest meal, flour, grain, and vegetable stores in Europe, and in the past few years have become very troublesome in this country, occasioning considerable alarm among millers, flour and feed dealers, grocers, and dealers in patent foods. It is not an uncommon pest in our museum collections, feeding on the dead bodies of insects. The adult insects are small, flat, reddish-brown beetles, about three sixteenths of an inch in length. Our most common species, *T. confusum*, is represented in its different stages in Fig. 5 (p. 39). The eggs are deposited in the flour, from which the young hatch a little later. There are four or five broods during the year. They are offensive creatures, and impart a disagreeable odor to the infested material. Their carnivorous habits, however, make some amends for the mischief they do. I have frequently seen the adults of both weevils preying upon the larvæ and pupæ of the flour moth in mills in California. In one reel, where a great number of the flour-moth larvæ had pupated, it was rather difficult to find a single cocoon which did not contain an adult of either *confusum* or *ferrugineum*, the former species being, however, most abundant. The flour-moth chrysalids, in most cases, had been completely devoured.

August 18, 1895, I placed a hundred adult beetles of *confusum*, received August 16 in flour from Toledo, Ohio, in a breeding-cage in which several hundred larvæ of the flour moth had just pupated, and left them undisturbed for several days. August 26, I made a careful examination and found that the weevils had penetrated two thirds of the cocoons and destroyed the chrysalids within them. August 30, two flour moths emerged from this cage, but no others issued at any time later. There was an abundance of wheat flour and corn meal in the cage, which fact alone would seem to suggest that the weevil prefers insect food when it is available. These weevils were left in the cage undisturbed, where they have been breeding continuously ever since, and there are now in the cage thousands of adults and larvæ.

One enthusiastic miller in San Francisco, California, who observed the flour weevil feeding upon the larva of the flour moth, made artificial breeding beds for the former and distributed them about his mill in the hope of reducing the flour moth, which was everywhere present in his mill. August 23, 1895, he wrote me the following letter on this subject: "I had hopes of some assistance from the little weevil, having observed them feasting on the larvæ of the flour moth. I cultivated colonies of them and distributed them through the mill, and watched them very closely for some weeks. I found that while they did attack the larvæ to some extent, it was still not enough to be of any particular benefit. The little beetles are themselves a pest, as they get into the meals and flour and make trouble there, so I have abandoned any hope in that direction."

I have seen the notorious cadelle (*Tenebrioides mauritanica*), known sometimes as the "bolting-cloth beetle" in California, attacking both the larva and pupa of the flour moth and devouring both the larva and adult of the flour weevil, *T. confusum*, in my

breeding-cages. I have also seen *Gnathocerus cornutus*, another mill pest, attack and devour the flour-moth larvæ in mills in California.

Parasitic Insects.—The larva of the flour moth is attacked by several species of very small hymenopterous parasites. They are delicate wasp-like creatures, which take advantage of the full-grown larva of the flour moth during its migratory period just prior to its pupation. While the delicate larva is thus exposed the winged parasite lays her eggs, usually upon its body. In one instance at least, that of *Bracon hebetor* Say*, the parent insect paralyzes the larva, reducing it to a helpless condition before the eggs are deposited.

The first true parasite of the flour-moth observed, *Bracon brevicornis* Wesm., was discovered by Mr. Sidney T. Klein in August, 1887, in a London warehouse. He describes the attack as follows: "I held an inspection in August, and brought away several of the full fed larvæ for examination, as I noted some irregular markings which had not been noticed before. These larvæ seemed to pupate quite regularly, and I did not suspect the state of the case until I went down again at the beginning of September. No sooner had I entered the warehouse than I noticed a most extraordinary change in the appearance of the large piles of flour. On closer examination I found this appearance was caused by enormous numbers of a small black fly * * *; and, upon examining several of the larvæ, the majority of which had markings on their backs, the startling fact was established that nature had come to the rescue and provided a remedy herself. It is very rarely that such a striking example of nature's wonderful counterbalancing powers is discovered."

Mr. Wm. H. Ashmead, of Washington, D. C., who is our best authority on this group, informs me that *Bracon brevicornis* is not found in North America so far as he knows.

Specimens of *Chremylus rubiginosus* were bred from *Ephestia kuehniella* and sent to Mr. J. B. Bridgman, of Norwich, England, who records the fact in a communication to the editors of "Insect Life" (Vol. II., p. 260). In a letter from Mr. Ashmead, dated September 21, 1895, he says: "I know this species only by European specimens. It is not yet recorded from North America."

The present economic relationship of *Bracon hebetor* Say to the flour moth was discovered by me September 2, 1895. The insect was first described by Thomas Say in February, 1835,† and is therefore an old-time species. Mr. Ashmead, who kindly determined it for me, says: "I have seen specimens from California, Indiana, Ohio, Illinois, District of Columbia, Virginia, New York, Massachusetts, and other New England States. It is therefore a widely distributed species. It comes very close to my *Bracon gelechiæ*, reared by yourself from *Canarsia hammondi*, in color and general facies, but differs in sculpture and antennal characters."

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* Belongs to Mr. Ashmead's new subgenus *Habrobracon*.

† Bost. Jour. Nat. Hist., Vol. 1, 1835, p. 252.

I bred another specimen, a male, from the same lot of flour-moth larvæ, which, although certainly different from typical males of *Bracon hebetor*, is probably only a small variety of this species. Mr. Ashmead characterizes it as follows: "It differs markedly in several particulars—number of joints in antennæ, its more elongated shape, much smaller size, and in color; but until the opposite sex is bred, it would be better to consider it only as a variety of *hebetor*." This little braconid has been bred from the Indian meal moth, *Plodia interpunctella*, in Massachusetts. I have reason to believe that we may expect some good results from it in this country. Out of several hundred flour-moth larvæ sent me by the California miller, only one moth emerged, all the others having been destroyed by the little parasites, of which I removed twenty-seven specimens from my breeding-cage. It is surprising how easily these little creatures can be colonized. It is only necessary to collect a quantity of the webbed flour containing the flour-moth larvæ and place it in a breeding-cage, into which the parasites are afterward introduced. Here they multiply rapidly, and can be liberated at will in the worst-infested parts of the mill. I have suggested this expedient to the president of the milling firm from whom I received the larvæ.

I will now give, somewhat in detail, notes of my own observations on *Bracon hebetor*. When I discovered this little parasite, I noticed that several of the flour-moth larvæ were lying in the bottom of the cage in a helpless condition, although presenting the fresh and plump appearance characteristic of living larvæ. Upon examination I found that they were not dead, but in a state of lethargy. Two larvæ in this condition were removed from the cage and placed in a glass tube, where they remained perfectly motionless, but still gave on the fifth day evident signs of life by a slight movement of the thoracic segments when touched with a needle point. This movement was not noticeable on the sixth day, and the larvæ were dried up and shriveled two days later. It is quite probable that this paralysis is caused by the adult parasite, but in what way has not yet been worked out satisfactorily. I have now several experiments in progress to determine this point if possible. I have observed the same paralytic state in larvæ of *Canarsia hammondi*, and in nearly every case have found the eggs of *Bracon gelechiæ* either on the body of the larvæ or on the silk or web immediately over them. In this latter case it is very important that the larvæ should not move after the eggs of the parasite have been deposited, as the little grubs hatching from them are legless, and could not crawl far in search of food. I am of the opinion that *B. hebetor* deposits its eggs in much the same way. I have not seen the eggs of this species, but have found grubs just hatched attached to the external surface of the flour-moth larvæ. In one instance, September 18, 1895, I removed a larva from a cage with five grubs, just emerged, feeding upon it, two of which were removed and placed in alcohol, and the others were left for development. The following morning, at 8 o'clock,

they had left the larva and were forming cocoons on the side of the tube. The cocoons were completed by 8 o'clock, September 20, and were whitish in color. The fully developed chrysalids could be plainly seen by the 23d, in which condition they remained until October 7, when the adult parasites emerged. From this one observation it appears that the grubs reach maturity in one or two days; that one day is required for the construction of the cocoon; and that a little over two weeks is passed in the pupa stage, making about three weeks for the complete life cycle of the parasite. It will be remembered that about nine weeks are required for the complete evolution of the flour moth, so that there would be three generations of the parasite during a like period.

PREVENTIVE AND REMEDIAL MEASURES AND MECHANICAL DEVICES.

It is now a well-known fact that this moth is carried from mill to mill in the greater number of cases through carelessness. Millers who have never been troubled with insect pests think there is nothing to fear, and carelessly permit all sorts of material, such as empty bags, barrels, boxes, and second-hand machinery, to enter their premises without even suspecting the presence of their worst enemy. The indifference displayed by most millers who have been fortunate enough to escape the ravages of insect pests in their mills, is truly lamentable. All preventive measures are ignored, the mills are often dirty through neglect, and unconcern prevails. These very people, sooner or later, will suffer severe mental anxiety and heavy financial loss for their negligence. Other firms neglect their mills simply because they are new, thinking they have nothing to fear from outside foes. Some of the worst flour-moth outbreaks recorded in this country have occurred in newly constructed mills. One of the newest mills in California was obliged to shut down before it had run six months, and employed a force of men to take down all spouts and elevators and clean out the accumulations from them. The Canadian outbreak at Valleyfield, Quebec, is another instance. The mill was constructed about a year ago, and has been obliged to shut down several times during the past season in order to clean out the webs from spouts and elevators. When a mill is clean and new it would certainly be good policy on the part of the owners to keep it fresh and clean. In this day of common insect pests, a sweeper or duster is indispensable to the successful operation of a mill. He should be thoroughly acquainted with all insects injurious to mills, mill products, and stored grain, and competent to apply such measures as may be requisite for their arrest and destruction. He should be responsible for the inspection of all incoming material, of whatever sort, where there is the slightest question as to its freedom from insect pests.

Where the flour moth has established itself in a mill, it can be kept in subjection only by the most persistent and energetic fighting. The standard remedies are steam, sulphur, and bisulphide of carbon, all of which are soon to be considered in detail. I shall

discuss here only such remedial measures as have been used successfully by milling firms, including suggestions warranted by my own experimental work.

Cleanliness.—The only safeguard against insect pests in mills is scrupulous cleanliness. This can be attained by constant sweeping and dusting; but a much more effective method has been perfected and used by one of my San Francisco correspondents, whose procedure is as follows: "I am now employing," he writes, "a scheme for cleaning our mill which I find the most efficacious, taking it all around, of anything I have tried. I have run a half-inch pipe under each ceiling of every story in the mill, and every twenty-five feet I have a steam-cock, so that I can attach a steam hose, on which I use a nozzle (the same as that used on any garden hose). With this arrangement I thoroughly steam all the spouts, corners, garners, walls, posts, in fact every part of the mill. It is the best cleaning apparatus for a mill that I have seen. One man in one day with this hose will sweep the mill cleaner of dust, dirt, and other accumulations, than twenty men could do with broom and brush. In fact it is impossible to clean out dust with broom and brush as well as it can be done with steam. I recommend this scheme to all those with whom I talk, and you can safely recommend it to all your correspondents as being an excellent thing. There is no other apparatus that will cleanse a mill so thoroughly." This is by far the most practical method known to me, and I commend these steam pipes to millers as a most necessary part of the equipment of a mill. No new mill should be contemplated without incorporating the "steam sweeper" in its plans and specifications. Such an equipment will pay for itself in a short time, and a clean well-kept mill certainly commends itself to public favor. The cautions to be observed when steam is used in mills are discussed on p. 54. Great care should be taken not to allow loose material, empty bags, boxes, and the like, to accumulate about a mill. All such rubbish should be burned if it has no commercial value.

Fumigation Box.—Every well-equipped mill should have a tight wooden box, large enough to hold all the bags, boxes, or barrels that usually come and go from the mill, or are in circulation among local customers. Such material should be thoroughly steamed, or subjected to the fumes of sulphur or bisulphide of carbon, before being permitted to re-enter the mill. Any second-hand machinery that may be bought should be treated in the same manner. Instances where the flour moth and other insect pests have been carelessly introduced on old bags and second-hand machinery have already been given.

Metal Spouts.—Any substitution of one piece of apparatus for another that will in any way make it more difficult for insects to find lodgement in a mill, will certainly be productive of good and lessen the chances of infestation. It is a well-known fact that the flour moth finds spouts and elevator legs its most favorable quarters. The wooden spouts are so arranged that the larvæ have no difficulty whatever in clinging to them, and consequently great quantities of flour are matted together and cause the trouble

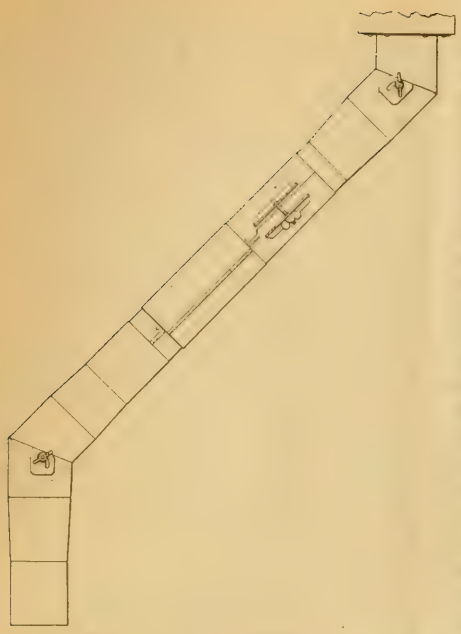

FIG. 6—Adjustable metal spout.

in such places. This liability may be removed by the substitution of metal for wooden spouts. The metal spout was first used for this purpose by the inventor, Mr. L. C. Schroeder, of Olean, New York, and is protected by a patent. These spouts are perfectly smooth and there is no chance for an insect to find lodgement within them. The inventor claims that they can be made for less money than the lumber costs for wooden ones, and that a millwright is not needed to put them in position. (See Fig. 6.) I might say in this connection that Mr. Schroeder has also applied for a patent for a metal elevator leg, which, when on the market, will afford another useful piece of apparatus for preventing the establishment of injurious insects in these parts of a mill.

Where metal spouts have been resorted to in mills overrun with this scourge, the results have been very satisfactory. In March, 1895, a New York miller wrote me the following letter on this subject: "I have discontinued the use of wooden spouts and have substituted metal ones. Since I adopted this spout I have had no trouble with the moth in the plant, but it has drifted from here to the flour department, and seems to be most abundant in the purifiers and rollers. I am now removing all the wooden spouts as fast as I can in the flour department, and I hope to be able to get rid of the pest before warm weather comes on."

This letter was followed by another communication from the same miller, dated August 14, which I quote in full, and which needs no comment: "The Mediterranean flour moth is a thing of the past, or nearly so, in our mill. When I wrote you last [March 17] this mill was alive with them; but I have rooted them out by degrees. I was confident I could do it. As I said before, they shifted about from the meal department to the buckwheat department and then to the flour department, all three plants being located under one and the same roof. The latter part of May I shut down four days for the sole purpose of cleaning out this pest. I ran down the stock as close as possible and then had the mill swept from top to bottom. I then took down all wooden spouts and replaced them with metal spouts. I have metal spouts here which were put in nearly twelve months ago in our meal department, and during that time not a moth has been seen in

them; in fact, they cannot locate in them, for they are perfectly round and smooth inside. It is in the corners of a wooden spout that the worms locate and spin their webs. It would be a hard matter for me to find a sample of stock in this mill, at present, that contains either the worms or moths."

Attachment of Brushes to Belts.—The fact that the larvæ of the flour moth cause most trouble in spouts and elevator legs has suggested the attachment of several brushes to the belts, so arranged that they constantly clean the sides and corners of the spouts and the elevator legs. Where it is necessary to retain the wooden spouts in an infested mill, this device is highly recommended and should be kept in constant use. It has been successful in France, and one of my California correspondents who is using the brushes says: "Our spouts were continually choking up, so that we had to employ one or two extra men in operating the mill in order to take care of the choke-ups that occurred. Now we have no difficulty whatever. The elevators and spouts are entirely clean, and we have no trouble with worms in our mill; in fact, we hardly notice the existence of the pest at all, but we realize that we must keep up a constant warfare on them or they will immediately increase to such an extent that we shall be in as great trouble as before."

The "American Miller" for December, 1895, contains a communication from a practical miller bearing directly upon this subject, and I quote it here in full:

"*Editor American Miller:* Millers are often troubled with elevators sweating and dust settling in them, which becomes musty and moldy. More or less of this is bolted into flour, and as a result musty flour comes back to the mill. I have designed an elevator brush to prevent this trouble, a drawing of which is presented in the accompanying illustration. [See Fig. 7.]

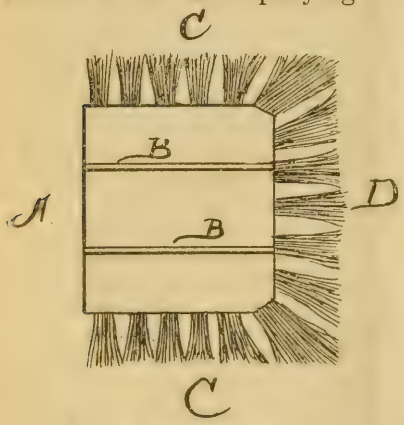

Fig. 7.—Elevator Brush.

"To make the brush take a piece of 1½-inch plank of the same dimensions as the elevator cups, and fasten bristles to three sides. The side A is fastened to the elevator belt with flat-headed bolts running through the plank, as shown at B, B, the bolts being ¼ or ⅜ of an inch. The bristles on the sides C, C, should be ¾ of an inch long, but those at D should be longer, so that they will give a good brushing to the outer side of the elevator. The brush is easily made, and the miller can make it of any size to fit his elevators."

I will now consider, in the order of their effectiveness, substances which have been used with the most satisfactory results in combating the flour moth. Bisulphide of carbon stands first, followed by steam, sulphur, and steam and sulphur combined.

Bisulphide of Carbon.—The simplest, most effective, and least expensive remedy for all mill pests is bisulphide of carbon, a very inflammable, volatile, foul-smelling liquid, as clear as water. Its vapor is heavier than air, and will penetrate every crack and crevice in a mill or warehouse when used in sufficient quantities. It can be thrown directly upon grain without injuring its edible qualities, and will not affect its vitality in the least. In mills it can be used about the machinery, spouts, and elevators with perfect assurance that the manufactured products will not be damaged. It is a powerful insecticide, the atmosphere produced by its vapors being sure death to insects, as well as to rats and mice. I know of no instance, however, where the slightest deleterious effect has been realized by persons applying it in mills, although they unavoidably inhale some of the fumes.

The amount of liquid to be used depends (1) on the size of the building, (2) on its tightness, and (3) on the magnitude of the attack. Where the building is reasonably tight and but slightly infested, one pound of bisulphide is sufficient for every thousand cubic feet of air space. If it is somewhat open or badly infested the amount should be doubled. When applied to bins containing stored grain, one pound of the liquid to every hundred bushels of grain is commonly used; but if the insects are very abundant the amount of bisulphide should be doubled.

A number of methods for the application of bisulphide of carbon have been suggested and tested, but the most effective manner of applying it in mills consists in simply pouring the liquid into shallow dishes, such as soup plates, or pans, and distributing them about the building. Bits of cotton-waste saturated with the liquid should also be thrust into spouts, elevator legs, machines, and other places where the pests usually congregate in great numbers. Spraying or throwing the liquid broadcast into badly infested corners, on machines, and other pieces of apparatus where the pests are particularly abundant, has been attended with very good results.

Saturday afternoon is the best time for fumigating a mill. After sweeping it from top to bottom, using a "steam sweeper" where it is practicable, all fires about the premises should be extinguished and the mill closed as tightly as possible. The dishes and cotton-waste should be previously distributed, so that there will be no unnecessary delay in the application of the foul-smelling fluid. The distribution of these vessels must of course depend, as already stated, upon the condition of the mill and the severity of the attack. It is best to begin with the lowest story and work up, as the operators can then keep above the settling gas. When the bisulphide has been applied throughout the mill it should be locked and kept closed until the following Monday morning. All windows and doors should then be thrown wide open and the building allowed to air an hour before any fire is started. Where the building is large and a great quantity of bisulphide has been used, it would be wise to observe the extra precaution of stationing a watchman without to prevent any one from entering the building during fumigation.

As a guide to millers who may use this method for exterminating insect pests in mills, I will quote several letters from practical millers who have used bisulphide of carbon successfully. The superintendent of a large Pennsylvania milling company, whose name is withheld by request, under date of July 12, 1895, wrote me the following letter, which is a valuable contribution to this subject, and should be read by every wide-awake miller and grain dealer:

"We have delayed answering your valued favor of May last until we were able to report the result of our efforts to destroy the weevils in our mill. Following in the line of your advice, we ran our stock down and thoroughly renovated our mill from top to bottom, cleaning all reels and purifiers. We then fumigated the whole mill with bisulphide of carbon. We distributed 300 soup plates about half filled with bisulphide through the mill, and saturated balls of cotton with the same material and placed them in all the reels and purifiers. This we did on Saturday night and closed the mill tight and left the weevils to their destruction.

"We opened the mill Monday morning and thoroughly ventilated it before starting. We found that we had destroyed thousands, and in the reels and purifiers we had killed them all. In the course of a few days, however, they began to show up in the cracks in the floors all over the mill, and in dark corners. Two weeks later we repeated the dose of bisulphide in the same manner and obtained about the same results. In the meantime, however, we whitewashed the mill from top to bottom, that is, every place that could be covered, putting on a good heavy coat. We have not destroyed them all by any means; but we have reduced their forces to a very small number. Eternal vigilance is the order of the day.

"We are still fighting them. Our plan is to keep a stock of bisulphide on hand outside of the mill building, as we do not think it advisable to store it in the mill on account of its inflammable nature. Wherever we find a place infested by the weevil we use it freely, taking care to do it when the mill is shut down and closed up tight. We find the best results from the use of bisulphide of carbon can be obtained by spraying it on the floors and infested places. We think when placed in plates it does not evaporate quick enough to produce the death atmosphere required. Before closing let us return our sincere thanks to you for the interest you have taken in the matter, and assure you that we appreciate your valuable advice."

The "American Miller" for July, 1895, contains another interesting and valuable communication on this subject, from Mr. H. J. Laurie, of Norwalk, Ohio, and I quote it here in full:

"As the season is now upon us when a large majority of the flouring-mills of the country are being troubled with insects of various kinds, such as weevils, worms, moths, etc., I thought it might not be out of place to give our experience here with bisulphide of carbon, which we have been using for several seasons with very satisfactory results.

"I have reason to believe that a number of millers have used this remedy with very indifferent results, owing, in my opinion, to the manner in which it was applied. In the first place, the mill should be thoroughly swept (as every mill should be daily), and if there are any broken panes of glass in the windows they should be replaced, the object being to make the mill as tight as possible. Then have a number of shallow tin pans, say, about fifty to every 100 pounds of the compound used. Begin at the top [bottom] of the mill, and place the pans where the insects are the thickest. It is best for two to go together, one placing the pans, the other filling them, using a watering-can or something of the kind having a spout.

"I apply it to the bolting reels and flour garners as follows: I get ready, beforehand, a number of medium-sized bunches of cotton-waste, two for each reel, with a string attached to each. I dip these bunches into the bucket of compound, pressing out with a paddle so they will not drip too much; then throw them under the reel and down on the conveyor, leaving the string on the outside so they can be recovered, then close the doors of the bolting chest tightly. I suspend one or two bunches in like manner in the flour garners and screening bins. In applying it to the wheat bins we level off the grain and place the pans on it filled with the liquid. By applying it in this way to wheat bins and taking proper care to have the bins emptied and swept out occasionally, no one need be troubled with weevils in their grain elevators. There is one thing that we have discovered, and that is that the compound must be reasonably fresh when used. If kept for any great length of time it loses its strength, consequently it should be used as soon as practicable after receiving it, and no more should be ordered than it is intended to use.

"Before commencing the use of bisulphide of carbon this mill was badly infested with weevils and other insects. Now we are nearly free from the pests. I do not say that this remedy will kill every insect in a mill. I do not think there is an insecticide made powerful enough to reach every nook and crevice, such as we have in mills; but we do know that by a judicious use of bisulphide of carbon in warm weather, when the insects are in full force, and by a due regard to cleanliness all over the mill, any mill can be rid of the pests.

"The compound being highly inflammable, there should be no fire or lights used in the mill at the time it is applied. The best time to apply it is Saturday evening, and the mill should be kept closed till Monday morning."

There have been so many exaggerated reports about the nature of this chemical compound that it is necessary to give a few notes regarding it in this place. In this connection I can do no greater service than to quote a letter from Mr. Edward R. Taylor, of Cleveland, Ohio, the leading manufacturer of bisulphide of carbon in this country. It appeared in the "American Miller" for September, 1895, and reads as follows:

"*Editor American Miller:* I have seen a great many very random statements on the subject of the inflammability of bisulphide of carbon. One says, 'Use the same care as with gunpowder.' Another says 'It is a very explosive liquid.' These are both very misleading statements with reference to the properties of bisulphide of carbon. I have quoted the statements, however, in my printed matter for the reason that farmers and many others use the goods, and will be sufficiently startled by such statements to be careful and have no light or fire about.

"Nearly everybody is now familiar with gasoline. The properties of that liquid and bisulphide are practically identical in that both are inflammable but neither of them explosive. The vapor of either of them mixed with air is explosive, but the liquids are not explosive. I have shipped thousands of pounds of bisulphide to millers, elevator operators, and farmers in the last few years, and I have yet to have the first report of any disaster, even of the most trivial character, from a single one of them. Need I say more? My directions are explicit: Do the work Saturday afternoon by daylight. Absolutely have no light or fire of any kind about. Close the mill and leave the bugs to their destruction till Monday morning. Then open doors and windows, and thoroughly ventilate before going to work."

Some of the insurance companies have commenced to feel a little uneasy lest they should suffer loss by fire originating from the use of bisulphide of carbon in mills. The "American Miller" has investigated this subject by sending letters of inquiry to all the more important millers' insurance companies in the United States and Canada, and so far has not learned of a single fire which is known to have been caused by the use of bisulphide of carbon. The properties of the fluid have been fully described repeatedly, and millers have been warned to keep lights and fire away from the vapor, lest an explosion should occur. The fact that it has been used so long without fires being traceable to it, gives strength to the opinion that millers, out of consideration for their own lives, have heeded the warning and have been exceedingly careful in applying it. When they become more familiar with its use they may grow careless, but we hope such will not be the case. It should not be stored near the mill, as this increases the fire risk. A break in the can might unexpectedly release fumes which would soon fill the mill.

Bisulphide of carbon is sold at drug stores at from 20 to 30 cents a pound, but can be bought much cheaper at wholesale, directly from the manufacturer. A grade known as "Fuma Bisulphide of Carbon" can be obtained directly from its manufacturer, Mr. Edward R. Taylor, Cleveland, Ohio, in fifty- or hundred-pound cans at ten cents a pound, and is as effective as the ordinary grades on the market. A carefully prepared circular containing full information for its use and the necessary precautions to be heeeded during its application is sent with each order sold.

Sulphur.—From a practical standpoint sulphur ranks next to bisulphide of carbon, as an effective remedial measure, but it

must be handled with great care. The burning of sulphur in infested mills has been attended with both good and evil results. The experience of the millers cited below, should be sufficient warning for all those who may resort to this method for the suppression of insect pests. The experience of an English miller, as related by Miss Ormerod in her Fourteenth Report (p. 58), is given in the following paragraph: "But we found that sulphuring has an effect which we did not anticipate or wish. We had standing in the mill when the fumigation was carried on, some eighty or a hundred sacks of flour, and we find to our dismay that the sulphur has penetrated right into these, and acted on the gluten of the flour in such a manner as to apparently break up all soluble albuminoids, and render the dough made from it more like a lot of weak putty than the strong, tough dough our customers require."

In May, 1892, the manager of a San Francisco mill, who tried the burning of sulphur in his mill for the destruction of the flour moth, wrote me as follows: "The fumes of the sulphur acting on the different cereals, destroys certain properties of the grain and flour, rendering both useless for bread-making purposes. On our first application of the sulphur fumes we nearly destroyed about a thousand barrels of flour. This was very discouraging and has since prevented us from applying that gas in so extensive a manner as is necessary to fully exterminate the moths."

Even after this sad experience, the same miller is of the opinion that sulphur is the best remedy for keeping the pest in check when used in the proper manner.

Another California miller, who has had much experience fighting the moth, writes me as follows: "We cannot use sulphur in the mill any more without taking out all the flour and grain that we usually carry in stock. We find that the fumes of sulphur destroy the vitality of the flour by some chemical action rendering the flour worthless for bread-making purposes. They also destroy the value of the wheat for flour-making purposes, as the flour made from fumigated wheat makes no better bread than the fumigated flour."

Other instances of this nature might be given, but these will suffice. In preparing to sulphur a mill the stock should be run down as low as possible, and all flour and wheat removed before the sulphur is ignited. Care should be taken also to see that all windows, doors, and other openings are closed. Various ways have been suggested and tried for burning sulphur. A California miller outlines his method as follows: "Our method of using the fumes of sulphur is to take an iron pot, set the same in a can of water, put in a quantity of sulphur, or pulverized brimstone, pour over it some alcohol and set the same on fire. Then close up everything tight, so that the fumes cannot escape. This will kill every living thing with which the gas comes in contact. We have frequently found dead mice on the floor after having fumigated the place. We use this sulphur in parts of the mill which can be tightly closed so as to prevent the escape of the fumes."

Dr. Bryce, speaking of destroying the flour moth in Canada, says: "This can be done by closing the windows, doors, or other apertures of the building, and, night after night, until all evidences of moths have disappeared, burning sulphur by placing it in shallow pans, upon a number of heated stoves, say, small coal-oil stoves, in different parts of the building and putting a match to it."

The following method is also given by Dr. Bryce:

"To prepare sulphur fumes: Place a metallic dish containing hot ashes on some support in a pan of water, or place in an old pan or other vessel a bed of ashes at least 6 inches deep, and about 15 inches in diameter, and place the sulphur and saltpetre in a slight depression in the centre and ignite. The proper proportions are 3 lbs. of sulphur and 3 oz. of saltpetre per 1,000 cubic feet of air space. All doors, windows, and other openings should be tightly closed before the sulphur and saltpetre are ignited."

There are certain necessary precautions to be carefully observed in burning sulphur in mills, which may be given briefly as follows: (1) Remove all grain, flour, or other manufactured products from the mill; (2) see that all external openings are closed before the sulphur is ignited; (3) have the vessels containing sulphur so arranged and situated, that there will be no danger of fire from that source; and (4) thoroughly air and clean the mill again before resuming work. Particular attention should be given to the cleansing of the machines, especially those used for manufacturing flour and other farinaceous foods, as the sulphur compounds will continue to act on the manufactured products some days after disinfection unless this caution is heeded.

Steam.—Steam has been used in mills for the suppression of insect pests with considerable success. Miss Ormerod suggested the possibility of destroying the larvæ of the flour moth by turning on steam from the boiler—a plan which had been entirely successful in clearing a cheese factory of maggots which had spread to every nook and corner. This method was tried by an English miller at Miss Ormerod's suggestion, and he outlines his method of procedure as follows: "The way I applied the steam was by carrying about forty yards of half-inch piping into the mill from the boilers, and attaching an india-rubber hose to it for the men to work about on the walls, floors, spouts, and machines, blowing the steam into all the crevices and holes. I stopped the mill for a week while this was being done. It has rusted all the shafting, etc., but this is quite a secondary matter as it can soon be cleaned again. After blowing the steam, which took two or three days, I set the men to work to wash the walls (and every other surface that they could without fear of affecting the flour) with paraffine [kerosene]. The inside of the machines I had washed with a strong solution of boiling water and soda."

In Canada the Local Government compelled the miller, on whose premises the pest was first found, to take down all the machinery

and apparatus in his mill and subject it to a thorough steaming. The sad experience of this miller is related by himself and is quoted here in full from Dr. Bryce's bulletin (26):

"In the meantime we took down our machinery and subjected it to steaming. Every part was thoroughly steamed. The mill was swept down, and subjected to sulphur fumes. The walls, ceilings, etc., were cleaned, and elevator spouts and loose wooden work burnt up. Paper bags and hundreds of dollars' worth of goods were burnt in the furnace, while the other bags, elevator belts, and cups were boiled for hours in a cauldron of water. The machines and all parts that were not destroyed were then burnt by means of a kerosene torch, which flamed and smoked through and around every part of them until we considered we had everything clean and ready for putting together again.

"But on the 19th of September, the Local Government passed an Order in Council compelling us to take more stringent steps, and on the 20th of September, we received an order from Dr. Bryce, which stated that before placing our machinery in position we should subject it to a thorough disinfecting process in a strong room, so arranged that steam under pressure might be drawn or driven into it.

"In compliance with this order we at once constructed a tight steam box 6 feet wide, 6 feet high, and 12 feet long, and attached a steam pipe to it from the boiler. In this box we put every machine, and even our mill stones and iron rollers. This process was very expensive, and took up considerable time, as we were over a week at the process and were delayed in the placing of our machinery. The Board of Health visited us in a body during the time this process was going on, and pronounced it a success. This was all done not only in our own interests, as was pointed out in the letter of the 20th of September from Dr. Bryce, but in the interests of the public health and commerce of the country.

"Having now got in a position to go to work again, after two months' loss of time, and loss of machinery, fixtures, and stock, attended with much expense, we have arranged for remedial measures to prevent the reappearance of the pest or to destroy it if we should ever again be attacked. We have erected a steam stand-pipe with hose or other connection on each flat of the mill building. By shutting up all the doors and windows of each flat and turning on the steam simultaneously to each floor, the whole building can be filled with hot live steam sufficient to kill anything. This will rust all bright parts of the machinery, but to remedy this we intend using oil on them, should we ever be under the necessity of resorting to the measure.

"Another purpose of this steam stand-pipe will be in cold weather to let on sufficient steam to moisten everything and every part of the building at night, and then throw open the windows for the night and let the frost penetrate so as to kill any eggs or insects that may have become lodged in unseen parts.

"By these measures, with plenty of light, thorough cleanliness, a cold mill, and caution in taking in stock and old bags, we hope to keep free of the pest which has occasioned us so much trouble and loss."

One of my California correspondents, who is now using steam for the destruction of this pest, says: "By the use of this system I am now keeping the flour moth in check, but I am compelled to go over the mill, from top to bottom, at least once a week. If I let it go longer than that I observe a decided increase of the moths in the mill and worms in the goods. On the whole, I find this the most efficacious method I have tried since the moths have been with us."

The most satisfactory method for equipping a mill with apparatus for steaming purposes, now known to me, is that described on page 44, and used by a San Francisco miller.

There are several points about this method of destroying insects that should be carefully considered.

1. Any grain, flour, or other manufactured product left in a mill during the steaming process is liable to become damp and seriously injured. All such material should therefore be removed before the steam is turned on.

2. The bright parts of machinery and other apparatus are liable to become rusty if not wiped thoroughly dry immediately after the operation, or oiled before the steam is turned on.

3. The "steam sweeper" or steam introduced by means of a hose and nozzle, is certainly more advantageous than steam introduced through other pipes where the entire mill is filled at one time, as in the former case it can be directed into corners, spouts, machines, or other places where the attack is severest, with less liability to the injuries specified under 1 and 2.

4. Steam can be used to best advantage during the summer months, as the windows and doors can be thrown open at this time. In cold weather, or during the winter months, when the mill is tightly closed, the steam on the cloths of the purifiers often causes trouble, the middlings running the wrong way. Steam sweeping, on the whole, is most successful in the summer months, except in California and some of the Southern States where there is a mild and equable temperature.

Steam and Sulphur.—The use of steam and sulphur combined has been attended by very satisfactory results. My California correspondent, after his bitter experience with the sulphur, writes again: "I think that there is no doubt but that the moth can be exterminated from any one mill by sufficiently long-continued applications of sulphur fumes and steam. This, however, necessitates a great expense in moving all the stock out of the mill, and also loss of time that would result in shutting down the mill to make the application. I do not believe that all the eggs, larvæ, pupæ and adults could be destroyed in less than one week's constant application of the gas and steam. This process would leave the mill in such a condition that unless the acid which is deposited by the gas could be neutralized by some agent it would

be impossible to make any flour that could be used for bread-making until all the acid deposited should have been absorbed and carried away, which would result in enormous waste of material. I find, however, that the acid could be neutralized to a great extent by ammonia, and this, or some other equally powerful agent, would have to be used before turning the mill on to making flour again after the application of the gas."

In dealing with the Mediterranean flour moth eternal vigilance should be the order of the day, and if the above methods are faithfully employed, I think that we shall, in a few years, hear little or nothing about the insect in the mills of this country.

MISCELLANEOUS EXPEDIENTS.

Many ineffective expedients have been resorted to in the warfare with the flour moth, but they deserve only passing notice, and are mentioned here mainly for the benefit of experimenters.

Kerosene.—We have used this substance for washing walls, apparatus, and the inside of machines, but find it slow and tedious, and I would suggest its use only in extreme cases, where it is necessary to take a machine or other piece of apparatus apart.

Solution of Soda and Water.—A strong solution of soda and water has been used to good advantage for washing the inside of machines, and is very effectual in destroying larvæ when it comes in actual contact with them.

Soap and Lime.—A mixture of soft lye-soap and lime has been used for washing elevators and bolting-reels. This, like the above washes, is used mainly for cleansing the machines, and is of very little value unless the washing is kept up at regular and frequent intervals.

Buhach.—This substance(also called pyrethrum, insect-powder, etc.) was burned in a single mill with slight success. It is not as effective as bisulphide of carbon or sulphur fumes, and is more expensive. Mr. Danysz has given quite a lengthy account of his experimental work with this substance in his paper.

Ammonia.—Ammonia has been tried without success.

Hydrocyanic Gas.—I have some hopes from the use of hydrocyanic gas, but have not carried my experiments far enough to be certain of its safety or of the feasibility of its application in mills.

Corrosive Sublimate.—A solution of this substance has been used in mills for spraying walls, floors, and ceilings, but on account of its poisonous nature I would not recommend it.

Lime.—Very many millers after thoroughly cleaning and then whitewashing their mills have found that the pest was more easily kept in check. If the ceilings and walls of the mill are not tight, I would suggest that a little glue be added to the whitewash before being applied. Various methods have been used for applying this substance. Some paint the ceilings, walls, and floors, using a brush; while others use a pump and sprayer, forcing the lime into every crack and crevice. Ordinary whitewash, as commonly used, rubs off easily and often becomes a source of annoy-

ance. This can be overcome by adding a handful of common salt and about half a teacupful of lard to each gallon of the wash, which should then be thoroughly stirred before being applied. One of my California correspondents, in a letter dated August 27, 1895, says: "When making the whitewash I put in all the sulphuric acid that can be used without burning the pipe through which the wash is sprayed on the walls. I believe this acid is a good thing."

Sulphuric Acid.—A strong solution of sulphuric acid has been used to wash machinery, elevators, and spouts with good results, the acid being afterwards washed off with water.

Tobacco.—The burning of tobacco in mills is not effective on a large scale, but has given fairly good results in small, tight rooms and bins. Tobacco infusion has also been used for washing and cleansing apparatus, but, on the whole, it is not a satisfactory substance for general use.

Flour Paste.—The value of this material is summed up in the following letter from one of my California correspondents: "In answer to your question, 'What led you to try the flour paste experiment? I would state that we use flour paste for putting up packages of small goods. This paste is made, as needed, by one of our workmen, and is composed of flour, water, and vinegar, and is boiled by steam. I pay particular attention, in a general way, to all the work going on in the mill, visiting it every morning and going through every department. On one or two mornings I noticed that during the night the moths had seemed to congregate about this paste, many of them having fallen into it, and as it is of a tenacious nature they could not get away, and had perished. This seemed to be a curious kind of a thing to me and I made some investigation—had some of the paste put out in shallow pans, and I discovered that it had an attraction for the moth. I found, however, that it must be in a certain stage of fermentation in order to be of any value as an exterminator. I then commenced a series of experiments on a large scale, and in a short time had so reduced the number of moths in the mill that I was very much delighted with the result. At the same time I carried on experiments with other materials, the cost of the paste being a considerable item, since it had to be renewed every few days in order to be of any service."

Vinegar and Water.—This experiment was suggested by the one immediately preceding, and is outlined by the same miller in a letter dated August 23, 1895, which I quote in full: "I have tried numerous ways of getting rid of the pest, and, if I remember rightly, when I saw you last I was experimenting with flour paste. My experiments in that direction gave some promise of success, but I eventually abandoned the flour paste for a mixture of vinegar and water—about one fourth vinegar to three fourths water. This seemed to attract them as much as the paste did, and was not nearly so inconvenient, for the pans did not need to

be replenished nearly so often as with the paste. The paste seemed to attract them only in a certain stage of its fermentation—after that stage was passed they did not appear to care anything for it. The vinegar, however, attracted them until it had evaporated; but the acid contained in the mixture soon ate the pans up, and I had to abandon its use."

Molasses and Vinegar.—We have found that a mixture of molasses and vinegar—three parts of the former to one of the latter—can be used to good advantage for the destruction of the moths. The materials should be well stirred and placed about the mill in shallow pans or dishes in the evening just before closing. This substance lasts longer than either the flour paste or the vinegar and water, and does not require as much attention. The moths are attracted to it and are caught in the sticky substance.

Fly-paper.—This paper, known also as "tangle-foot," is rather expensive for use in mills, but we have used it with very good results, catching from fifty to a hundred moths on a single sheet in one night. Care should be taken to place the paper in such places as are likely to be visited by the moths for the deposition of their eggs; for example, on piles of flour in bags.

Coal-tar.—This substance has been used to good advantage by smearing it over large pieces of heavy paper and placing them about the mill. The tar dries out rapidly, and must be renewed at least every twenty-four hours. Coal-tar has also been used, with surprisingly good results, for painting rough walls and other places about a mill, thus stopping up cracks where insects would find lodgement and escape unnoticed.

Coal-tar and Vaseline.—We have tried an equal mixture of these two substances with no better results than with coal-tar alone, except that paper smeared with this mixture, not drying out so rapidly, does not need to be renewed so often.

Hand picking.—Many millers whose premises have been overrun with the flour moth, have kept it in check somewhat by "hand-picking." For this purpose extra help was employed, which added materially to the operating expenses of the plant. One firm in California kept several boys and one man at work several months killing moths in this manner. This method was, however, finally abandoned, and the mill was fitted up with steam pipes; and now one man does the entire work of sweeping, cleaning, and inspecting all incoming material, of whatever kind, and the moth is kept in such subjection that it gives them little or no inconvenience.

Hay Ropes.—I have already referred to the outbreak in Germany in 1858 on page 22. The miller who told me of this instance said the moth was most abundant during the month of June. This, he says, was the haying season, and long ropes of newly mown hay were made and placed about the mill in coils. He says the moths collected in great numbers in these coils, which were gathered up and burned each week.

High and Low Temperatures.—It has been ascertained by experiment that a temperature of 120° to 130° Fah., continued for two or three hours, is fatal to the larvæ in flour or other manufactured products, and if continued five or six hours is destructive to the eggs. In case whole grain is found infested, a very much greater heat is permissible. Wheat has been subjected to a temperature of 150° Fah. for a short time without destroying its germinating power.

As before mentioned, infested mills in Canada have been filled with steam and then thrown open, the cold winter air, as it penetrated every part of the mill, destroying many larvæ and pupæ. Cold weather, however, has little or no effect on the larvæ when left undisturbed in their silken tunnels.

The following references to the places of publication of the more important articles that have been written on the Mediterranean flour moth are given below in convenient, compact form, usually with an indication of the character of the contribution. The articles marked with an asterisk I have not seen.

BIBLIOGRAPHICAL LIST.

1879.

1. Zeller, P. C.—Stett. Ent. Zeit., 1879, pp. 466–471.
Original description of species, with notes on outbreak.

1881.

2. Snellen, P. C. T.—Tijdschr. voor Ent., 1881, pp. 20–22.
Mention of Prof. Zeller's paper (1879).

1884.

3. Girard, Maurice.—Bull. Soc. Ent. France, 1884, pp. lxxiii, lxxiv.
Note on ravages of the moth at Lodelinsarte, Belgium.

4. Karsch, F.—Ent. Nachr., May, 1884.
Record of the appearance of the moth on the lower Rhine.

5. Preudhomme de Borre, A.—Compt. Rend. Soc. Ent. Belgique, July 5, 1884.
An account of injury done in a noodle factory in Belgium.

1885.

6. Entomologische Nachrichten, 1885, pp. 46, 47, 239, 240.
Editorial mention of the appearance of the flour moth at Bremworde.
Review of a communication by Prof. Landois to the *Braunschweiger Tageblatt.*

7. SNELLEN, P. C. T.—Tijdschr. voor Ent., 1885, v. 28, pp. 237–251.

An illustrated article of considerable importance.

1887.

8. LINTNER, J. A.—Thirty-ninth Ann. Rep. N. Y. State Mus. Nat. Hist., pp. 99, 100.

Reply to a letter from Mr. A. Seigel, German Consul-General at New York City, asking information regarding the flour moth.

9. THOMPSON, W.—The Entomologist, 1887, v. 20, pp. 66, 139.

Finds this insect—first recorded (p. 66) as *Myelois ceratoniæ*—feeding on rice cones.

10. TUTT, J. W.—The Entomologist, 1887, v. 20, p. 212.

Records breeding of the adult from larvæ found feeding in a cargo of flour at the London docks, and gives short account of larval feeding habits.

11. COCKERELL, T. D. A.—Proc. S. Lond. Ent. Soc., 1887, p. 58.

Exhibition of larvæ, with statement that they lived in flour which had been shipped from America to Trieste, and thence to London. (See No. 20.)

12. BARRETT, C. G.—Ent. Month. Mag. 1887, v. 23, p. 255.

Account of breeding experiments, with brief description of moth and note of distinctive characters.

13. KLEIN, S. T.—Trans. Ent. Soc. Lond., 1887, pp. lii–liv.

Record of observations made in a large warehouse in the east end of London, in which the discovery of a flour-moth parasite (*Bracon brevicornis*) is mentioned.

*14. ——— The Miller (London) 1887, p. 446.

Full details concerning a lot of flour from Trieste infested with larvæ. Reference also made to the parasite noted above.

*15. ———Mark Lane Express (London) Nov. 14, 1887.

A note regarding the introduction of the flour moth into England.

16. ENTOMOLOGIST'S MONTHLY MAGAZINE, 1887, p. 163.

Editorial notice of paper read by Mr. Klein before the Entomological Society of London. (See No. 13.)

17. GEIKIE, A.—Proc. County of Middlesex Nat. Hist. and Sci. Soc. for Nov. 8, 1887.

Note on the destruction of the flour moth by a parasite (*Bracon brevicornis*).

*18. ADKIN, R.—Field, 1887, p. 829.

*19. ——— Proc. S. Lond. Ent. Soc., 1887, p. 20.

1888.

20. Cockerell, T. D. A.—The Entomologist, Nov. 1888, p. 279.

States that the larvæ exhibited before the South London Entomological Society in June, 1887 (see No. 11), although found in flour which came from America, are supposed to have come from some infested Trieste flour which was in the same warehouse.

21. Poulton, E. B.—Trans. Ent. Soc. Lond., Dec., 1888, pp. 598, 599.

Under the caption "The Determination of Sex in certain Lepidopterous Larvæ," gives an interesting item concerning the larva of *Ephestia kuehniella*. Demonstrated by observation and experiment that larvæ with dark spots on the dorsal surface of the fifth abdominal segment always developed as males, and that the spots are embryonic testicles.

22. Brocchi, P.—Bull. du Ministére de l'Agriculture, 1888.

A brief summary of the past history of the pest, with mention of remedies.

1889.

23. Ormerod, E. A.—Insect Life, Mar., 1889, v. 1, p. 314.

A letter to Dr. C. V. Riley regarding this pest in England.

24. ——— Twelfth Rep. Inj. Ins. 1888, pp. 66–72.

An interesting account of the outbreak of the flour moth in England.

25. Riley, C. V., & Howard, L. O.—Insect Life, May, 1889, v. 1, p. 355.

Mention of *Ephestia kuehniella* in connection with a review of Miss Ormerod's Twelfth Report.

26. Bryce, P. H.—Bull. I., Provincial Bd. Health, Ont. (Issued by Ont. Dept. Agr., Oct., 1889.)

An important article concerning the Canadian outbreak.

27. Riley, C. V., & Howard, L. O.—Insect Life, Dec., 1889, v. 2, pp. 166–171.

Summary of history and literature, with original notes and observations.

28. Fletcher, James.—Insect Life, Dec., 1889, v. 2, pp. 187–189.

A letter to Dr. Riley regarding the Canadian outbreak.

1890.

29. Fletcher, James.—Rep. Minister Agr. [Ottawa], 1889, App., pp. 73–79.

A review of Dr. Bryce's Bulletin (see No. 26), with much additional information regarding the Canadian outbreak.

30. FLETCHER, JAMES.—Rep. Ont. Ent. Soc., 1889, pp. 95–100.

A general review of the history of the flour moth in Canada.

31. RILEY, C. V., & HOWARD, L. O.—Insect Life, Jan.–Feb., 1890, v. 2, p. 260.

Mention of the rearing of *Chremylus rubiginosus* from *Ephestia kuehniella.*

32. ORMEROD, E. A.—Thirteenth Rep. Inj. Ins., 1889, pp. 49–54.

A partial review of matter in her Twelfth Report concerning the flour moth, with many other notes upon it.

33. BRYCE, P. H.—App. Bull. I., Provincial Bd. Health, Ont. Oct. 15, 1890.

A circular letter urging millers and dealers to take active steps to eradicate the flour moth.

34. PATTON, W. H.—Insect Life, Nov. 1890, v. 3, pp. 158, 159.

Under caption "Notes upon *Ephestia interpunctella* (Hübn) Zeller," both *E. kuehniella* and *Tinea zeæ* are listed as synonyms of *E. interpunctella.*

35. RILEY, C. V., & HOWARD, L. O.—Insect Life, Nov. 1890, v. 3, p. 134.

Dissent from Patton's views (See No. 34) believing *Ephestia kuehniella* to be a distinct species.

1891.

36. HULST, G. D.—Trans. Am. Ent. Soc., 1890, v. 17, pp. 198–200.

Some notes on *Ephestia kuehniella* in monograph of North American Phycitidæ.

37. FLETCHER, JAMES.—Rep. Minister Agr. [Ottawa], 1890, App., pp. 168–171.

General summary concerning the Canadian outbreak.

38. ORMEROD, E. A.—Fourteenth Rep. Inj. Ins., 1890, pp. 49–54.

A general review of the English outbreak, for the year 1890, with much additional information on the subject.

39. RILEY, C. V., & HOWARD, L. O.—Insect Life, Apr. 1891, v. 3, p. 333.

Mention of a species of Ephestia (either *kuehniella* or *interpunctella*) in corn from Venezuela.

1892.

*40. COCKERELL, T. D. A.—Daily Gleaner, Aug. 11, 1892; Tri-Weekly Budget, Aug. 11, 1892; Jamaica Post, Aug. 13, 1892.

Reprint by the above Jamaica newspapers of a circular letter announcing the appearance in Jamaica of what was at first supposed to be the flour moth, but which proved to be *Ephestia desuetella.*

*41. Decaux, C.—Arch. de Med. et de Pharm. Militaire (France,) No. 8, 1892.

Notes and record of experiments with *Ephestia kuehniella.*

*42. ——— Ann. Soc. Ent. France, v. 62 (Bull.), pp. ccii, cciii.

A communication concerning *Ephestia kuehniella* to the *Congrés des Sociétés Savantes*, notice of which is published in the *Annales* above cited.

*43. ——— Ann. Soc. Ent. France, v. 62 (Bull.), pp. ccii, cciii.

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44. Riley, C. V., & Howard, L. O.—Insect Life, Nov. 1892, v. 5, p. 141.

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45. Adkin, R.—The Entomologist, 1892, v. 25, pp. 53, 54.

A short article on the English outbreak, and original notes.

46. Johnson, W. G.—Sacramento Record Union, Dec. 5, 1892; Santa Cruz Surf, Dec. 5, 1892; Los Angeles Times, Dec. 5, 1892; Santa Barbara Morning Press, Dec. 8, 1892.

An "emergency circular" (for copy see p. 33.) reprinted in the California newspapers.

47. ——— San Francisco Call, Dec. 6, 1892.

Matter furnished a reporter in an interview concerning *Ephestia kuehniella.*

48. ——— Stockton [Cal.] Mail, Dec. 12, 1892.

A short account of the flour moth with reference to its occurrence in California.

49. Ragonot, E. L.—Ann. Soc. Ent. France (Bull.) Dec. 28, 1892, p. cclxxiv.

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1893.

50. Johnson, W. G.—Milling (Indianapolis, Ind.) Jan., 1893, v. 2. pp. 177–180; reprinted in American Miller (Chicago) Feb., 1893, v. 21, p. 119.

Brief summary of past history, and notes on the California outbreak.

51. Decaux, F.—Ann. Soc. Ent. France (Bull.) 1893, p. xii.

Remarks upon the distribution of *Ephestia kuehniella* and upon the experimental work of Dr. C. Decaux.

52. RAGONOT, E. L.—Ann. Soc. Ent. France (Bull.), 1893, pp. xii, xiii.

General remarks upon the habits of *Ephestia kuehniella* and on means for its destruction.

53. RILEY, C. V., AND HOWARD, L. O.—Insect Life, Apr., 1893, v. 5, p. 276.

Mention of the article by W. G. Johnson in "American Miller," for February, 1893 (see No. 50), and notice of Mr. Danysz's preliminary studies on the flour moth.

54. DANYSZ, J.—Mém. du Lab. de Parasitologie Végétale de la Bourse de Commerce, v. 1, 60 pp.

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55. ——— Ann. Soc. Ent. France, (Bull.), 1893, pp. clxxviii, clxxix.

Note on the pigment spots of the larva.

56. DECAUX, F.—Rev. Sci. Nat. Apliquées, 1st Semestre, 1893, pp. 220–225.

An article with illustrations, treating of the habits of the flour moth and of means for its destruction.

57. RILEY, C. V., & HOWARD, L. O.—Insect Life, July, 1893, v. 5, pp. 290, 291.

A review of Mr. Danysz's pamphlet, mentioned above.

58. ——— Insect Life, July, 1893, v. 5, p. 350.

Announcement that the insect reported from Jamaica as *Ephestia kuehniella* (see No. 41) proved to be *E. desuetella* Walker.

59. ——— Insect Life, July, 1893, v. 5, p. 353.

Mention of Mr. Ragonot's views concerning the origin of *Ephestia kuehniella.*

60. ——— Insect Life, Nov., 1893, v. 6, pp. 44, 45.

Note concerning Mr. Danysz's observations on the pigment spots of *Ephestia kuehniella.*

61. BRUNER, LAWRENCE.—Rep. Neb. State Bd. Agr. 1893, p. 401.

A short, compiled, illustrated article.

1894.

62. MCCARTHY, G.—Bull. 96, N. C. Agr. Exper. Station, Jan. 1894, p. 64.

A notice regarding *Ephestia kuehniella* in which it is said to be present in North Carolina.

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64. RILEY, C. V., & HOWARD, L. O.—Insect Life, May, 1894, v. 6, p. 355.

Reference to Mr. E. B. Poulton's paper on the embryonic testicles of the larvæ of *Ephestia kuehniella.* (See No. 21.)

1895.

65. JOHNSON, W. G.—Am. Miller, Jan., 1895, v. 23, p. 33.

Mentions finding *Tribolium ferrugineum* feeding upon the larvæ of *Ephestia kuehniella* in a California mill.

66. AMERICAN MILLER, Jan., 1895, v. 23, p. 50.

Editorial notice of the proposed work on the flour moth in Eastern United States.

67. JOHNSON, W. G.—Am. Miller, Mar. 1895, v. 22, p. 198.

A preliminary account of experiments with the flour moth, with notes on observations.

68. ———Am. Miller, May, 1895, v. 23, p. 347.

Announcement of the appearance of the flour moth in New York State.

69. AMERICAN MILLER, May, 1895, v. 23, pp. 367, 368.

Editorial comments on the New York outbreak mentioned above, and (p. 368) a note on the flour moth quoted from Prof. Landois.

70. RILEY, C. V., & HOWARD, L. O.—Insect Life, July, 1895, v. 7, p. 416.

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71. CHITTENDEN, F. H.—Year-book of the U. S. Dept. of Agr. for 1894, pp. 283–285.

A short, illustrated, somewhat popular account of the flour moth, with notes.

72. JOHNSON, W. G.—Am. Miller, Oct. 1895, v. 23, pp. 738, 739.

Brief account of the methods used in New York and California in fighting the flour moth.

73. ———Am. Miller, Nov., 1895, v. 23, p. 810.

Notes on the discovery of *Bracon hebetor* Say, a new parasite of *Ephestia kuehniella,*—the first observed in America,—and on a new locality for the moth in Canada.

74. ———Ent. News, Dec., 1895, v. 6, p. 324.

A preliminary note on the discovery of *Bracon hebetor* Say preying upon larvæ of *Ephestia kuehniella.*

75. Burns, E.—Am. Miller, Dec., 1895, v. 23, p. 910.

A communication from a Pennsylvania miller, giving an account of his three years' experience in fighting the flour moth.

1896.

76. Johnson, W. G.—Am. Miller, Jan., 1896, v. 24, p. 32.

A few notes on the flour moth with reference to the new outbreak in Pennsylvania. Illustrated.

77. ——— Can. Ent. Jan., 1896, v. 28, p. 13.

Note on the new outbreak of the flour moth in Canada.

78. ——— Am. Miller, Feb., 1896, v. 24, p. 114.

Answer to a query from a milling firm in Melbourne, Australia.

79. Trelease, William.—Science, Feb. 14, 1896, v. 3 (n. s.), p. 252; Can. Ent., March, 1896, v. 28, p. 61; Am. Nat. v. 30, p. 258.

Reports that he exhibited at a meeting of the St. Louis Academy of Science, a silk fabric from Mexico, supposed to be the work of the Mediterranean flour moth.

Note.—I am in receipt (March 5, 1896) of a package of infested flour from a mill in Saltillo, Mexico, which has been forwarded to me by the editor of the "American Miller." The flour is one mass of web, and contains hundreds of larvæ, pupæ, and dead moths of the Mediterranean flour moth *Ephestia kuehniella*. The material was taken from a flouring-mill, where the moth is doing much mischief.